Key Challenges in Geography
EUROGEO Book Series

Stoyan Nedkov · Georgi Zhelezov · Nadezhda Ilieva · Mariyana Nikolova · Boian Koulov · Kliment Naydenov · Steliyan Dimitrov *Editors*

Smart Geography

100 Years of the Bulgarian Geographical Society

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Key Challenges in Geography

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Editorial: Smart Geography: 100 Years Bulgarian Geographical Society

Stoyan Nedkov, Boian Koulov, Mariyana Nikolova, Nadezhda Ilieva, Georgi Zhelezov and Kliment Naydenov

Abstract Geography of the twenty-first century is expected to contribute to the development of human capital and the knowledge society, to offer place-specific solutions for sustainable regional development and use of the planet's natural and human capital. With this idea, we prepared this book which presents selected contributions from the *International Conference "Smart Geography: 100 years Bulgarian Geographical Society"*. They are focused on various themes related to smart spatial solution in different geographical disciplines as well as interdisciplinary studies with pronounced spatial aspect. The book illustrates the great variety of themes the contemporary geography is dealing with. Most of them have real potential to contribute by smart spatial solution to the human well-being. The examples presented in the book cover case studies from Bulgaria and many other countries worldwide.

Keywords Physical geography · Human geography · Landscape ecology · Ecosystem services · Smart spatial solutions

The celebration of the 100th anniversary of the Bulgarian Geographical Society is undoubtedly the time to pay tribute and extend gratitude, first of all, to the founder of the Society, Academician Anastas Ishirkov, as well as to all geographers who gave their best for its development in the past century. This anniversary is as much an occasion for retrospection, analysis, and assessment of the past development and current state of the geographical science in Bulgaria, as it is a chance for a glimpse into the future and an attempt to outline the prospects of geography, geographic education, and practice. Last, but not the least, this is an opportunity to widen the space for creation and dissemination of new research in different geographic disciplines and discuss the changes that would adequately address the natural and societal challenges of the twenty-first century.

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Global change comprises all transformations in the geo-systems, human society, and its environment that have begun at the end of the twentieth century and continue at present with increasing dynamism. Scientific and technological developments, particularly the information technology revolution, including the geo-information, are radically changing the ways in which economic, social, and public systems function. Conceptualizations of basic geographic notions, such as "place", "geo-space", "environment", "sustainability", "identity" are also constantly been amended. Information security threats and greater access to the exponentially increasing geo-information flows have become the key features that allow for new means of describing location, situation, boundaries, and other geographic characteristics. Big geo-spatial databases, generated by the new technologies, play a progressively important role in the choice of policies for governing states, regions, and localities, including adaptation of the geo-space to the impacts and consequences of global change. It is geographers who play a key role in the utilization of the "flood" of geo-spatial information, uncover and analyze the ever-changing processes and interconnections in the geo-systems, evaluate and predict their sustainability and future dynamics. Research on ecosystems and their services has already proven its value to environmental protection and sustainable use of natural resources. In view of the intensive migration and urbanization processes in today's world, cities are trying to offer "smart" solutions, in order to deal effectively with global demographic and environmental pressures. The complex interrelations and interdependences among these processes raise a number of geographic problems that require innovative approaches and solutions, which significantly contribute to the implementation and further development of the OECD and EU Smart Specialization Strategies.

The geography of the twenty-first century is projected to directly contribute to the development of natural and human capital and the knowledge society, to offer evidence-based and place-specific solutions for sustainable regional development and improvement of the human well-being. The multitude of challenges that humanity is currently facing require nothing less than really "smart decisions". Such ideas that include ways of "letting the gene out of the bottle" provoke a discussion on what is and should "smart" geography be that motivated the organization of the International Conference "Smart Geography: 100 years Bulgarian Geographical Society".

This book presents a careful selection of some of the best conference contributions, which focus on smart spatial solutions in different geographical disciplines, as well as interdisciplinary studies with pronounced spatial aspect. The volume is organized in five parts, corresponding to the main conference themes. The **first part** includes contributions from the plenary session dealing with various aspects of the geographical science and the perspectives for its development. The first chapter (Nikolova et al. 2019) presents an overview of the history and development of the geographical science and higher education in Bulgaria over the years and the important role of the Bulgarian Geographical Society in this process. The history and current priorities in the work of the leading Bulgarian geographical institutions are described in brief. Their contributions to the geographical science and higher education in geography, as well as to the future of "smart geography", are also discussed. The chapter points to the most successful periods of the Bulgarian Geographical Society and the forces and influences that impact the Society's members throughout the first 100 years of its history. The conclusion stresses some of the challenges to "smart" geography and geographical education at the end of the twentieth century.

Pickles (2019) discusses the local consequences and responses to the changing geographies of economic governance. The author states that the structure and practice of these geographies have become more influential in response to the financial crisis of 2008, which led to the development of "smart specialization strategies aimed at revitalizing core economies and flexibilizing regional development pathways". The study illustrates the emerging discourses by presenting examples of specific regional problems from Central and Eastern Europe.

In his study on climate change implications, Gonencgil (2019) applies cluster analysis for classification of general climate characteristics and reveals different patterns of temperature and precipitation distribution in Turkey. The work of Rizou and Klonari (2019) concludes that modern education reform demonstrates a shift from the classic teacher-centered model to one where interdisciplinary and holistic approaches play a central role in the curricula. They advocate an active and positive approach built around the use of web tools aided by teacher interventions, particularly for integrating geo-spatial statistics through open-source web-based platforms and sound a warning about the embedded assumptions and regional consequences of smart specialization programs and their "high-tech fantasies."

The **second part** of the book contains contributions to physical geography, which deals with the interaction between smart technologies and studies on climatology, hydrology, geomorphology, and geology. Monitoring of geomorphological processes, air and water quality, and climate and hydrological data collection depends on a wide range of smart equipment, including sensors, displays, and computing devices. They are self-organized, possess the capabilities to network with each other and beyond, provide diverse services, and manipulate and publish complex data sets through the internet. Smart technology supplies users with information for better understanding and governance of human environment. The use of geo-information technology for processing and analyzing the increasing data flows provides new knowledge about nature's geo-spatial and temporal features and their dynamics. Various web-based applications increase significantly the access to scientific information and enhance public awareness to current environmental issues, like climate change, natural hazards and risks, ecosystem services, quality of the natural environment, and the need to adapt to its changes. At present, some of the challenges include the conceptualization of how the use of smart technology changes human understanding about some of the basic concepts in geography, as well as the methods and means to control and manage natural processes through smart technology. A total of six chapters are devoted to these contemporary problems.

In the first chapter Dobrev et al. (2019) present the initial results of the 3D monitoring of West Pirin fault in the Brezhani village area of southwest Bulgaria. The analysis of the data, obtained with the use of extensometer TM71 during the period from August 2013 to August 2018, prompts the authors to suppose recent activity along the West Pirin fault.

Mateeva (2019) studies the impact of climate change and other natural and man-made stressors on human health and the quality of the living environment. The chapter discusses the climatic factors of highest effect and gives "an idea about the general vulnerability of the human health sector in Bulgaria" to the climate changes. Seymenov (2019) presents a different aspect of climate change influences. He studies the hydrological response to the long-term climate change by estimating the climate elasticity of streamflow in seven catchments in northwest Bulgaria. Judging by the obtained results, he concludes that "the assessment of climate elasticity of streamflow is an informative approach for estimation of climate change impacts on hydrological systems and provides an opportunity for effective water resources management".

The work of Lim et al. (2019) deals with the use of microclimate data in students learning. The experiment was conducted in two cities, Singapore and Hanoi, and the results can be considered "a proof-of-concept of an experiment and curriculum in which local, real-time data are collected and used by learners as they seek to go beyond canonical knowledge from textbooks". The chapter of Peshich and Joksimovic (2019) focuses on flood hazard as one of the most common natural disasters in Serbia. It uses probability theory and mathematical statistics analyses of time series of maximum discharges for 50 years of observations at four hydrological gauges to analyze the most severe flood since the beginning of the twenty-first century (May 2014 in the Kolubara River Basin) and estimates the flood magnitude for a given recurrence interval T (T-year flood). Radeva and Seymenov (2019) deal with the problem of water quality in the Lom river on the basis of data from three water sampling points, which include information about 14 parameters, measured from 2012 until 2016, using CCME Water Quality Index and Oregon Water Quality Index (OWQI). The calculated overall water quality index turned below the "marginal" water class and shows worsening of the physico-chemical properties of the water moving to the downstream river sections.

The **third part** of the book covers the human geography field. A profound demographic transformation has taken place in Europe since the Industrial Revolution, evidenced by the changes in the reproductive attitudes and values and human migratory behavior. Only in the course of a century-and-a-half, the total fertility rate in Europe decreases significantly and the one-child family model is gradually established, together with higher level of education, increased requirements toward child-raising, and rapid urbanization processes. At the same time, as a result of the increased standard of living, improved quality of life, and greater access to medical care, the average life expectancy has grown more than 2.5 times, reaching about 80 years or more in most European countries. Some of the consequences, however, include unprecedented aging of the population and notable reduction of the fertile contingent. Along with that, the demographic explosion and the uncertain political and economic environment in South Asia, the Middle East, and Africa have resulted in increasing migratory pressure on Europe in recent years. The dynamics of these processes affects both the number and geo-spatial distribution of the population, as well as transformation of ethnic and national identities. In the twenty-first century, Europe is facing serious challenges, even risks, but also real opportunities for the overall development of the continent. Each region needs to implement "smart" policies, geared to the geographic specifics of the particular territory, both to adapt and address the problems outlined.

One challenge which requires smart decisions is urban shrinkage. While this process is typical for many developed states, the dramatic political, economic, and social transformations in the post-socialist countries, since the beginning of the 1990s, have led to changes in the settlement patterns, caused by large-scale external and internal migrations to metropolitan and the largest regional urban centers at the expense of the remote, mountainous, and peripheral regions. Bulgaria is no exception to these processes where urban areas have been subjected to shrinkage, resulting in further demographic and economic decline.

Simeonova and Milkova's (2019) chapter proposes grouping of the Bulgarian cities, according to the causes and the dynamics of their shrinkage throughout the last century and up until 2017, with a focus on the changes after 1989. The process of urban shrinkage in Bulgaria has been analyzed, as well as its causes, in view of urban areas' functional changes under the market economy conditions and the social and demographic crises, expressed in the loss of population and urban decline.

The work of Mitrica et al. (2019) focuses on regional geo-spatial and statistical analyses of the urban–rural relationships in Romania (case-study: the Romanian plain). Generally, a high social and economic dependency on the closest urban areas characterizes these relationships, thus leading to a series of geo-spatial and functional interactions. The authors perform regional scale analysis and assessment of the geo-spatial and functional linkages between 34 cities and 318 rural settlements located in their impact area. At the local administrative level (LAU), they use statistical regression models, where the key driving factors, such as demographic size, functional profile, and connectivity, are independent variables and population growth, size of living area, age dependency, economic dependency, built-up areas' expansion, water supply, migratory balance, unemployment rate, which reflect the degree of rural development, are accepted as dependent variables. The study results help identify areas with different rural development potential and allow for better understanding of the urban–rural interactions in the last several decades.

One of the main regional policy objectives refers to improvement of the population's quality of life. To this end, Simeonov et al. (2019) propose a model for assessing the quality of life of the population, which aims to quantify the concept and, at the same time, eliminate the use of subjective criteria. The research team tests the suggested model to assess the quality of life of the population in north-central Bulgaria.

Ilieva et al. (2019) consider Roma integration and the intensifying geo-spatial segregation processes affecting that ethnic group as another issue which requires application of smart decisions. Post-socialist societies are facing numerous challenges leading to complex structural changes. New models of socio-spatial polarization of the cities have emerged. In recent decades, Bulgaria has seen a clear trend of growing number of Roma people residing in cities. In the majority of cases, the Roma settle either in already existing Roma quarters or form completely new ones. The swift expansion of the Roma quarters in both horizontal (spatially) and vertical (height) aspect makes it difficult to trace the changes. Considering that most buildings are illegal, they are not present on cadastral maps and urban geo-spatial plans. The serious difficulties which Bulgaria has been encountering regarding the integration of its Roma population, together with the increased ghettoization of the Roma living in cities and the eventual threats of social cataclysms, are among the reasons why the chapter pays attention to the issue of the expansion of the so-called ghettoized urban structures which hinder the development of smart cities. Based on the case study of the Roma-inhabited Harman Mahala quarter in the city of Plovdiv, this investigation analyzes geo-spatial development trends and the internal structure of the Roma quarters aided by remote sensing and field research methods.

In the following chapter, Burdarov and Tsvetkov (2019) identify the reasons for the difficulties that Europeans face in their attempts to integrate the Roma into their cultural system. The authors review and analyze successful integration policies toward the above ethnic group in Europe and points to those that can be adapted and implemented successfully in Bulgaria. One of the crucial problems, specifically related to the integration of the Roma minority, is education. The smart decisions in that respect should target disbandment of segregated schools and creation of mixed school establishments. School segregation represents a serious social and educational problem in a number of countries across Europe, including Bulgaria. While in some countries this problem arises on the basis of social stratification and concerns both local ethnic minority and immigrant communities, in Bulgaria—as in other Eastern and Central European countries—school segregation is mainly associated with the Roma ethnic group. Education of Roma children is still almost entirely provided in segregated schools, located in or near the Roma quarters, regardless of the government efforts to implement measures for overcoming the problem. Those issues are addressed in a separate chapter, which analyzes the specifics and the trends of the Roma school segregation in Bulgaria, based on a case study of the Roma children from Harman Mahala in the city of Plovdiv (Ravnachka et al. 2019).

The human geography part of the book concludes with another contemporary example of self-segregation, very informative for Europe, despite the many and substantial dissimilarities, due, mainly, to its geographic setting in a different part of world. Kotze et al. (2019) describe and analyze the socio-economic and political development and the current potential of the rural town of Orania in the Republic of South Africa. Established in the early 1960s to accommodate construction workers, the town has been subsequently abandoned by the government and passes through a "ghost" town phase. Bought by AVSTIG (Afrikaner Freedom Foundation) in 1991, this settlement has been envisaged as the first homeland for the Afrikaans-speaking white population. It has entered an agricultural economic phase, which brought about steady growth in the town's population: the 2011 census has shown a growth of approximately 49%, with a significant increase in the age group younger than 20 years. Twenty-four years after the apartheid, on account of the authority wielded by the village council to act as gatekeeper, Orania still has a whites-only population.

The **fourth part** of the book includes the contributions in the field of landscape ecology. Asenov and Grigorov (2019) examine the presence of tree cover on agricultural land in Mala Planina, located in the Western Balkan Range, and study its role in carbon collection. The trees provide a number of ecosystem services, such as wood, erosion protection, carbon collection, and so on. The authors of the research recommend planting of specific species (*Quercus*, *Fagus*, *Carpinus*, and *Fraxinus*) as best agricultural practice and conclude that the study can be used as model in other agriculture regions.

The second chapter (Nikolova 2019) focuses on monitoring heavy metals (Cu, Zn, Pb, Cd, Mn) in the sediments of Blagoevgradska Bistritsa River Catchment, southwestern Bulgaria. The research reveals different periods of pollution with heavy metals. The first two periods are characterized with high concentration of heavy metals (zinc, lead, and copper), while in the third period, the concentration of heavy metals has decreased. The author concludes that the transformation in the industrial production of the region and the construction of wastewater purification plants are the main reasons for reduction of the heavy metals pollution. The third chapter (Tamburadzhiev and Cholakova 2019) focuses on the structure and peculiarities of the karst landscapes in the Besaparski ridges, central-south Bulgaria. It investigates the morphometric, landscape-geophysical, and landscape-geochemical characteristics of the karst formations and presents a map of the contemporary karst landscapes. Zhelezov's chapter (2019) relates to the development of geo-spatial reconstruction models of the landscapes in the Aydemirska wetland system, in northeastern Bulgaria, based on old maps from different periods. This method provides an opportunity for reconstruction of the state of the landscapes and wetland system before the active anthropogenic impact in the region. Its results can be used in the planning of future economic activities and restoration of the wetlands. Prodanova (2019) presents **an** empirical study of the geo-ecological state of selected landscapes in north-central Bulgaria (Stara Planina Mountain, Predbalkan, and Danubian Plain). Its main objective is to reveal the contemporary geo-ecological problems, based on semi-stationary and field investigations. The results reveal nine categories of geo-ecological problems, grouped in three main groups. For the most part, the landscape transformations relate to the changes in vegetation and relief, as a result of the anthropogenic impact.

The application of the ecosystem services (ES) concept, as a tool for smart geospatial solutions of human-environmental problems features in the **fifth part** of this volume. The ES concept rests on the facts that ecosystems provide a range of services of fundamental importance to human well-being and their sustainable use could balance environmental conservation and economic activities and interests. The geospatial aspects of ecosystem services attracted significant attention in the last years through development of various mapping and modeling methods and tools, as well as major EU-funded initiatives and projects, such as MAES (Mapping and Assessment of Ecosystems and their Services), ESMERALDA (Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking), and MAIA (Mapping and Assessment for Integrated ecosystem Accounting). On the other hand, there is an ever-growing need for robust geo-spatial data and models describing the supply, demand, and flow of ecosystem services in order to meet the urgent needs of policymakers. The contributions in this part bring together researchers from different disciplines, who are members of the Working Group of Landscape Ecology and Ecosystem Services at the Bulgarian Geographical Society, as well as the Bulgarian, Greek, and Turkish

National Networks, participants in the south-east European Chapter of the Ecosystem Services Partnership (ESP).

The chapters in this part deal with various aspects of mapping and assessment of ecosystem services based on field observations, remote sensing data, geo-spatial proxy methods, modeling approaches for generation of geo-spatial data and production of ES maps. Bratanova-Doncheva and Gocheva (2019) state that climate change, together with other stressors, decreases the capacity of ecosystems to buffer impacts from extreme events, like fires, floods, and storms. The author's case studies illustrate the advantages and challenges of both the deterministic and holistic approaches to cost–benefit analysis for climate change adaptation. Thus, the wetlands in the transboundary Nestos/Mesta river basin are mapped and assessed as important landscape features that can contribute to the ecological coherence of the Natura 2000 network (Fitoka and Hatziiordanou 2019). The results provide baseline knowledge on connected areas of high value for biodiversity and seek to support management and conservation interventions.

Yaneva and Munoz (2019) study the societal demand for ES, due to the construction of an open-pit mining project in the semi-arid southern Arizona, USA. It produces supply/demand maps which reveal a geo-spatial understanding of the ES, in the hypothetical judgments of the involved stakeholders. The maps can be used to analyze the geo-spatial aspects of the impact of the mining industry on the provision of ES, thus supporting the stakeholders with an appropriate tool for decision making.

Zhiyansky (2019) investigates the role of mountain forest in the provision of a wide range of ES. The study uses a LPJ-GUESS ecosystem model to analyze carbon sequestration in mountain forests in different vegetation zones of Bulgaria under realistic and pessimistic scenarios of climate change. The author also defines tendencies in the vulnerability and adaptive potential of the mountain forests. Vatandaslar et al. (2019) also focus on forests ecosystems in their ability to supply erosion control services. The investigators use field observations, direct measurements and data of growing stock, basal area, and soil erodibility to assess the statistical relationships of soil properties and forest inventory data. The results show that the higher number of trees per unit area reduces the erosion rates.

The book illustrates the great variety of themes the contemporary geography is dealing with. Most of them have real potential to contribute by smart spatial solution to the human well-being. The examples presented in the book cover case studies from Bulgaria and many other countries worldwide. The geographical scope of the studies ranges from USA to Singapore and from Romania to South Africa.

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Towards Smart Geography

Stoyan Nedkov, Steliyan Dimitrov, Mariyana Nikoilova and Kliment Naydenov

BGS and the Contemporary Progress of the Geographical Science Towards Smart Geography

Mariyana Nikolova, Stoyan Nedkov, Kliment Naydenov, Svetla Stankova, Dimitar Simeonov and Krasimir Stoyanov

Abstract Starting with an overview of the first Bulgarian geographical studies and publications, the paper presents the development of the process of collection and interpretation of geographical knowledge for Bulgaria from different Bulgarian sources for centuries in the past to nowadays. As a classical discipline, geography goes through the time adding new discoveries, methods and applications. Becoming more and more open to other scientific disciplines, geography shows its incredible ability to gain and provide new knowledge and to answer some of the most important scientific challenges. In Bulgaria, there are several leading scientific institutions which work persistently from the beginning of the twentieth century to develop the geographical science and higher education: Sofia University „St. Kliment Ohridski", Institute of Geography at Bulgarian Academy of Science (BAS), now Department of „Geography" at the National Institute of Geophysics, Geodesy and Geography—BAS, „Konstantin Preslavski" University of Shumen, „St. Cyril and St. Methodius" University of Veliko Tarnovo and South-West University „Neofit Rilski" of Blago-

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evgrad. The geographical units in each one of them have its specificity, achievements and research priorities, but all of them actually build the fundament of geography in Bulgaria. That is why we discuss in this paper their history, their contribution to the geography of Bulgaria and their current way to the future of smart geography. The Bulgarian Geographical Society (BGS) plays an important role in the last 100 years to keep all Bulgarian geographers in line with the most actual problems of the geographical science and education. In this paper we also show which historical periods of the Society were the most successful, and why and how it has changed and influenced Bulgarian geographers during the last few years.

Keywords Bulgaria · History of geography · Science and education

Introduction

Starting with an overview of the first Bulgarian geographical studies and publications, the paper presents the development of the process of collection and interpretation of geographical knowledge for Bulgaria from different Bulgarian sources for centuries in the past to nowadays. As a classical discipline, geography goes through the time adding new discoveries, methods and applications. Becoming more and more open to other scientific disciplines, geography shows its incredible ability to gain and provide new knowledge and to answer some of the most important scientific challenges. In Bulgaria, there are several leading scientific institutions which work persistently from the beginning of the twentieth century to develop the geographical science and higher education: Sofia University „St. Kliment Ohridski", Institute of Geography at Bulgarian Academy of Science (BAS), now Department of „Geography" at the National Institute of Geophysics, Geodesy and Geography—BAS, „Konstantin Preslavski" University of Shumen, University of Veliko Tarnovo „St. Cyril and St. Methodius" and South-West University „Neofit Rilski" of Blagoevgrad. The geographical units in each one of them have its specificity, achievements and research priorities, but all of them actually build the fundament of geography in Bulgaria. That is why we discuss in this paper their history, their contribution to the geography of Bulgaria and their current way to the future of smart geography. The Bulgarian Geographical Society plays an important role in the last 100 years to keep all Bulgarian geographers in line with the most actual problems of the geographical science and education. In this paper we also show which historical periods of the Society were the most successful, and why and how it has changed and influenced Bulgarian geographers during the last few years.

Bulgarian sources with geographical descriptions for our lands have been known since the time of the Bulgarian Emperor Simeon the Great, as well as from the books and texts written during the Renaissance. In 1843, Alexander Hadji Ruset issued the first Bulgarian map titled, „Map of Contemporary Bulgaria, Thrace and Macedonia and Adjacent Lands". Later, the famous Bulgarian poet Petko Rachov Slaveykov wrote „Geographical dictionary of Bulgaria" (Slaveykov 2008a, b).

The development of geography as a science in Bulgaria marks its beginning in 1898 with the creation of the Department of Geography and Geographic Institute in Sofia University as a result of the efforts of Prof. Anastas Ishirkov. He is a member of the Bulgarian Academy of Sciences (BAS), academician from 1904 and is the author of the first scientific monograph „*A Brief Geography of Bulgaria*" and of more than 300 scientific publications. Anastas Ishirkov was appointed as the first associate professor in Sofia University on 19 March 1898 when he gave an introductory lecture titled, "Objective and content of the contemporary geographical science" in which he discusses the objectives and scope of geography, division and fields of study, and main task and challenges in front of Bulgarian geographical science. In 1918, Anastas Ishirkov founded the Bulgarian Geographical Society, and in 1933 issued the first journal of geography in Bulgaria. Along with Ishirkov, there are enormous contributions to the development of the Bulgarian geography by Akademician Anastas Beshkov and Prof. Jordan Zahariev, Corr.-member of BAS, Prof. Zheko Radev, Prof. Ivan Batakliev, Prof. Dimitar Yaranov, Prof. Lubomir Dinev and many others. In 1950, Prof. DSc. Zhivko Galabov, Corr.-member of BAS, became the founder and the first Director of the Geographical Institute of the Bulgarian Academy of Sciences. During the next decade geographical courses and majors appear in Shumen University (1964), University of Veliko Tarnovo (1984) and South-West University (1993).

Bulgarian Geographical Society: A Retrospective Review

The Bulgarian Geographical Society was established on 9 November 1918. Its development can be divided into four periods: (1) 1918–1945; (2) 1945–1989; (3) 1989–2014; and (4) after 2014.

The **first period** is the time of foundation and consolidation of the Society under the leadership of two remarkable persons, Prof. Anastas Ishirkov and Prof. Ivan Batakliev. Prof. Ishirkov initiates the establishments of the Society and leads it as a Chair until 1934. Prof. Batakliev is the second Chair from 1934 to 1945. According to the first statutes of the Society, its governing body is the Board of Trustees consisting of 13 members elected by the General Assembly. The Society was very active in the first few years in organizing various lectures, edition of geographical issues and attracting new members. A collection of books called „*Geographical Library*" started in 1920 with the renowned work of Anastas Ishirkov „*West Thrace and the peace treaty in Neuilly*" (Ishirkov 1920). The number of society members gradually increased, reaching 170 in 1925. After this year, its activity declined mainly due to financial reasons and the General Assembly does not convene in the next 7 years. After 1932, the Society restarted its activity by establishing new statutes and election of new board of trustees which manage to restore the society member during the next 2 years. The first Bulgarian scientific issue, *Journal of Bulgarian Geographical Society* (Izvestia na Balgarskoto Geographsko Drujestvo) was established in 1933. The journal was issued annually until 1943, publishing papers in various geographical fields by Bulgarian and foreign researchers. Among the famous authors of the journal during this time are Albrecht Penck, Albrecht Burkard, Herbert Louis and Arthur Gavatsi. The most remarkable event during this time is the organization of the Fourth Congress of Slavic Geographers and Ethnographers in 1936. It was attended by 325 scientists from 12 European countries.

The start of the **second period** is marked by the political changes in the country after the World War II, which led to significant changes in the scientific community also. Leading geographers, such as Ivan Batakliev and Dimitar Jaranov, were forced to leave the academia, and the autonomy of the institution was reduced. The activity of the Bulgarian Geographical Society declined again until the mid-1950s when it was taken under the full control of the State. The government support during the 1960 and 1970 enabled to restore and extend the membership, publication and organization activities. The Society became popular, especially for the secondary school teachers and reached more than 1300 members in mid-1980s. Regional offices were established in many cities. The organization activities include conferences, bilateral symposia, jubilee sessions, secondary school teaching seminars, and so on. The main events during this period are the National Geographical Congresses held every four years between 1966 and 1989. Their programme includes scientific sessions, discussions on the results of research activities and debates on the state and perspective of the geography in the country. The publication activities were restored in 1953 with a new issue of the *Journal of BGS* which had new format and editorial board. During this period the journal published 28 issues with 580 papers. BGS published also the journal „*Problems of Geography*" in collaboration with the Institute of Geography and Sofia University from 1964 to 1978. Several popular issues such as „Geographical review", „Countries and People" and „Geography" were published.

The **third period** is marked by the transition in the country to democracy and marked economy. These changes led to the withdrawal of the State from many activities, including the support of the organizations such as BGS (Petrov and Nedkov 2014). Without the regular funding from the State, the activities of the Society gradually declined in the 1990s. The *Journal of BGS* was not published after 1992, no more Congresses were organized and the membership was significantly reduced. The new regulation under the Law of NGSs in 2001 required re-establishment of all organizations but the BGS did not manage to register its legal status and was cancelled.

The **fourth period** began in 2014 with the re-establishment of the legal status of the Society. The preparation started in 2012 by few members of Geology and Geography Faculty of Sofia University „St. Kliment Ohridski" and the Department of Geography at NIGGG BAS. For this purpose, new statutes were developed, which was based on the provisions of the first statutes of the Society from 1918. The registration of the new statute and the executive committee was established on 29 May 2014 by a decision of Sofia City Court. The first General Assembly of the restored Society was held on 11 August 2014 in Sofia University which elected regular executive committee and Chair Stoyan Nedkov. The fifth General Assembly of the Society was held on 11 April 2018 in Sofia University which elected the current executive committee chaired by Kliment Nydenov. During this period most of its former activities such as organization of regular events (conferences, seminars, workshops), publication of the *Journal of BGS* and support of student through various initiatives (grants, mobilities, seminars) have been restored. The Society has now well-functioning website and regular newsletter. In 2018, the Society celebrated its 100th anniversary and the 150th anniversary of its founder Anastas Ishirkov by a series of events in several places of the country, such as seminars, exhibitions, issue of jubilee postage stamp, campaign in Wikipedia, and so on. The most important event was the international conference "Smart Geography" which took part in Sofia University in November with more than 150 participants all over the world.

Leading Bulgarian Research and Education Institutions in Geography

Faculty of Geology and Geography at Sofia University "St. Kliment Ohridski"

On 19 March 2018, the Faculty of Geology and Geography (GGF) of the Sofia University "St. Kliment Ohridski" notes 55 years since it was found. The first department of "Geography and Ethnography" was established at the Faculty of History and Literature in Sofia University in February 1898 and its dean was Acad. Anastas Ishirkov. In 1908, he founded the Institute of Geography at the same school. In this institute later two departments were created—"Anthropogeography" and "Physical Geography". Lectures on geography had been read to the students with major pedagogy and philosophy by 1909. In 1910, specialty "History and Geography", and in 1924, specialty „Geography" were established. In 1949, specialty „Geology" was created, and in 1967—specialty „Tourism". In 2005, training of students in „Regional development and policy" began. The faculty members give lectures also to the students from the specialties „History and Geography" and „Geography and Biology" from 1999. The latest geographical specialties are „Geography and English" and „Geoinformation systems and technologies", which run, respectively, in 2018 and 2019. Nowadays, GGF is a national centre for training in the field of geography, regional development and policy, tourism and geology. Over the past 55 years, the structure of the faculty is constantly updated and optimized, developing new research directions and specialties.

The faculty has a good base for training and research. There are three specialized libraries: geology, geography and tourism, as well as GIS laboratory, Centers of Regional Development and of Multimedia training, two field stations—in towns of Elena and Zemen—and two museums of national importance. The faculty maintains a regular edition of book 2—„Geography"—of the Yearbook of the Sofia University „St. Kliment Ohridski" (SU).

Despite the relatively small number of scientists in GGF (52 professors and associate professors and 37 lecturers), the actual presence of the faculty in the structure and evolution of the university and of higher education in the country is significant. Many notable scientists and geographers have held executive positions at SU. Acad. A. Ishirkov in 1915 was elected Rector of Sofia University „St. Kliment Ohridski". Prof. Zhivko Galabov was the first Dean of Biology-Geologic-Geographical Faculty of SU. Vice Rectors of the SU were, at different times, the geographers Prof. M. Michev, Prof. D. Kanev, Assoc. Prof. H. Konstantinov, Prof. DSc. Todor Hristov, Corr.-member of BAS, and Prof. D. Toplijski. Faculty was guided successively by several Deans: Prof. M. Michev, Prof. P. Penchev, Prof. D. Kanev, Assoc. Prof. M. Glovnia, Assoc. Prof. Demerdjiev, Prof. P. Petrov, Prof. D. Topliiski, Prof. M. Vodenska and Prof. P. Slaveykov.

An attempt to unite the scientific knowledge of geography was made in 1972 with the creation of the Centre of Earth Sciences by BAS and SU. Its governing body includes President (Academician or Corr.-member of BAS), Deputy Research Director from BAS and Deputy Director of Education (Dean of GGF). Despite the good attempt for integration of the scientific potential of the BAS and GGF, this structure did not exist long due to unresolved administrative problems.

GGF, specialty "Geography", is represented by the departments of „Physical geography", „Physical geography of Bulgaria and the continents", „Economic geography" and „Economic Geography of Bulgaria and other countries" in the beginning. In 1967, the specialty includes „Geography" and „Geography of tourism", which later evolved into a separate specialty. During the period 1972–1973, the specialty includes the following geographical departments: „Geomorphology and Cartography", „Geography of Population and Settlements", „Hydrology and Climatology", „Economic Geography", „Physical Geography" and „Geography of Tourism". These departments, with minor modifications, still exist in the structure of GGF. The specialty „Regional and political geography" was established in 2000, and in 2002—„Cartography and GIS" and „Hydrology, Climatology and Geomorphology". After the establishment of the specialty „Regional Development and Policy" in 2005, the latest department in GGF—„Regional Development" in 2011 was formed.

There are over 8000 students graduated in GGF in the following scientific areas: geographic information systems and cartography, geomorphology, climate change and water management, landscape ecology and natural capital, regional and political geography, regional development and management, regional resources and strategies, cultural and political geography, geographical education, development and management of rural areas, tourism, planning and management of territorial regional security systems, and human resources management. The faculty has rich history and worthy representatives, both in science and in all areas of public life. Today, the faculty is a national centre for the training of specialists in geography, regional development and politics, tourism and geology.

Institute of Geography at Bulgarian Academy of Sciences

The Institute of Geography (IG) at the Bulgarian Academy of Sciences (BAS) was founded in 1950. Since then the institute passes through four periods of development in accordance with the social and economic conditions and changes in Bulgaria.

In the **first period**, from 1950 to 1970, fundamental studies in the field of physical, economic and social geography of Bulgaria are carried out. There is extensive fieldwork, gaining and processing massive amounts of empirical material. The results from these fundamental studies are published in a number of scientific works, among which the most significant is the monograph „*Geography of Bulgaria*", published in two volumes (vol. I, 1966 and t. II, 1961), and the „*National Geographic Atlas of Bulgaria*" (1973). During this period, Prof. Zhivko Galabov was the director of the Institute of Geography.

In the **second period**, the institute operates in the framework of the Center for Earth Sciences at the Bulgarian Academy of Sciences (1972–1988) under the leadership of the geographer Prof. DSc. Kiril Mishev, Corr.-member of BAS. With the increase in the number of scientists and the development of scientific staff, the sections: „Geomorphology and Cartography", „Climatology and Hydrology", „Landscape and Protection of the Natural Environment", „Socio-economic Geography" and "Geography of Population and Settlements" were established. During this period, regional studies and studies related to different geographical aspects of environmental protection and ecology are dominated. In the early 1980s, the Institute of Geography was the coordinator of a complex study of mountains in Bulgaria. The results are published in the monograph „*Natural and Socio-economic Potential of the Mountains in Bulgaria*" in two volumes (1989). During the same period the geographical regionalization of the country was carried out, published in the third volume of monograph „*Geography of Bulgaria*" (1981, 1982, 1989), which is the first work in the field of regional geography in the country. In 1974, the institute start to publish the scientific journal „*Problems of Geography*", which up to now is the most authoritative specialized academic geographical journal in Bulgaria. It is the successor of the journal „*Annals of the Geographical Institute of the Bulgarian Academy of Sciences*".

The **third period** began with the start of political and economic reforms in the country in 1989. During this period, number of structural changes was carried out and the institute was guided successively by several directors: Prof. Donch Donchev, Prof. Petar Popov, Prof. Ivan Vaptsarov, Assoc. Prof. Stefan Velev, Assoc. Prof. Gesho Geshev, Assoc. Prof. Marina Jordanova, Prof. Georgi Alexiev and Prof. Mariyana Nikolova. During the transitional period, the number of sections were reduced from five to two, "Physical Geography" and "Social and Economic Geography", and the number of scientists and specialists in the institute declined by approximately 50% over the next two decades of the country's transition to a market economy. However, in the 1990s of the twentieth century, the geographers from the institute adopted the difficulties of the transitional period as a unique scientific challenge and together with their counterparts from the United States were among the first scholars who place the focus of their research interest on the geographical aspects of the transition. The results of this joint research were published in the book „*Bulgaria in Transition*" (Paskaleva et al. 1998), and later the monograph of Prof. DSc Margarita Ilieva „*Socio-economic transformation in Bulgaria—characteristics and territorial differences*" was published in 2012. With the political changes after 1989 the need of up-to-date geographical information for Bulgaria is growing strongly. Publication of the monograph „*Geography of Bulgaria*" in 1997 was followed 5 years later by the new edition of the monograph „*Geography of Bulgaria*" (2002). Also „*Atlas of Eastern and South-eastern Europe*" (2004) and „*Bulgaria. Current Development and Problems*" (Ermann and Ilieva 2006) were published.

In 2007, after entering the country in the EU, stages of institutional stabilization, growth in research capacity, improvement of scientific infrastructure and significant expansion of the international cooperation started. In 2008, a centre of geo-informatics at the Institute of Geography is created, which aims to broaden and deepen the application of geo-information technology in geographical research and in the training of doctoral students. In 2010, scientists from the Institute of Geography issued the first bilingual Atlas of the country, „Bulgaria. Geographical Atlas" (2010) and a year later—„Geographical Glossary" (2011) and many other publications, reflected in the reference book „Scientific publications of researchers by the Institute of Geography, BAS for the period 1990–2009" (Metodieva and Ilieva 2010). The opportunities for realization of the scientific potential of the Institute of Geography in the European research area were found to be growing during this period. Institute's personnel increase is represented by 42 people. Traditionally, good partnership with the colleagues from the countries in Southeast Europe and United States expanded and in 2010 almost all European countries, Japan and China were included. The department participated in various forms of bilateral cooperation or in international research projects and networks (6 FP, 7FP, NATO/CCMS, INTERREG, CEEPUS, COST, etc.). This cooperation contributes to the application of new methods and approaches in research and to disseminate the results amongst the international geographical community through publications such as: „*Use of Landscape Sciences for the Assessment of Environmental Security*" (Petrosillo et al. 2007), „*Cities of the World* " (Brunn et al. 2008), „*The Moving Frontier: The Changing Geography of Production in Labour Intensive Industries*" (Labrianidis et al. 2008), and „*Sustainable Development in Mountain Regions: South Eastern Europe*" (Georgiev 2011).

The **fourth period** of the development of geographical science in BAS coincides largely with the structural changes in the Bulgarian Academy of Sciences in 2010, which led to the merger of the Institute of Geography with three other research units of the Academy and the creation of the National Institute of Geophysics, Geodesy and Geography (NIGGG) at the Bulgarian Academy of Sciences on 7 January 2010. In this new institute, the Institute of Geography operates as Department of Geography. In 2018, there are 27 scientists of 34 personnel and 7 Ph.D. students. At the department there are one library, two labs and two research stations. Currently, in the Department of Geography sections of„Physical Geography", „Economic and Social Geography" and „GIS" operate. During this period the unit integration deepens in the European research area through the participation of geographers in projects financed by the

EU's framework programmes for research and development (FP7 and Horizon 2020), cross-border cooperation projects, as well as such projects under the Operational Programme for Development and Smart Growth. This significantly improved the quality of geographical studies, opened new opportunities for doctoral students in the field of application of geo-information technologies and paved the way for geographical research to the „Smart Geography". Proof of this is the contribution of scientists of the unit in books such as „*Sustainable Mountain Regions: Challenges and Perspectives in Southeastern Europe*" (Koulov and Zhelezov 2016), „*Climate Change Adaptation, Resilience and Hazards*" (Leal et al. 2016), „*Sustainable Development in Mountain Regions. South Eastern Europe*" (Zhelezov 2016), „*Water Bankruptcy in the Land of Plenty*" (Poupeau et al. 2016), „*Articulations of Capital: Global Production Networks and Regional Transformations*" (Pickles et al. 2016), „*Traditions and Innovations in Contemporary Tourism*" (Vodenska et al. 2018) and so on.

This brief analysis shows that, while in the period up to 1989, geographical research in the institute has been focused primarily on the study of the territory of Bulgaria. Over the past three decades, the geographical science in BAS successfully integrates into the European research area and transferees new knowledge for Bulgaria.

"Konstantin Preslavski" University of Shumen

The establishment of a faculty, affiliated to the Sofia University "St. Kliment Ohridski" in 1964 in the town of Shumen, marked the beginning of the training of students in geography in north-eastern Bulgaria. This process is connected with attraction of the teaching staff of the country's leading lectures on subjects in the specialty "Geography and Turkish language". The professor in geography Ignat Penkov was appointed as the Dean of the Faculty. At the same time, the Department of Geography was created, headed by the senior lecturer Tsanko Murgin and later by Prof. Martin Glovnija. In 1973, as a result of structural changes in the Pedagogical Institute, specialty „Geography and Turkish language" was closed. The higher education in geography in Shumen is renewed in 1991. Then starts new specialty—„Biology and Geography", thanks to the efforts of Prof. Veliko Velikov and the Rector of the higher school, the biologist Prof. Delcho Kamenov. Number of prominent scientists-geographers such as Prof. Nikolay Michev, Prof. Dimitar Toplijski, Prof. Stephan Karastoyanov, Prof. Doncho Donchev, Prof. Todor Krastev, Prof. Slavcho Slavev, Prof. Tsanko Tsankov and others are attracted for lecturers. In 2002, with the active support of Prof. DSc. Todor Krastev, at the Department of Geography in Shumen University „Bishop Konstantin Preslavski" began the training of students in specialty "Tourism" (Vladev 2011c, 2016).

The development and updating of lecture courses on geographical disciplines in the department goes in parallel with the regional studies in north-eastern Bulgaria and in other regions in the country. Successful are the results of field research with application of the regional morfostruktural and morfoskulptural analysis. The scientists of the department contribute to the application plate-tectonics model to clarify the development of landscape in the eastern part of the Balkan Peninsula. They conducted extensive research on the socio-economic development of northeast Bulgaria with a focus on demographic processes and town planning. Geographers from Shumen University work in collaboration with colleagues from other geographical units in the country, and this leads to the continuous enrichment of the thematic and the theoretical base of teaching.

In the Department of Geographical Sciences at the Shumen University there are nine professors and associate professors, three assistant professors and Ph.D. students. At present, Department of „Geography, Regional Development and Tourism" carried out training of students in four undergraduate majors: „Geography and regional policy", „Geography and Biology", „History and Geography" and „Tourism", and four masters programs: „Applied Geography and GIS", „Regional Development and Tourism", „Geography and Interactive Education" and „Local area studies". In the department graduate students are trained in „Teaching Methodology of Geography". The faculty staff trained students from other courses at the Faculty of „Natural Sciences" and the Faculty of „Humanities", as well as in undergraduate and graduate programs in "Ecology and Environmental protection", „Geodesy", „Meteorology", and so on.

Research activity of the geographers from Shumen University is mainly in the field of physical geography, demography, pedagogy of teaching geography and tourism, studying mainly the geological and geo-morphological development of parts of northeastern Bulgaria, the eastern Balkan mountains, eastern Fore Balkan range, the Black Sea coast, as well as the specifics of climate change in these regions of the country. They also include analyses of the adverse and risk processes and phenomena in northeastern Bulgaria and their reflection on the socio-economic development, land-use and tourism resources. The results of these studies have been published in dozens of scientific monographs, among which are "*Landscapes and Climate of Bulgaria*" (Velikov and Stoyanova 2007), "*The Specifics of the Bulgarian Coastal Area*" (Penerliev 2012), "*Modern Aspects of the System of Education in Geography*" (Vladeva 2016), "*Tourism—modern theoretical aspects*" (Penerliev 2016), "*Electronic Atlas with maps of the actual gradients in the basins of the rivers Golijama Kamchiya and Provadiya*" (1:25,000 M) (Vladev 2018), "*Morphostructure Map of Rila-Pirin Mountains Range*" (Tzankov et al. 2017), "*Morphostructural Map of East Fore Balkan*" (Stankova et al. 2018) and other.

Priority issues in the field of geographical education are: the application of interactive methods in teaching geography, didactic-geographical interpretation of space, projects-based geographical education and interdisciplinary approach in teaching natural sciences. Teaching staff of the department supports the learning process on contemporary level, by issuing and updating of textbooks and teaching-aid materials. There are 10 textbooks published by the faculty staff: General Geodemography (2003), General Climatology and Hydrology (2004), Geography of the Balkan Countries (2006), Natural Geography of Bulgaria and the Black Sea. Part I—General Characteristics of the National Geographic Space (2008a), Geography of Tourism (2011), Natural Geography of Bulgaria and the Black Sea Part II—

Regional Characteristics—Natural Areas (2011b), Short Terminology Reference in Geology and Geomorphology, Vol. I, Tourism Resources of the Balkan Countries (2014), Fundamentals of General Geology and Geomorphology (2017) and so on.

Despite the problems over the years, the geographical science in Shumen University managed to preserve and develop, thanks to the work of the lecturers and the objective need for training in higher geographical education in the region.

"St. Cyril and St. Methodius" University of Veliko Tarnovo

Beginning of the academic geography in St. Cyril and St. Methodius University of Veliko Tarnovo was initiated with the creation of the Department of Geography at the Faculty of History in the fall of 1984. Its first Dean was Prof. Marin Devedzhiev. The goal in front of the newly created department was to provide geographical knowledge for students from specialty "History and geography", and later in "Geography and Geo-ecology" and "Geography". Violeta Blagoeva, Prof. Ivan Markov, Prof. DSCc. Atanas Dermendzhiev, Assoc. Prof. Ivan Penkov, Prof. Angel Zvezdarov, Prof. Rumen Yankov, Prof. Veliko Velikov, Assoc. Prof. Nikolai Monchev, Prof. Stella Dermendzhieva, Assoc. Prof. Trifon Kadev and Prof. Vasil Doikov initiate the foundation of the geographical school in VTU (Petrov and Sabeva 2014). In the course of his 34-year-old development, the Department of Geography has established itself in the structure of national higher education, following the European standards in higher education and science. Continuity and adaptation to changing conditions allow the expansion of the department. The current faculty staff includes 16 academic teachers, including three professors, one of whom is DSc., seven associate professors, six young scientists, as well as eight Ph.D. students.

Currently, the teaching process is carried out in three professional areas („Earth sciences", "Education" and „Education sociology, anthropology and cultural studies") and in five accredited undergraduate programs: „Geography", „Regional development and geo-economics", „Pedagogy of teaching in history and geography", „Pedagogy of teaching in Bulgarian language and geography" and „Cultural tourism". The Masters programs offered by the Department are: „Regional development", „Geography and economy", „Geographical education", „Civil and intercultural education" and „Cultural tourism". The University is accredited to train graduate students in the following doctoral programs: „Human geography", „Physical geography and landscape science" and „Methodology of teaching geography".

Department of Geography at the VTU carried out extensive research work, which is illustrated by its faculty over 1000 scientific publications. Of these 150 are monographs, books, textbooks and educational aids materials. Many of the academic textbooks are used by students and teachers from across the country. Research activity is mainly in the field of the basic geographical topics—regional studies, methodology of teaching geography, environmental security and tourism. An important place in the research takes the development and realization of national and international research projects, participation in international scientific forums, expeditions and field studies, and practical training with the students. Bilateral agreements or Erasmus and Erasmus + at the department are taught for students from Spain, Belgium, Poland, Lithuania, Kazakhstan, Macedonia, and so on. Scientists from the department are specialized in Russia, Ukraine, Portugal, Spain, Austria, Poland, Germany, Romania, France and Belgium. Methodological Centre, and Laboratory of geographic information systems, as well as a Centre for Geo-archaeology and Archaeological Modelling are found in the department.

Department of Geography performs responsibly its mission dedicated to high-quality training of the students, generating new geographical knowledge. It is an example of interdisciplinary scientific links with good traditions in Bulgarian education and classical research.

South-West University „Neofit Rilski" in Blagoevgrad

The South-West University „Neofit Rilski" (SWU) is one of the largest universities in the country and has established itself as a leading educational and scientific centre in the region. For over 40 years, it offers education to students and graduate students by 30 professional branches and carries out active scientific research at an international level.

Education of students in geography at the university began in 1993, on the initiative of the geographer Prof. Dimitar Stoilov. The geographic unit is created at the Department of "Engineering Ecology and Geography" in Faculty of Engineering and Pedagogy. Prof. Hristo Hristov becomes first lecturer. At this stage the need of professors for training in geography is filled by attracting guest lecturers, mainly from the Institute of Geography (BAS) (Ivan Vaptsarov, Gesho Geshev, Marina Yordanova, Svetlin Kiradzhiev, Milko Mihajlov and Emil Dimitrov) and Sofia University (Neno Dimov, Todor Hristov, Mimoza Konteva, Narcis Gadev). Cartography subject is taught by Prof. Nicola Bambaldokov, head of section "Cartography" of the Research Institute of Geodesy and Photogrammetry.

In 2001, the department was renamed „Geography, Ecology and Environmental Protection" (GEEP) and passed in the structure of Faculty of Mathematics and Natural Sciences of the University. The capacity for research and training of the unit increased steadily since then, to reach 15 faculty members of whom 6 are qualified in geography and the rest are ecologists, geologists and geodesists. There are 11 Ph.D. students graduated in the department. Heads of the Department over the years were Prof. DSc Hristo Hristov and Assoc. Prof. Mihail Mihaylov and from 2012 onwards Assoc. Prof. Konstantin Tyufekchiev (http://www.swu.bg).

Currently the department is training students in four bachelor programs (Geography and Regional Policy, Ecology and Environmental Protection, Pedagogy of Geography and History Education), four master programs (Natural and Historical Heritage, Regional Development, Ecology and Environmental Protection, and Geographic Information Systems) and in three doctoral programs (Economic and Social Geography, Physical Geography and Cartography and Thematic Mapping).

Over the years, the research infrastructure was significantly enriched and renewed. There is GIS Lab, Laboratory of Climatology and Hydrology with specialized equipment, Laboratory of Geology and Geomorphology, centre for geo-ecological monitoring, data processing and analysis of remote sensing information with specialized software, a geological collection with valuable mineral, fossil and rock samples, and so on. Part of this equipment is used in the educational process in the practical exercises and field work.

The faculty staff and students actively participate in many national and international research projects, as well as those funded by the University. Some of them are with the focus on field studies of the Highland landscape of Durmitor Mountains and Prokletija, on the territory of Montenegro and Albania. The main scientific directions, which employ geographers in Blagoevgrad, include the two main branches of geography—physical geography and economic and social geography. In the field of physical geography, research and publications in climatology (changes of temperature and precipitation) are leading, followed by those of geo-morphology (mountainous, contemporary and relict glaciation, periglacial and karst geo-morphology and risk geo-morphological processes) and geo-chemistry of landscapes (landscapes, pollution of soils, water and bottom sediment with heavy metals and radionuclides, etc.). In the field of economic and social geography, the leading publications are on regional development and policy, problems of rural areas, cross-border cooperation in the Balkans, regional socio-economic geography of Bulgaria, alternative tourism, migrations, population mobility, urbanization, population and settlements, sustainable development and demography. Many of the faculty are authors of publications in the field of training in geography and geographic education, e-learning, and so on.

Towards Smart Geography

We are living in the time of global changes and they are even more rapid in the twenty-first century. Technological development, particularly information, including geo-information, technologies are radically changing the ways in which economic, social and public systems function. Our conceptualizations of basic geographic notions, such as „place", „space", „environment", „sustainability", and so on, are also constantly being amended. Geo-spatial databases, generated by the new technology, play an increasingly important role in the choice of policies for governing regions, as well as managing and adapting to the consequences of global change. It is the geographers, who play a key role in the utilization of the "flood" of geo-spatial information to uncover processes and interconnections in geo-systems, evaluate and predict their sustainability and future development. Research on ecosystems and their services has proven its value to environmental protection and sustainable use of natural resources. The complex interdependence among these processes raises a number of geographic problems that require innovative approaches and solutions.

Geography of the twenty-first century is expected to: (i) facilitate the development of human capital and the knowledge society; (ii) offer place-specific solutions for sustainable regional development; (iii) contribute for utilization of the planet's natural and human capital to improve social wellbeing. In order to achieve this, we need smart spatial solutions that can cope with the complex problems.

The review of the past and a short analysis of prospects of geographical science show that while researching the changes in the world around us, the geography itself is changing and evolving. Entering into the other areas of knowledge, geography attracts the interest of scientists from these areas to the geographical aspects of their research, and thus provides a platform for the expansion of interdisciplinary research and opens up new opportunities for their innovative application. At the same time, more and more studies directly or indirectly address different geographical problems and this stems from the constantly growing need of geographical knowledge in terms of ongoing dynamic changes in the modern world, as well as by the rapid development of geo-information technologies. A very important role in this process has the cooperation with national and international geographic community and relationship with the higher geographic education.

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Smart Geographies and the Political Economy of Innovation and Inequality

John Pickles

> The regional problem is not a problem of the region…. Not a problem of lack….
> The regional problem is a problem of London!.
> Doreen Massey (1979).

Abstract This chapter focuses on recent changes in the structure and practices of geographies of global economic governance that have become more influential in response to the financial crisis of 2008. At their core is a 'smart specialization strategy' aimed at revitalizing core economies and flexibilizing regional development pathways through targeted research and innovation investments. While ostensibly directed at regionally and locality sensitive development strategies, the paper argues that these smart specialization initiatives intersect in important ways with the growing economic and political dominance of large cities, especially capital cities. Such primate city concentration of wealth, political influence, and social capital poses real political risks in shaping future political and economic agendas, and efforts to manage regional inequalities.

Keywords Regional development · Capital cities · Concentration · Smart specialization · The regional problem

Introduction

In recent decades I have been trying to understand the ways in which post-socialist transitions in Central and Eastern Europe have been shaped by a combination of local and national actors, EU institutions and policies, and the practices and regulations of the global manufacturing and trading system. Throughout, I have been

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interested in the local consequences of and responses to changing geographies of economic governance. Variously, I have thought about this through the political economy of transitions and transformations (Pickles and Smith 1998; Paskaleva et al. 1998; Pickles 2008a), the politics of state enterprises (Pickles 2008b), environmental politics and social movements (Pavlinek and Pickles 2000), and EU enlargement and post-socialist integration (Pickles and Smith 2016).

In this paper, I focus on these changes in the structure and practices of these geographies of global economic governance that have become more influential in response to the financial crisis of 2008. At their core is the EU commitment to a 'smart specialization strategy' aimed at revitalizing core economies and flexibilizing regional development pathways. In this renewal initiative smart specialization is seen as "a strategic approach to economic development through targeted support to research and innovation…. More generally, smart specialization involves a process of developing a vision, identifying competitive advantage, setting strategic priorities, and making use of smart policies to maximize the knowledge-based development potential of any region, strong or weak, high-tech or low-tech" (EC 2019).

Since the financial crisis of 2008, smart specialization initiatives—what Massey et al. (1992) referred to much earlier as 'high-tech fantasies'—have refocused public policy in the EU and member states around programs of 'Knowledge for Growth' (Capello 2014) in order to enhance productivity and innovation in industry (Lopes et al. 2018). These initiatives have reframed EU Regional Development and Cohesion policies and they are centered on expanded, and well-funded, commitments to technology, knowledge-based growth, and digital futures. In this paper I am interested in the ways in which this nexus of programs and commitments is reinforcing long-term trends in Europe in which large cities, particularly capital cities, have become relatively more important centers of capital accumulation and political influence in ways that may run counter to social and spatial inclusion imperatives. We might think of this re-configuring of capital and political influence around primate cities as either one response to the financial crisis of neoliberal globalization or a direct consequence of it.

This paper focuses on the interaction among neoliberal restructuring, smart specialization programs, and the growing primacy of capital cities in European national space economies. I outline this change and then illustrate its emerging discourses through some illustrative evidence from Central and Eastern Europe. I conclude with a return to Doreen Massey's challenge to traditional regional development analyses of 'the regional problem'.

Smart Specialization and the Contemporary World Economy

The Changing Political Economy of Economic Governance

When Brenner (1998) referred to 'global city-centric capitalism' or what Ward and Jonas (2004) called 'city regionalism' they were signaling a more general change in the structure and operation of the global economy. Increasingly the city was becoming—or had come to be seen as—the dominant dynamo of economic innovation, growth, and accumulation. For Brenner the growing importance of global city-centric capitalism was not necessarily eroding the institutions of the state, but was instead rearticulating and reterritorializing space in ways which enhanced the 'global city' as a node of post-Fordist accumulation. As Allen Scott (2001: 4) suggested: "city regions are coming to function as the basic motors of the global economy, a proposition that points as a corollary to the further important notion that globalization and city-region development are but two facets of a single integrated reality."

In the face of the global financial meltdown of 2008, long-standing EU commitments to neoliberal trade policies and economic integration morphed easily into the emerging logics of knowledge economies, financialization, intelligent growth, and social capital concentration to re-position the city at the heart of regional policy. In this dynamic, as Ivan Fernandez, Industry Director for Frost & Sullivan Australia & New Zealand suggested, "Cities will collaborate with each other to drive smart city innovation by entering into partnerships with each other. Technology and ecosystem convergence, collaboration and partnerships between stakeholders from different industries, such as energy and infrastructure, IT, telecoms and government will also expedite the delivery of integrated services." https://www.newswiretoday.com/news/148711.

In this vision, the city, and especially the capital city, is being re-positioned as the dominant location for regional innovation and growth. As Massey (1973, 1978, 1979) has shown in her studies on the role of London in British regional development policy, the economic and political dominance of the capital city shapes national policies and investments in regard to everything from taxes, wages, transport, educational, and social policies. With growing transnational economic networks, the capital city—in a network of capital cities and large city regions—has come to dominate not only the economic performance of the national economy but also the political agenda in that space economy. Access to government combined with historical manufacturing power and new service-knowledge industries to consolidate a nexus of spatial power.

Neoliberalism and Structural Adjustment

Since the re-orientation of post-war Bretton Woods Institutions in the 1980s, neoliberal economic programs gained almost hegemonic status in Western economic policy.

As centrally planned economies in Eastern Europe gradually shifted from their rapid growth phase of the 1960s and early 1970s to increasingly constrained economies of shortage and insufficient re-investment, Western economies struggled against external oil shocks and internal stagflation. The result in the West was a rapid alignment of economic governance around the rolling back state regulations and social protections and the rolling out of policies that privileged finance capital and specific business sectors (Peck and Theodor 2015). Organized around basic premises of the 'efficiencies' of private property regimes and the inefficiencies of state-owned enterprises (whether in state socialist countries or social welfare Britain), capital was swiftly reorganized around a global—albeit highly regionalized—expansion of manufacturing and trade (see Pickles and Smith 2016), a growing dominance of financial and rentier capital, and a declining share of profits to wages. Deep losses of employment and the legitimization of austerity programs followed. These began with the attacks on strong trade unions, such as the National Union of Mine Workers in the UK and the air-traffic controllers in the USA, and soon expanded to the bargain basement sales of state properties such as the mines, railroads, and airways. Social welfare was re-defined as 'problem' instead of 'solution' to economic inequalities. In CEE the transition was delayed, but the process—when it came—operated with a similar logic and was implemented much more quickly, and with much sharper consequences for social and regional equality and well-being (Pickles and Smith 1998).

The complex series of discursive and political shifts that occurred in this process transformed the nature and meaning of regional policy. In Western economies hi-tech fantasies and value chain upgrading emerged as the foundations of economic policy (Massey et al. 1992). Regional policy was re-defined away from earlier logics of system integration and socio-spatial justice to ones of regional growth poles and peripheries characterized as lack, absence, and need (Massey 1979). In CEE in the 1980s the fiscal crisis of the state deepened the legitimacy crisis of party control, *nomenklatura* and security personnel were able to secure the channels for capital flow, and large amounts of state funds were shipped out of the country. Under-investment in large state enterprises increased the environmental problems while the ability to provide consumption goods declined, and the explanations for the decline and the responses to it were passed off as the failure of state ownership.

After 1989, in economies, throughout Central and Eastern European countries, structural adjustment policies—thoroughly consolidated in Western economies (particularly in the USA and the UK)—were readily unrolled and embraced. Quickly articulated with the tunneling of state property and funds, structural adjustment policies were literally introduced overnight. With its technologies of privatization, de-regulation, and liberalization underscored by an economics of capital growth, trickle-down, and the cleansing effects of austerity, what was referred to by some as 'wild West' 'cowboy' economy enabled partial enrichment amidst widespread economic hardship.

There is much to be said about these parallel histories, but for my purposes here it is sufficient to note that the genuine excitement and entirely reasonable expectations that accompanied the accession and enlargement of EU member states, particularly in 2004 and 2007, in turn fueled a very particular understanding in Brussels and member state governments of the policies and instruments of economic integration and regional development.

The old world of trade (pre-1980) in finished goods produced by national industries, often based on import substitution policies, shifted in the 1980s to a more global understanding of international and regional comparative advantage. Trade liberalization and global trade rules guided national policies to open product and capital markets, and countries saw the expansion of their trade in intermediate goods. Correspondingly firms had to expand their international profiles to capitalize on the economic opportunities of the global shift (Dicken 2015), to take advantage of the deregulation of capital and banking controls (Pickles 2008a), and to manage the complex global value chains that resulted from export-oriented industrialization (Pickles and Smith 2016). By 2013, 80% of world trade was occurring through global value chains of such interlocked companies. Trade in intermediate goods grew from 20% in 1990 to 40% in 2010, and is predicted to grow to 60% in 2030 (UNCTAD 2013).

Smart Specialization as Economic Governance

In the European Union, smart specialization was institutionalized in response to the structural and institutional deficiencies that became clear by the 2008 crisis. Several key programs were introduced. In 2009, the *Barca Report to the Commission for Regional Policies* (Barca 2009) pointed to the urgency of making clear distinctions between ‘efficiency’ objectives in EU economic policy and ‘social inclusion’ goals to reduce social and regional inequalities (p. viii). According to Barca this required a thorough-going reform of Cohesion Policy through 10 pillars aimed at creating much greater clarity and coherence about territorial and place-based development. Launched in 2010 the *EU Cohesion Policy Reform* aimed to promote the development of lagging regions and reduce disparities across the EU, and it did so, in part, by recognizing the need to invest in all regions, tailoring development investments and programs to specific regional needs, and fostering local involvement in them. The parallel *Europe 2020* (EC 2019) was a long-term vision to create smart, sustainable, and inclusive growth. The report contained seven flagship initiatives to boost innovation including proposals and programs on the ‘*Innovation Union*’, “A digital agenda for Europe’, ‘An industrial policy for the globalization era’, and ‘An agenda for new skills and jobs.’ [http://www.efesme.org/europe-2020-a-strategy-for-smart-sustainable-and-inclusive-growth]. The primary goals of the ‘Innovation Union’ are to make Europe into a world leader in science and technology, and to foster high-technology and knowledge-intensive industries.

As an assemblage of these and related programs and policies, smart specialization emerged as the driver of EU Cohesion Policy and the European Commission ‘Innovation Union’ initiative. As McCann and Ortega-Argiles (2015: 1292) have argued, “The aim of the Innovation Union initiative is to foster the dissemination and the realization of EU-wide economies of scale in high-technology and knowledge-intensive sectors, while the aim of the EU cohesion policy is to *promote the development of many of Europe's weaker regions*." (emphasis added).

These two goals—hi-tech innovation regions and the development of lagging regions may—appear to be at odds with each other, but for McCann and Ortega-Argiles (2015: 1292; also OECD 2013) "the distinctive feature of the smart specialization concept is that it builds on these literatures in order to provide a clear policy-prioritization logic which is well suited to promoting innovation in a wide variety of regional settings, and in particular in the heterogeneous environment of European Union (EU) regions." The result is a set of programs that, in their view, allow for innovation regions while simultaneously underwriting a variety of regional development paths. As Ballan et al. (2018: 1) have recently argued, smart specialization strategies offer "a vision of regional growth possibilities built around existing place-based capabilities." Identifying existing regional strengths, identifying hidden opportunities, and focusing on place-specific capacities, smart specialization programs seek to support and enable the development of high value-added activities without the presumption that regional development must follow a particular path or model. The result is seen to be, as the OECD (2013) suggested, the emergence of innovation-driven regional growth.

This multiplicity of evolutionary regional paths may well emerge from these programs, but there are several reasons to be skeptical. First, in their description of regional futures in the EU, Camagni and Capello (2013) had already pointed out how the program had created some deep underlying regional disadvantages. In their characterization of regional capacities across the EU, they distinguished five types of regional assemblage; science-based areas; applied science area; smart technological application areas, smart and creative diversification areas, and finally what they refer to indicatively as imitative innovation areas. These latter were further disaggregated into specific characterizations of four likely regional economic futures: (i) regions with low knowledge and innovation intensity; (ii) regions with low levels of entrepreneurship and creativity; (iii) regions that are highly attractive for FDI; and (iv) regions that have some innovation potential; the EU itself.

The characterization of regional economic potentials and evolutionary futures in these terms may well have political power, but they do not adequately take into account the urban–rural divides that characterized post-socialist landscapes after 1989 or the processes of city-centric growth that are fueling regional underdevelopment as skills and capital concentrate in the city at the expense of small towns and rural areas. In each VISEGRAD country, as well as in Bulgaria, strong and extended state-owned informatics and computer sectors were abandoned or disassembled and integrated manufacturing enterprises in textiles, clothing, and shoes were broken up, assets were stripped, and even state policymakers saw no future in them (Pickles and Smith 1998). In their place, low-cost assembly contracts particularly from German and other EU manufacturers soaked up free labor pools at rock-bottom wages. In this way, the rapid growth in FDI that followed 1989 and particularly after accession to the EU in 2004 and 2007 led to distorted forms of regional economic development, trapping peripheral areas in export contracting relations that provided few, if any, learning and upgrading opportunities.

Inward investment did create employment opportunities, supported skill development, and transferred technology (such as the Czech and Slovak automobile industry (Pavlinek 2019)). But such inward investments were offset by the enormous outflow of profits and other property incomes. In Hungary, net outflows of profits and other property incomes were nearly double those of net inflows (Fig. 1). Even more shocking was Czechia, where net EU inflows amounted to just less than 2% of GDP, but net outflow of profits and other property incomes was nearly 8% of GDP. CEE essentially became tributary to West European companies, particularly after the 2008 financial crisis (Fig. 2) (see also Smith et al. 2014).

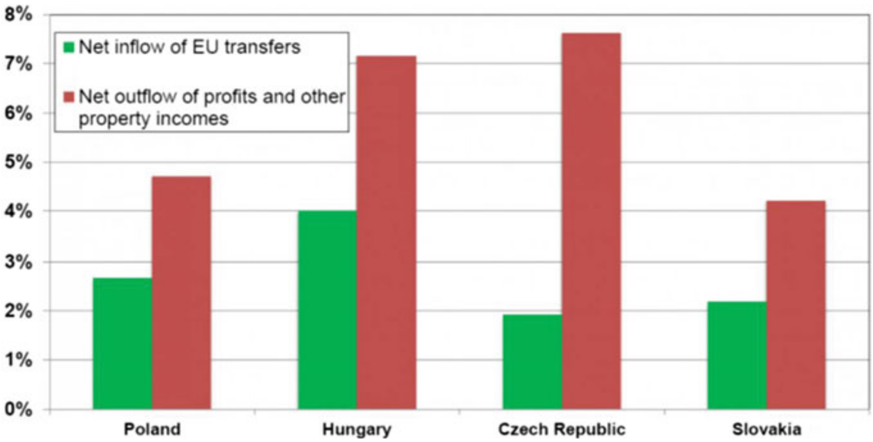

Fig. 1 Inflows versus outflows in Eastern Europe (% GDP, annual average, 2010–2016)

Relative share of GDP and employed of the metropolitan regions in selected CEE countries (%)						
Years	**2000**		**2008**		**2013**	
Indicators	**GDP**	**Employed**	**GDP**	**Employed**	**GDP**	**Employed**
Bulgaria	50	44	61	49	63	50
Czechia	62	58	65	59	65	60
Croatia	46	--	48	46	49	47
Hungary	60	--	63	59	63	58
Poland	60	52	61	54	61	55
Romania	49	37	53	40	56	40
Slovakia	38	31	38	31	40	32

Fig. 2 Relative share of GDP and employment of the metropolitan regions in selected CEE countries (%). *Source* EUROSTAT

Re-Thinking the Regional Problem

In her questioning of 'the regional problem', Doreen Massey (1973, 1978, 1979, 1987) made clear that the logics of regional 'lack' that under-pinned so much post-War British regional development was not sufficiently contextual, eliding the wider relations in the space economy. For Massey regional decline was not first and foremost a problem of 'lack', not a problem of the lagging region itself, but more importantly a result of policy choices that favored particular fractions of capital, specific regions (particularly the hyper-growth of London and the Southeast), and assemblages of power that had come to dominate decision-making around increasingly taken-for-granted and 'normalized' liberal and financialized models of the economy and individualized models of social life. The result was the growing dominance of the global city of London and the dynamic of its over-heated property markets in shaping the national agenda and restructuring the geographies of opportunities across the country. Increasingly supported by investment, tax, and credit policies aimed at solving the challenges of growth in London and in the Southeast, other regions experienced intense disadvantage and under-development.

In response to these dynamics Massey asked how a neoliberal commitment to London's financial markets was solidified and normalized by large-scale effort and investment of resources to produce a new border of neoliberal commitments. That border consolidated the boundary lines around one set of political beliefs, economic opportunities, and likely futures. Doreen saw this border—like all borders—as both political and material. Here, regional development programs organized around 'high-tech fantasies' have a series of interconnected indirect consequences. First, the need for investment capital in new industries gives a privileged position to financial and banking sectors. These in turn have gained influence in shaping housing, tax, transport, and trade policy relative to older forms of capital and social organizations. Second, the commitment to innovation regions and high value-added industries has also enhanced the role and influence of education in regional development. As Rehak (2019) has shown for Slovakia, even where the government has invested in higher education institutions to encourage the economies of peripheral regions, graduating students neither return to their homes nor remain in the university towns. Instead, they take positions for which they have been trained, but in Bratislava. Those studying in Bratislava similarly do not return to their home regions or take positions in peripheral regions, but take up work in the booming knowledge industries of Bratislava.

As with London, capital cities like Bratislava seem to be differentially advantaged by this shift to knowledge industries and their commitment to innovation-led growth. Such smart specialization strategies thus carry within them a series of important spatial implications, perhaps the most important of which is that—despite the claims for place-based and regionally diverse possibilities and pathways—metropolitan regions have become ever more significant sites of opportunity and wealth. Across Central and Eastern Europe metropolitan regions have increased their share of GDP and employment at the expense of rural areas and smaller towns.

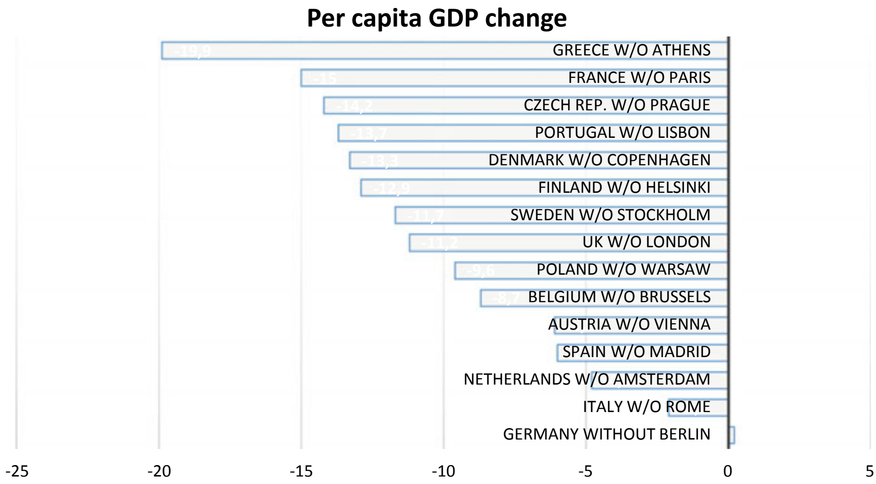

Fig. 3 The economic power of capital cities: reduction in GDP per capita if the capital city were removed from national GDP (2015). *Data* Cologne Institute for Economic Research based on Statista 2016

The situation is even clearer when looking at the growing economic power of *capital* cities within the national space economy. With the exception of Berlin and to a lesser extent Rome—capital cities with particular governmental roles in their respective countries—capital cities account for ever larger shares of per capita GDP (Fig. 3). They literally are becoming the cities of capital, accounting for as much as 15–20% of per capita GDP. Their effects on regional development are becoming even clearer as peripheral regions age with the outflow of younger people and become relatively poorer as wages and wealth accrue increasingly to residents of the capital city.

Conclusion

In his 1975 analysis of Athens, Guy Burgel pointed out that its wealth appeared to be "based much more on consumption than on production, its dynamism supported by acquired wealth rather than by the advantages of undisputed location." He continued "The observer cannot simply understand the budgets of either the conurbation or of its inhabitants, so disproportionate are the resources to the expenditure…. Its mode of growth makes Athens representative of a new generation of urban centers."

Capital city growth as a new generation of urban centers was also highly disturbing for Gottmann 1977: 240) who cautioned that there were very real political risks of such primate city concentration in shaping regional futures and political agendas: "The distrust of the turbulence and power of the organized interests in a large commercial and industrial metropolis has long been deeply ingrained in the political process, especially of democratic systems. Representatives of the people who live outside the primate city are naturally suspicious of the wealth, greed, ambitions, adventurous spirit of individuals and organizations normally concentrated in great, bustling economic centers with far-flung networks of interests."

At a time when far right political parties and illiberal democracies are seemingly become more attractive to a larger part of the electorate, especially in smaller towns and lagging regions, it behooves us to take seriously Gottmann's caution and think very carefully about the embedded assumptions and regional consequences of smart specialization programs and their high-tech fantasies.

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Evaluate Turkey's Climate Classification by Clustering Analysis Method

Barbaros Gönençgil

Abstract Climate change, which has become one of the most important issues of our time, is spoken and evaluated in many environments. It is a fact that this issue, which is also discussed outside the scientific fields, is not known enough by the society. Evaluation linking climate change to human impact is one of the most important evidence of this lack of information. Those who work in climate studies, especially geographers, know that climate change has anthropogenic causes as well as natural causes. Another issue here is what is changing. So, what is the climate feature and how can we show that there is a change in these features. In this respect, climate types and climate classifications are some important issues. General climate characters can be classified by some methods. Accordingly, climate-related researchers can make evaluations for a country or region based on these classifications. However, climate is a dynamic phenomenon. Consequently, classical climate classification methods now require an update. Although different studies have been carried out on climate classification, we aim to bring a different perspective to the classical climate classification by cluster analysis. Turkey, due to its special location, is a country with many different climate types. The most important reason for having different climate classes is the mathematical location, the effects of air masses and fronts, and a special topography. Classification of Turkey's climate has been under many studies since the 1900 s. In particular, these studies contributed significantly to the scientific sense since the 1950 s.

Keywords Climate · Classification · Cluster analysis

Introduction

Climate classifications are done using different methods in order to know the properties of a region in terms of temperature and precipitation in long timescales. Climate classification is widely used for planning and forecasting in many disciplines (meteorology, climatology, agriculture, irrigation, tourism, etc.). There are many global

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climate classification systems based on empirical and observational data in the past. Many of these classifications have been adapted to the present day by making some updates.

Today, there is a need for a number of revisions in climate classification based on increasing environmental problems. The most commonly used global climate classification methods are Köppen, De Martonne, Thornthwaite. These methods have been applied to many local scales by expanding or revising. Nowadays, a number of revisions are needed in climate classification based on increasing environmental problems. The chronology of commonly used methods for global climate classification is as follows: Köppen (1900), Thornthwaite (1943), Strahler and Strahler (1987), and so on.

The commonly used parameters within the scope of climate classifications are precipitation and temperature data. There are many evaluations or classifications from the past to the present in global to regional scale. Climate classification made for Turkey varies from the global to the local. For example, precipitation and precipitation regime (Darkot 1943a; Tümertekin and Contürk 1960; Erinç 1965; Temuçin 1990; Çiçek 2001) and temperature and temperature regime (Darkot 1943b; Erinç 1950; Sezer 1990; Çiçek 2000; Elibüyük and Yılmaz 2012) have been examined in many studies.

General Characteristics of the Climate of Turkey

As is known, Turkey extends between 36 and 42° north parallel and 26–45° East longitude. It is located in the mid-latitudes between 30 and 60° (Fig. 1).

Fig. 1 Location map of Turkey

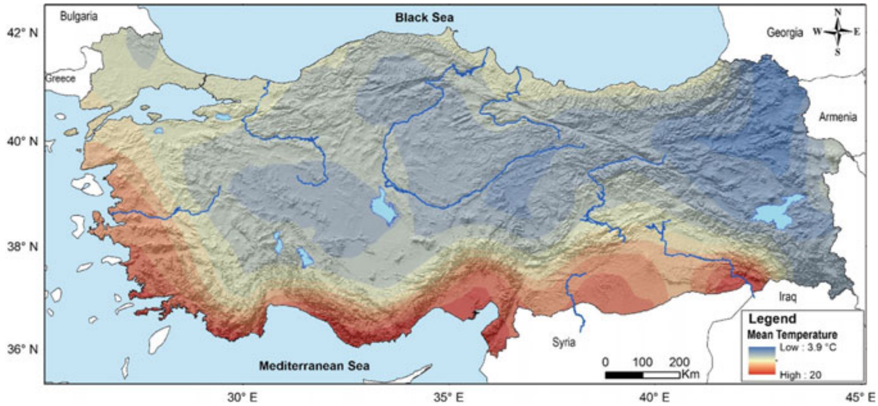

Fig. 2 Temperature distribution map of Turkey

Therefore, it falls within the temperate climates of the mid-latitudes (Figs. 2 and 3). The mid-latitudes remain within the domain of tropical air masses from the south and polar air masses from the north. This air mass shows periodically throughout the year dominance over Turkey. One's sovereignty will soon be replaced by another. In this respect, Turkey is a transit area in terms of the dynamic air conditioning. Turkey, under the influence of tropical and polar air masses, is divided into some subtypes: maritime types and continental types. Indeed, the period and types of effects of these air masses are undoubtedly not the same.

The effects of various air masses and their frequent displacement make the climate characteristics of the country quite complicated. That is because all these features of Turkey's macroclimatic conditions defined mainly and thereby shaped the seasonal variation in these different air mass types and frequencies, depending on the cyclogenesis and frontogenesis conditions that occur in the coinciding section to mid-latitudes of the general circulation.

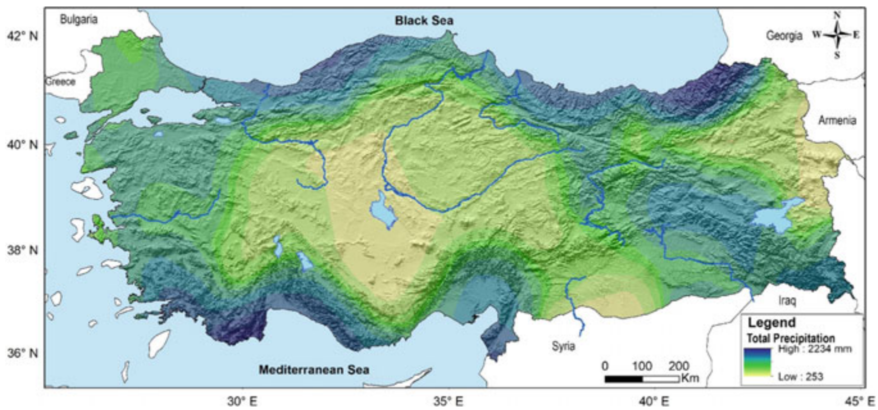

Fig. 3 Precipitation distribution map of Turkey

Factors Related to Physical Geography

Physical geographical characteristics of Turkey have important effects on regional climate differences. Factors such as elevation, orography, and continentality create thermic and dynamic modifications of macroclimate characters occurring under planetary conditions. It is possible to evaluate the effects of physical geography factors affecting macroclimate characteristics as follows:

Altitude: Turkey has an average altitude of over 1000 m, and regional average altitude is increasing from west to east (Fig. 4).

The mountains of Turkey show a wide extension in West-East direction. Elevation is influential on meteorological events such as temperature, humidity, wind, precipitation and pressure. But the most important effect is undoubtedly on the temperature. Basically, it is the increase of the climate that creates the climate differences between the regions in Turkey. In Turkey, which includes large elevation differences within short distances, significant climate differences occur within short distances in parallel with this situation.

Orography (extension of mountains and exposure): The mountains of Turkey show a wide extension in W–E direction. This prevents the N–S directional air mass movement from entering into the interior. However, air masses exceeding mountains change their character and effect due to this movement. Thus, there are strong differences between the coasts and the inner parts. For example, in Kemalpaşa (Hopa), which is the most rainfall station of Turkey, the average annual rainfall is over 2600 mm and this figure is around 300 mm in Yusufeli, just a few hours south of it. Thus, there are strong differences due to the orography and also the conditions of exposure. Similar situations can be encountered on the Mediterranean coast. However, western regions of Turkey have a different situation in this respect. As a result of the mountains stretching out to the sea in the Aegean region, the middle latitude pressure systems coming from the Mediterranean, in particular, can pass through the

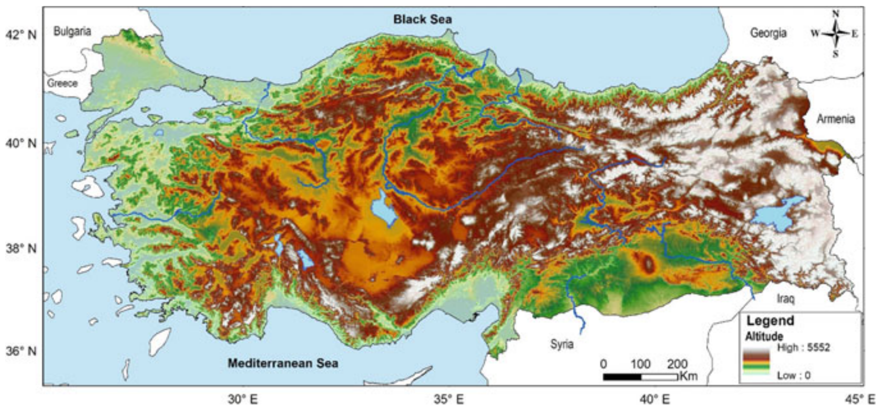

Fig. 4 The elevation map of Turkey

inner Aegean region without any change. However, the same air masses can pass the Black Sea through the Marmara region and the Straits, which are a relatively low area.

W–E extension of mountain ranges such as the North Anatolian Mountains and the Taurus Mountains may also cause an occlusion in the form of an obstacle in front of middle-latitude depressions. As a result, there are significant rainfall differences between the surfaces facing the sea and the surfaces facing the interior. Sometimes this situation causes precipitation above the expected level and brings with it floods. Orographic conditions create significant differences between the interior regions and coastal areas such as temperature, humidity, cloudiness wind direction and wind speed.

Continentalite, Land and Sea Distribution: It shows significant continental conditions due to the fact that the three sides of the Turkey are bounded by the seas and connected to Asia, which is a large terrestrial mass. However, the distance from the sea and the elevation are important for the severity of the terrestrial. As mentioned above, as a result of the extending of the mountains of the Turkey in general parallel to the sea, real sea conditions are seen in a narrow coastline. For this reason, the average annual temperature difference in coastal stations in Turkey does not exceed 20 °C, while terrestrial inland reaches 30 °C.

Stability affects the temperature conditions as well as the amount of precipitation and the shape of precipitation. Continentalite is not only effective on climate characters. It also determines the upper limit of natural vegetation and agricultural activities. This border, which can reach 2000 m in the west, can exceed 2500 m in the east. Again in the cold period due to the influence of terrestrial climates we can see different types of climate, while in summer, the temperature differences between the terrestrial inland and overheated terrains will decrease; in general, a single, Mediterranean macroclimate becomes dominant.

However, based on Turkey's current climate, we made a grouping according to the topographical features of the country, which can be assessed as follows:

Step climate: The dominant character is the semi-arid conditions. The rainfall regime is similar to that of the Mediterranean coast, but the annual rainfall is much less. The thermal character is closer to the continental conditions.

Black sea climate: Marine impact, which is characterized by a regular rainfall regime, has priority in this type. Also in this type, high rainfall for all months, relatively warm winters and hot summers are main characteristic futurities.

Mediterranean climate: There is a severe summer drought in this climate. In fact, annual precipitation is high in terms of quantity. However, a significant portion of this precipitation falls in winter.

E Anatolia climate: It is a type of continentality with snowy, frost, cold and long winters. This is the harshest of climates in Turkey. These climatic types can show in this map (Fig. 5).

There are significant differences between the methods used in climate classifications due to differences in calculation. According to the general assessment made for climate classification, humid Black Sea region, arid Central Anatolia and Southeast Anatolia and Thrace and Igdir, Turkey has a semi-arid or semi-humid climate.

Fig. 5 Climatic classification of Turkey (Erinç 1984)

Turkey's climate classification is as follows according to different methods: De Martonne climate classification has been used for many years in total rainfall (P), average air temperature (T) for many years, the most dry month rainfall (p), and the driest month average temperature (t) data (Fig. 6). With this method, Konya-Karaman-Aksaray-Niğde, Malatya, Elazığ, Şanlıurfa, Diyarbakır, Batman and Iğdır

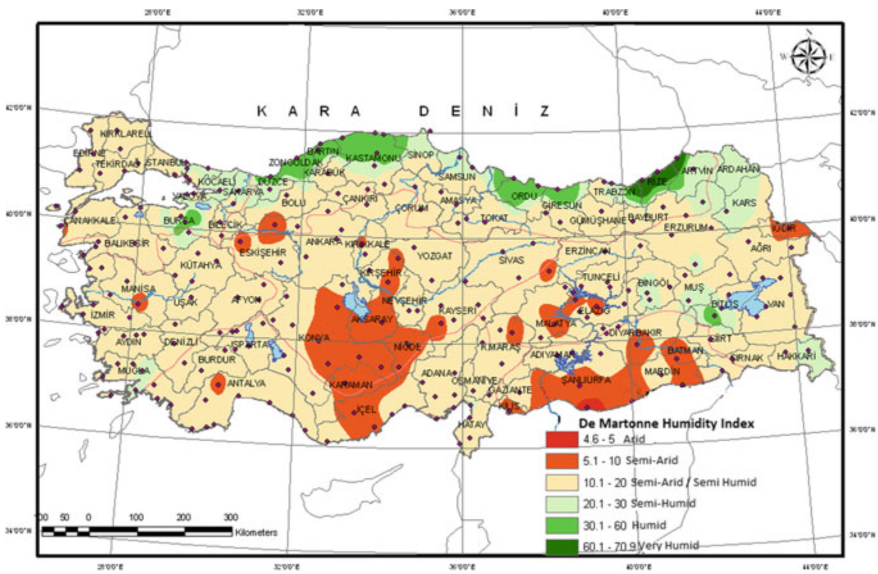

Fig. 6 Turkey's climate classification according to De Martonne method (Turkish State, Meteorological Service 2016a)

have semi-arid climates. Black Sea coastal belt has humid environment outside of Samsun. Generally, Turkey is located in the steppe and semi-humid climate category.

The annual total rainfall (P) and the annual average maximum temperature (Tm) data are used in the Erinç climate classification (Fig. 7). The months when the average maximum temperature falls below 0°C are not taken into consideration as there is no evapotranspiration. With this method, six different climate classes are calculated. It also provides information on the vegetation of the indices.

Thornthwaite's climate classification is based on the balance between precipitation–evaporation and temperature–evaporation (Fig. 8). In this method, where the rain is more than evaporation, the soil is saturated with moisture. There is an excess of water in the soil saturated with moisture. The stations in this category are therefore humid. In places where precipitation is less than evaporation, soil needs moisture. In these stations, the soil has water deficiency and the climate of the stations where the evaporation is greater than the precipitation is arid.

The monthly average temperature and precipitation data produced by Hijmans et al. (2005) offer a wide range of spatial resolution options to cover the whole world. In Turkey climate classification produced using these data only shows the general trend to reverse falling precipitation characteristics in terms of a limited area. In addition, it is a more compatible classification method for temperature. In addition, it is a more compatible classification method for temperature. Yilmaz and Çiçek (2016) studies and Hijmans et al. (2005) utilized data Lambert Cone with conformal projection monthly average temperature, and precipitation values of 805.000 points

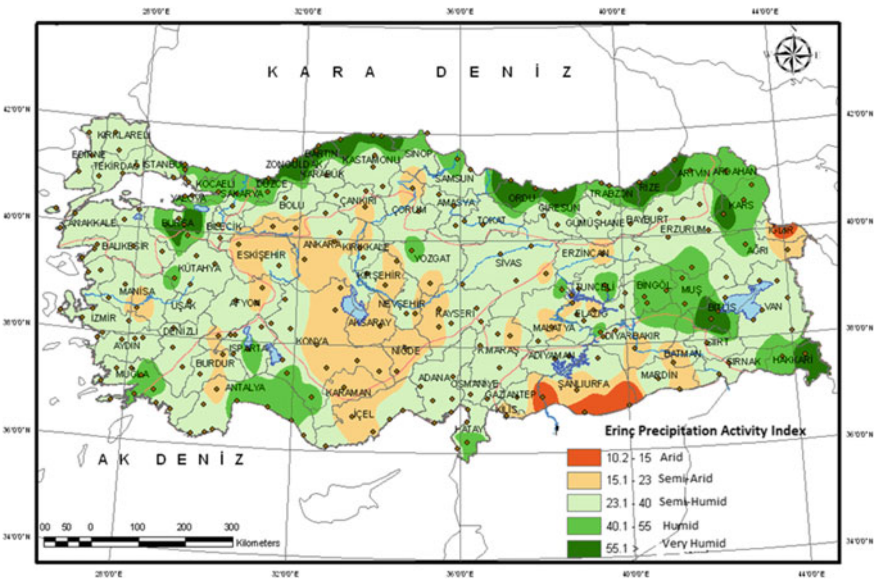

Fig. 7 Turkey's climate classification according to Erinç method (Turkish State, Meteorological Service 2016b)

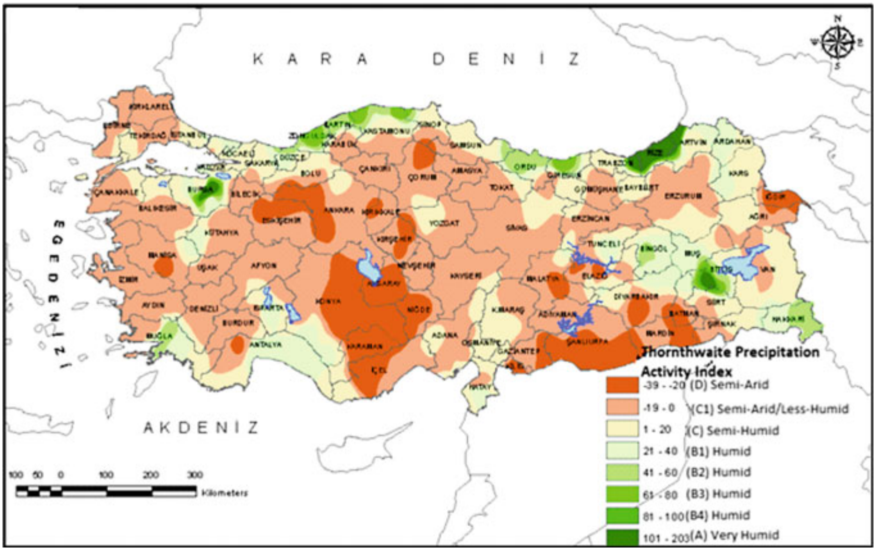

Fig. 8 Turkey's climate classification according to Thornthwaite method (Turkish State, Meteorological Service 2016c)

belonging to Turkey were obtained. In this study, eight different rainfall regimes, six different temperature regimes, and seven different drought-humidity classes were determined.

Turkey has made climate classification using different methods for multiple sites. Besides the climate classifications made by MGM, there are studies on local or regional scale. Some studies make the climate classification taking into account the results of temperature and rainfall data (Yılmaz and Çiçek 2016; Temuçin 1990; Çiçek 1996, 2001).

Climatic classification can be done by the method of interpersonal relationship analysis. Clustering analysis is one of the multivariate statistical methods. The purpose of this method is to examine the linear connection between the variables of two data sets or between the elements of two climatological data sets (Cheery 1996). With this method it is possible to make climate classification using more than one variable. For example, climate and rainfall data are evaluated together and climate assessments are made. With this method, areas with significant similarity in temperature and precipitation data present similar climate zones.

On climate classification, relationship clustering analysis for the classification of climatic regions of Turkey method has not yet been used. It is aimed to produce a climatic classification which will provide ease of application by using this statistical method in which the temporal changes of temperature and precipitation data can be taken into account besides spatial distributions.

A classification in which temperature and precipitation data are evaluated together and the effects of global climate change can be observed will provide valuable information for all kinds of planning (agriculture, animal husbandry and socioeconomic) in recent years.

In earlier studies, we only determined the spatial distribution of the extreme temperature areas in the temperature data. With this method, stations where the extreme temperatures are shared are located in the same cluster. In this way, areas with different temperature characteristics are divided into various groups.

For extreme temperatures during summer, Turkey's temperature assessment was done using the clustering method.

The number of sets for summer day index is 5. The most significant homogeneity is observed in stations in the whole coastal Aegean, Mediterranean coastal zone and in the southeastern Anatolia Region. There is a significant transition area between the Black Sea coast and the Central Anatolia Region. Iğdır has similar features with the microclimate in terms of summer day with Mediterranean and Aegean regions. Similarly, the stations in Thrace show high temperatures in the Aegean and Mediterranean regions depending on their terrestrial characteristics.

Findings

Cluster analysis is applied to classify the time series and to find out the similarities in the stations. Theoretically, there are two basic methods for cluster analysis, namely, hierarchical and nonhierarchical methods. SPSS has three different procedures that can be used to cluster data: hierarchical cluster analysis, k-means cluster and two-step cluster. If the data set is a mixture of continuous and categorical variables, the two-step procedure should be used. If the data set is small and increasing numbers of clusters are allowed, hierarchical clustering can be used. Lastly, if the number of clusters is known and the data set is moderately sized then k-means clustering can be used.

In this analysis, we use hierarchical clustering based on the measure of interval with squared Euclidean distance, which is the distance of squared distance on dimension x and y. Squared Euclidean distance is probably the most popular method used in the literature. The distance increases the importance of large distances while weakening the importance of small distance. Squared Euclidean distance can be shown as follows (Ozdamar 2002):

$$d(i,j)=\sum_{k=1}^{p} (x_{ik}-x_{jk})^2 \quad (1)$$

where x is the data matrix, i = 1,2, …, n; j = 1,2, …, n and k = 1, …, p. n is the sample size, p is the number of variables.

The visual presentation of the distance at which clusters are combined is given by the dendrograms. The dendrogram is read from left to right. Vertical lines show joined clusters. In the next section, the dendrograms and their interpretations are given for each extreme. The interpretation of clusters is given by reading the dendrograms.

According to canonical correlation analysis, Turkey precipitation can be analyzed in eight different clusters (Fig. 9a, b). When the total distribution of precipitation and clusters are evaluated together, there is a homogeneity in the distribution of the clusters. Only some stations do not have spatial consistency. The most important reason for this is the temporal variability in station data.

It is also possible to see different groups at close distances from time to time in the implementation of this method.

According to the analysis performed for the spatial distribution of temperature, five clusters were determined to be compatible. These are mostly horizontally extending from south to north (Fig. 10).

Climate classification with temperature and precipitation data can be made by clustering analysis method (in Fig. 11). With this method, it is possible to classify

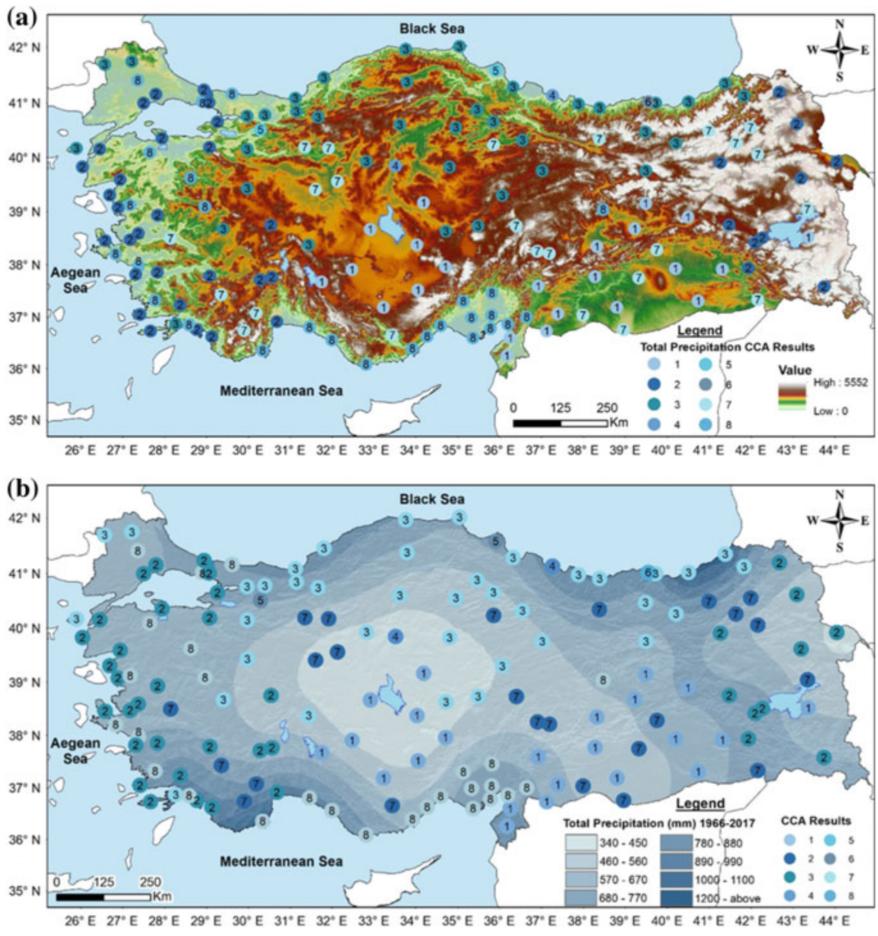

Fig. 9 **a**, **b** Turkey's total precipitation classification according to clustering method

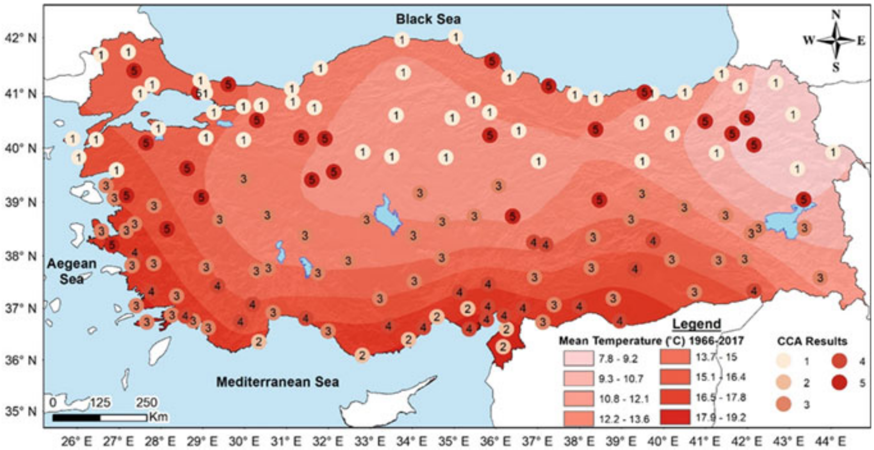

Fig. 10 Turkey's mean temperature classification according to clustering method

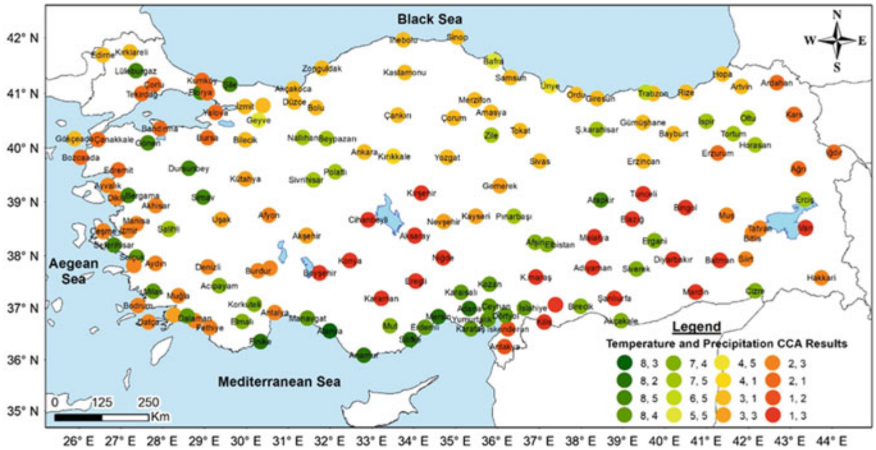

Fig. 11 Turkey's mean temperature and total precipitation classification according to clustering method

climate using multiple variables. For example, temperature and precipitation data are evaluated together and climate assessments are performed. With this method, areas with a significant similarity in temperature and rainfall data offer similar climate regions.

Results

Cluster analysis performed using Turkey precipitation and temperature may be cited as four separate sets of spatial uniformity. Some of these clusters show a very homogeneous distribution, such as Black sea region or Aegean region. The most important reason for the distribution is the effect of long term trends and changes in temperature and precipitation of the station. In addition, Turkey's many stations, depending on the temperature and precipitation differences of topographical features is continuing in a homogeneous way.

The cluster analysis represented by the most important cluster 3.1, which is common in temperature and precipitation variability. It has the widest distribution. The 31 stations used in the study are represented by this cluster with similar feature. It mostly represents the climate of the Black Sea region. The second cluster is an important area covering the western part of Turkey. 23 stations exhibit similar temperature and precipitation patterns. The third important area extends from the southeast Anatolia region to the interior of the Mediterranean region. It reflects similar trends in terms of temperature and precipitation characteristics in this area. The fourth cluster mostly represents the Marmara region, precipitation and temperature characteristics. The clusters formed thereafter are often the transition between climate zones.

According to this assessment, prepared considering the average temperature and total rainfall in Turkey, Turkey basically has four main climate types. In some areas the intersection types of these four climate types are available.

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Using Web 2.0 Tools in Teaching Spatial Statistics: Secondary Teachers' Views from Greece

Ourania Rizou and Aikaterini Klonari

Abstract Modern education reform demonstrates a shift from the classic teacher-centered model to one where interdisciplinary and holistic approaches play a central role in the curricula. Additionally, it has been found that the visual (re)presentation of statistical data, using simple or complex graphs, 3D maps and visual narrative, significantly develops students' comprehension of the educational material as well as enhances their cognitive skills. This study was conducted to identify teachers' awareness, views and skills regarding the use of Web 2.0 services, as well as their willingness to adopt in their own classroom teaching material prepared by colleagues, via a web-based platform created specifically to meet their needs. An online questionnaire was created and sent to secondary schools teachers' throughout Greece and their responses were analyzed. The results show that (i) a high percentage of teachers in Greece acquire the basic ICT skills, (ii) they can use their PC or other smart devices to organize courses and search for educational material through Web 2.0 services (cloud etc.), (iii) they believe that familiarity with web-based platform teaching methods requires considerable time and effort, (iv) they mainly trust cloud and Web 2.0 services in order to better organize their courses and (v) they are willing to both share and adopt training material through suitable web-based platforms, under certain conditions. It is our assumption that an active and innovative approach based on such tools will lead to a higher level of comprehension and integration of geospatial statistics, for teachers and their students alike.

Keywords Geospatial statistics · Data visualization · Web-based platform · Secondary teachers · Geography education

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Introduction

Umar and Hassan (2015) reported that globalization and rapid technological change led to the concepts of a borderless world, liberalization of global information and global learning. Lately, we witness the rise of a new, both on international (Sheaffer and Jacobbe 2014; Forbes 2014; Guler et al. 2016) and national level (CTCF/CC 2003, Mathematics Curriculum Lower Secondary Education 2011, Official Gazette 162/22-1-2015) where emphasis is given in statistical literacy (Gal 2004; Zwartjes et al. 2014), statistical reasoning and statistical thinking (Ben-Zvi and Garfield 2004; Watson 2011). However, statistics require a suitable reference framework for rational data management, and geography can become this framework. The use of maps and geospatial information, as well as the integration of ICT in school practice (e.g. GIS, educational software, hypermedia applications, virtual environments, etc.), supports the development of students' spatial thinking and other key competences (Klonari et al. 2011), while at the same time functions as innovative tools to support the educational process as a whole (Hermans et al. 2008; Tzimoyannis and Komis 2004; Goufas 2007). This way, students acquire the necessary visual, spatial and statistical literacy in order to be able to make rational decisions and achieve a better quality of life (Klonari et al. 2015).

This study investigates Greek schools secondary teachers' views on the need and usefulness of a web-based tool, which combines statistical and geospatial data, especially for those who implement STEM approaches. In particular, and within this context, we tried to explore these teachers' awareness of the existence of web-based platforms (such as photodentroetc) that could be integrated either in the classroom per se, or in planning and creating teaching scenarios. Additionally, we would like to identify the obstacles—and the reasons educators refer—which may not allow the use of these platforms. Obviously, it is imperative to examine and take into account the teachers' views on this issue in order to effectively address them through better planning in the implementation of future web-based applications.

Research Questions

In this survey, three primary research questions were addressed:

1. What are the secondary school teachers' views on the need and usefulness of a web-based tool which combines statistical and geospatial data?
2. How aware and familiarized are teachers regarding the existence and use of web-based platforms which aid at organizing teaching material?
3. Which issues do teachers consider when it comes to putting those platforms in use, either in the classroom or when planning out their courses and preparing teaching material?

Table 1 Description on the sections of the questionnaire instrument

Section	Description	Number of items	Aim
A	Demographic data	7	
B	Use of PC and Web 2.0 services	16	Familiarity with Web 2.0 services and their use
C	Evaluate the use of Web 2.0 services, statistical and geospatial data	14	Evaluation of knowledge in cloud services, statistical and geospatial data; attitude toward using online platforms and applications for educational purpose
D	Benefits and obstacles of using and sharing teaching material	10	Investigation of willingness to use and share teaching material via an open source tool
	Total	47	

Research Methodology

The population for this research was secondary school teachers throughout Greece. The sample for the study was selected by simple random sampling. A total of 285 secondary education level schools were selected at random, and a total of 331 secondary school teachers participated in the survey, which was conducted from January till March 2018.

An online questionnaire was created for this purpose (with the aid of Google Forms) and sent to these schools. It consisted of both open- and closed-type questions, 47 items in total, and it was estimated that 15 min were enough for completing and submitting it. The responses were organized, coded and analyzed with IBM SPSS v25.

The questions in the questionnaire were grouped into four sections. The details of each section are summarized in Table 1.

Results and Discussion

A total of 331 teachers responded by submitting the questionnaire which was e-mailed to the Head of each school. The composition of the sample is as in Table 2.

Demographic data indicate that 161 respondents (48.60%) are male and 170 respondents (51.40%) are female. One fact worth noting is that majority of them were between 41 and 50 years old (147 respondents, or 44.40%) and 106 (32.00%) were more than 50 years old. In other terms, we see that teachers in Greece are aging. Additionally, 188 (56.80%) of the respondents possessed a single diploma, 14 (4.20%) possessed a second, 119 (35.95%) held a master's degree and 10 of them are PhD graduates. Lastly, a total of 251 or 75.80% of the respondents possess basic

Table 2 Teachers demographics

Gender	Male	Female		
	48.60%	51.40%		
Age	21–30	31–40	41–50	50+
	2.70%	20.80%	44.40%	32.00%
Studies	1st diploma	2nd diploma	Master	Doctorate
	56.80%	4.20%	36.00%	3.00%
Seminar in ICT	A' Level	B' Level	No seminar	
	45.30%	30.50%	24.20%	
School	Low secondary	Upper secondary	Vocational	
	35.60%	32.00%	32.30%	

skills in ICT, as those who possess the B' Level must also have the A' Level, since it is a prerequisite.

In terms of digital device ownership, majority of the respondents (81.60%) have got a laptop at home and 64.40% a personal computer. Also, a total of 230 respondents (69.50%) own a smart phone and only 165 or 49.80% out of 331 respondents possess a tablet. Nearly all of them (except three) claimed that they are connected to the Internet at home. Meanwhile, from the aspect of computer usage at home, majority of them (283 respondents or 85.50%) use it every day, while 33 out of 331 respondents use it three to four times per week. Only 10 respondents use computers just one or two times per week.

Likewise, a total of 305 out of 331 respondents (92.10%) use digital devices at home to access the Internet for 'personal reasons' and 283 of them (85.50%) also use them for searching information about school project or work. Among the reasons for which they use the Internet, the most popular was for reading the news (93.10%) and searching for educational material (87.90%).

The respondents were also asked whether they own a personal computer in their schools. Interestingly enough, 215 respondents (65.00%) own one. Concurrently, on the matter of searching the Internet for educational material using their workplace computer, one-third of these 215 (i.e. 70 or 21.10%) use it on a daily basis, another 90 of them (28.70%) one to two times per week, while 41 of them use it one to two times per month. A very small number of them do not use it at all.

They were also asked to declare the purpose for using the computer at school. Overall, their responses are shown in Table 3.

Based on Table 3, it is obvious that nearly three quarters of the respondents use it for accessing educational material on the web. The most popular among the offered digital platforms with educational material is photodentro (91.4%)—a digital platform authorized by the Greek government which contains material for educational purposes in several subjects.

Moving on to the research questions now, the first step was to determine the extent to which secondary school teachers consider a web-based tool which combines

Table 3 The tasks' respondents computer use at school (N:215)

Tasks	Yes	No
	n (%)	n (%)
Send or/and receive email	160 (74.8)	55 (25.2)
Organizing lessons	156 (72.9)	59 (27.1)
Administrative purposes	133 (62.1)	82 (37.9)
Updating on educational issues	148 (69.2)	67 (30.8)
Searching in the Internet for educational material	157 (73.4)	58 (26.6)

Table 4 Use of open web-based platforms in the teaching process

	Gender		Age	ICT experience level		
	Male	Female	(on avg)	A-level	B-level	None
Mean	3,63	3,38	3,66	3,67	3,73	3,55
SD	1,05	0,87	0,96	0,97	0,97	0,91

statistical and geospatial data to be useful and nice to have at hand. We were jolted to find that just barely half of the respondents (193 or 58.5%) consider open, web-based tutoring platforms helpful in organizing their courses. This percentage was nearly equally divided between men and women (94 versus 99, respectively). Overall, the general consensus across all three measured criteria (gender, age and ICT skills) was marginally in favor of the use of such platforms, that is, showing a mean value[1] greater than 3.00 with a positive standard deviation close to 1.00.

Based on Table 4, we can tell that female respondents feel slightly less positive about the benefits of the use of such platforms in their teaching process. It comes as no surprise that teachers who had higher ICT level training agreed more with this statement, although not really as much as we had hoped again. The cross-tabulation of age and the question at hand showed that younger respondents were vastly in favor and that this feeling grew weaker as the age got higher. For example, people in the '21–30' age group agreed at a percentage of 77.8%, with zero negative ('disagree/completely disagree') responses. On the far end, people in the '50+' group showed a 55.7% agreement (lowest overall) paired with a 17.0% disagreement (highest percentage overall).

Teachers were also presented with a similar question, only this time it involved (other) Web 2.0 services, such as Google Drive, Dropbox and others, and their feelings toward their usefulness in preparation for, or during, the teaching process. Again, there was a modest agreement across all three measured criteria, featuring the same trends as above. It is worth mentioning that in both these questions, there is a significant percentage (48.8%) of teachers who share the positive feeling despite not owning any level of ICT certification.

[1] 1: Completely disagree—5: Completely agree.

On the topic of teaching statistics via ICT methods, we observed that the teachers believe it makes the course more interesting for their students and easier to follow. Again, this feeling was stronger among the male and younger respondents, as before. Owing to the subject (i.e. ICT) however, the percentage of the ones in favor among those who possess a B' Level certification was higher than in the previous question [mean (A-Level) = 3.633, mean (B-Level) = 3.97]. At the same time, statistical data visualization with the aid of geospatial data and digital maps was agreed to be helpful for students, to motivate them and to engage more during classes. Finally, there appears to be a positive disposition toward the combined use of ICT methods and interdisciplinary teaching in the way geospatial data are used and presented in the classroom, in that they contribute to make the course more appealing.

The next step was aimed at determining the degree of awareness and familiarization of teachers regarding the existence of web-based platforms and their use as aiding tools in organizing (their) teaching material. For the first part, it was found that 198 out of the 331 respondents (59.82%) are using one platform or another on a daily basis. When cross-tabbed against their level of ICT certification, we found that 41.9% of them had completed the A-Level seminar and another 36.9% the B-Level one. If we take into consideration the fact that, in order to attend the B-Level seminar one must already have A-Level certified, we see that a cumulative percentage of 78.8% (156 of the 198 respondents) make use of such web-based platforms in their everyday occupation. It is also worth mentioning that the remaining 21.2% of the respondents, who have not attended any level of ICT training, also said they knew and used such platforms for their educational purposes.

When asked if they make use of any Web 2.0 services to create and/or organize their teaching material, an impressive 93.96% (311 out of the 331) replied that they do—mainly cloud-based ones, with Google Drive being the most popular (40.6%) among them. Again, a check was run to see how much their level of ICT training affected this occupational habit. It turned out that 75.2% had received A-Level training (cumulative: 30.5% were B-Level certified) and another one-fourth of them (24.8%) had not received any certified ICT training and still made use of such services, similarly to what we observed above.

The third research question was about identifying the main issues secondary school teachers take into consideration when deciding whether they wish to put these platforms in use. In particular, we were interested in those factors which affect their decision in two different but associated aspects: planning out their courses and preparing teaching material, and putting this material, or scenario, in use in the classroom itself. We identified time to be the key factor here; both the time it takes, in their opinion, to learn to use and become fairly fluent in the handling of such teaching methods and tools, as well as the time they believe it takes to put these scenarios to work. Responders were found to 'generally agree' with both statements: the former had a mean value of 3.435 (SD = 0.943), and the latter a mean of 3.469 (SD = 1.031). Age and ICT education level had a similar effect on both. In particular, responders in the [21–30] age range felt mostly 'neutral' about both statements (88.9% and 55.6%, respectively) while the rest were around 50% in agreement. Similarly, those who possessed the A-Level training felt neutral to consensual about both statements

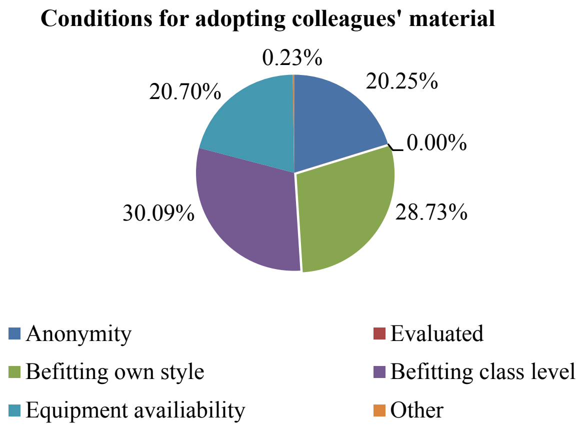

Fig. 1 Conditions for adopting colleagues' material

(44.7% and 49.3%, respectively), B-Level owners showed to mostly agree (46.5% and 44.6%, respectively), while those who had not received any formal ICT training were found to be clearly in the 'fully agree' range (55.0% and 60.0%, respectively).

Our findings on the matter of trust in cloud-based services indicate a diminishing agreement as the respondents' age is growing: 77.8% [21–30], 58.0% [31–40], 54.4% [41–50] and 36.8% [50+]. On the other hand, 'ICT experience level' seems to boost their confidence, as one would expect. However, even those who lacked any formal ICT training were found to mostly agree (42.5%). On average, teachers of all age groups and ICT training levels demonstrated a marginal trust toward cloud-based services (mean = 3.411, SD = 0.997). For the majority of the respondents this trust depended on a number of specific conditions being met. There was, however, a notable percentage (25.0–32.7%) of teachers who put their trust in cloud-based services at face value. What was not surprising was the fact that as the age and the level of their ICT knowledge grow, the 'unconditional' rating is rising too.

The final step was to identify these conditions under which they would adopt other colleagues' material in their classes, as well as whatever reasons would keep them from doing so. The graphs demonstrate their priorities and concerns (Figs. 1 and 2).

Findings Discussion

Overall, it was found that a high percentage of teachers in Greece have the basic ICT skills and are able to use their PC or other smart devices to organize their courses and search for educational material on the Web. Interestingly, 47.7% of the sample believes that familiarity with web-based platform teaching methods requires considerable time and effort on their part, but they do consider it worthwhile for it lending to greater efficiency in the classroom. Furthermore, they mainly trust cloud and Web 2.0 services and employ them at a satisfying level in order to better

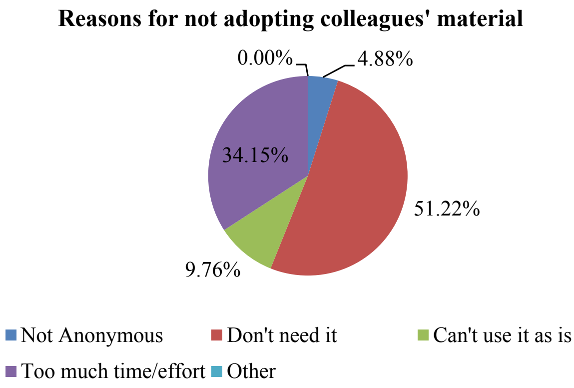

Fig. 2 Conditions for not adopting colleagues' material

organize their courses. Indicatively, 70.1% of them stated that they were familiar with searching for tutoring material on the Web (forums and online platforms). As far as using teaching material prepared by colleagues is concerned, they are in favor of this idea, provided certain conditions are met—such as secure transactions, copyright and ease of access, to name but a few.

Conclusions

In a rapidly changing modern world, decision-making is based on information which becomes available in real time. Owing to this, teachers must be highly educated and open-minded in the use of Web 2.0 and 3.0 services, such as cloud computing, web-based platforms, digital educational material etcand so on, in their courses. From our research we found that they are positive toward adopting teaching material built around geospatial data from Greece, prepared by experienced colleagues and accessed via an open source, secure and potent web platform. We believe that an active and positive approach on their behalf, built around the use of Web tools during their interventions will lead to a higher level of comprehending and integrating geospatial statistics, through (ICT) open-source web-based platforms.

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Physical Geography

Mariyana Nikolova

First Results from the Instrumental 3D Monitoring of Microdisplacements Along West Pirin Fault, SW Bulgaria

Nikolai Dobrev, Valentin Nikolov and Plamen Ivanov

Abstract This article presents the initial results of the 3D monitoring of West Pirin Fault in the area of the village of Brezhani, SW Bulgaria. The monitoring equipment—extensometer TM71 was installed in August 2013. The data obtained from the observations until August 2018 were processed. The results show four stages in the dynamics of this part of the fault. One of them is associated as a probable co-seismic effect (sharp movement) resulted from a local weak seismic event. The obtained results show that Y-axis movements reflect significant trends, representing right-lateral strike-slip movements with a rate of 0.76 mm/year for the whole period of observation. During the last 2 years of the observations the strike-strip velocity is estimated as ~0.84 mm/year with a high coefficient of determination. The vertical component of movements shows ~0.14 mm/year reverse movements. These results give us reason to prove a recent activity along West Pirin Fault.

Keywords West Pirin fault · 3D monitoring · Active faults

Introduction

The territory of Bulgaria is characterized by a high degree of geodynamic activity, the most active is its southwestern part. About 75% of the recent Bulgarian earthquakes occur annually there (Botev and Glavcheva 2003). Here is registered the most powerful earthquake in Bulgaria and one of the strongest in Europe—April 4, 1904 M7.8 Krupnik-Kresna Earthquake (Shebalin et al. 1974). For this reason, a series of detail studies on geodynamics in this area started in 1982. In the beginning of the research, three extensometers for 3D in situ monitoring were installed at selected places to detect micro-displacements along the most active fault structures. The first one was monitoring site called K5 on the Struma Fault in the Kresna Gorge, after—monitoring site B6 on the Krupnik fault near Brezhani Village, and site K7 on a large unstable slope (of gravitational sagging type) located near the village of Krupnik. Results to

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date have been published in: Košťák and Avramova-Tacheva (1988), Dobrev and Kostak (2000), Dobrev (2011), etc. Monitoring site K7 ceased to operate in 1994. In 2003, a new monitoring point (called K12) was installed in a fault of Struma system in Kresna Gorge. The last one—called B14 was installed in 2013 on West Pirin Fault Zone—which is the subject of the present study (Fig. 1).

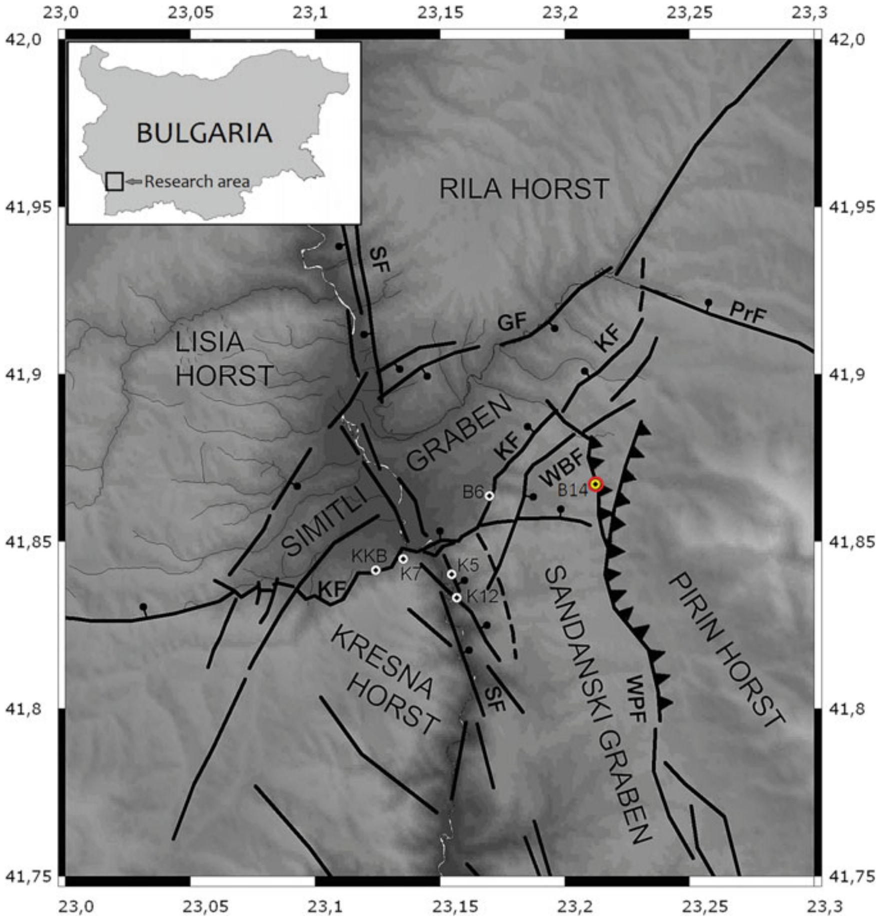

Fig. 1 Simplified sketch of the research area and a location of monitoring site B14 (after Dobrev 2011). The map shows the main tectonic structures, faults and observation points. The main faults are as follows: KF, Krupnik Fault; GF, Gradevo Fault; SF, Struma Fault Zone; WPF, West Pirin Fault (mostly reverse); PrF, Predela Fault; WBF, West Brezhani Fault. The monitoring points localities are shown, KKB is the Seismic Station Krupnik. Red-yellow circle shows the location of new monitoring site B14

Geomorphology and Geological-Tectonic Structure

According to the last tectonic division of the country, the area of research falls within the NW periphery of the Rhodope massif within the boundaries of the Pirin-Pangaion unit (Dabovski et al. 2002). West Pirin Fault represents the western boundary between the Pirin horst and two Tertiary grabens, namely Brezhani and Sandanski Graben.

Studies on geomorphology of the area and relationship with tectonic movements were the subject of research of many scientists (Radev 1933; Jaranoff 1960, 1963; Galabov et al. 1962; Kanev 1969, 1977; Vrablyanski 1970, 1975; Tzankov 2008; Baltakov 2003; Nedyalkov 2004, and others). The first geomorphological studies of research area belong to Radev (1933) with analysis of epigenetic gorges downstream of the Struma River. Subsequently Galabov et al. (1962) describes Struma River terraces between the Kresna and Rupel Gorges. Neotectonic levels in the catchment area of Middle Struma (SW Bulgaria) were investigated by Vrablyanski (1970). Morphotectonical studies in SW Bulgaria were performed by Kanev (1969, 1977), Stoyanov and Tzankov (2000), and Tzankov (2008).

Geological and geomorphological studies suggest that the total amplitude of lifting of the Pirin horst from Neogene could be estimated as 3500 m, of which 100 m are during the Quaternary (Jaranoff 1960, 1963; Vrablianski 1975; Zagorchev 1970, 1975, 1992). The calculated lifting velocity during the Quaternary is 0.1 mm/year (Zagorchev 1992). Kanev (1969) suggests lifting velocity of 2 mm/year. The field studies carried out in the 1960s showed that the West Pirin Fault has a variable character (Jaranoff 1960; Zagorchev 1970, 1971, and others), ranging from normal to reverse movements. In summary, all authors (Jaranoff 1960, 1963; Zagorchev 1970, 1971, 1992, and others) admit that the basic movements were realized during the Neogene.

The geological structure of Pirin Mts. is composed by metamorphic, magmatic, and sedimentary rocks. Metamorphic rocks are represented mainly by gneiss, granite, amphibolite, slate, and marble. The geological structure of NW part of Pirin Mts. is represented by predominantly marble rocks of Predela Metamorphic Complex (Milovanov et al. 2009). Within the boundaries of the study area, the Predela complex is represented by marbles and slates. Marbles are mainly thicker, ubiquitously cracked or crushed. The age of the metamorphic complex is assumed to be Neoproterozoic.

Tertiary grabens, limited by the West Pirin fault, are filled with Oligocene-Miocene deposits. The sediments in the research area are presented by Rakitna Formation (Vatsev 1984; Gaudant and Vatsev 2003). The formation is composed mainly of gray to gray-green and beige sandstones, gravels and conglomerates.

Monitoring Technique

Guided by the idea to obtain real data of recent fault movements (Briestenský et al. 2007), we use a high-precision TM-71 extensometer (Kostak 1991).

The device of the TM-71 type allows a direct (in situ) reading of the displacements on the three spatial axes X, Y, and Z. Its measuring range is 25 mm, and after reaching the limit it could be adjusted. The set of one TM-71 includes two horizontal and vertical measuring elements, metallic frames holding two pairs of specially designed glass sheets, steel consoles 40 mm in diameter connecting the fault/crack walls, and a protective cover. Movements of the walls of a crack are transferred via consoles to the device, which consists of two double-glass grid tiles with a specially applied emulsion lying on two mutually perpendicular planes. The instrument works on the principle of mechano-optical interference and the associated Moire effect. A detailed description of the apparatus and its effect is made by Kostak (1991). The displacements on the three coordinate axes are calculated by trigonometric formulas. The device allows a periodic adjustment after accumulation of large displacement values. The registration of the shifts is performed at regular intervals depending on the dynamics of the observed process. The accuracy of the instrument varies from 0.001 to 0.01 mm depending on the width of the crack (area), the length of the installation tubes, and the exposure to direct weathering such as sunshine, precipitation, etc. (Kostak 1991).

The site is located in the area of Brezhani Village. It is a fault structure belonging to West Pirin Fault Zone, in an area where the fault is marked by clearly expressed inverse movements (established by slickensides). In this area, the Precambrian marbles of Predela Metamorphic Complex overlay the sediments of the Rakitna Formation (Fig. 2). The apparatus is installed in a sub-parallel fracture zone formed in the Precambrian marbles, very close (about 20 m) to the main fault. The zone is 0.7–0.9 m wide. The local characteristics of the observed fault are as follows: direction 155–180° and dipping 50–52°NE. According to the accepted numbering of this type of monitoring points in a country, it has the number B14.

Results

The results of the 5-year lasting monitoring are shown in Table 1 and Fig. 3. In general, three periods can be separated and one sharp displacement. Preliminary data show that the most stable is the lateral slip movement along the fault, which reveals a right character (axis Y). The other two spatial axes show slight thrusting (axis Z) and alternating extension and compression of the monitored fracture zone (axis X). An impact of a local earthquake (December 4, 2015, M2.3, depth 1 km according to the data from the EMSC) could be discussed, and probably it is connected with this fault zone. The data obtained at this stage of the monitoring revealed significantly higher rates of movements along West Pirin Fault zone than those previously determined by geomorphological and geological analyzes of this area. The initially obtained results show that the monitoring is necessary to be continued and expanded along other sites on the monitored fault zone.

(a)

(b)

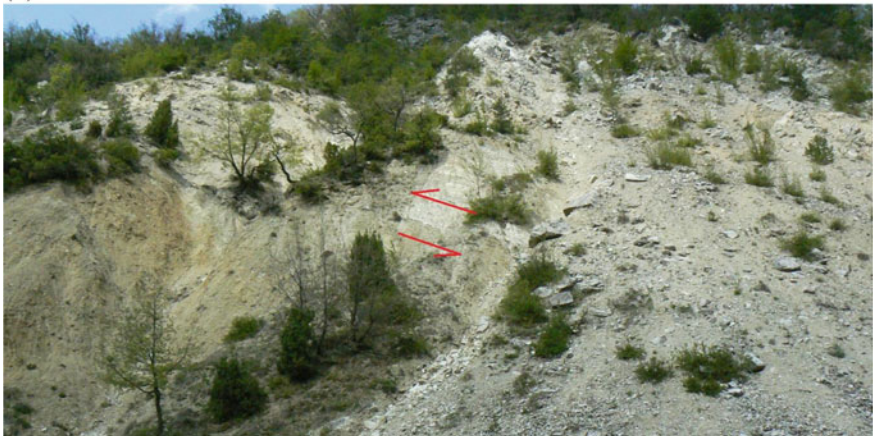

Fig. 2 Characteristic of the place of monitoring point B14: **a** A general view of the monitoring site. **b** Thrusting of Predela Metamorphic complex (Precambrian marbles) over Rakitna Formation (Oligocene-Miocene clayey sands) at Brezhani River bank, located near to the monitoring point

Coincidence of locations between the monitoring site B14 and the seismic event gives reason to assume that a sharp movement can have a co-seismic origin associated with this earthquake.

In general, the results can be summarized as follows:

Displacements at axis X have a variable character showing varieties from opening to shrinking of the fault zone. The calculated trends are shown in Table 1 and their meanings are referred in the text of Fig. 3. The graph shows significant peak-to-peak amplitudes due to the seasonal temperature fluctuations in the rock massif.

The most stable are the movements since the beginning of 2017—a clearly marked clear velocity of dextral slip of fault zone (Y-axis) with ~0.84 mm/year with high

Table 1 Preliminary obtained velocities of fault movements established at point B14

Period and type of movement	Axis X	Axis Y	Axis Z
Aug. 2013–Nov. 2015 creep	−0.228 mm/year	0.164 mm/year right-lateral strike-slip	0.273 mm/year reverse movement
Nov. 2015–Feb. 2016 sharp displacement	0.024 mm	1.238 mm right-lateral strike-slip	0.736 mm reverse movement
Feb. 2016–Feb. 2017 creep	−0.191 mm/year	0.067 mm/year left lateral strike-slip	0.616 mm/year normal movement
Feb. 2017–Sep. 2018 creep	0.019 mm/year	0.844 mm/year right-lateral strike-slip	0.004 mm/year
Whole period, Aug. 2013–Sep. 2018	0.062 mm/year opening	0.758 mm/year right-lateral strike-slip	0.138 mm/year reverse movement

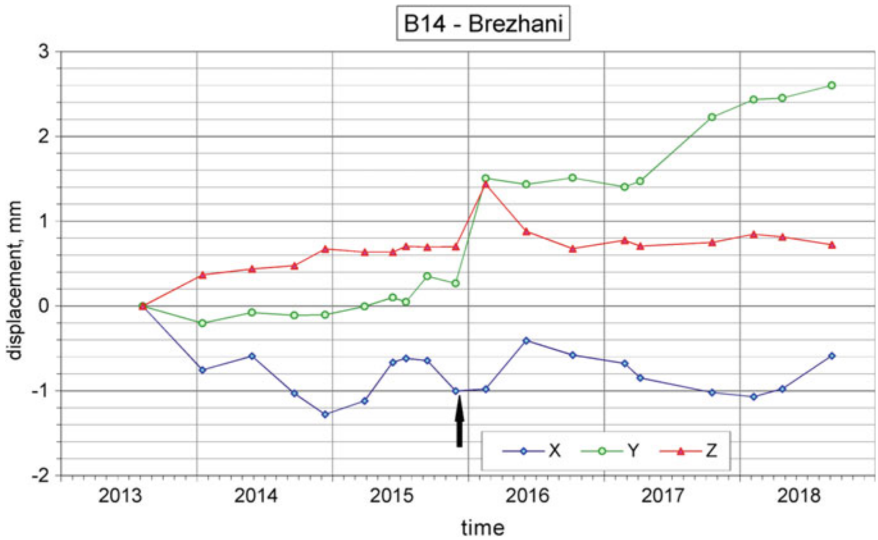

Fig. 3 Graph of displacements found at monitoring point B14. Meaning of spatial axes: +X—opening the fault zone; +Y—right-lateral movement; +Z—positive vertical movement of hanging block. The arrow shows the time of the local earthquake on 4 December 2015

coefficient of determination $r^2 = 0.921$ (Table 1). For the whole period the right-hand strike slip is ~0.76 mm/year. The coefficients of determination are high for all periods.

The Z-direction, expressing the vertical component of the movement, shows a variable character of movements with predominant thrusting. The highest velocity was established during the last period (2016–2017) 0.62 mm/year normal slip. However, the generalized data for the whole period shows a lower velocity of reverse movements estimated as ~0.14 mm/year.

Discussion

The data obtained at this stage show that the observed fault zone is currently active despite the accepted perceptions of most researchers that activity has stopped at the end of Neogene. The most active movements are outlined on the strike-slip component (axis Y), where the velocity for the entire observation period is ~0.76 mm per year. For better clarification of the dynamics of the area, it is necessary to continue observation, extension of the monitoring network and correlation with the data from the local seismicity.

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Climate Change: Human Health-Related Risks and Vulnerability—Some Global and Local (Bulgarian) Pictures

Zoya Mateeva

Abstract Changes in climate and weather extremes affect the environment that provides us with clean air, food, water, shelter, and security. Climate change (CC), together with other natural and human-made health stressors, threatens human health and well-being in numerous ways. The most affecting climatic factors are an increasingly warmer climate, periods with extreme maximum and minimum temperatures, lasting and intensive precipitations, disastrous weather phenomena (windstorms, cyclones, floods), droughts, poor air quality, stratospheric ozone depletion, and corresponding changes in ultraviolet (UV) radiation. The present work reviews the health effects of climate change worldwide, for Europe, and—to a certain extent—for the territory of Bulgaria, and assesses the population's sensitivity to these changes as well as the willingness of the health sector in Bulgaria to cope with the challenges of climate change, giving thus an idea about the general vulnerability of the human health sector to the changes of climate.

Keywords Climate change · Human health · Health sector vulnerability · Bulgaria

Introduction

The aim of this chapter is to address the human health sector-related climate change risks and vulnerabilities, colligating some global (worldwide and European) and local (Bulgarian) foreshortenings. In Bulgaria this issue is still poorly illuminated, which makes it necessary to review and study international experience and good practices in order to translate them to the local level of Bulgarian conditions. This can help to connect our understanding of how climate is changing, with an understanding of how those changes may affect human health, and can inform about adapting to current and future climate change, as well as suggest priorities for protecting public health and help in identifying the corresponding knowledge-base gaps, uncertainties, challenges, and opportunities.

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Human Health Effects from Climate Change

Human health is a subject of a number of direct and indirect effects of climate change and can be influenced by a great number of weather manifestations expressing climate changeability during the last decade. The most affecting climatic events are warmer climate, periods with extreme maximum and minimum temperatures, durable and intensive precipitation, emergency weather phenomena (windstorms, cyclones, and floods), droughts, air quality, stratospheric ozone depletion, and change in intensity of ultraviolet (UV) radiation.

The health effects from climate change concern the following diseases: Heat-related morbidity and mortality; emergency weather-related morbidity and mortality; cardiovascular diseases and strokes; asthma, respiratory allergies, and airway diseases; cancer; vector-borne and zoonotic diseases; food-borne diseases and nutritional deficiencies; water-borne diseases; mental health and stress-related disorders; neurological diseases and disorders, and others.

Health Consequences from Temperature Changes

Temperature, particularly temperature extremes, is associated with a wide range of health impacts. The health outcomes of prolonged heat exposure include heat exhaustion, heat cramps, heat stroke, and death (Ellis 1976; Kilbourne et al. 1982). Extreme heat events cause more deaths annually than all other extreme weather events combined (Luber et al. 2008). Prolonged exposure to heat may also result in additional illness and death by exacerbating pre-existing chronic conditions, such as various respiratory, cerebral, and cardiovascular diseases (Kovats et al. 2008), as well as increasing risk for patients taking psychotropic drug treatment for mental disorders (Davido et al. 2006), due to the body's impaired ability to regulate temperature. Figures for these illnesses and deaths may be dramatically underestimated as disparities in healthcare make morbidity measurements difficult and heat is rarely identified as an official cause of death. Public health response organizations should develop early warning systems for anticipated heat wave events and extended warm periods.

Based on the daily values of the Heat Wave Magnitude Index (HWMId), it is observed that Europe experienced intense and prolonged heat waves after 1950, most of which occurred after 2000 (Russo et al. 2015). Indices for extreme temperatures, including the annual maximum value of daily maximum temperature (Txx), have shown significant upward trends across Europe since the 1950s (Donat et al. 2013). The number of unusual warm days (Tx90p) has increased by up to 10 days per decade since 1960. Bulgaria shows a considerable rate of 7–8 days per decade (Fig. 1). In the last few decades, after the 1990s, the average decade air temperature anomaly in the country has steadily increased in the positive direction (Fig. 2). The deviation of the average annual temperature in 2014 compared to the 1961–1990 climate rate is shown in Fig. 3. For the territory of Bulgaria, it is within the temperature intervals

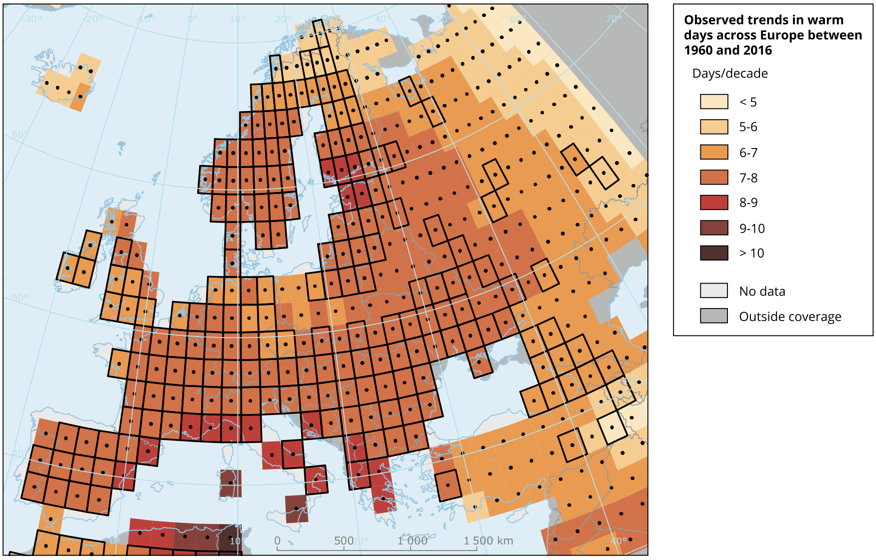

Fig. 1 Observed trends in warm days between 1960 and 2015. *Source* EEA and UK Met Office, based on HadEX2 (updated from Donat et al. 2013). *Note* Warm days are defined as being above the 90th percentile of the daily maximum temperature centered on a five-day window for a reference period. Grid boxes outlined with solid black lines contain at least three stations and thus trends are more robust. High confidence in the long-term trend (at the 5% level) is shown by a black dot (which is the case for all grid boxes in this map). The reference period is 1971–2000

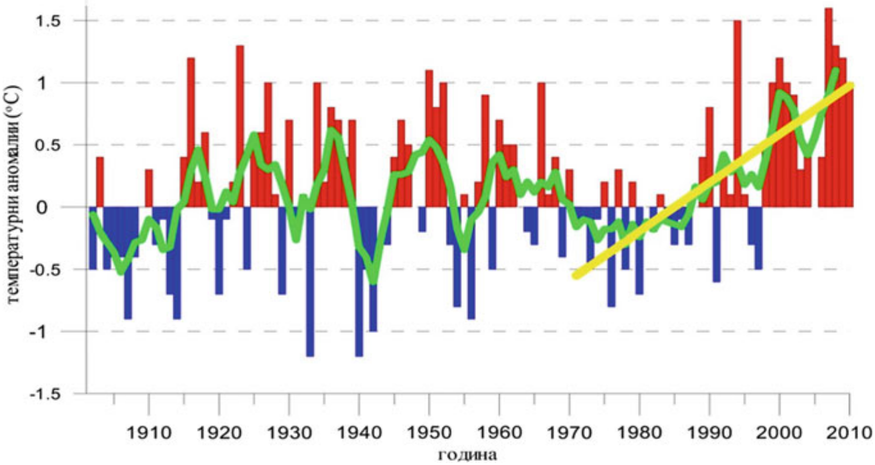

Fig. 2 Air temperature anomalies in Bulgaria by decades (*Source* Ecological Assessment of Operative Programm "Environment" 2014–2020, MOEW). Red—positive anomaly of the average annual air temperature compared to the climate norm for the period 1961–1990. Blue—negative anomaly of the average annual air temperature compared to the climate norm for the period 1961–1990. Green—Moving average to determine variations in mean annual air temperature abnormalities. Yellow—linear trend of average annual air temperature abnormalities

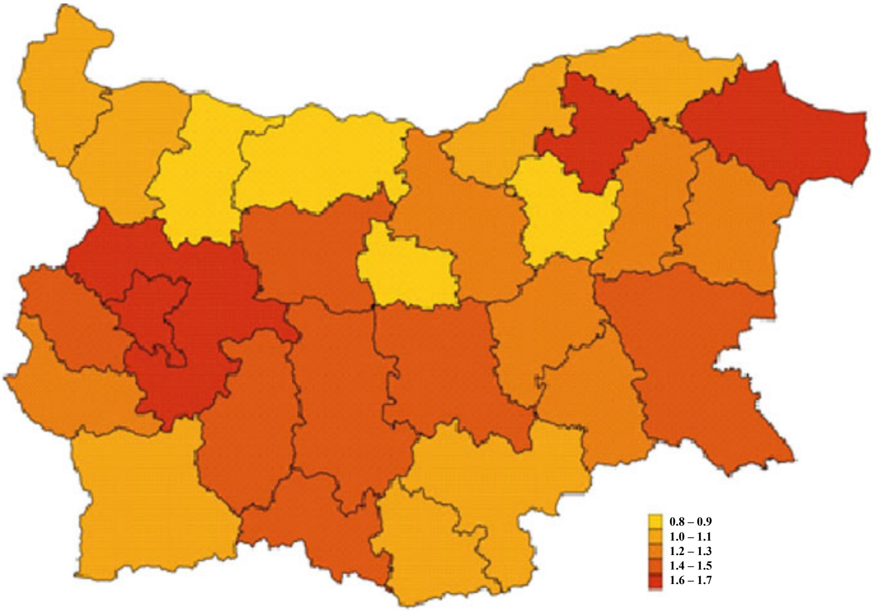

Fig. 3 Deviation of the average annual air temperature in 2014 compared to the climatic norm 1961–1990 in district areas of Bulgaria (*Source* Executive Agency "Environment"/MOEW)

0.9–1.0 and 1.5–1.6 °C, respectively, for the different regions of the country.

The results of the climate change forecasts for Bulgaria over the next 100 years, obtained by applying the regional model ALADIN, show that the warming in the country in 2050 will be within the temperature interval 0.75–1.5 °C according to the most optimistic scenario (RCP 2.6) and within 2.5–3.5 °C according to the most pessimistic scenario (RCP 8.5). In 2070, the temperature increase is projected to be even more significant—by 1.5–2.5 °C according to the optimistic scenario and 3.5–4.5 °C according to the pessimistic scenario. At the end of the twenty-first century, the expected changes in air temperature are shown in Fig. 4.

An increase in heat extremes will lead to a marked increase in heat-attributable deaths under future warming, unless adaptation measures are taken. Highly urbanized areas are projected to be at an increased risk of heat stress compared with surrounding areas. Projections of future heat effects on human health need to consider that the European population, including Bulgarians, is projected to age, because elderly populations are especially vulnerable (Lung et al. 2013; Watts et al. 2015). Several studies have estimated future heat-related mortality using similar methods and have arrived at largely comparable results, namely PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on bottom-up Analysis), Climate Cost, and PESETA II (Ciscar 2011; Kovats et al. 2011; Watkiss and Hunt 2012; Paci 2014). The PESETA study estimates that, without adaptation and physiological acclimatization, heat-related mortality in Europe would increase between

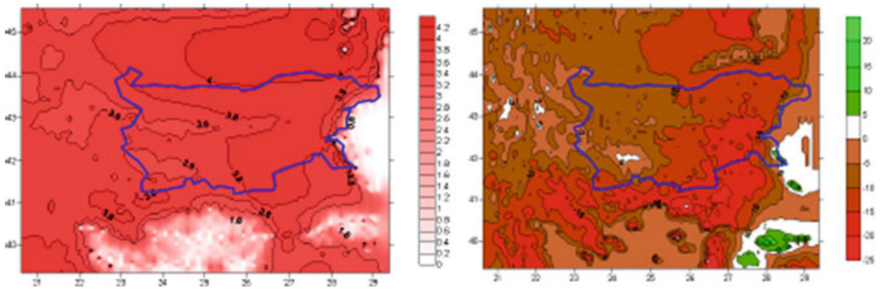

Fig. 4 Differences of the average annual temperatures (left) and the average annual precipitation (right) between the period 1961–1990 and the end of the twenty-first century in Bulgaria (*Source* Ecological Assessment of Operative Programme "Environment" 2014–2020, MOEW)

60,000 and 165,000 deaths per year by the 2080s compared with the present baseline, with the highest impacts in southern parts of the continent, damaging Bulgaria too. The results vary across climate models and emissions scenarios, with high-emissions scenarios leading to much higher heat-related mortality than low-emissions scenarios. Heat-related mortality would be significantly lower under full acclimatization if, for example, currently cool regions were able to achieve the temperature–mortality relationship of currently warm regions. Another study estimates that climate change will lead to an increase in hospital admissions owing to heat-related respiratory diseases from 11,000 admissions (0.18%) in the period 1981–2010 to 26,000 (0.4%) in 2021–2050. The total number of hospital admissions and the increase because of climate change are the largest in southern Europe, with the proportion of heat-related admissions for respiratory conditions expected to approximately triple in this region over this time period (Aström et al. 2013). In low resolution, these studies cover also the territory of Bulgaria but there is a need to extend the investigations to a larger scale and districts level of the country.

Despite an increase of mean global temperature, not only an increase of extremely hot weather phenomena has been observed but also of extremely cold ones. Cold-season deaths are largely associated with increases in respiratory infections such as influenza (Kinney et al. 2015). In cold weather, the body can lose heat faster than it is produced, which uses up stored energy and can lead to hypothermia, defined as a core temperature below 35 °C. Low temperatures cause veins and arteries to narrow and blood to become more viscous, increasing cardiac workload and leading to many of the same cardiovascular stresses such as heat. In true hypothermia, this extra-cardiac workload is coupled with a host of other concerns, including increased cardiac muscle sensitivity that can lead to dysrhythmias. In addition to straining the heart and other organs, impaired blood flow and decreased metabolic activity due to low temperatures can affect the brain, making the victim unable to think clearly or move well (Seltenrich 2015).

Hypothermia is most likely to occur at extremely low temperatures, but it is also possible well-above freezing if a person becomes chilled from rain, sweat, or immersion in cool water. Many hypothermia diagnoses occur in tandem with other illnesses and environmental exposures; some patients, for example, have systemic infections that disrupt thermoregulation and allow sepsis-related hypothermia to occur even in the summer. For cold-related deaths, the most frequently cited underlying cause of death was exposure to excessive cold.

People most at risk of illness or death from exposure to high or low temperatures include those less able to regulate their body temperature due to age, those with pre-existing conditions or chronic diseases, and (especially heavy) users of alcohol or drugs (Benmarhnia et al. 2015; Berko et al. 2014). Individual vulnerability to heat and cold has also been found to vary with sex and race.

Based on numerous studies from all over the world, the general conclusions about the expected health consequences of projected temperature changes are the following: A 40–60% increase in the number of deaths from cardiovascular diseases and strokes; a 10–30% rise in vector-borne morbidity, owing to the vectors' longer vegetation cycle; a 50–100% increase in the incidence of Salmonella and Campylobacteriosis infections due to the longer growing period and more favorable conditions; a 10–30% increase and exacerbation of respiratory diseases due to the higher concentration of carbon dioxide (CO_2), dust, and PM in the air, further interacting in conditions of high temperature and humidity; a 10–30% rise in the number of allergic diseases due to earlier flowering and increased concentration of pollen, spores, and other allergens in the air.

Health Consequences from the Expected Changes of Some Weather Emergencies

European territory, including Bulgaria, is damaged by weather emergencies that are different by their nature, intensity, and frequency. For a medium emissions scenario (SRES A1B) and in the absence of adaptation, river flooding is estimated to affect about 300,000 people per year by the 2050s and 390,000 people by the 2080s; the latter figure corresponds to more than a doubling with respect to the baseline period (1961–1990). If no additional adaptation measures are taken, the number of people affected by coastal flooding at the end of the twenty-first century would range from 775,000 to 5.5 million people annually, depending on the emissions scenario. The number of deaths due to coastal flooding in the 2080s would increase by 3000, assuming an 88 cm sea-level rise. Flooding is also associated with mental health impacts. Coastal flooding could potentially cause 5 million additional cases of mild depression annually by the end of the twenty-first century under a high sea-level rise scenario in the absence of adaptation (Watkiss and Hunt 2012; Bosello et al. 2011). In Bulgaria, the changes in expected annual damages for the 2020s, 2050s, and 2080s, compared to the control period (1961–1990), are shown in Fig. 5.

Based on numerous studies from all over the world, the general conclusions about the expected health consequences of some other projected weather emergencies are (Mihaylova 2014).

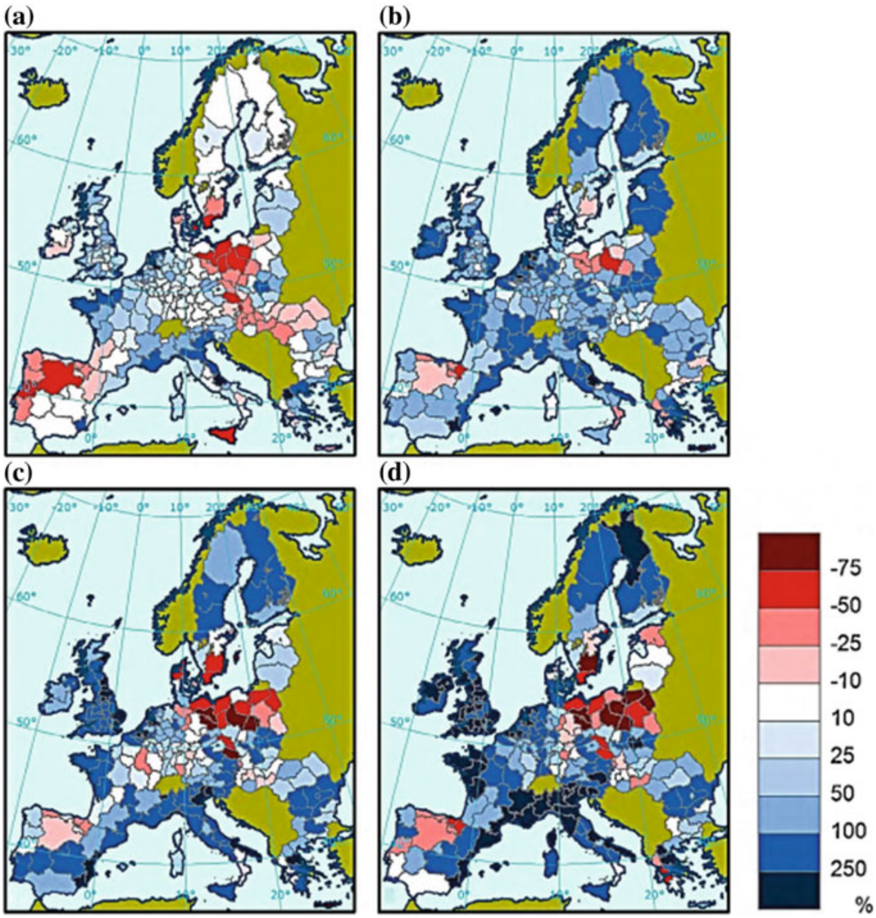

Fig. 5 Changes in expected annual damages compared to the control period (1961–1990) for the **a** 2000s, **b** 2020s, **c** 2050s, and **d** 2080s. *Source* Rojas, Feyen, and Watkiss 2013. *Note* Scenario with only climate change, with flood protection up to the current 100-year flood event assumed constant in time. Ensemble-based average estimates based on 12-member climate ensemble for the A1B scenario. Values are aggregated at administrative level NUTS2 regions

A 10% increase in mortality due to extreme weather events and fires, with that increase being even higher among vulnerable groups—up to 30%; a 10–30% rise in water-borne and food-borne morbidity due to damaged infrastructure; and a 10% increase in cases of PTSD.

Health Consequences of the Expected Changes of Precipitations

Global warming is projected to lead to a higher intensity of precipitation and longer dry periods. Evidence from high-resolution climate models suggests that the intensity of sub-daily extreme rainfall is likely to increase in the future, whereby a theoretically estimated increase of approximately 7% per 1 °C appears most likely in many regions.

Projections show an increase in heavy daily precipitation in large parts of Europe in winter, by up to 35% during the twenty-first century. Heavy precipitation in winter is projected to increase over most parts of the Europe, with increases of up to 30%. This is true for Bulgaria, in its north-western and north-eastern parts (Fig. 3). In the remaining part of the country territory, heavy precipitations will increase up to 5–15% or 15–25%. In summer, an increase is also projected up to 15% in some northern and mountain parts of Bulgaria, but decreases are projected for other parts of Bulgarian territory too (Fig. 6). The pessimistic scenario, however, provided for this time horizon reduces precipitation by 100–200 mm. According to this scenario, changes will also occur in rainfall regimes—they will decrease during the growing season but will increase during the cold season. The expected changes in the amount of rainfall at the end of the twenty-first century are shown in Fig. 4.

The expected health consequences include (Aström et al. 2013; Kovats et al. 2003):

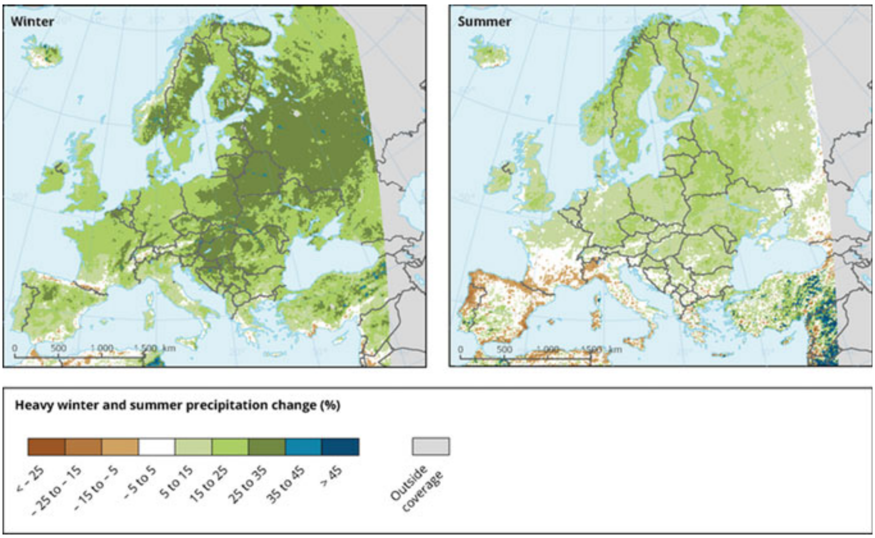

Fig. 6 Projected changes in heavy precipitation in winter and summer. *Source* EURO-CORDEX (Jacob et al. 2014). *Note* This map shows projected changes in heavy daily precipitation (percentage) in winter and summer for 2071–2100, compared with the baseline period 1971–2000, for the RCP8.5 scenario based on the ensemble mean of different RCMs nested in different GCMs

About 10% rise in the incidence of cryptosporidiosis in north-western Bulgaria due to more frequent and more abundant precipitation; a 10–100% surge in the cases of Campylobacteriosis in north-western Bulgaria due to a combination of more frequent precipitation and higher annual average temperatures; and increased incidence of diarrheal infections caused by non-cholera vibrio due to more abundant precipitation and higher levels of humidity in north-western Bulgaria and the Black Sea region.

Non-climatic Drivers of Health Vulnerability to Climate Change

Some socioeconomic drivers of human health, such as income, housing, employment, education, gender, and lifestyle, can lead to uneven distribution of climate change health effects, becoming additional burdens for certain vulnerable groups (lower income groups, children, those working outdoors, the elderly, women, the homeless, people with a pre-existing illness and/or disability, and so on).

At this stage, Bulgarian healthcare services are unable to meet the challenges of an aging population, the continuous development of medical technology, and the increasing demands of the population for quality of life, and hence, for quality healthcare. Bulgaria continues to be one of the countries with the highest mortality rates in the EU and the lowest population growth. As a whole, the demographic processes in Bulgaria are characterized by a persistent downward trend in population and aging. An unfavorable trend in the labor force is also reported—the absolute number of people within working age is declining in a situation of significant increase in the relative proportion of elderly workers. Data from a representative survey of mental health among the population showed that 22% had a psychiatric disorder in their lifetime, and in about 25–30% of the cases, contact with the health system included mental maladies. The healthcare provided for children does not yet correspond to the EU average. Despite the positive downward trend, the infant mortality indicator counting 9.4 promille in 2010 is still above the values of that indicator in other EU countries (according to the National Statistical Institute's 2015 paper 'Zdrave'). This situation was still the case in 2016 with a figure of 8.5 promille. The health status of the working population is characterized by higher levels of risk conditions (injuries, illnesses, low safety at work, and stress) than those in the EU. Although the total number of accidents and lost calendar days has significantly declined, the increase in accidents with fatalities is alarming. Significant problems exist in the system, such as structure of costs spent to finance healthcare. In 2010, public spending on healthcare in the country accounted for only 4.3% of GDP. With respect to this indicator, Bulgaria still occupies one of the last places among the 27 Member States of the EU. According to a report by the World Bank, Bulgaria has the highest proportion of own resources payments as a percentage of total health expenditure. That fact, as well as the extremely low incomes of the population, poses serious problems for the citizens' access to health services. One of the main problems in Bulgaria's healthcare system over the past few years has been linked to illegal payments, which not only violate fundamental principles and values of contemporary Bulgarian society but also increase the social burden on the population.

The outlined picture of the unfavorable level of public health is not only due to the described socioeconomic determinants (low income, poverty, social exclusion), but also of the fact that the Bulgarian population is 'burdened' with multiple health risk factors. The results of a number of studies provide grounds to consider that, in the country there are approximately 30% smokers (according to data from the European Health Interview Survey (EHIS) 2014, conducted by the National Statistical Institute of Bulgaria); on average about 40% men and women aged 15 and older are overweight; about 10% people with daily drinking of alcohol; about 345,000–360,000 Bulgarian citizens from 15 to 60 years have at least one drug use in their life; two-thirds of the population have low physical activity; and about 30% are hypertensive patients. A serious problem represents smoking at a young age. A survey conducted in 2008 among students aged 13–15 years found that smokers were 28.2%. In 21.2% of the cases children have lit their first cigarette before reaching the age of 10 years.

According to the EU 'health consumer index' Bulgaria occupies the last position among 35 countries (Member States of the EU and candidate countries).

Uncertainties

Assessing health outcomes in relation to climate change is a complex task that must accommodate the multiple types of uncertainty that compound across the antecedent environmental and social changes. Many different types of uncertainty relate to the health effects of climate change. A major source of uncertainty relates to the degree to which future emissions of greenhouse gases (GHG) will change radiative forcing over the coming century. GHG emissions are driven by complex factors, such as population growth, economic growth, and energy policy. Addressing this level of uncertainty is limited to the emissions scenarios that are available. Table 1 shows some of the main aspects of uncertainty in assessing the health sector.

Health-Related Climate Change Vulnerability and Risk

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the degree to which individuals and systems are susceptible to or unable to cope with the adverse effects of climate change, including climate variability and extremes. The vulnerability of human health to climate change is a function of exposure (E),

Table 1 Sources of uncertainty (*Source* Modification based on Watkiss and Hunt, 2012)

Sources of uncertainty	Examples
Problems with data	• Missing components or errors in data • 'Noise' in data associated with bias or incomplete observations • Random sampling error and biases (non-representativeness) in a sample
Problems with models (relationships between climate and health)	• Known process but unknown functional relationships or errors in structure of model • Known structure but unknown or erroneous values of some important parameters • Known historical data and model structure but reasons to believe that the parameters or model or the relationship between climate and health will change over time • Uncertainty regarding the predictability of the system or effect

sensitivity (S), and adaptive capacity (A) components (Kovats et al. 2003). E represents weather- or climate-related hazard, including the character, magnitude, and rate of climate variation. S and A represent the social sustainability to environmental impacts, which determines the differences in vulnerability by region and group depending on the interaction of these three components in space and time. In this sense, health vulnerability is materially and socially dependent. The material aspects include the built-up surroundings, buildings, infrastructure, transport, urbanization, and so on, while the social ones include the social institutions and existing concepts of disease and health.

Populations, subgroups, and systems that cannot or will not adapt are more vulnerable, as are those that are more susceptible to weather and climate changes. Understanding a population's capacity to adapt to new climate conditions is crucial to realistically assessing the potential health and other effects of climate change. In general, the vulnerability of a population to a health risk depends on the local environment, the level of material resources, effectiveness of governance and civil institutions, quality of the public health infrastructure, and access to relevant local information on extreme weather threats (Woodward et al. 1998). These factors are not uniform across a region or country or across time and differ based on geography, demography, and socioeconomic factors. Effectively targeting prevention or adaptation strategies requires understanding of which demographic or geographical subpopulations may be most at risk and when that risk is likely to increase. Thus, individual, community, and geographical factors determine vulnerability.

According to the Notre Dame Global Adaptation Index (ND-GAIN), the health sector is represented by six indicators that represent the three cross-cutting components: the exposure to climate-related or climate-exacerbated hazards; the sensitivity of the sector to the impacts of the hazard; and the adaptive capacity of the sector to cope or adapt to these impacts. The six vulnerability indicators of ND-GAIN index are shown correspondingly in Table 2.

Additionally, ND-GAIN also assesses the health sector readiness to leverage private and public sector investment for adaptive actions (Chen et al. 2015). The readiness indicators of the health sector used by ND-GAIN index are shown in Table 3.

The climate change vulnerability score of the health sector in Bulgaria for 2015 is 0.128 (0–1, higher is better), ranking the country at the 51st position among 192 countries. It shows a considerable decrease since 1995 (Fig. 7).

The climate change readiness score of Bulgaria for 2015 is 0.560 (0–1, lower is better), ranking the country at the 54th position among 185 countries. The readiness score includes the economic readiness score (0.646), governance readiness score (0.507), and social readiness score (0.528). It shows a considerable increase since 1995 (Fig. 8).

Table 2 ND-GAIN vulnerability indicators for the health sector (*Source* Bosello et al. 2011; Watkiss and Hunt 2012)

Exposure indicators	Sensitivity indicators	Adaptive capacity indicators
Projected change of deaths from climate change induced diseases	Slum population	Medical staff (physicians, nurses, and midwives)
Projected change of length of transmission season of vector-borne diseases	Dependency on external resource for health services	Access to improved sanitation facilities

Table 3 ND-GAIN readiness indicators for the health sector (*Source* Bosello et al. 2011; Watkiss and Hunt 2012)

Readiness component	Indicators			
Economic readiness	Doing business indicators			
Governance readiness	Political stability and non-violence	Control of corruption	Rule of law	Regulatory quality
Social readiness	Social inequality	ICT infrastructure	Education	Innovation

Note ICT = Information and Communication Technology. The Doing Business indicators are composed of 10 sub-indicators

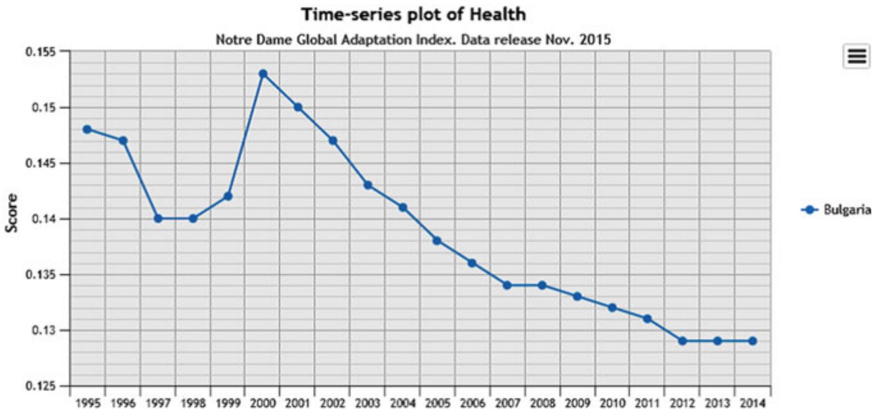

Fig. 7 Vulnerability score of health sector in Bulgaria

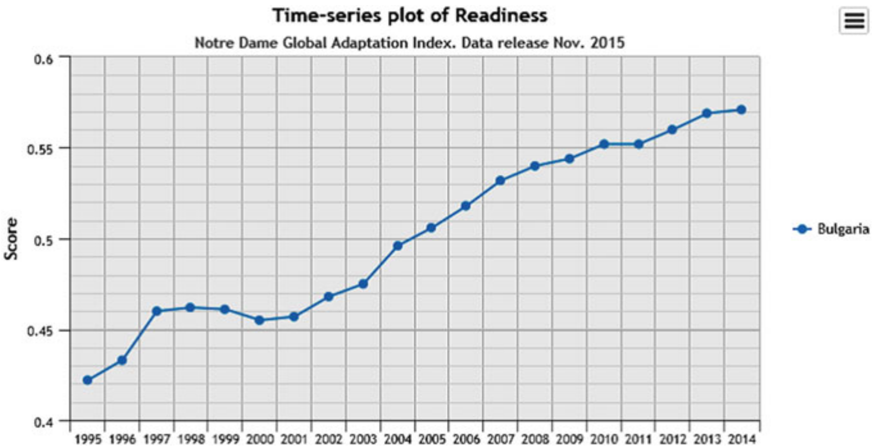

Fig. 8 Readiness score of Bulgaria

Conclusions

Climate change in Bulgaria is manifested by an increase in the average annual air and water temperatures, an increase in over-warming and over-cold rushes, a change in the annual rainfall, an increase in heavy rainfall, an increase in dry periods, wind, thunder, and snow storms, contrast shifts of weather, river floods, as well as droughts, and UV radiation. These changes affect the bio-status of man and his health in a complex and individual way, depending on various climatic, socioeconomic, health, personal, and other factors.

The numerous, health-influencing factors of the changing climate in Bulgaria can be generally attributed to two broad groups: sudden (such as storms, floods, and fires) and gradual, emerging (as changes in heat-humidity, precipitation, and solar conditions).

The health effects of these climate change phenomena can be extremely varied, and in general they can be differentiated as primary and secondary. Primary effects directly affect human health such as, for example, heat waves and cold spells, ultraviolet radiation, and floods. Secondary effects indirectly affect human health through other climatic-influenced factors such as pollen, vector-borne diseases, fires, contaminated food, water and air, and compromised crops. The primary and secondary health effects of climate change can be differentiated into the following groups: heat-related morbidity and mortality, extreme weather-related morbidity and mortality, cardiovascular diseases, including strokes, asthma, respiratory allergies and airway diseases, cancer, vector-borne and zoonotic diseases, food-borne diseases and nutrition factors, water-borne diseases, mental health and stress-related disorders, and neurological diseases and disorders.

Climate-related health effects mostly affect the more vulnerable groups of the population—children and adults, people with chronic illnesses, people with a low socioeconomic status, those living in poverty, or those with harmful personal habits (use of alcohol, drugs, tobacco). In Bulgaria, over the last decades, aging and impoverishment trends have been observed, and for most vulnerability indicators, the country is in a less favorable position than many of the countries in the European Union.

The health vulnerability of the country to climate change is also rising because of some features of the health sector. It is necessary to optimize the health infrastructure and structure, increase understanding and competencies of health personnel on the impact of climate change on human health, and introduce the topic in training programs of universities and colleges in medical schools in the country.

Furthermore, it is necessary to deepen the knowledge and assessment of the manifestations of climate change in Bulgaria, the mechanisms of their impact on human health and socioeconomic and demographic parameters of vulnerability, through a large-scale plan.

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The Use of Microclimatic Data in Authentic Learning: A Two-Site Case Study Between Hanoi and Singapore

Kenneth Y. T. Lim, Hieu Nguyen Vu, Jun You Sim, Ming De Yuen and Joshua Lee

Abstract This chapter introduces a study of microclimate data by two students, conducted in two different cities. In doing so, we attempt to highlight how each learner's respective lived environment and experience give rise to different questions and ideas. The project reported in this paper was conducted by two high-school students as part of their internship with the lead author. It can be considered a proof-of-concept of an experiment and curriculum in which local, real-time data are collected and used by learners as they seek to go beyond canonical knowledge from textbooks. Data, in the form of environmental readings comprising temperature, relative humidity, air pressure and air quality, were collected via Arduino-based sensors set up in Hanoi, Vietnam and Singapore.

Keywords Real-world data · Open-source · Learner intuition · Environmental science · Microclimate · Geography education

Introduction

In this chapter, we introduce a case study of a pair of high-school students who have asked questions about their environment and used computation to answer those questions and to make sense of the answers. They designed and constructed a system

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of collecting weather data from their respective lived environments and adopted a variety of strategies and practices for answering questions about their world.

Since 2013, the lead author and his team of researchers from the National Institute of Education in Singapore have been working on the use of a network of low-cost, open-source unobtrusive environmental sensors placed throughout any given learning environment. Through this network, teachers have the wherewithal to design curriculum which would permit and encourage the interrogation of real-world microclimatic data from within an environment already familiar to the students, so that their intuitions about local environmental factors and systemic relationships—which would otherwise have remained tacit—might be surfaced and dialogued upon in collaboration with their peers and teachers.

The study reported in this chapter describes one such intervention, enacted by two high-school interns attached to the lead author's team. Data were collected through an Arduino board which had several sensors installed (Fig. 1). The sensors could collect data about several microclimatic variables, such as sound, light, humidity, temperature, air pressure and air quality. Once data was collected, it was immediately streamed via wireless signal to a receiver which was connected to the internet. The receiver uploaded the data to a Dropbox account in the cloud where it was compiled into an Excel spreadsheet file. The power timer turned the sensor on for 5 min every 3 h, which means it collected data every 3 h. The conceptual framework underlying the design of the experiment is that alignment between the assessment of children and

Fig. 1 Open-source environmental sensor mote

their day-to-day lived experience is critical to developing an enduring understanding beyond rudimentary textbook recitation. This framework is broadly described by the present author's work in disciplinary intuitions, which is elaborated by Lim (2015).

Review of Literature

In education, constructivism is the concept that by letting the learner makes sense of the world around them on their own, they are empowered to construct their own ideas and knowledge about the world based on their prior understandings and experiences (Driver and Leach 1983; Ianello et al. 2011). By providing real-world information to students, so that they could apply their received wisdom on, can further develop their own ideas and knowledge about the subject. To encourage students to deepen their conceptual understanding instead of simply memorising textbooks, real-world data can be brought in to show students real-world applications of concepts and ideas taught in textbooks. For example, geography students can be shown empirical environmental data for them to compare to conventional classroom materials, and to determine trends and create hypotheses on certain observed data.

There is a growing awareness among science educators of the need to de-emphasise the memorising of de-contextualised scientific facts and place greater emphasis on science in the everyday world, developing deep understanding through inquiry-based learning (Singer et al. 2000). The multi-disciplinary nature of environmental science (together with its values orientation) makes it an ideal candidate for a science, technology, engineering and mathematics (STEM)-based curriculum design. Designing curriculum around STEM is often predicated upon finding tasks which are meaningful and authentic to students. Traditionally, however, data presented to students is often abstract, de-contextualised and presented in forms which presume relatively high numeracy and graphicacy among students. Thus, for example, conventional weather data is complicated by the microclimate of the built environment, especially of urban heat island effects. As students typically have no access to a mesh of data points, nor the means to observe concomitant weather phenomena, the cause-and-effect reasoning is usually abstract and far removed from the experience of daily lives.

We have recognised that the current method of climatic variation analysis is limited by the lack of effective means to account for the changes in surrounding environment conditions. This leads to an inadequate data representation of the climate condition at studied sites, which potentially cause misinterpretation of real-world data collected and misunderstanding of concepts taught in classes.

One of the seminal researchers on children's conceptions about weather phenomena is Henriques (2002). Her review of the literature was initiated on the basis that relatively few studies had been carried out to understand what children think about topics in the earth sciences. One of her most salient findings is that while weather is ostensibly a topic within the earth sciences, many of the misconceptions students held regarding weather originated from the natural sciences; examples included properties of water, phase changes and the water cycle. Her often-cited cautionary conclusion was that "in many cases, students' misconceptions are not addressed in the curriculum, allowing them to exist unchallenged".

Some of the studies Henriques unearthed in her review were Sere's (1985) and that of Driver et al. (1994). These served to highlight misconceptions which students held—for example, that air has weight was challenging even for high-school students (Sere 1985), and that air exerts pressure only when it is moving downwards (Driver et al. 1994). With regards to humidity, Bar (1989) commented on the difficulty children have in understanding air as a "permanent substance", and how this—in turn—led to what Russell and Watt (1990) observed was the difficulty that fifth-graders had in identifying air as the final location of evaporating water. Lee et al. (1993) built on their preceding work to suggest that such difficulties of understanding persist in middle-school students. Likewise, when Aron et al. (1994) conducted a study on participants ranging from pre-service teachers and students of various ages (from middle-school to college) on topics such as air pressure, humidity and cloud composition, their conclusion was that across all age levels, people did not understand weather concepts.

This alarming pattern of results arising from research into children's understanding of natural weather events has continued beyond Henriques's study and into the early twenty-first century. In their 2008 study on middle-school and college students' conceptions about extreme weather events and hazards, Polito, Tanner and Monteverdi came to the rather damning conclusion that while

> conceptual research in science education has advanced during the past fifty years… conceptual research in meteorology is clearly lacking… for example, there are apparently no research articles about alternative conceptions of weather in the Journal of Geoscience Education, the main publication for educational research in the geosciences.

Notwithstanding the preceding, Rappaport (2009) did publish a paper in that same journal a year later. Echoing Henriques's original critique, he first remarked that "little exists in the literature to specifically address how students understand weather, particularly at the secondary and undergraduate levels". Insightfully, he went on to say that

> along with formal instruction, young people possess a lifetime of observational experience with the water cycle. They have all seen kettles boiling, bathtubs steaming, and the accumulation of clouds in the sky before a rainstorm… to the instructor, this suite of common examples represents a windfall of opportunity. Any classroom with a window and a thermometer may become a laboratory for the discussion of weather.

Critically, though, Rappaport ended this rosy promise with the lament that "personal experience suggests that these connections are not being made in many classrooms. Consequently, undergraduates are unable to connect theories with actual phenomena".

Hypotheses and Experimentation Design

Singapore is an island one degree north of the Equator, at the southern tip of Peninsular Malaysia. It is generally low-lying, with the highest point being only 163 m above the sea level. Hills and valleys of sedimentary rock dominate the northwest, while the eastern region consists of sandy and flatter land. Singapore has no natural lakes, but reservoirs and water catchment areas have been constructed to store fresh water for Singapore's water supply.

Hanoi is in the northern region of Vietnam, situated in the Vietnam's Red River delta, nearly 90 km away from the coastal area. Hanoi contains three basic kinds of terrain, which are the delta area, the midland area and mountainous zone. In general, the terrain is gradually lower from the north to the south and from the west to the east, with the average height ranging from 5 to 20 m above the sea level. The hills and mountainous zones are in the northern and western part of the city.

In a report published in 2018 by the Green Innovation and Development Centre, air pollution in preceding year in the Vietnamese capital of Hanoi was four times higher than the standards deemed acceptable by the World Health Organisation. Exposure to high levels of air pollution may affect respiratory systems over the long run, alongside other health risks.

The students came up with some questions about the weather in Singapore and Vietnam, Hanoi. Some of these questions are:

- What's the weather like in Singapore and Hanoi?
- Are there any patterns to the changes in the weather from day to day?
- What are the patterns in temperature and precipitation?
- How does the change differ from Singapore and Hanoi?
- Does change in one area predict changes in another area?
- Can we predict what the weather will be like ahead of time?

Based on these questions and their understanding of the sensors equipment, they designed a study of the various environmental factors to be conducted at two sites in Singapore and Hanoi, Vietnam.

The students hypothesised that there would be environmental patterns based on the geographical landscape and elevation of the respective locations as well as seasonal patterns based on the months that the experiment was carried out. The experiment was conducted in October 2016, and they hypothesised that since Vietnam experiences the northwest monsoon while Singapore experiences the northeast monsoon during the fourth quarter of the calendar year, the two locations will have distinctively different weather during this period. Therefore, they expect the data collected to be distinct as well, backing up their current understanding of the geographical features of the two studied sites.

The data was collected through an Arduino board which has several sensors installed. The sensors collected data about sound, light, humidity, temperature, air pressure and air quality. Once data was collected, it was immediately streamed via wireless signal to a receiver which is connected to the internet. The receiver uploaded the data to a Dropbox account in the cloud where it is compiled into a spreadsheet file.

There was a question of how much data points to collect that will accurately reflect data for any given time. Generally speaking, the sensors are constrained by their power supply and the more they are "on" and collecting data, the more power they will consume.

The students finally decided that they could program the power timer to turn the sensor on for 5 min every 3 h, which means it collected data every 3 h. Since the sensor took multiple readings during the 5 min (e.g. 1500 to 1505 h), the readings during those 5 min were averaged into a single set of readings for that hour.

The aim was to observe the trends over time in each location, as well as the differences between the two sites. From there, they could determine whether the trends from the empirical data that we have collected disputes received wisdom of microclimatic differences in the two geographical locations.

In Singapore, the sensor was placed at Jurong West Street 41 in a public housing apartment. Its latitude is 1.348973; longitude 103.720062; 20 m above the street level. The location of the site in Singapore was on the western side of the island, near a man-made lake which is part of a park known as the Chinese Garden.

In Vietnam, the sensor was placed at 260 Cau Giay Street, Hanoi. Its latitude is 21.0346711; longitude 105.7953941; 17 m above the sea level. The location of the site in Hanoi is on the floodplain of the Red River, near a distributary known as the Tô Lịch.

The sensor in Singapore was placed next to a window facing an open area with a road. The window faced east, so high light levels were expected in the morning to early afternoon. In the late afternoon, the sensor was in the shade. The sensor was placed here to provide the sensor with good airflow and exposure to the sun while being sheltered from the rain, ensuring a high accuracy of environmental readings by the sensor (Fig. 2).

The sensor in Vietnam was placed outside on the balcony of the third floor overlooking an open area of an alley. The location chosen ensured that the sensor mote had the opportunity to receive ample exposure to sunlight from the morning to the afternoon, which served to provide reliable and accurate microclimatic data from the surrounding environment. Furthermore, as the sensor mote was placed in the shelter, it would not be directly exposed to rainfall or other harmful weather conditions, prolonging the lifespan of the equipment used (Fig. 3).

Testing and Analysis

Data was collated into a spreadsheet csv file in a Dropbox folder by the receiver, with one file each for the two sensors in Singapore and Vietnam. On 28 December 2016, the files were downloaded for analysis.

The files contained the following variables:

Fig. 2 Sensor mote in Singapore

moteID, referring to the identity of the sensor. moteID 0 is the sensor in Singapore, while moteID 1 is the sensor in Vietnam.
timestamp, referring to the time of the reading.
lightAnalog, referring to the reading of the light sensor. This variable is not discussed in this paper. This is in part due to the low sensitivity of the light sensor: during the night it generally registers as 0.
temperature, referring to the temperature at the time of the reading in Celsius.
humidityAnalog, referring to the relative humidity at the time of the reading.
airQuality, referring to the air quality at the time of the reading. This is an analogue reading as well.
pressure, referring to the air pressure.

The students then graphically expressed the data by taking readings from each day for each site. A graph was created for each reading (temperature, humidity, etc.). The graphs depicted in Figs. 4, 5, 6, and 7.

These are the analysis and reporting by the students from the data.

Fig. 3 Sensor mote in Vietnam, Hanoi

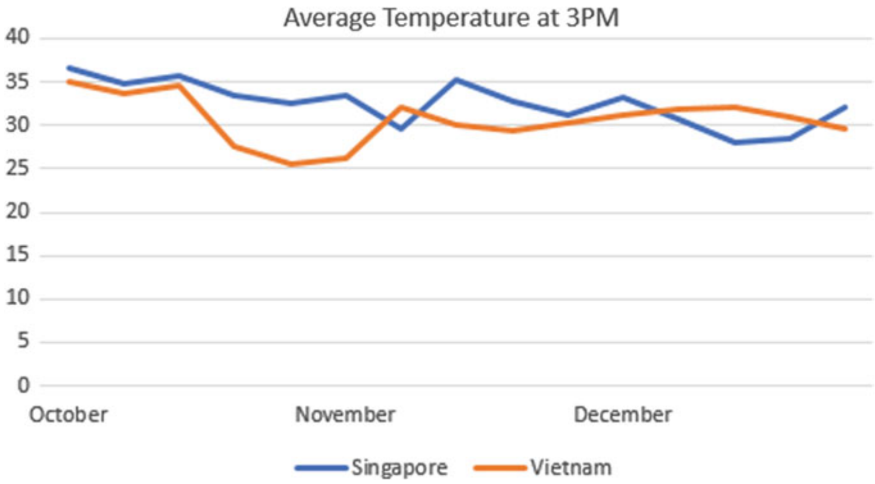

Fig. 4 Graph of temperature at 3 p.m. from October to December in Singapore and Vietnam

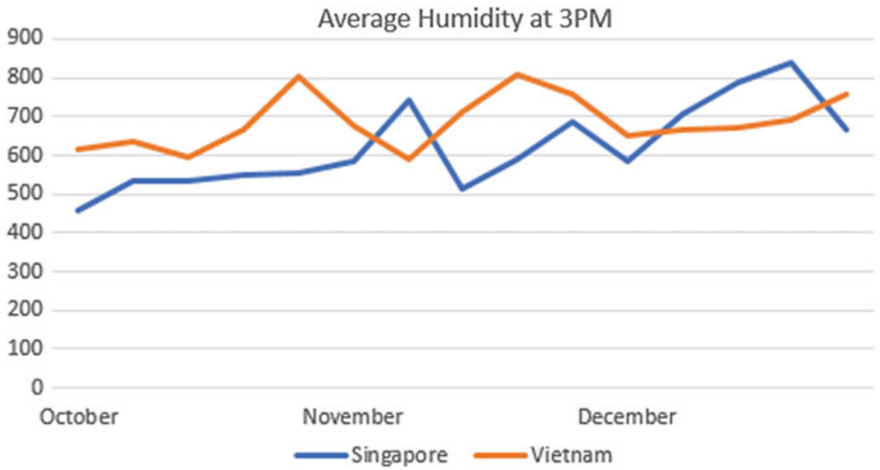

Fig. 5 Graph of relative humidity at 3 p.m. from October to December in Singapore and Vietnam

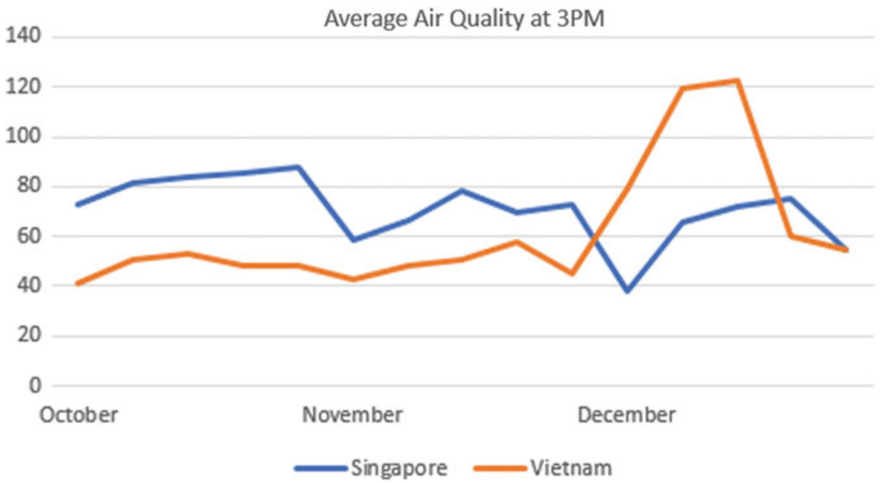

Fig. 6 Graph of air quality at 3 p.m. from October to December in Singapore and Vietnam

Temperature

The temperature at both sides trended lower from towards the onset of the northern hemisphere winter. From the data available, the mean temperatures recorded in Singapore were 32.3, 31.8 and 29.8 °C for the months of October, November and December, respectively. The mean temperatures recorded at the site in Hanoi were 31.9, 29.7 and 27.8 °C for the 3 months over the same period, respectively.

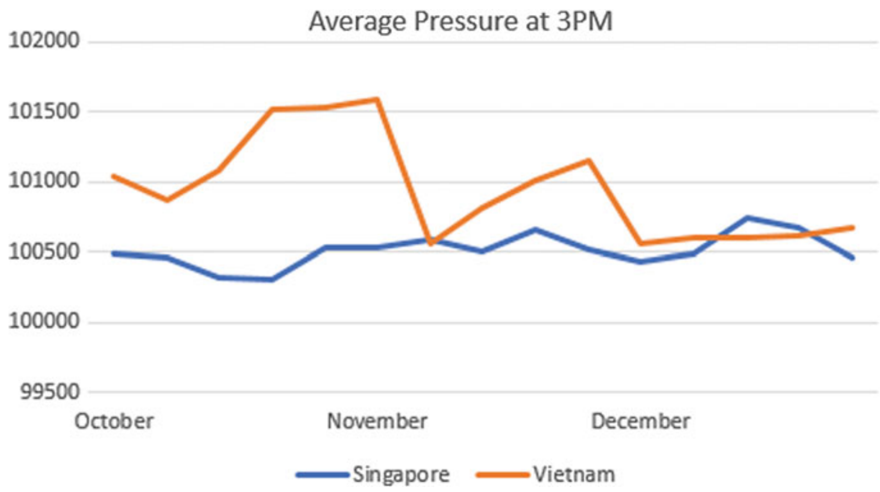

Fig. 7 Graph of air pressure at 3 p.m. from October to December in Singapore and Vietnam

Relative Humidity

The trends in relative humidity for the two sites in this study differed from October 2016 to December 2016. Relative humidity at the site in Singapore increased as the calendar year drew to a close, while relative humidity at the site in Hanoi remained largely stable. From the data available, the mean relative humidity recorded in Singapore was 67.9%, 73.9% and 92.4% for the months of October, November and December, respectively. The mean relatively humidity recorded at the site in Hanoi was 89.1%, 88.8% and 95.0% for the 3 months over the same period, respectively.

Air quality

The trends in air quality for the two sites in this study differed from October 2016 to December 2016. For much of the time over these 3 months, the air quality in Singapore was worse than at the site in Hanoi. However, the site in Hanoi experienced a spike in the deterioration of air quality towards the end of the calendar year.

Air pressure

The trends in air pressure for the two sites in this study differed from October 2016 to December 2016. Air pressure remained largely stable at the site in Singapore, while air pressure at the site in Hanoi decreased as the calendar year drew to a close. From the data available, the mean air pressure recorded in Singapore was 100,756, 100,571 and 100,717 Pa for the months of October, November and December, respec-

Table 1 Changes in readings in Singapore and Vietnam from October to December

	Singapore	Vietnam	Singapore versus Vietnam
Average temperature	Decreased	Unchanged	Singapore is higher
Average relative humidity	Increased	Unchanged	No great difference
Average air quality	Decreased	Increased	No great difference
Average pressure	Unchanged	Decreased	Vietnam is higher

tively. The mean air pressure recorded at the site in Hanoi was 100,453, 101,037 and 100,984 Pa for the 3 months over the same time period, respectively.

The graphs in Figs. 4, 5, 6 and 7 express the comparison over time periods (October to December) within each site as well as the comparison between the sites from October to December. From the average temperature graph, it can be determined that there is a fall in average temperature in Singapore from October to December.

By applying this reasoning to the other readings, the students summarised their observations in Table 1.

Abstracting and Modularising: Exploring Patterns and Connections

Based on the data that they collected, the students attempted to explain and identify factors that might have contributed to the data; in doing so, relate them to their own understanding of the environment and weather. Their edited analysis of each data set is as follows:

Temperature

As the study is performed from October to December, it was winter season in Vietnam. Vietnam's climate is classified as humid subtropical climate. As such, Vietnam experiences a milder winter as compared to Singapore whose climate is tropical rainforest climate where there is no summer or winter and experiences high temperature year-round. Thus, the average temperature of Singapore is higher than Hanoi, Vietnam from October to December.

We noticed a slight decrease in Singapore and Hanoi's temperature during the month of November and December. This was congruent with expectations associated with the onset of the northern hemisphere winter. The average temperature of the whole day would, in turn, decrease.

However, the decrease in Hanoi's temperature during November was more marked. This was due to the northern part of Vietnam experiencing a cold wave (Pham Huong 2016) which caused a drop in the temperature of Hanoi as seen from the graph.

Relative humidity

Relative humidity in both Singapore and Hanoi fluctuated during the months of October to December. However, it was observed that the relative humidity of both Singapore and Hanoi remained high as compared to each other with no great difference in general. This corroborates with the nature of both the tropical rainforest climate and humid subtropical climate, respectively.

Singapore has high relative humidity as it is surrounded by sea and with the high temperature experienced by the country, the rate of water evaporation would be high. The studied site is at Jurong West, which is on the west side of the island. This can explain why the humidity recorded is high as the west side of the island experiences rain shadowing, which is caused by high landmarks such as the so-called Bukit Timah Hill.

Vietnam experiences humid subtropical climate, which has high average relative humidity due to the dominance of the warm and moist maritime tropical air. Hanoi, Vietnam, however, experiences higher relative humidity because it lies on the eastern side of the Hoang Lien Son mountain range, which causes winds from the East Sea to be blocked, and unable to pass through the high mountain range. This would cause Hanoi to experience high relative humidity as the warm air is trapped on the eastern slope of the mountain range, forming rain and raising the relative humidity level.

Air quality

As seen from the graph, the air quality of Singapore was relatively poorer than Hanoi, Vietnam. This may be because the site chosen for studied at Jurong West had higher traffic density as compared to the studied site from Hanoi, which experiences less traffic as it was located at a closed residential area.

In addition, Singapore experiences stronger maritime winds as it is surrounded by seas in all directions. During the months of October to December, the northeast monsoon is prevalent in Singapore, causing the pollutants in the air to be dispersed to a larger area over Singapore, in turn can reduce the air quality of the studied location.

As for Hanoi, Vietnam, the air quality is relatively better than Singapore. However, in December, we observed a large spike in the air quality level of Vietnam where the amount of pollutants in the atmosphere increased sharply. This was because when Hanoi, Vietnam experiences a cold wave from the north, together with Hanoi being 20 m above the sea level, can cause temperature inversion, which causes any pollutants emitted from the surface to be trapped and build up in the colder layer below. This can cause the amount of pollutants in the air to increase during the winter of Hanoi.

Air Pressure

Air pressure in Singapore is generally lower than in Vietnam. This is because the sensor mote in Singapore was placed higher above the sea level than its counterpart in Vietnam, which meant that there was less air to exert forces to the surface, causing the pressure to be lower.

Singapore is also closer to the Equator, making the air pressure in Singapore to be lower as it experiences warm air and moisture, while Vietnam experiences colder and dry air during its winter.

Conclusion

Every day we ask questions with geographical and spatial components. Students may already have a lot of tacit information and data of their immediate day-to-day environment, but often have difficulty describing it with precision and clarity. A local data collecting network can help them make accurate observation of data patterns and see subtle variations in those patterns. The present system can help the forming and investigation of hypotheses on the environment. Specifically, it helps the students to develop the ability to conduct and monitor investigations of the local environment and verify the data against hypotheses. Students can use the data as evidence for an argument and move from observing a pattern to developing a geographical claim.

While the Vietnamese government launched a national action plan in 2016 to monitor emissions and improve air quality, the study reported in this chapter suggests that students can carry out investigative experiment and collect data over time to answer questions about the external world. In doing so, they break down their questions into problems, and then breaks down that problem into a series of small, more manageable problems. Each of these smaller problems can then be looked at individually, considering how similar problems have been solved previously and, based on their personal experiences, take simple steps to solve each of the smaller problems. The data collected can be analysed and irrelevant information can be ignored, while relevant information can be used to identify patterns and generalisation that in turn generate new questions to be answered, and new problems to be investigated.

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Climate Elasticity of Annual Streamflow in Northwest Bulgaria

Kalin Seymenov

Abstract The study of hydrological response to long-term climate changes is a particularly significant problem and an important task for the applied hydrology. This topic is also a challenge for geography. There are many different methods and criteria for the determination of this hydro-climatic relationship. The aim of present work is to explore one of these approaches: climate elasticity of streamflow (ε_p). As a case region, the territory of seven catchment areas situated in Northwest Bulgaria was selected. Results obtained show relatively large variations of ε_p—it ranges from 0.526 to 1.404, thus a ten percent change in mean annual precipitation would be reflected within 5.26–14.04% change in mean annual flow. The calculations in this paper establish strong inverse correlations between ε_p, runoff coefficient and mean annual streamflow (a coefficient of determination: $R^2 > 0.80$), explained by the nonlinear "rainfall–runoff" relationships. There are also spatial variations of the ε_p value—it is lower in the upper streams and increases toward the mouths of the rivers. The assessment of climate elasticity of streamflow is an informative approach for an estimate of climate change impacts to hydrological systems and provides an opportunity for effective water resources management.

Keywords Climate elasticity · Climate changes · Hydrological response · Streamflow · Precipitation

Introduction

Climate changes represent one of the most important challenges for the functioning of environmental processes. The hydrological cycle is no exception because it is closely related to the climate system. Any change in climatic parameters has direct or indirect hydrological effects (Zaharia et al. 2018). Estimates of the sensitivity of streamflow to long-term climate changes are required for different water planning and water management activities. This study is prompted by the need to extend these assessments in the context of already established global and regional rainfall

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changes and increasing air temperature trends. Furthermore, numerous research of the hydrological response to long-term climate changes, including those describing the hydro-climatic relationships, are theoretical (model-based): Schaake and Němec (1992) used the Sacramento model; Yates et al. (1998), (1999) worked by the linear regression coefficients; Chiew and McMahon (2002), Chiew (2006) used the SIMHYD and AWBM models, Gelfan et al. (2015) worked by the ECOMAG and SWAP models; Guo et al. (2016)—SWAT model, etc. Excluding the hydrological models, sometimes showing uncertain results, an alternative approach to estimate the runoff sensitivity is directly from the hydro-climatic data set. A similar empirical (data-based) method is a climate (precipitation) elasticity of streamflow (Sankarasubramanian and Vogel 2001; Chiew 2006; Chiew et al. 2006; Fu et al. 2007, 2011; Sun et al. 2013; Allaire et al. 2015; Tsai 2017; Andréassian et al. 2017; Xing et al. 2018; Hristova et al. 2018). The primary goal of present study is to explore this approach for seven catchments in Northwest Bulgaria, using a nonparametric estimator which calculates the elasticity values directly from the rainfall and runoff time series data.

Study Area

Study area includes the drainage basins of seven right tributaries of the Danube River, situated in Northwest Bulgaria. This region is located between 43° 24′–44° 04′ N latitude and 22° 21′–23° 32′ E longitude, it covers an area of 3790.5 km^2 (3.4% of the country's territory) (Fig. 1, Table 1).

The catchment areas drain in three geomorphological units: the Balkan Mountains, the Fore-Balkans, and the Danube Plain. Study area belongs to the temperate-continental climate type (DFA according to Köppen classification). Mean annual air temperature, measured during the 1961–2015 period, varies from 4.2 °C (in the Chuprene Reserve area) to 11.6 °C (in the town of Lom). Average precipitation sums for the 1960–2017 period, vary from 538 mm (Lom) to 773 mm (Stakevtsi) and reach up to 1200 mm in the Balkan Mountains. Study area is an important agricultural region (cereal and technical crops: wheat, barley, corn, and sunflower production; perennial vineyards cultivation). There are over 50 small reservoirs and a hydropower cascade, located in the upstream of the Lom River. Listed activities reflect the favorable soil-climatic conditions and the environmental transformations due to human impact in this area.

Data and Methods

Annual discharge data provided by the National Institute of Meteorology and Hydrology are used. There are seven hydrometric stations, covering areas from 53 to 1087 km^2, at the mean elevation 193–1411 m above sea level (Hydrological Reference…, 1981; Hristova et al. 2017). Precipitation output data from seven meteoro-

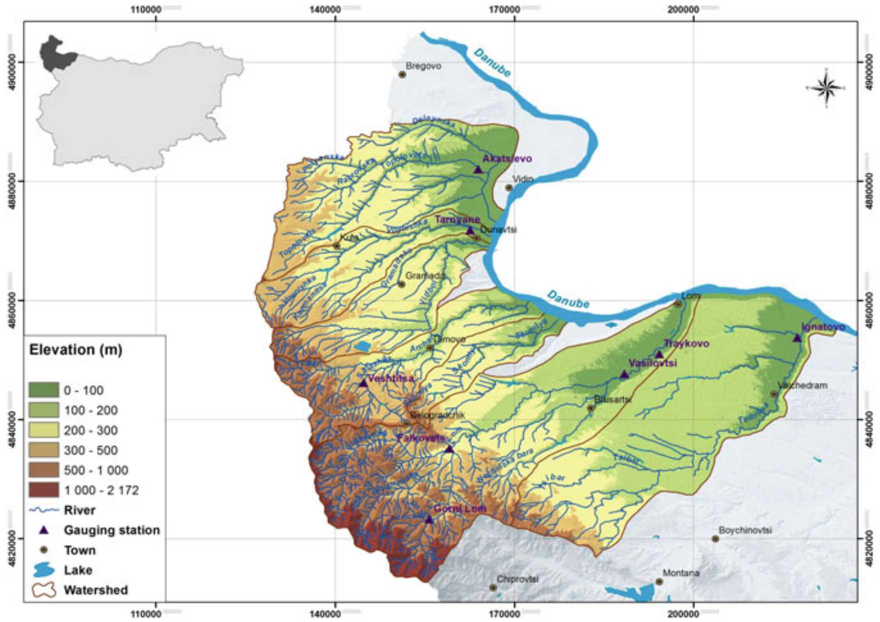

Fig. 1 Relief, hydrographic, and hydrometric features in study area (Hristova et al. 2017)

logical stations within the same catchments or up to 10 km near them for correlations with streamflow are used (Table 3). The length of time series used critically influences the estimation of the climate elasticity. It is recommended to use as long a record as possible to estimate elasticity in order to capture the full range of observed variability. Hydro-climatic output data for 58 years, recorded during the 1960–2017 period are selected.

Climate elasticity of streamflow, also called "precipitation elasticity" or "streamflow sensitivity factor", is an indicator for the sensitivity of hydrological systems to the long-term climate fluctuations. It is based on a conceptual catchment model and represents a proportional change of annual streamflow (Q) to precipitation variability (P) (Sankarasubramanian and Vogel 2001; Chiew 2006; Chiew et al. 2006; Fu et al. 2007, 2011; Allaire et al. 2015; Gao et al. 2016; Andréassian et al. 2017). This relation is calculated by the formula

$$\varepsilon_p(P, Q) = \frac{dQ/Q}{dP/P} = \frac{dQ}{dP}\frac{P}{Q},$$

transformed into the nonparametric estimator (Sankarasubramanian and Vogel 2001):

$$\varepsilon_p = median\left(\frac{Q_i - \bar{Q}}{P_i - \bar{P}}\ \frac{\bar{P}}{\bar{Q}}\right),$$

Table 1 Hydrographic information about the main rivers and catchments

Main river	The longest tributary	Length (km)	Catchment area (km^2)	Altitude (m)		Geographic coordinates			
				Source	Mouth	Source		Mouth	
						X	Y	X	Y
Topolovets	Deleynska	67.6	582.8	404	33	22.382	43.833	22.851	43.936
Voynishka	Kormanitsa	55.2	276.3	664	32	22.401	43.766	22.842	43.914
Vidbol	Gramadska	61.8	329.8	998	29	22.407	43.718	22.839	43.898
Archar	Salashka	59.4	365.4	1060	30	22.406	43.716	22.927	43.820
Skomlya	Manastirska	41.6	162.8	560	29	22.690	43.646	22.993	43.797
Lom	Stakevska	92.5	1139.8	2100	28	22.682	43.395	23.249	43.836
Tsibritsa	Tsibar	87.5	933.6	818	27	22.954	43.474	23.526	43.814

Sources Hydrological Reference Book … (1981), Hristova (2012), Hristova et al. (2017)

where ε_p is a climate elasticity, $\bar{P}$ and $\bar{Q}$ are mean annual precipitation and streamflow for the whole period, P_i and Q_i are annual precipitation and streamflow for the ith year.

To compute climate elasticity estimates, the output hydro-climatic data was calculated for each pair of annual time series (P_i, Q_i). As the nonparametric estimate of ε_p, the median value of annual data set obtained was defined. The statistical results established were mapped in the software program ArcGIS 10.4, using the KRIGING interpolation technique (already applied and recommended as a reliable approach in similar studies) (Khanal et al. 2014; Gao et al. 2016). They are grouped in equal classes by a color legend, according to their values.

Results and Discussions

To achieve more objective researches on the hydrological response to rainfall changes, the streamflow and precipitation time series were computed for every possible 12-month annual periods. Table 2 presents the coefficient of determination (R^2) of the "Q_i (mm) $-$ P_i" relationship (for each pair of annual data), it also shows the corresponding ε_p values. To define the most reliable ε_p for three catchments in the United States, China, and Australia this coefficient was used, because of "the time-series having the strongest precipitation-streamflow relationship, i.e., the highest coefficient of determination, is inferred as producing a more appropriate elasticity value" (Fu et al. 2011). The results surprisingly show: the highest R^2 value coincides with the calendar year. Exceptions are the catchments of the Salashka River, Stakevska River, and Lom River (at Gorni Lom), where it approximates the water year accepted in Bulgaria and many countries across the world, respectively (Table 2). These fragments contradict the diverse results obtained from Fu et al. (2011), but listed numbers confirm their statement that the ε_p values are higher in annual cycles, starting from the dry season. This fact allows implement of a seasonal approach in the climate elasticity of streamflow studies and needs more research. Henceforth, only the annual time series having the largest coefficient of determination will be shown here.

Results obtained show significant variations of ε_p value—it ranges within 0.526–1.404, therefore indicating that an eventually ten percent change in mean annual precipitation would be reflected as increase/decrease from 5.26 to 14.04% in mean annual streamflow (Table 3). Some of the abovementioned values are slightly higher than the climate elasticity results established from Hristova et al. (2018) for the entire Bulgarian territory and are partly similar or slightly higher/lower to the calculated numbers for 1337 drainage basins in the United States, for above 200 catchments in the middle and high latitudes of the Northern Hemisphere (chiefly in the territories of Europe and Northern America), for 519 drainage basins in France and for 79 catchments in the Poyang Lake basin in China (Sankarasubramanian and Vogel 2001; Chiew et al. 2006; Sun et al. 2013, Andréassian et al. 2017). Furthermore, the long-term climate forecasts, the optimistic (RCP 4.5) and the pes-

Table 2 The coefficient of determination (R^2) and the climate elasticity values (ε_p), computed for different 12-month annual periods for more reliable results

Annual periods (Months)	Catchment areas													
	Topolovets at Akatsievo		Voynishka at Tarnyane		Salashka at Veshtitsa		Stakevska at Falkovets		Lom at Gorni Lom		Lom at Vasilovtsi		Tsibritsa at Ignatovo	
	R^2	ε_p	R^2	ε_p	R^2	ε_p	R^2	ε_p	R^2	ε_p	R^2	ε_p	R^2	ε_p
Jan–Dec	0.34	1.183	0.34	1.394	0.35	0.921	0.44	0.765	0.41	0.521	0.47	1.404	0.39	1.137
Feb–Jan	0.29	1.148	0.30	1.420	0.32	0.894	0.41	0.743	0.42	0.533	0.42	1.381	0.34	1.189
Mar–Feb	0.24	1.108	0.31	1.386	0.33	0.858	0.38	0.751	0.37	0.546	0.39	1.343	0.30	1.202
Apr–Mar	0.25	1.126	0.31	1.351	0.30	0.831	0.38	0.728	0.38	0.518	0.34	1.352	0.32	1.119
May–Apr	0.25	1.113	0.29	1.232	0.30	0.836	0.42	0.692	0.33	0.531	0.37	1.397	0.26	1.105
Jun–May	0.28	1.132	0.32	1.248	0.28	0.885	0.35	0.717	0.31	0.616	0.35	1.428	0.23	1.196
Jul–Jun	0.21	1.275	0.28	1.432	0.25	0.959	0.36	0.802	0.32	0.628	0.34	1.511	0.21	1.285
Aug–Jul	0.24	1.306	0.26	1.446	0.24	0.982	0.33	0.811	0.31	0.604	0.32	1.486	0.26	1.259
Sep–Aug	0.29	1.294	0.30	1.382	0.31	0.985	0.42	0.806	0.35	0.557	0.30	1.435	0.28	1.207
Oct–Sep	0.31	1.208	0.28	1.331	0.32	0.968	0.49	0.790	0.44	0.526	0.37	1.392	0.31	1.174
Nov–Oct	0.30	1.195	0.33	1.371	0.38	0.982	0.40	0.783	0.41	0.531	0.40	1.401	0.32	1.181
Dec–Nov	0.32	1.178	0.31	1.388	0.35	0.963	0.42	0.774	0.39	0.548	0.38	1.384	0.37	1.145

Table 3 Linked gauging stations and hydro-climatic statistics for the catchments in Northwest Bulgaria

Gauging stations: hydrological/meteorological	Mean annual Q (m^3/s)	Mean annual Q (mm)	C_v of Q	Mean annual P (mm)	C_v of P	Runoff coeff. Q/P	Climate elasticity ε_p
Topolovets at Akatsievo/Kula	1.01	104.36	0.53	618	0.21	0.16	1.183
Voynishka at Tarnyane/Gramada	0.80	93.73	0.56	614	0.22	0.15	1.394
Salashka at Veshtitsa/Belogradchik	0.59	224.65	0.45	702	0.19	0.32	0.982
Stakevska at Falkovets/Stakevtsi	3.29	313.25	0.28	773	0.21	0.41	0.790
Lom at Gorni Lom/Dolni Lom	0.68	404.97	0.25	714	0.24	0.57	0.526
Lom at Vasilovtsi/Lom	6.07	155.42	0.38	538	0.23	0.28	1.404
Tsibritsa at Ignatovo/Valchedram	1.84	68.79	0.43	544	0.22	0.13	1.137

simistic (RCP 8.5) scenarios predict a change of annual streamflow from −8.0 to 9.0% in study area for 2071–2100, compared to the 1976–2005 period, according to the "National Plan for river basins… (2016–2021)" at the Danube River basin Directorate. The computed ε_p values nearly approximated these numbers.

The results in this paper confirm the following characteristics: relatively strong inverse correlations: "ε_p—runoff coefficient" and "ε_p—mean annual streamflow (mm)" (Fig. 2).

This specificity is explained by the fact that "rainfall–runoff" processes are nonlinear, suggesting: "the absolute streamflow change for a given absolute change in rainfall would be reflected as a higher ε_p in catchments with a lower runoff coefficient" (Chiew 2006). Results obtained contradict the especially clear inverse relationship "ε_p—mean annual precipitation" ($R^2 = 0.6711$; the graphic is not shown here), even proven as a stronger than the correlation between ε_p and mean annual streamflow (mm) for 219 catchments in Australia (Chiew 2006). There is a limited number of available rainfall stations—it could be a possible reason explaining the weaker correlation. Despite the abovementioned contradictions, considering all ana-

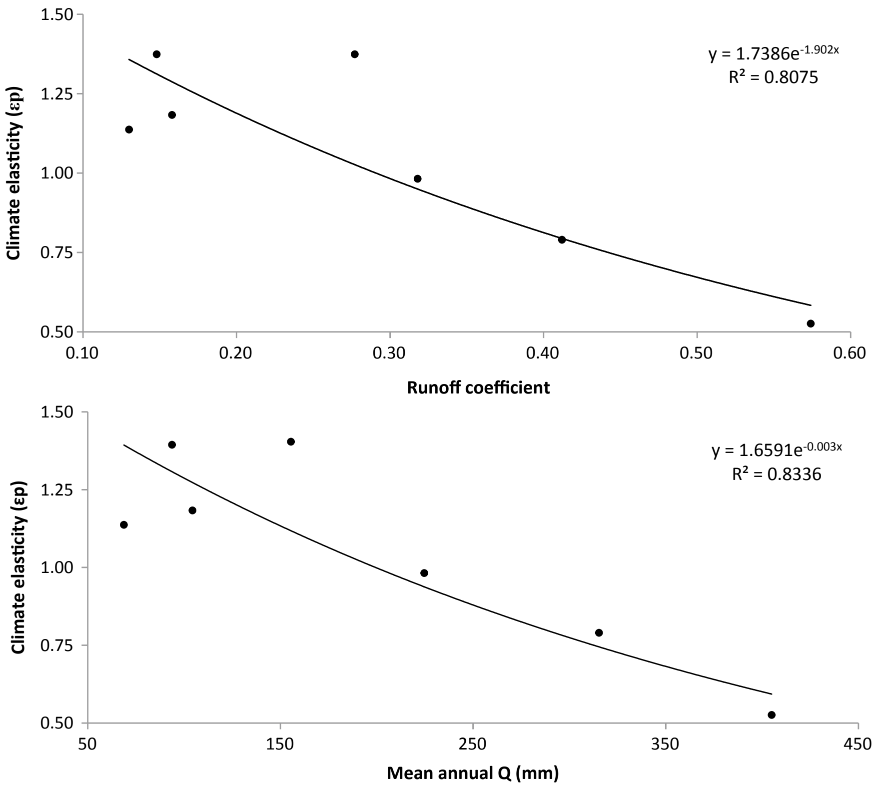

Fig. 2 Inverse correlations between the climate elasticity of streamflow (ε_p) values and key hydrological indicators (runoff coefficient and mean annual Q, mm)

lyzed “precipitation–streamflow” relationships, it could be summarized that they are so powerful because of the direct response of runoff to rainfall. Some multivariate regression relationships, arising from the hydro-climatic correlations, e.g., “ε_p vs. mean annual temperature, rainfall, and streamflow (mm)”, show the following: “the climate elasticity value increases with the temperature and streamflow if the precipitation decreases, but it decreases with the temperature and streamflow if the precipitation increases” (Fu et al. 2007). Although there are not used annual temperature data, the hydro-climatic conditions in the investigated area indirectly confirm this statement.

The calculations in present work establish spatial variations of the climate elasticity between the mountainous and flat part of studied catchments (an inverse relationship “ε_p vs. the altitude of catchments”; $R^2 = 0.7754$). The geographical analysis shows the elasticity is lower in the upper streams and increases toward the mouths of the rivers (Fig. 3). Similar peculiarities were described for drainage basins in the United States and Australia, where the sources of the rivers belong to humid climate type with long snow cover duration, while the downstream sections flows through semiarid desert landscapes (Sankarasubramanian and Vogel 2001; Chiew et al. 2006). Although the hydrological processes in Northwest Bulgaria occur at different climate, geological, geomorphological, and biogeographical conditions, the

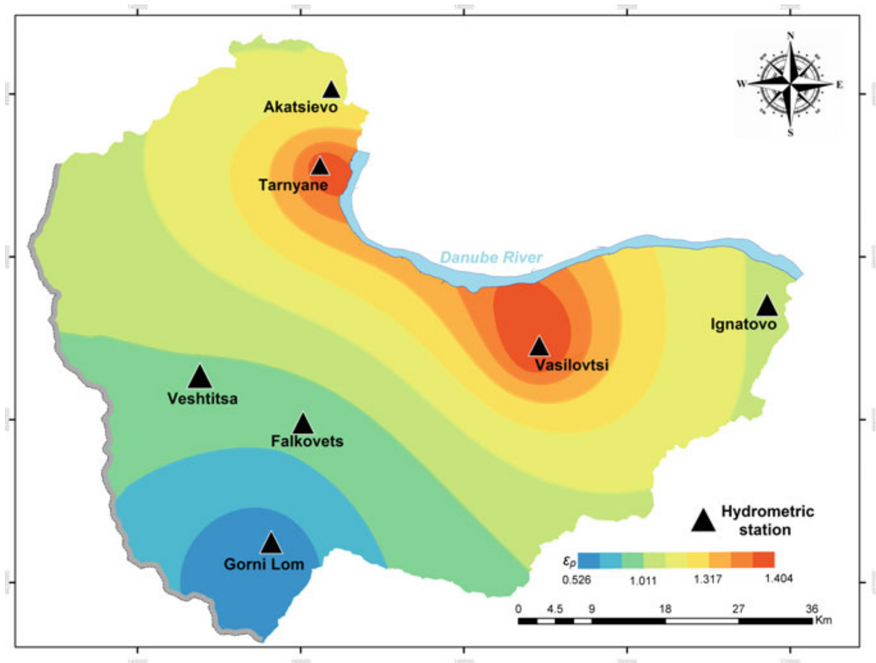

Fig. 3 Spatial variations of climate elasticity of streamflow (ε_p) values in Northwest Bulgaria

results establish analogous spatial characteristics. Further researches explaining this phenomenon are needed.

Conclusion

The main findings of present work are the following: (1) the climate elasticity (ε_p) values are related to the coefficient of determination (R^2) of the "rainfall–runoff" annual time series. The nonparametric estimator is computed for calendar or water years, according to the highest R^2 value; (2) a ten percent change in mean annual precipitation would be reflected within 5–14% change in mean annual flow; (3) there are strong inverse correlations between the ε_p, runoff coefficient and annual streamflow, due to the nonlinear hydro-climatic processes; (4) there are spatial differences of the ε_p value—it is lower in the upper streams and increasing toward the mouths of the rivers. This paper presents the climate elasticity of streamflow (ε_p) as an informative and easy to use approach for an estimate of hydrological response to long-term rainfall changes. In future, this research could be extended with other climatic parameters for more in-depth results, e.g., mean annual air temperature, potential evapotranspiration (PET), humidity index, etc., and their impacts on runoff.

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Hydrological Aspects of the Floods in the Kolubara River Basin (Serbia)—Analyses and Flood Mitigation Measures

Ana Milanović Pešić

Abstract Flood events, as one of the most common natural disasters in Serbia are the subject of research from different aspects. In this chapter, the estimation of flood peaks in the Kolubara river basin are analysed based on the data collected at four hydrological gauges (Valjevo, Slovac, Beli Brod, and Bogovadja) in 1961–2015 period. Using probability theory and mathematical statistics, analyses of time series of maximum discharges were made. Then theoretical functions of the maximum discharges occurrence were obtained and estimation of flood magnitude for a given recurrence interval T (T-year flood) was calculated based on these data. The results have shown that floods mostly occur in late spring or early summer, in the periods of frequent cyclones. After 1980, the greatest floods in the Kolubara river basin were recorded in 2014, 2010, 2001, and 1981. In this chapter, special focus is on flood in May 2014, which is considered to be the greatest flood recorded in Serbia and in this basin since the beginning of the twenty-first century.

Keywords Extreme flood events · The maximum discharge · Flood magnitude · Kolubara river

Introduction

According to the Emergency Events Database (EM-DAT 2018) and International Federation of Red Cross and Red Crescent Societies (IFRC 2006, 2017) data on disasters caused by natural hazards in the 2001–2017 period, flooding is one of the most common (45% of all events), most affected (45% of all affected people), and most damaging (22% of all economic losses) natural hazards worldwide. With the frequency and magnitude of flood disasters projected to increase due to both climate change and growing population exposure (Kundzewicz et al. 2014; Winsemius et al. 2015), flooding is one of the key societal challenges for this century (Trigg et al. 2016). Therefore, special attention is paid to the disaster risk reduction, which requires

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knowledge of the expected flood hazard for a given probability. For planning the risk prevention strategy, it is necessary to examine the hydrometeorological variability in an entire area (Arnaud et al. 2016). This analysis can include mapping flood-prone areas, defining the frequency of extreme flood events, planning, and designing hydraulic structures, etc.

Flood is the most common natural disaster in Serbia, with 53% of all events (EM-DAT 2018). In Serbia, the floods having 100-year recurrence interval potentially threaten 16,000 km^2 of area (about 18% of the territory), and the largest flood-prone areas are in north part (Vojvodina) and central part (Posavina-area along the Sava river course, Pomoravlje-area along the Velika Morava river course) of territory. The largest flood-prone areas are located in the river valleys of the greatest rivers Tisza (2,800 km^2), Sava (2,243 km^2), Velika Morava (2,240 km^2), and the Danube (2,070 km^2) (Gavrilović and Dukić 2002). Due to very high concentrations of the population and industrial facilities, the dense infrastructure network and the fertile soil in the valleys of these rivers, flood damage is always great. Therefore, hydrological analyses of floods in Serbia have been the subject of numerous studies. From the geographical approach, it is significant monograph on floods causes and damage in Serbia during twentieth century (Gavrilović 1981), as well as articles on hydrological analyses of the greatest floods in the second half of the twentieth century and the first decade of the twenty-first century (Milanović et al. 2010; Gavrilović et al. 2012).

Kolubara river, located in western part of Serbia (Fig. 1), is one of the most vulnerable area to floods in Serbia. It has one of the highest coefficients of deviation of month discharge in comparison with other larger river basins in Serbia, and very disbalanced ratio between high and low waters (Petrović et al. 2015). This territory is extremely vulnerable to the torrential floods, which were analysed in several studies (Petrović et al. 2015; Kostadinov et al. 2017). According to the analysis of natural conditions in the Kolubara river basin this area is predisposed to a greater number of torrential floods due to its geomorphological and hydrological features, and land use properties. Torrential floods are closely related to the intensity and spatial distribution of erosive processes in the upper part of the Kolubara basin (Dragićević et al. 2016). Floods in the Kolubara river basin cause great damage in Valjevo town and its surroundings (Basarić and Bezbradica 2016), as well as Obrenovac municipality (Dragićević et al. 2007). As flood in May 2014, which is considered to be the greatest flood recorded in Serbia caused enormous damage in Kolubara river basin, this study will be mostly focused on the analyses of maximum discharges in great rivers—Kolubara and its largest tributary Ljig.

Study Area

The Kolubara river is 86 km long and its basin covers the area of 3,628 km^2 which is 4.1% of total area of Serbia (Urošev et al. 2017). It is located in the western part of Serbia (Fig. 1). The rivers Obnica and Jablanica join together 1 km upstream from Valjevo town forming the Kolubara river, which is the right tributary of the Sava

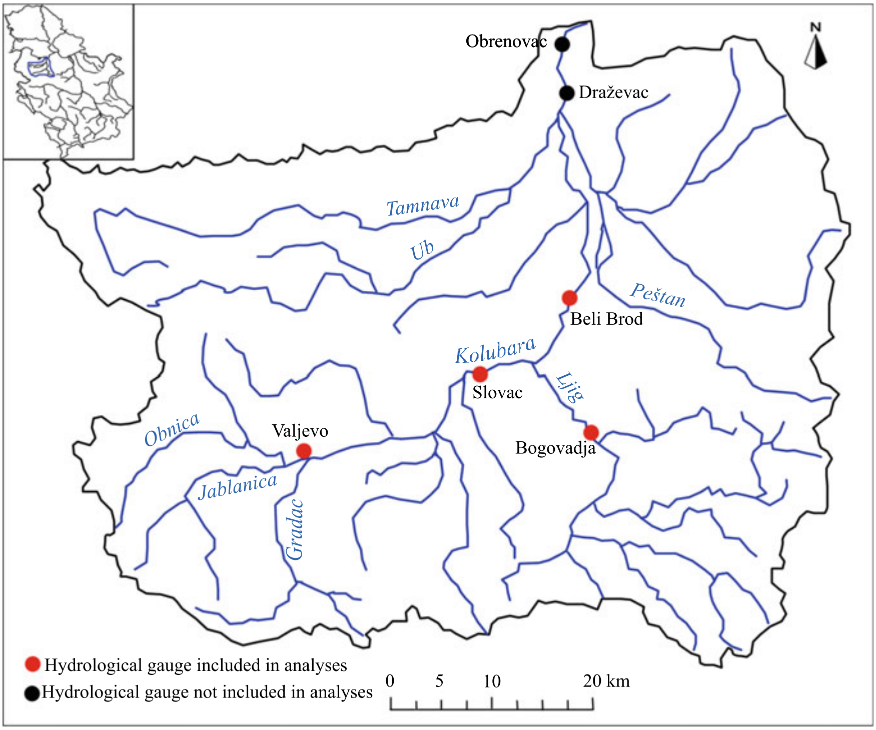

Fig. 1 Kolubara river basin

river with the confluence nearby Obrenovac. Larger left tributaries of Kolubara river are Tamnava river and Ub river, and right tributaries are Gradac river, Ljig river and Peštan river. The total length of watercourses in this basin amounts 1,182 km, and river network density 325 m/km^2 (Urošev et al. 2017). Average altitude of Kolubara river basin is 275 m (Urošev et al. 2017).

According to the database by Geographical Institute "Jovan Cvijić" SASA in 1961–2010 period, it is calculated that Kolubara river flows into Sava river about 16 m^3/s or about 0.5×10^9 m^3 of water annually. Its biggest tributary is Ljig river (4.3 m^3/s) (Urošev et al. 2017). The water balance in this basin indicates the dominance of evaporation. Average annual precipitation amounts 777 mm, runoff is 139 mm (17.8%), and evaporation is 638 mm (82.2%) (Urošev et al. 2017). Using the Mann–Kendall test and Sen's method, trends of annual discharges in Kolubara river basin were analysed. Based on results, it can be concluded that there is not statistical significant trend in Kolubara river and its tributaries, except in Jablanica river, where was recorded a significant decrease (−0.01 m^3/s per year) (Kovačević-Majkić and Urošev 2014). According to analysis of observed data of Republic Hydrometeorological Service of Serbia between 1961 and 2015, it can be concluded that the maximum discharges at all hydrological gauges occur in March, except in its tributary Peštan, where it occurs in February. The minimum discharges are related to the end of the summer and the beginning of autumn (August–September) (Milanović Pešić 2015).

Methodology and Data Collection

Flood frequency analysis (FFA) is one of the main techniques used for the at-site estimation of flood recurrence magnitude. It defines the relationship between the magnitude of an event and the frequency with which that event is exceeded. In general, FFA involves the fitting of a probability model to the sample of annual flood peaks recorded over a period of observation, for a river basin of a given region (Bhagat 2017). Estimation of flood magnitude for a given recurrence interval T (T-year flood) at a specific location is need for design of hydraulic and civil infrastructure facilities (Chen and Singh 2017) and it is used by engineers and hydrologist worldwide.

Reliable flood frequency estimates are very important for floodplain management such as to public protection, mitigations of flood damages, for designing and locating hydraulic structures, flood risk assessment, etc. Therefore, the main problem in FFA is the selection of a suitable distribution for flood magnitudes and the choice of parameter estimation. Although several probability distributions and parameter estimation methods have been proposed, none had gained worldwide acceptance. Different probability distributions are adopted and used depending on the climatic and the geographical features of the study region (Shenglian et al. 2018) or availability of observation data and the specific hydrometeorological features (Arnaud et al. 2016).

The question of best fit has always been of concern and many studies of this issue have been reported (Kidson and Richards 2005; Stedinger and Griffis 2008). Commonly used statistical distribution for FFA include: the Normal, log-Normal, Gumbel, Generalized extreme value, Pearson type III, log-Pearson type III. Some of these distributions have been adopted in different countries. For example, the generalized extreme value distribution has been used in Europe, log-Pearson type III in the United States (Chen and Singh 2017), the Pearson type III distribution in China and Australia (Chen et al. 2012). The second step in FFA is to estimate associated parameters of the selected distribution. There are several standard parameter estimation methods, such as moments, maximum likelihood, L-moments, probability weighted moments, and least square (Chen and Singh 2017). Among these methods, maximum likelihood and L-moment are the most commonly used.

Flood frequency analyses can be divided by the issue there are dealing with: nonstationarity of data, regional flood frequency analyses, seasonal frequency analyses, and uncertainty in flood frequency analyses (Gavrilović et al. 2012). Many studies have analysed the nonstationarity in single hydrological variables due to changing environments (Cunderlik and Burn 2003; Gilroy and McCuen 2012). Regional flood frequency analyses are developed and used in hydrological studies worldwide (Sarhadi and Modarres 2011; Aydoğan et al. 2016). They are used for the estimation of floods for ungauged sites or gauged sites in which the hydrological information is insufficient for the reliable estimation of extreme events. It involves the identification of groups (or regions) of hydrological homogeneous river basins and the application of a regional estimation method in the identified homogeneous region. A seasonal flood frequency analysis is discussed in Karmaker and Dutta (2010). Flood risk analyses are based on assumptions and decisions about models, parameters, and data. In many cases it can be argued for different options.

In order to estimate flood frequency and the probability of the maximum discharges occurence in this study, it has performed a statistical analysis for the data collected at four hydrological gauges (Valjevo, Slovac, Beli Brod, and Bogovadja). It was used maximum annual discharges recorded between 1961 and 2015. The obtained data were taken from the Yearbook I of the Republic Hydrometeorological Service of Serbia. Among 15 hydrological gauges, four are selected on which thirty-year or longer time series of the maximum annual discharges were established.

At the beginning, it is examined the randomness of the maximum annual discharges series using the consecutive differences test (Neyman's test) and the first-order serial correlation test (Anderson's test). This was followed by a stationarity examination of the statistical parameters for particular sequences of the established time series, i.e., by determining the time series homogeneity. For these analyses were used Student's test (for testing the homogeneity of average values), Fischer's F-test (for testing the homogeneity of dispersion) and the Wilcoxon inversion test (for the distribution function). After these examinations, the empirical distribution and the probability distribution function parameter were calculated. The maximum discharges for theoretical functions of the probability distribution commonly used in hydrology were also calculated: the Normal, log—Normal, Gumbel, three-parameter gamma distributions—Pearson type III and log-Pearson type III. Evaluation of most commonly used distribution methods for flood magnitudes is reported in many studies, such as study for at-site flood frequency analysis in Australia (Rahman et al. 2013) and at Swat river in Pakistan (Farooq et al. 2018). In the next step, three goodness-of-fit tests were applied to the fitted distributions: Kolmogorov–Smirnov, Cramér-von-Mises, and Chi-squared at 5% significance level. Based on the data obtained by these tests, the final selection of the applicable theoretical distribution function was made and the corresponding confidence intervals were calculated.

Results and Discussion

The results of the analyses from this study have given detailed information of likelihood discharges to be expected in the Kolubara river and its tributary Ljig at the various return periods based on the observed data. Based on statistical analyses, it has been found that a single distribution cannot be specified as the best-fit distribution for all hydrological gauges in Kolubara river basin. The results indicate that log-Normal, Pearson type III and log-Pearson type III distribution have been identified as the best-fit distributions in Kolubara river and log-Pearson type III in Ljig river (Table 1).

Table 1 Exceedance probabilities (P) and recurrence interval (T) of the greatest floods on the Kolubara river basin

Year	Gauge	Probability distribution	Q max (m^3/s)	P (%)	T (year)	Date
Kolubara river						
2014	Valjevo	Pearson type III	396	0.49	203	15.05
	Slovac	Log-Pearson type III	1100	0.29	335	15.05
	Beli Brod	Log-Normal	1360	0.34	299	15.05
2010	Beli Brod	Log-Normal	767	3.45	29	23.06
2001 1981	2001 Valjevo	Pearson type III	182	9.43	11	20.03
	1981 Beli Brod	Log-Normal	672	5.34	19	26.03
Ljig river						
2014	Bogovadja	Log-Pearson type III	651	0.28	354	15.05
2001	Bogovadja	Log-Pearson type III	269	5.2	19	27.09

According to Table 1, Data Fund by Republic Hydrometeorological Service of Serbia and disaster damages reports the greatest floods in Kolubara river basin were recorded in: May 2014 at all sites, and then in June 2010, March and September 2001, and March 1981.

Flood in May 2014

In the central part of Serbia, including the Kolubara river basin the largest floods of the twenty-first century were recorded in the middle of May 2014. During this flood, absolute maximum water levels and discharges have been reached at all hydrological gauges in observation period. As the main cause of these extremely devastating floods can be marked the three significant rainy periods that occurred in the second half of April, early May, and middle May. Severe precipitation in middle May occurred due to the slow movement of the spacious cyclone from the Mediterranean region toward the Balkan Peninsula. Cold air penetration across the western Europe and the Alps, on May 13 led to the deepening of the altitude valley, within which the frontal system connected with the cyclone in the Adriatic area moved.

Based on the data from Table 2, it can be concluded that the total precipitation for two days at some meteorological gauges in Serbia exceeded two or three times the average amount for the 50-year period. A particular problem in more detailed flood analysis is the lack of gauges and observation in the mountainous regions of Serbia, especially in the zones of torrents. One of examples are mountains nearby Valjevo town in Kolubara river basin. Based on the synoptic condition, it can be

Table 2 Precipitation at some meteorological gauges in Serbia in May 2014 in comparison with average amount for the 50-year period

Gauge	14–15.05	15–16.05	Total (mm)[a]	Average amount (mm) for May (1961–2015)[b]
Loznica	160.6	52.6	213.2	79.2
Valjevo	108	87	195	59.9
Belgrade	108	45	153	64.1
Smederevska Palanka	96	30	126	62.2

[a]Data fund by Republic Hydrometeorological Service of Serbia
[b]Data fund by Geographical Institute "Jovan Cvijić" SASA

concluded that large amounts of precipitation have fallen in this area, however there is no precise data.

Anthropogenic factor can also be mentioned as one of the important causes of extreme flood. During the 1970s of twentieth century, the Kolubara riverbad was relocated in order to expand the coal mine. More precisely, Kolubara riverbad was removed 800 m upstream from the place where its tributary Peštan flows into it (Dragićević 2007). Thus, Kolubara water course flows into Peštan, which led to the fossilization of the old riverbed. As a result of this process, erosion and sediment transport have increased in river basin. Also, Kolubara riverbed is filled with sediments, which reduced its permeability.

It is important to highlight that during the middle of May 2014, maximum discharges are also recorded along the Sava river in Croatia, Bosnia and Herzegovina, and Serbia, which reduced its capacity to receive flood flow formed in the Kolubara river basin (Milanović Pešić 2015). Thus, at all hydrological gauges along the Kolubara river and most of its tributaries absolute maximum discharges were recorded. According to the results from Table 1, recorded discharge at Beli Brod was 1,360 m^3/s (299-year return period), at Valjevo was 396 m^3/s (203-year return period), at Slovac 1,100 m^3/s (335-year return period) and at Bogovadja 651 m^3/s (354-year return period). Based on HEC–HMS model made by the Jaroslav Černi Institute for the Development of Water Resources, in the lower part of Kolubara at Draževac site, upstream from Obrenovac, the maximum calculated discharge was 2,767 m^3/s (precondition: there was no flooding into Kolubara lignite mine), which corresponds to 650-year return period. According to the volume of the flood flow 528.2 × 106 m^3, the return period at this site was 360 year (Jaroslav Černi Institute for the Development of Water Resources, 2016). These results indicate a significantly lower return period at upstream sites (Slovac, Beli Brod) in comparison with the downstream sites (Draževac). Based on that, it can be concluded that tributaries Tamnava and partly Peštan had significant influence on formation of devastating flood flow near Obrenovac (Milanović Pešić 2015).

Based on the available data of the movement of flood peak between Valjevo and Beli Brod sites, calculation showed that its velocity was 10.5 km/h (Urošev et al. 2017). After this site, Kolubara floods on larger areas and the flood flow propagation (transformation) occured. Near Draževac site, upstream from Obrenovac, Kolubara broke through a dike, flooded Obrenovac settlement and 80% of its municipality. During this flood, Obrenovac was completely evacuated (over 25,000 people), and great damage were recorded in other settlements of Kolubara river basin (Ljig, Lazarevac, Osečina, and Koceljeva). Thermal power plant “Nikola Tesla”, as well as Kolubara lignite mine were flooded and preliminary economic loss was estimated at 300,000,000 euro (Government of the Republic of Serbia 2014). There is no precise data of economic loss (in euros) for the Kolubara river basin. However the total economic loss in Serbia during the flood in May 2014 was about 1.7 billion euro (Government of the Republic of Serbia 2014).

Conclusion

The results of the flood frequency analysis from the study gives detailed information of maximum likelihood discharges to be expected in the Kolubara river basin based on the observed data. This can be applied to predict the extreme flood events and can aid future water resources planning and management. The flood prediction can be utilized in the designing of important hydraulic structures in or near the river, which directly influences both the economy and the design of the project. Also, in case of extreme floods emergency evacuation of people can be carried out well in advance.

The plans for flood risk reduction in Kolubara river basin include several technical and biological measures. The main goal is to prevent further development in flood-prone areas and to implement adequate flood mitigation measures. The results obtained from this study can be used as an input for flood hazard models development. Also, they can be applied to planning certain technical measures. According to the Studija unapređenja zaštite od voda u slivu Kolubare [Study of increased protection of water in the Kolubara river basin] (2016) the following technical measures are foreseen: construction of facilities for the acceptance and reduction of flood flows—frontal retention at Kolubara river and its tributaries (20 facilities); dikes reconstruction/ construction for better flood protection in the most important areas (it is done for surface lignite mine area; in plan is reconstruction of 31 km long dike in the lower part of Kolubara river to protect Obrenovac municipality (from flood having 500-year recurrence interval) and dike construction for the flood protection of Termal power plant “Nikola Tesla”. The study also includes biological measures, such as afforestation in Kolubara river basin in order to decrease erosion process. The effect of this measure will be visible in 2035.

In addition to traditional, so called “hard engineering” approaches like dikes and barriers, there are new approaches to flood management in recent decades. Dikes are a common flood defence system to protect urban environments worldwide. Despite the fact that they cannot guarantee 100% flood protection, they also create a visual and geographical barrier between the river and the town. Therefore, special attention has been paid to new spatial solutions. For example, Netherlands developed the concept of “room for the rivers” in which more space to the water is given. It allows the river to expand when high water is occurring. It is not fighting against water, it is living with water. Some cities in The Netherlands now use parks and public spaces as emergency reservoirs for floodwaters caused by heavy rainfall. Other projects that have been developed for inventing flood management include dike parks with special regard to integrated flood control in Germany. For example, the green space around the dike in Deggendorf has been turned into a dike park which is now one of its most attractive recreational areas. Building with nature is a special challenge in urban areas and has not been applied in Serbia yet. Some of these solutions could be included in spatial planning process in the Kolubara river basin and benefits (such as cost-effective and minimum environmental impact) can be achieved in the development of new areas or within existing ones.

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Assessment of Physicochemical Properties and Water Quality of the Lom River (NW Bulgaria)

Kalina Radeva and Kalin Seymenov

Abstract This study presents results of physicochemical monitoring and water quality assessment of a small lowland river, located in an agricultural region. The analysis is conducted in compliance with the Bulgarian river water quality standard. It is based on output data from three water sampling points, which include information about 14 parameters, measured from 2012 until 2016. An assessment of the pollution status was carried using CCME Water Quality Index and Oregon Water Quality Index (OWQI). The overall water quality index was calculated as 58.78 which fell under the "marginal" water class (index value ranges from 0 to 100). Results showed worsening of the physicochemical properties as moving downstream the river sections. Downstream is observed a slight deterioration in the values and concentrations of some physicochemical parameters (BOD_5, $N\text{-}NO_3$, Total Nitrogen, and Total Phosphorous) due to the effects of urban sewerage, urban wastewater and agricultural wastes. Based on the used indexes, the water quality is categorized as "Good" to "Poor". CCME WQI indicates the water in the upstream can maintain healthy river ecosystems but in the downstream the quality is frequently endangered. OWQI index showed the water in the upstream river section is suitable for daily living activities, but in the downstream quality is in the "Poor" category and it needs "Special treatment".

Keywords Water quality · Pollution · CCME WQI · OWQI · Lom river

Introduction

Water quality is affected by a wide range of natural and anthropogenic factors, whose share is variable in a spatial and temporal aspect (UNEP/WHO 1996; Ostrowski et al. 2005; Kanownik et al. 2013). The river water pollution is directly connected with agriculture and industrial activities (Carpenter et al. 1998), precipitations and inadequately treated household sewage (Igbinosa and Okoh 2009). Water Framework

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Directive (WFD) seeks to achieve good ecological status of surface waters across the European Union by 2027. Despite some improvements recent years, the majority of Europe's water bodies still fail to meet the European Union's minimum target for "good status" according to the EEA report "European waters—assessment of status and pressures 2018". The report identifies that the one of the main threats which hinders progress in meeting the EU targets is nitrate pollution from agricultural activities into water bodies. To get a true reflection of what happens within the catchment of a river basin, either through point or nonpoint sources of pollution, studies of spatial and temporal changes in water quality are very important (Raburu and Okeyo-Owuor 1999). Regular water quality monitoring of the water resources are absolutely necessary to assess the quality of water for ecosystem health and hygiene, industrial use, agricultural use, and domestic use. However, when a large number of samples analyzed and parameters are monitored, it becomes too difficult to evaluate and present the water quality as a single unit (Chapman 1992). Traditional approaches to assessing water quality are based on a comparison of experimentally determined parameter values with existing guidelines. This does not readily give an overall view of the spatial and temporal trends in the overall water quality in a watershed (Debels et al. 2005). Water Quality Index (WQI) is considered as the most effective method of measuring water quality. This is an effective method that allows to compare the quality of various water samples based on a single numerical value, and not only the parameters values of each sample. It helps to gather whole scenarios of water quality parameters into useful information that is easily comprehensible, and thus can be used by the state agencies as well as the general public (Uddin et al. 2017).

This work presents results of physicochemical monitoring and water quality assessment of the Lom River—a small lowland river, situated in the Danube Plain. The Lom River is one of the few relatively unpolluted by industry rivers in the Danube Plain. However, in recent decades due to unsustainable human activities the river basin has suffered serious deterioration in downstream water quality. The primary cause of water quality problems are the discharge of domestic and agriculture wastes, and the excessive use of pesticides and fertilizers. In the present study to evaluate the overall water quality status in the river, the Canadian Council of Ministers of the Environment Water Quality Index 1.0 (CCME WQI) was used, following the Bulgarian river water quality standard (Regulation 12/2002, 4/2012). CCME WQI is a well-accepted and universally applicable computer model for evaluating the water quality (Canadian Council of Ministers of the Environment). In Bulgaria, it was recently used to evaluate the water quality status of several river basins (Varbanov and Gartsiyanova 2017; Gartsiyanova 2017). Besides the applications of CCME WQI in Canada, this index also has been adopted in several other countries: Albania (Damo and Icka 2013), Spain (Terrado et al. 2010), Chile (Espejo et al. 2012), India (Sharma and Kansal 2011; Venkatramanan et al. 2016), Bangladesh (Reza and Singh 2010), and Iran (Mohebbi et al. 2013; Jafarabadi et al. 2016). In addition, to assess the water suitability for specific human uses, the Oregon Water Quality Index (OWQI) was applied, which is used also for a trend analysis in water quality status in the United States (Cude 2001; Walsh and Wheeler 2012).

Study Area

The catchment of the Lom River is situated in the western part of the Danube drainage basin in Bulgaria. It covers an area of 1139.8 km^2 (Hristova 2012) (Fig. 1). The catchment area of the Lom River covers part of the north slopes of the Western Stara Planina (Chiprovska and Svetinikolka planina), the hill Vederenik of Western Fore-Balkans and part of the Western Danube Plain. The Lom River flows in length of 92.5 km. It springs from the Balkan Mountains and flows into the Danube River within the Danube Plain. Mean annual flow for 1960÷2017 period varies from 0.68 m^3/s (at Gorni Lom) to 6.07 m^3/s (at Vasilovtsi). The coefficients of variation, Cv, vary between 0.25 at Gorni Lom, to 0.38 at Vasilovtsi. The seasonal discharge regime is characterized by a high flow phase during the spring months (April–May) and a low flow period in the summer–autumn hydrological season (August–September). The climate conditions in the catchment are moderate continental. The annual average air temperatures range from 4.2 °C (in the Chuprene Reserve area) to 11.8 °C (cf. Lom). The annual amount of precipitation increases from 500–550 mm, on the Danube coast, to 800–1200 mm, in the Chiprovska Stara Planina, with a maximum in the months of May–June and minimum in the months of February–March (Climate Reference Book …, 1990). In the mountainous area, the river basin is covered with dense pine, spruce, beech and oak forests and in the plain due to the deforestation events, the natural vegetation is reduced and replaced with a cultural one.

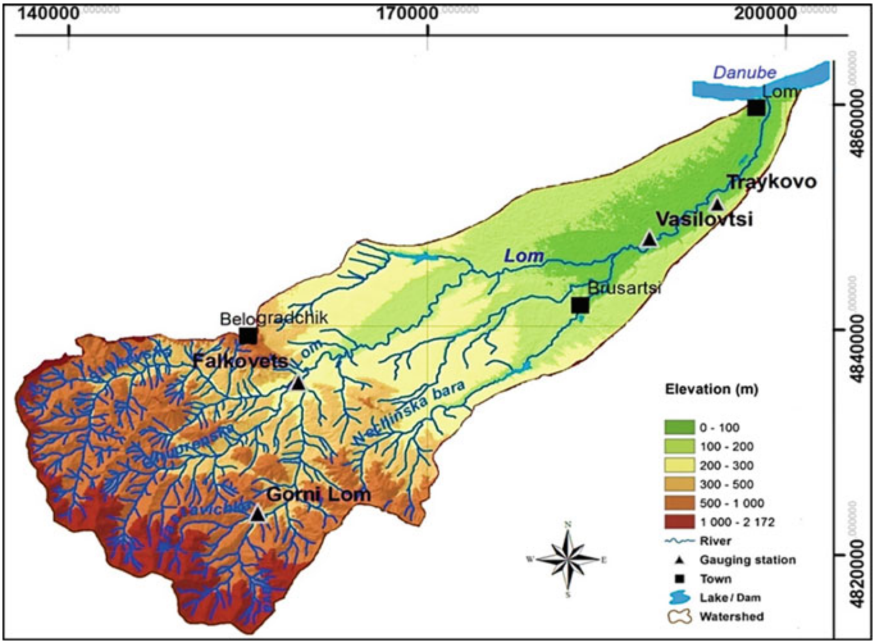

Fig. 1 Relief, hydrographic and hydrometric structure in the Lom River basin (Hristova et al. 2017)

The predominant land use type in the Lom River basin is agricultural, covering an area of 579.1 km^2 (50.8%). The high-altitude zone of the Lom River is characterized by livestock grazing activities and forest coverage (dominating from broad-leaved forests). The main source of water pollution is from soil runoff sediments, fecal material, and household wastewater from small urban settlements. The lower area is a flat landscape cultivation zone with extensive agricultural production (cereal and technical crops: wheat, barley, corn, sunflower, and perennial vineyards), as well as cattle-grazing activities. In addition, urban expansion and industrial developments are also important. The river basin concentrates 42 settlements, including three cities, with a total population of 47.000, which corresponds to population density of 41 people per km^2. Water contamination arises from the agricultural, domestic and industrial activities.

Output Information and Research Methods

The objects of analysis are the values and concentrations of physicochemical indices for the Lom River's water, investigated during the 2012–2016 period. Output data is provided by the Danube Basin Directorate for three water sampling points, situated in the upper stream and downstream river sections. The water quality status is conducted in compliance with the Bulgarian river water quality standard (Regulation 12/2002, 4/2012). Total of 14 water parameters are analyzed: Dissolved Oxygen, Oxygen saturation, pH-value, conductivity EC, Ammonium-Nitrogen (N-NH_4), Nitrate nitrogen (N-NO_3), Nitrite nitrogen (N-NO_2), Total Nitrogen, Total Phosphorous, Orthophosphate (P-PO_4), Biochemical Oxygen Demand (BOD_5), Suspended Solids, Chloride, Sulfates. Descriptive statistics are presented, i.e., minimum and maximum and arithmetic mean, calculated for each individual parameter. An assessment of the water quality is carried using two selected indexes: Canadian Council of Ministers of the Environment (CCME) and Oregon Water Quality Index (OWQI). Current study sought to test the listed indexes due to their simplicity, but robust nature of reporting water quality issues (Cude 2001; CCME 2001; UNEP 2007). CCME WQI is an overall rating, which relies of three factors: (1) the numbers of variables whose objectives are not met (scope); (2) the frequency with which the objectives are not met; (3) the amount by which the objectives are not met (amplitude) (El-Jabi et al. 2014). These factors are calculated as a ratio between the "failed tests" to total number of conducted test, only the third (amplitude) factor requires some additional steps (Saffran 2001; Uddin et al. 2017). The CCME WQI rating is computed by the formula

$$\text{CCME WQI} = 100 - \frac{\sqrt{F_1^2 F_2^2 F_3^2}}{1.732}$$

where the numerators are the factors: scope F_1^2, frequency F_2^2, amplitude F_3^2, the constant 1.732 is a normalization factor used to render the CCME as a value from 0 to 100.

CCME values are converted into rankings by using the categorization scheme presented in Table 1.

CCME WQI is based on "desirable stats". In this paper, they are fixed for each individual sampling point. The calculations are conducted in compliance with the reference values for excellent quality status, recommended for the surface water body types R2 and R8 (Regulation 4/2012) (Table 2). This approach is useful for describes of water as a biotope of the aquatic flora and fauna, wildlife habitats, etc., also for evaluating of water suitability for human uses, i.e., it applies for an integral assessment (CCME 2001; El-Jabi et al. 2014).

OWQI is a water quality rating, combining data for eight parameters or sub-indices (DO%, BOD_5, T °C, pH, Total P, N-NH_3, Susp. Solids and Bacteria coliform *E. Coli*). Each one of parameters has a different weight in the final estimate (Appendix A: Cude 2001). Six of the listed sub-indices are used here (those whose data are available). For this purpose, the numbers of parameters in the original formula was corrected. The OWQI assessment is computed as follows:

$$\text{OWQI} = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}}$$

where n—total numbers of sub-indices (parameters); SI_i—sub-index i.

This formula allows the most impaired variable to import the greatest influence on the water quality index and acknowledges that different water quality variables will pose differing significance to overall water quality at different times and locations.

Table 1 CCME WQI and OWQI ratings and values (CCME 2001; Cude 2001)

WQI	Value rating of water quality
Canadian council of ministers of the environment water quality index (CCME WQI)	
95–100	Excellent water quality
80–94	Good water quality
60–79	Fair water quality
45–59	Marginal water quality
0–44	Poor water quality
Oregon water quality index (OWQI)	
90–100	Excellent water quality
85–89	Good water quality
80–84	Fair water quality
60–79	Poor water quality
0–59	Very poor water quality

Table 2 Variables and objectives (Reg. 4/2012)

Variables	Objectives for excellent status	
	R2 type Mountain rivers (*Krastavichka river/Lom river—Gorni Lom*)	R8 type Lowland rivers (*Lom River—before the town of Lom*)
DO_2, mg/l	10.5÷8.00	9.00÷7.00
DO_2 Sat., %	>90	>80
pH	6.5÷8.5	6.5÷8.5
EC, μS/cm	700	700
N-NH_4, mg/l	<0.04	<0.10
N-NO_3, mg/l	<0,1	<0.7
N-NO_2, mg/l	<0.03	<0.03
Total N, mg/l	<0.2	<0,5
Total P, mg/l	<0.012	<0.15
P-PO_4, mg/l	<0.01	<0,07
BOD_5, mg/l	<1	<2
Cl, mg/l	>200	>200
SO_4, mg/l	>250	>250

(Cude 2001). OWQI values also cover a ranking system, where a result of 100 is the best achievement and a value of 0 is the worst result (Table 1).

OWQI is a possible tool for assessing of trends (annual, seasonal) in water quality status because of its final assessment represents an average value of the water quality ratings, calculated for each individual measurement during the study term (Cude, 2001). Trend ratings are not applied here, because the observation period is relatively short, but the values obtained give an informative result about the water suitability for human uses. This is the strength of the index—it is targeted at a specific type of water use, such as drinking, fishing or irrigation.

Results

Among the 14 investigated quality parameters, 8 meet the requirements for excellent water quality state in each measurement sampling point: Dissolved Oxygen, Oxygen saturation, pH-value, conductivity (EC), Suspended Solids, Nitrite nitrogen, Chloride, Sulfates (Tables 2 and 3). In good ecological status, general physicochemical quality elements should not reach levels outside the range established to ensure ecosystem functioning (Table 2). According to Bulgarian river water quality standard, water quality in the upper stream river sections (at the Krastavichka River and Lom River—Gorni Lom) is in better condition than the downstream river

Table 3 Values of physicochemical indices and water quality status of the Lom River (2012–2016)

Parameters	Water sampling station								
	Krastavichka River			Lom River—Gorni Lom			Lom River—before Lom		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
pH	6.89	8.28	7.72	7.24	8.46	7.83	7.36	8.83	8.09
EC, μS/cm	87.10	272.00	168.10	75.00	202.00	127.00	216.00	525.00	359.00
DO_2 Sat., %	78.90	124.50	90.81	71.30	118.00	89.58	55.10	119.30	82.04
DO_2, mg/l	7.70	12.30	9.90	7.10	12.10	9.68	6.40	12.90	10.30
N-NH_4, mg/l	0.02	0.07	0.03	0.02	0.09	0.04	0.03	0.21	0.08
N-NO_3, mg/l	0.04	1.66	0.42	0.04	1.91	0.53	0.37	3.70	1.29
N-NO_2, mg/l	0.002	0.011	0.005	0.003	0.036	0.007	0.006	0.079	0.018
Total N, mg/l	0.29	2.00	1.04	0.44	4.10	1.64	0.72	3.00	1.81
PO_4-P, mg/l	0.007	0.045	0.021	0.005	0.04	0.016	0.006	0.1	0.03
Total P, mg/l	0.01	0.03	0.02	0.01	0.03	0.02	0.02	0.20	0.06
BOD_5, mg/l	0.90	3.00	1.79	0.70	3.30	1.70	1.30	4.40	2.53
Cl, mg/l	1.05	9.80	4.04	0.66	13.30	4.78	4.20	17.50	9.61
SO_4, mg/l	4.40	22.10	11.47	5.20	26.50	14.11	18.80	51.40	30.19
Und. Sub. mg/l	12.00	41.00	21.73	16.00	42.00	23.95	24.00	95.00	36.12

section (Lom River—before the town of Lom). Downstream is observed a deterioration in the values of some physicochemical water quality parameters (BOD_5, N-NO_3,$NH_4^+ - N$ and Total Phosphorous) (Table 3). Concentrations of ammonium, BOD and nitrate in water are used as indicators of organic matter pollution and the impacts of sewage release into rivers (WHO 2006; Bilotta & Brazier, 2008). BOD_5 indicates high concentration of organic pollution and high concentration of biodegradable organic material in water. Ammonium occurs at high concentration in sewage, when present in stream water, ammonium utilizes the available oxygen for oxidation process to nitrate. All settlements in the area do not have wastewater treatment plants, i.e., the waste water is discharged into the Lom River. Further, nutrient loads from agricultural areas are prevailing in downstream areas. As a consequence, a chemical analysis of the Lom River quality data indicates that water pollution increased downstream, as shown by the statistically significant differences in ammonium, BOD_5, nitrate and Total Phosphorous between upstream and downstream sampling points (Table 3). The increasing of the nitrate values during the summer season confirms the statement for water pollution by agricultural activities. Upstream is observed and increased concentrations of nitrogen. Farming practices like uses of nitrogen-rich fertilizers and organic manure from pastoral livestock are the major sources of excess nitrogen in the upstream part of Lom river.

The applied water quality indices generally show a decrease of water quality from upstream to downstream. In this study, the primary focus was on fourteen (14) water quality parameters. The total numbers of individual tests are 794. The number of parameters not meeting Reg. 4/2012 objectives are six (Ammonium-Nitrogen, Nitrate nitrogen, Total Nitrogen, Total Phosphorous, Orthophosphate, Biochemical Oxygen Demand (BOD_5) and the number of tests not meeting objectives are 189. The quality ratings at the Krastavichka River are "Fair"(CCME WQI is 65) or the water can maintain a healthy ecosystems (Table 4). At the sampling points of the Lom River (Gorni Lom and before town of Lom), exceedances of nutrients resulted in an overall quality rating of "Marginal" (CCME WQI varies from 53.14 to 58.10) (Table 5).

OWQI rating in the sampling points at the Krastavichka River and Lom River at Gorni Lom is "Good" and "Fair" (OWQI rating is 86 and 84, respectively). These assessments mean the water is suitable for fishing and irrigation purposes and it is acceptable for drinking after an initially treated. The water sampling point at the Lom River—before town of Lom, achieves an overall score of "Poor"(OWQI is 73), which means the river waters are seriously polluted (Table 6).

Table 4 The calculated values of CCME WQI in Lom River

Stations	Number of failed variables	Number of failed tests	Value
Lom River—before town of Lom	3	56	58.10
Lom River—Gorni Lom	6	86	53.15
Krastavichka River	6	47	65.10

Table 5 CCME ratings, values and descriptions, as stated in CCME (2005b)

Rating	CCME values	Interpretive description
Excellent	95–100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine level
Good	80–94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels
Fair	60–79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Marginal	45–59	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
Poor	0–44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels

Table 6 OWQI ratings, values and descriptions, as stated in Cude—OWQI (2001)

Rating	OWQI values	Interpretive description
Excellent	90–100	Water quality is unaffected. Water is suitable for drinking, fishing, irrigation and industrial purposes. A construction of treatment plants is not required
Good	85–89	Water quality is almost unaffected. Water is suitable for fishing, irrigation and industry. Water use for drinking requires a construction of treatment plant
Fair	80–84	Water quality is affected. Water is acceptable for irrigation and industry and unacceptable for drinking. A construction of treatment plants is advisable
Poor	60–79	Water quality is impaired. Water is acceptable for industrial purposes. Water uses for irrigation and vital activities obliges a construction of treatment plant
Very poor	0–59	Water quality is seriously impaired. Water is inappropriate for human uses and industrial purposes. A construction of treatment plants is compulsory

Correlation analysis is a preliminary descriptive technique to estimate the degree of association among the variables involved (Ahmed et al. 2012). CCME WQI is positively corelated with Conductivity and Dissolve Oxygen parameters, besides all others parameters negatively impacted the WQI. The results showed that water quality index decreases with increase in parameter concentration and vice versa for parameter Dissolve Oxygen (Table 7).

Table 7 Correlation between CCME WQI and water quality parameters

Parameter	pH	EC, µS/cm	DO_2, mg/l	$N\text{-}NH_4$ mg/l	$N\text{-}NO_2$ mg/l	$N\text{-}NO_3$ mg/l	Tot. N, mg/l	PO_4–P mg/l	Tot. P, mg/l	BOD_5 mg/l	WQI
pH	1										
EC, µS/cm	0.159	1									
DO_2, mg/l	0.026	0.295	1								
$N\text{-}NH_4$, mg/l	0.039	0.001	−0.057	1							
$N\text{-}NO_2$, mg/l	0.041	0.150	0.160	0.311	1						
$N\text{-}NO_3$, mg/l	0.027	0.191	−0.081	0.313	0.009	1					
Total N, mg/l	−0.025	0.255	−0.062	0.273	−0.006	0.915	1				
PO_4–P, mg/l	0,009	0.048	0.187	0.165	0.535	−0.104	−0.051	1			
Total P, mg/l	0.123	0.006	0.094	−0.007	0.151	0.362	0.280	0.436	1		
BOD_5, mg/l	0.027	0.393	0.203	−0.053	0.396	−0.086	−0.064	0.275	−0.018	1	
WQI	−0.084	0.139	0.305	−0.463	−0.230	−0.344	−0.297	−0.312	−0.285	−0.095	1

Conclusion

The results show that CCME WQI and QWQI is an effective and sensitive tool for evaluating the state of the river water quality depending on the objectives to be met. Based on CCME WQIs model, the water quality in the Lom River is categorized as marginal to fair. The Canadian Water Index indicated that the water quality is frequently endangered, conditions very often deviate from natural levels. The quality of surface water in the upstream of the Lom River is in fair condition. The main source of water pollution upstream is mountain livestock farming, which results in the increased concentration of nitrogen. Downstream the water quality gradually deteriorates, due to wastes from living and agricultural practices. BOD_5, N-NO_3, Total Nitrogen, and Total Phosphorus are the most important parameters that determinate the rating of water quality, not meeting the standards (objective) of good water quality status. In order to achieve a good quality status of the Lom River's water, it is necessary to implement an adequate wastewater management through the construction of modern and efficient waste water treatment plants and to reduce the diffuse water pollution from agriculture.

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Human Geography

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"Shrinking Cities" in Bulgaria: An Attempt for Defining the Models of "Urban Shrinkage"

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Abstract The process of *urban shrinkage* is not new in Europe. In post-socialist countries, the economic transformations since the beginning of the 1990s have led to changes in the settlement patterns caused by large-scale internal migrations in favour of metropolitan and regional urban centres and for the account of the remote and peripheral regions. Bulgaria is no exception to these processes where urban areas have been subjected to complex shrinkage, resulting in demographic and economic decline after the political changes in 1989. The economic and functional restructuring of the Bulgarian cities according to the market economy conditions have led to the inability of these areas to provide sufficient jobs and quality of life to other urban areas, leading to a progressive decline in their populations. This study groups the Bulgarian cities according to the causes and dynamics of their shrinkage from the last century to 2017, with a focus on the functional changes in the market economy after 1989, accompanied by demographic crisis and urban decline.

Keywords Urban shrinkage · Bulgaria · Urban decline · Population

Introduction

The common symptoms of shrinkage are well described in the scientific literature. These include decline in number of the population, which resulted in a number of negative effects, for example, a growing gap between supply and demand of services. This creates difficulties for both, the public and the private sectors and, as a result of weak local markets, the services become insufficiently "used", poorly maintained and often "with no use". Local conditions and quality of life are getting worse, unemployment is increasing and the number of skilled workers is being reduced. These facts further reduce the attractiveness of the region, thus rotating the spiral of

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demographic decline by reducing the percentage of fertility and ageing of the rest of the population (ESPON 2017).

Urban shrinkage processes are not unfamiliar or new in Europe (Wiechmann and Wolff 2013). They cover regions, metropolitan areas, cities or parts of cities and urban zones that are subject to demographic, social and economic changes. These are the areas which suffered from loss of population, deterioration of the economy and fall down of employment. As symptoms of the structural crisis, they are experiencing social problems and conflicts (Martinez-Fernandez et al. 2012). In Central and Eastern Europe, these are also caused by political changes after the fall of the communist regimes and the so-called "Shock Therapy" (Bontje 2004). This led to the rapid and irreversible phenomenon of "shrinkage", involving migrations and natural population loss (Wiechmann and Wolff 2013).

In Bulgaria, from the beginning to the 90 years of the last century, the processes of urban shrinkage are the result of political, social and economic changes and transformations of the transition to market economy. The economic and functional restructuring of the Bulgarian urban network under the market economy conditions, like other Eastern European countries, led to the inability of a number of cities to provide sufficient jobs and quality of life, respectively, and migration of their population. A large number of reasons for this are not only the consequences of de-industrialization but the lack of response from the implementation of the territorial instruments for planning and development.

The purpose of this study is to explore the situation of urban shrinkage in Bulgarian cities and to analyse the causes of shrinkage, in view of their functional changes under the market economy conditions, the structural, social and demographic crisis, expressed in the loss of their population and urban decline.

The timeliness of the study is also expressed by the fact that the urban shrinkage phenomenon is poorly developed in the Bulgarian (geographic) literature.

Urban Shrinkage: Theoretical Focuses

Urban shrinkage is a multi-dimensional and global phenomenon (Fol and Cunningham-Sabot 2010) covering regions, cities and parts of cities, metropolitan areas or areas that experience a sharp decline in their economic and social bases (Pallagst and Aber 2009; Martínez-Fernández et al. 2012). The reasons for this urban decline are many and complex, albeit with a common indication—each "shrinking city" is influenced by globalization and its dimensions.

There is no clear definition of shrinking cities, but rather a number of different interpretations of the phenomenon. According to Martínez-Fernández et al. (2012) shrinking cities share common elements or they have a similar "shrinking identity". The term "urban shrinking" is used to focus on the fact that this phenomenon is a multi-faceted process with multi-dimensional effects. There are economic, demographic, geographic, social and physical dimensions. The term extends our understanding of the “decline” beyond the ordinary linear process, which is usually understood to follow de-industrialization.

Urban shrinkage processes develop in parallel with those of demographic shrinkage—population reduction. Although demographic indicators are the key to defining urban “shrinkage”, some authors (Olsen 2013) are defending and discussing the idea that the city cannot be defined as a “shrinking city” only because there is a period of loss of population and economic downturn. With regard to the shrinking of the Eastern European post-socialist cities, the process is identified with the transformation of urban areas that are subjected to dramatic de-population and de-industrialization after 1989 (Martinez-Fernández et al. 2012).

Despite the fact that globalization has a strong influence in creating shrinking cities, the economic change does not affect all the cities and countries in the same way. On the contrary, shrinking can show many different characteristics depending on the national, regional and local context (Anguelov 2016).

Pallagst (2008) proposes zoning of urban shrinkage processes in Europe. Large parts of the areas with shrinkage processes are concentrated in the post-socialist countries (Latvia, Bulgaria, Romania, Hungary, Slovakia and the eastern part of Germany), the Nordic countries (in particular, Finland and Sweden) and the countries of Southern Europe (Italy and Spain). Emphasized is that the causes of shrinkage in Europe are complex and even partially overlapping. For example, in post-socialist countries, shrinkage is the result of the economic transformations after 1989, which led to changes in the settlement patterns, largely caused by migration processes. A large number of migrations occur as new economic migrations in favour of capital cities, while remote and peripheral regions are losing their population (e.g. Slovakia, Romania, Bulgaria).

Martínez-Fernández et al. (2012) identified three models of shrinkage: urban shrinkage, rural shrinkage and the decline of industrial centres. Urban shrinkage is characterized by a loss of population and/or a long-lasting economic decline in cities, parts of them, or in metropolitan areas or zones. This is probably the most widely studied case of shrinkage. Rural shrinkage, on the other hand, is related to the loss of population and/or economic decline over a long period, typical of smaller cities or a group of small cities located in rural areas (rural-type regions). Shrinkage in rural territories (regions) is a demographic and economic phenomenon, which is part of the trends of European territorial restructuring. In these regions, agriculture has become less labour intensive, and economic growth and employment are gradually “tretized”. Shrinkage of rural areas is indicative of a broader structural crisis in the economic downturn and the fall in the labour market, peripheralization and deepening the division between urban and rural areas—intensifying the inherent disadvantages of rural regions (ESPON 2017).

The third case described by Martínez-Fernández et al. (2012) is the shrinkage of industrial zones. This refers to the loss of population and/or economic decline over an extended period to mainly small- and medium-sized cities that have held an important place in the industrial production. Although the classification has been united based on other territorial characteristics, given the focus of the ESPON research, this could be adapted to national territorial characteristics and based on the empirical data (e.g. cities with mono-structural economy in the past).

The effects of shrinkage of cities are identified with the increased number of vacant dwellings, demolition of industrial facilities (physical space), transformed into the so-called "gloomy places", a lack of users of the commercial space, physically degraded and differentiated into problematic environmental and social areas, a large number of services with no consumers, and so on.

Yovcheva (2012) accentuates four main reasons for the shrinking processes of cities that should be taken into account in the empirical studies: de-industrialization, suburbanization, radical change of the political system and demographic ageing. Sometimes the combination of these factors leads to "urban depression", which can lead to shrinking of not only urban areas but also shrinking at a regional scale, or even at national scale. This "depression" is the result of the uneven spatial development and lack of adequate spatial policy and is often preceded by long-term unemployment, de-population and marginalization processes. Urban depression or urban blight is a transient state of the social and infrastructural entropy (Anguelov 2016).

Particularly significant is the study and defining of shrinkage types in Europe by Wiechmann and Wolff (2013). The authors studied cities from Eastern and Western Europe in the period 1990–2010 and defined three types of urban shrinkage: temporary shrinkage, episodic shrinkage and continuous shrinkage. There are 31 Bulgarian cities in this study, most of which are administrative regional centres. Shrinking processes have been reported for about 28 of them, of which 22 are of continuous shrinking type or "these cities had lost at least 0.15% of their residents annually in all four five-year intervals since 1990" (Wiechmann and Wolff 2013: 13).

Methodology

One of the main scientific challenges in the field of geography is the measuring of urban shrinkage in its spatial–temporal specification and the selection of indicators. Taking into account the scale, the intensity of the urban shrinkage depends largely on the timeline, from the point of view of the region (typology) and the scale the observations made on. This way, the measurement indicators can suggest a shrinking process during short periods, while this is not proven for a longer period and may occur vice versa. The importance of the spatial–temporal specification and the appropriate indicators is not purely formal but related to the political and economic transformations concomitant with the urban development in Bulgaria. In this regard, taken into account for the purposes of the analysis was the period of demographic shrinkage at the demographic peak (population censuses) of urban settlements to 2017 (NSI 2018).

Unlike other urban shrinkage studies in Europe (Wiechmann and Wolff 2013), here no additional criteria for a minimum population of cities have been taken into account, given the specificities of the national urban network and the presence of a large number of small cities in the country with a population below 5000 people. The grouping of the surveyed cities has been done on the following criteria:

- Cities with administrative and regional functions
- Geographic location—cities located near and far from economic development centres. In this group, taken as a secondary criterion for the purposes of the analysis is the proximity to a political state border that further defines their isolation and implies different dynamics of development, unlike cities located inside the country.
- Cities with monostructural economy and loss of military functions.

The calculation of the demographic loss is based on the population data from the official censuses.

Empirical Study Results

Historical Context of Cities and Villages Development in Bulgaria Until 1989

Bulgaria, in the period from the Second World War to the mid-1980s of twentieth century, had been exposed to the Soviet influence in the field of planning, urban planning and architecture. A new transition had begun, which dominated the ideology of the planned economy, the unified centralized economy management, the radical socio-economic reorganizations and the centralized planning of the urban network. This period coincided with the imposition of the zonal urbanism (expression of the Athens Charter) and the doctrine of functional planning, war destruction and the need to resolve the housing problem quickly (the emergence of large residential complexes in cities), the rapid growth of cities and the search for "satellite vents" (Alexandrov 2006) or creating new ones whose main function would be related to the industrial upsurge of the country.

The new law on Settlements Planned Construction was adopted in 1949, and it covered not only the planning of urban areas but also those out of them. The law was repeatedly amended and supplemented, but for the first time it affected problems related to construction and terrains out of the planning scheme of the settlements. It remained in force until the first half of the 1970s (Kovachev 2009). Together with it began the implementation of the so-called 5-year plans (5-year period) for the development of the economy, concomitantly parallel with the process of intensive urbanization. In that period, industrial and agricultural enterprises became much stronger factors of the regional development than the local communities with their resources did. Moreover, they became the stimulus for the growth of the urban population in Bulgaria and intensified the internal migrations in favour of those urban territories that had consolidated important centres for the country's economic and industrial progress. The localization of these enterprises served to solve various territorial problems.

Urbanization during the communist regime was the result of the economic policy of forced industrialization, when the population massively migrated from villages to cities. Bulgaria is among the countries that have gone through a very fast urbanization process. In 1950, the urban population was only 25% of the total population of the country, and today this relative share is 73.5% (2017). From 1985 to 2017, the settlements in Bulgaria dropped off by 81, but on the other hand, the number of cities increased by 20.

A special feature of this period in the development of the national urban system is the practice of declaring new cities (Anguelov 2016). The number of cities was increasing rapidly from the beginning of the 1960s to the mid-1970s of the last century, as only for that period 102 new cities were declared. The swarming of cities was for subjective reasons, and most of the newly declared cities had an agrarian nature, and did not adopt the urban way of life. Predominating in Bulgaria are the very small (according to the Spatial Planning Act) (under 10,000 people) and the small (10,000–30,000 people) cities. There are five cities with population below 1000 thousand people in the country. These facts are an indicator of the quantitative and qualitative characteristics of urbanization in the country.

Urban Shrinkage in Bulgaria

It would be logical to associate the phenomenon of urban shrinkage with a number of the Bulgarian cities. According to Yovcheva (2012), the most severely affected cities and regional centres are: Smolyan, Kyustendil, Razgrad and Gabrovo. The idea of the decline (demographic and economic) of the area is not applicable only for some regions in Bulgaria, as only in specific regions there is no expressed concentration of the settlements concerned. Urban shrinkage is even throughout the country. It is important to note that, in this context, the birth rate and mortality dynamics define the existence of a sustained trend of shrinking the natural reproduction of the population. Demographic statistics show that for more than 25 years, Bulgaria has been experiencing significant demographic losses, resulting from the negative natural and mechanical growth, projected in serious territorial imbalances. As of 2016, the proportion of areas with irretrievable de-population was 22%, and in the medium term (2030), this proportion shall be expected to cover more than half of the national territory (Burdarov and Ilieva 2018).

Yovcheva (2012) accepts the idea of the quantitative frames of the shrinking city as an area (village, city) whose minimum number of inhabitants is 10,000 people, with a drop off the population over a period longer than 2 years and a flowing economic transformation, with signs of a structural crisis. According to her, this specification is very well applicable for most Bulgarian settlements, from the smallest settlement units to the “large cities”, under the Bulgarian legal classification.

In view of the prevalence of the small cities in Bulgaria, in this paper we shall make a broader interpretation of the narrowing of the cities and we shall not limit ourselves to the minimum quantitative threshold of 10,000 people and high density.

We accept the decline of the population for an extended period of time as one of the main signs for "dying cities" and our retrospective analysis covers the statistical array from 1946 to 2017, by measuring the population decline from the demographic peak (from the official censuses) of the settlements to 2017, thus the period for individual cities shall be different.

Shrinking of Cities with Administrative and Regional Functions

The reduction of the population in the cities covers not only the small- and middle-sized cities in Bulgaria but also the administrative regional centres. This process is registered in the regional cities with varying intensity, except for Sofia, Plovdiv, Varna and Bourgas, which have ascending demographic trend. Differentiated are several groups of regional cities according to the relative share of population decline compared to their demographic peak (1975, 1985, 1992) (Mashke 2018).

The first group covers regional cities, where shrinkage is from 30 to 45%, in the period from their demographic peak to 2017—Silistra, Razgrad, Gabrovo, Lovech, Vidin; the second group—from 20 to 30%—Vratsa, Kyustendil, Shumen, Yambol, Pleven, Montana, Targovishte, Dobrich, Ruse, Pernik, Kardzhali; the third group—from 10 to 20%—Haskovo, Sliven, Smolyan, Pazardzhik; the fourth group—less than 10%—Stara Zagora, Blagoevgrad, Veliko Tarnovo. The last group of regional cities shall not be classified as shrinking cities, as the city of Veliko Turnovo stands out with a population reduction of only 1.2% and Blagoevgrad with 3%. We shall accept the third group with some conditionality, because most literary sources determine shrinking cities as those with a decrease of the population of over 25% (Shetty 2009). What makes an impression is that the demographic peak for 56% of the regional cities was in the 1980s and for about 40%—the 1990s. Silistra had a demographic peak in the 1970s, which can be considered an indicator for the earliest process of loss of human resources among the regional cities. The demographic shrinkage of cities is the result of the post-socialist political and economic processes in Bulgaria related to de-industrialization, expressed mainly in the inefficient privatization with the subsequent closure of the key industries enterprises (Shumen, Vratsa, Vidin, etc.), liquidation of companies, established in the wrong socio-economic environment (Silistra, Targovishte, Yambol, etc.). The first group of cities with the most intensive population reduction, with the exception of Gabrovo, includes cities that are centres of areas with low index of the localization of the industry and a higher index of localization of agriculture, as well as with some of the lowest levels of foreign investment in the last 15 years. De-industrialization, the weak flow of foreign direct investment and the small number of newly emerged economic operators are undoubtedly the determinants of urban shrinkage and the manifestation of destructive processes of spatial disintegration and disorganization of the settlement area. A large part of the regional cities of the first and second groups form the areas of the former industrial zones that had lost not only their functions but also violating the urban cultural landscape, and transformed into "zones of risk"—ecological, social. These areas lower the aesthetic and economic value of whole regions. The utilization of the former industrial sites shall lead to the utilization of the architectural potential, the urban environment and its full development.

Shrinking in Cities with Monostructural Economy and Loss of Military Functions

The demographic collapse has a particularly strong manifestation in some of the small cities, some of which have been threatened to disappear. Many of these cities have a monostructural economy (inherited from the Communist period), which became one of the main reasons for their shrinkage due to the lack of diversification of the industry. Madzharovo stands out (584 people, 2017) in this group, with a drop off the population of about 70% from 1985 to 2017, which gives a reason to be defined as "dying", or a ghost city. For long years its economy had been supported by mining and flotation of lead–zinc ore enterprises, which later closed. This fate was shared by the ore-mining Rhodope cities (Rhodope mining cities) Madan (50.9% population reduction from 1965 to 2017) and Rudozem (49.9%, 1975–2017). At the other pole, for example, are the coal centres Galabovo and Radnevo, which have significantly lower values of population reduction due to the functioning of companies, such as Maritsa Iztok Energy Complex, which attract daily work trips from the neighbouring municipalities. On the other hand, the two cities have facilitated transport access to the administrative regional centre and to the national infrastructure facilities, as opposed to the ore-mining settlements in the Rhodope Mountains, being distant from highly developed centres and investment nuclei.

A group of "shrinking cities" has been formed, with declining population due to the loss of its military garrisoning functions, as a result of the reforms in the Bulgarian Army after 1989 and/or the closing of the military industrial complex units—Malko Tarnovo (56.4% reduction of population, 1992–2017), Bolyarovo (42.8%, 1992–2017), Topolovgrad (33.8%, 1992–2017), Elhovo (31.7%, 1992–2017), Cherven Bryag, Pordim, Sopot, and so on. The abandoned barracks and non-settled former military units create a prerequisite for the settlement of Roma and marginalized populations, concomitant with an increase in crime and a manifestation of a number of socio-economic problems. The change in ethno-confessional and social structure of the population in some places has created social unrest and is a secondary factor for the continuing shrinkage of cities. The availability of arable land and alternative employment programmes are not a sufficient compensatory factor for the keeping human resources in these settlements.

Cities Distant from Better Developed Centres

The results of the changes in demographic shrinkage show that another group of shrinking cities can be set apart in rural areas, distant from large, developed economic and cultural centres. They have no operating enterprises and no elements of social infrastructure needed for the modern life. Urban lifestyle in these settlements is being adapted to the agricultural specifics, which draws them closer to the rural type of settlement. Typical representatives of this group, for example, is Gramada with a population decrease of 69% from its demographic peak in 1965 to 2017, with an unemployment rate of 39.8% (2016); Valchedram—59.8% demographic shrinkage and 47.9% unemployment; Boichinovtsi—59.7% reduction in population and unemployment rates 40.3%; Byala Slatina—37.8% demographic loss and 34.8% of unemployment, Tran—31.8 and 36.9%, respectively, and so on. Given the correlations between the population decline and the unemployment rate and the analysis of statistical ranks of the population by cities, it is evident that the Northwest statistical region is moving quickly along the axis of a shrinking city.

This group of cities includes most small urban cities with agrarian nature, mainly in northern Bulgaria, for example, Pleven region (Iskar, Gulyantsi, etc.), Targovishte (Antonovo, Opaka), Veliko Turnovo (Strazhitsa, etc.) and other areas. It is notable that small and very small cities with a higher share of the Roma population have lower values of population reduction (Varbitsa, Kotel, Dalgopol, Ihtiman, Tvarditsa, Shivachevo, etc.). For example, the city of Kostenets, close to the city of Ihtiman, with similar demographic potential in the past, with common features in its economic development, but with a negligible number of Roma population unlike the city of Ihtiman, has high rates of reduction of population (44.8%, 1985–2017). Less-pronounced urban shrinkage is reported in settlements with a concentration of Turkish and Bulgarian-Muslim populations at the Mesta River valley (Yakoruda, Belitsa, etc.) although they have high unemployment rates (2016). These conclusions give reason to suggest the ethno-cultural models of spatial behaviour that directly affect the urban development.

Discussion

Most coastal cities show no pronounced decreasing trend of the population, some of which conduct a targeted local policy for stimulating the birth rate and keeping of the young population (Primorsko, etc.). Relatively low shrinkage of cities (less than 10%) can be found in the frontier zone with Greece and its close proximity in south-western Bulgaria-Bansko (9.6% reduction from 1975), Gotse Delchev (9.9%, from 1992), Petrich (9.5%, from 2005) and Sandanski (7.8% from 2010). The last two cities increase their population in the first years after the political and economic changes in the country, unlike most of the Bulgarian cities. The opening of the border with the southern neighbour has changed the geopolitical and economic position of the settlements and has made them attractive places for foreign investment and living. The peripheral frontier position in this case plays a stimulating role, unlike the southern Rhodope and Sakar-Strandzha cities, which are unable to derive positives from the cross-border potential of their areas. This is why the latter has formed an intensive zone of “shrinking cities”.

Undoubtedly, the three groups of shrinkages, as described by Martínez-Fernández et al. (2012), can be found in Bulgaria. In parallel, there is a number of issues that still have to be explored: what forms the urban context of "shrinking cities"; how to integrate the former production areas into the spatial "composing" of the urban environment on an environmental principle; how to stop the process of creating new types of peripherality in the spatial and urban planning and new types of territorial marginality; to what extent re-industrialization related to the modernization of the industrial system and to the formation of new economic activities and segments can stop the shrinking of urban formations, and so on. Urban development with its four key systems—economy, areas, infrastructure and governance requires an interdisciplinary and integrated approach to problem-solving; inclusion of local communities and elites on the principle of territorial empathy and topophilia; stimulating the territorial identity and the identity of the territory; improving the territorial image of the city, not only as an investment and a tourist destination but also as a place for living; creation of an effective industrial urban policy and conversion strategies as a tool for development of the territory and capitalization of competitive advantages; effective use of the mechanisms of city governance—regulation, control, coordination and communication concept.

Conclusion

As of 2017, the process of urban and demographic shrinkage seemed irreversible, given the demographic trends and the deepening regional disparities in the development of the territory. The de-industrialization and loss of industrial identity in many regions are undoubtedly among the main reasons for the loss of human capital and the deepening effects of migratory processes that define the current state of the urban network.

The territorial and targeted policies, as well as the long-standing lack of spatial planning instruments, fail to formulate a long-term solution to the problem of demographic shrinkage and social inequalities, especially in those regions that the National Concept of Spatial Development (2013–2025) defines as shrinking area due to the rapid loss of population (National Spatial Development Concept 2012). The lack of economic diversification and the conditions for attracting investment has turned many small and medium-sized Bulgarian cities into vulnerable declining and degrading urban areas. Bulgaria is among the Eastern European countries that shows the extreme cases of de-population. In this context, one of the important issues the Bulgarian planning has to solve is how urban areas with complex shrinkage can revive their economic and social base.

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Regional Spatial and Statistical Analyses of the Urban-Rural Relationships in Romania. Case Study: Romanian Plain

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Abstract In Romania, the majority of settlements are rural. Generally, they are characterised by a high social and economic dependency on the closest urban areas, thus leading to a series of spatial and functional interactions. The paper is aiming to perform a regional scale (Romanian Plain) analysis of the spatial and functional linkages between 34 cities and 318 rural settlements located in their influence area. For the assessment of the urban-rural relationships, spatial analysis and statistical regression models at Local Administrative Level (LAU) were performed. The authors used three independent variables (demographic size, functional profile and connectivity) considered as driving factors for the selected cities, and eight socio-economic dependent variables (population growth, living floor, age dependency, economic dependency, built-up areas expansion, water supply, migratory balance, unemployment rate) reflecting the degree of rural development. The study results help identify areas with different rural development potential and better understand urban-rural interactions of the last decades.

Keywords Urban-rural interactions · Spatial and statistical analysis · Urban sprawl · Regional approach · Romanian plain

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Introduction

Urban and rural areas are the engines behind the urban-rural interactions, each facing different processes conditioning the type and dimension of their relationships. In extended parts of Europe, the settlement pattern cannot longer be understood as either urban or rural (Wandl et al. 2014). Hence, urban and rural areas should be analysed in an integrated manner as the distinction between the two has increasingly blurred, and the interdependency has amplified (Davoudi and Stead 2002; Piacentini and Trapasso 2010). The vitality of rural regions is under threat in large parts of Europe, as they are undergoing a dynamic transition. In many cases, this is the result of a combination between depopulation and agricultural decline (Zonneveld and Stead 2007) or urbanisation, changes in agriculture, new patterns of production and consumption and new societal demands (Horlings and Marsden 2014). In metropolitan landscapes, under the growing interlinking between urban and rural activities, rural areas are no longer lying outside the city, often being placed 'in between' the urbanised spots (Horlings et al. 2009) giving birth to a new spatial development typology 'territories-in-between' (Wandl et al. 2014).

Rural–urban relationships are tightly connected to the evolution and development of the processes that are taking place in urban areas. Moreover, processes related to urbanisation continue to broaden affecting even the remotest small village (Antrop 2004). Hence, the influence of cities on their surrounding territory is also associated with the urban development stages of van den Berg et al. (1982): urbanisation, suburbanisation, desurbanisation and reurbanisation, which rely on the population (growth and decline) and spatial changes between the *core* and *ring*. Suburbanisation, however, holds the most extensive processes of population change and migration from cities to the adjacent hinterland involving the decentralisation of the city (Šimon 2014). It is regularly associated with the rapid growth of population in the commuting suburbs, triggering changes in transport and growth of residential areas driven by lower land prices, high-quality environment and more pleasant surroundings (Stanilov and Sýkora 2014). In post-socialist countries (i.e. Romania), suburbanisation is the most important urban process contributing to reshaping the morphology, land use patterns and socio-economic structure of metropolitan regions (Sýkora and Ouředníček 2007). Overall, urban development (in all its phases), involves a variety of spatial and functional changes between urban and rural areas, mainly involving population shifts from the urban core to suburban areas, as well as the conversion of agricultural land to urban built-up land in the peripheral areas (Frenkel and Ashkenazi 2008).

The concept of urban-rural relationships emerged as a way to promote an integrated model of cities and the surrounding regions based on their spatial and functional interdependencies (Davoudi and Stead 2002). Urban and rural areas have become even more interdependent and connected economically, politically, socially and physically through housing, employment, education, commuting, resource use, etc. (Stead 2002; Zonneveld and Stead 2007). The Study Programme on European Spatial Planning distinguishes eight kinds of relationships: homework (commuting);

central place; metropolitan areas and urban centres in rural and intermediate areas; between rural and urban enterprises; rural areas as consumption areas for urban dwellers; rural areas as open spaces for urban areas; rural areas as carriers for urban infrastructure; rural areas as suppliers of natural resources for urban areas (Strubelt et al. 2001). Tacoli (2003) identifies different types of flows (e.g. agricultural, people, information, financial) which when defining the rural–urban linkages. Bengs and Schmidt-Thomé (2006) sums up a concise classification of the rural–urban linkages referring to the structural and functional relationships they develop.

From a policy viewpoint, the European Spatial Development Perspective (ESDP) was the first document to draw attention to 'urban-rural partnerships' at European, national, regional and local levels as a way to re-evaluate the relationships between city and countryside (Davoudi and Stead 2002; Kawka 2013; Lucatelli and De Matteris 2013). Urban-rural partnerships include a large variety of issues from peripheral rural areas with dispersed small settlements to sprawling spaces in metropolitan areas (Zonneveld and Stead 2007). Later on, build upon the aim of the ESDP, the Territorial Agenda of the European Union 2020 also stressed the importance of developing a balanced and polycentric urban system and new urban-rural partnerships (Jacuniak-Suda et al. 2014). Within the EU Regional Policy on territorial cohesion, urban-rural linkages are seen as partnerships for sustainable urban-rural development (RURBAN), through analysing territorial towns/cities–rural areas partnerships practices; attaining better cooperation between different actors in developing and implementing urban-rural initiatives; promoting territorial multilevel governance; assessing possible economic and social gains from enhanced rural–urban cooperation and identify the potential role of urban-rural partnerships for improving regional competitiveness and governance.[1] In line with this, urban-rural cooperation is documented as an essential driver of social and economic success, especially in metropolitan areas (Bański 2014) in view of addressing EU cohesion policy goals or achieving the EU 2020 targets.

Within this broad context, two main objectives have been set for the current paper: (1) to provide quantitative and qualitative investigation of the relationships between cities/town and their surrounding rural areas using several socio-economic indicators in order to (2) understand their role in local and regional development over the last decades.

Overview of the Rural–Urban Relationships in Romania

In 2017, the system of settlements in Romania included 3,181 LAU (Local Administrative Units), most of which rural (2,861 communes/12,957 villages). In contrast, the urban system appears to be underdeveloped in terms of number of cities (320) relative to the overall population of Romania.[2] After 2000, the urban population has grown

[1] http://ec.europa.eu/regional_policy/ro/policy/what/territorial-cohesion/urban-rural-linkages/.

[2] http://statistici.insse.ro/shop/index.jsp?page=tempo3&lang=en&ind=LOC103B.

following the declaration of new cities, rather than the positive demographic dynamics. As a result, the urbanisation rate reached 56.4% (2016), the maximum value ever recorded in Romania mainly based on the rural–urban inflows, the urban status granted to some communes and the inclusion of some villages within the administrative perimeter of towns (Mitrică et al. 2016). Rural–urban migration exceeded 2.2 million inhabitants between 1990 and 2014, while urban-rural migration (especially rural areas surrounding the big cities) reached 1.8 million inhabitants. Therefore, the villages are still exposed to the depopulation started during the industrialisation communist period, which has been recently replaced by the external migration of the rural labour force (Nancu 2016).

Before 1990, the urban-rural relationships have been largely driven by the socialist industrialisation, collectivisation of agriculture and the centralised plan-based system which mainly conditioned the workforce flows from rural to urban areas. After 1990, the dynamics and dimension of the urban/suburban/rural landscapes have been dictated by the general socio-economic transformations which have marked central and south-eastern European cities (Soós and Ignits 2003; Degórska 2004; Popovici et al. 2013; Stanilov and Sýkora 2014). Thus, subsequent to the fall of communism, profound socio-economic transformations conditioned by the transition from a centralised to a market-based society occurred. The relationships between towns and the villages located in their influence area developed within a new economic and legislative context. After the collapse of industry, when the job opportunities in the major cities were no longer available, commuting dropped sharply (Mitrică et al. 2016). Moreover, the main post-communist agrarian reform, which reconstituted the property right over agricultural and forest land to its former owners (Law no. 18/1991) had led to an important return of town dwellers to their places of origin. Steaming from the various differences between the two environments in terms of size, functions or patterns, new types of flows between the surrounding rural territories and urban areas emerged. From a legislative perspective, the increasing transformation of communes, viewed as local polarisation cores, into towns has also influenced the evolution trend in the urban-rural progress.

In the recent years, urban development, in all its stages, has become the main and most visible spatial processes taking place in the rural–urban interface. Thus, its dynamics has been mainly conditioned by urbanisation (Benedek 2006; Furdui et al. 2011; Dumitrache et al. 2016; Guran-Nica et al. 2016) suburbanisation (Nicolae 2002; Benedek and Bagoly 2005; Suditu 2012; Cocheci 2015; Grigorescu et al. 2015; Dumitrache et al. 2016; Guran-Nica et al. 2016; Grigorescu and Kucsicsa 2017), counter-urbanisation (Guran-Nica and Sofer 2012; Guran-Nica et al. 2016) and metropolisation (Ianoş et al. 2012; Guran-Nica et al. 2016; Mitrică et al. 2016). These urban development processes have triggered significant structural and functional transformations at the urban-rural interface. Hence, the urban-rural fringe is progressively shifted even further to the surrounding rural–agricultural space, the first to be consumed as a land resource in the urban sprawl process.

The complexity of urban-rural relationships in Romania steam from the variety of interactions evidencing the territorial transformations, disparities and patterns at different spatial scales (Pavel 2004; Istrate 2008; Stoica et al. 2010; Furdui et al.

2011). Local scales, however, (e.g. Bucharest, Craiova, Cluj-Napoca), have better identified and described the range of urban-rural interactions (Ianoş et al. 2010; Guran-Nica et al. 2011; Stoica et al. 2011; Vânău 2011; Pocol and Jitea 2013; Şoşea 2013). Moreover, the diversity of spatial transformations is dictated by the evolution of the socio-economic characteristics of the urban and rural areas determining the type of linkages that might develop: spatial or functional. The spatial relationships are reflected by the urban development and sprawl-related processes, regularly quantified by the land use/cover changes in general, and built-up areas dynamics, in particular. Among these, land use/cover changes, mainly in relation to urban sprawl and suburbanisation processes are more active in the urban-rural interface (e.g. Gavrilidis et al. 2015; Iojă et al. 2011; Grigorescu and Kucsicsa 2017; Kucsicsa and Grigorescu 2018). On the other hand, functional relationships are largely dictated by the social and economic changes that involve different types of flows (e.g. commuting, economic, demographic, provisioning) (Tălângă et al., 2010; Guran-Nica and Sofer 2012) maintaining strong relations between urban areas and the surrounding suburban villages.

Methodology

General Concepts

Spatial and statistical analyses are important for understanding the relationships between rural and urban settlements, but there is limited research on investigating their interactions using such methods. Spatial analysis has been used to explore the processes taking place in rural areas (Cho and Newman 2005; Van Eupen et al. 2012; Caschili et al. 2015; Bański and Mazur, 2016) or to explain the causes and effects of urban growth-related process and patterns (Sudhira et al. 2004; Rahman et al. 2011; Shahraki et al. 2011). However, through the spatial dimension and the functional and structural changes of the urban growth-related process, urban-rural interactions were indirectly addressed through the ties developed between the urban centres and the rural surrounding territories.

Some studies have focused on particular aspects of urban-rural relations such as migration determinants (Helbich and Leitner 2009), employment (Wójcik 2014) or the different spatial and functional processes taking place at the urban-rural interface (Carrion-Flores and Irwin 2004; Liu et al. 2013). Therewith, spatial-based regional typologies (urban, peri-urban or rural) aimed at providing analysis and modelling of the urban-rural regions were developed within some research projects such as ESPON 1.1.2 (Bengs and Schmidt-Thome 2006) or PLUREL (Zasada et al. 2013) and other approaches (OECD 2007; Dijkstra and Poelman 2008; OECD 2009; Dijkstra and Ruiz 2010; Brezzi et al. 2011; van Eupen et al. 2012; Wandl et al. 2014; Gonçalves et al. 2017).

Spatial and Statistical Analysis of the Urban-Rural Relationships in the Romanian Plain

The main scope of the current paper is to perform a regional-scale analysis of the spatial and functional linkages between cities/towns and their surrounding rural LAU in one of the most dynamic areas in Romania, Romanian Plain. The region has been the most affected by the structural and functional transformations of the last century, generally driven by the continuous population growth which required the expansion of agricultural areas for extensive and intensive farming, followed by the intensification of the urbanisation and forced industrialisation processes. After 1990, the gradual transition from the traditional rural–agrarian society to the urban–industrial society (Mitrică 2016) has been followed by the spatial and structural changes brought in by the fundamental political and socio-economic transformations of the post-communist period. Hence, urban-rural relationships have changed significantly in the last decades due to the increasing pressures of the cities on the surrounding agricultural land which occupies nearly 80% of its territory.

The Romanian Plain is located in the southern and south-eastern part of the country. It includes about 650 LAU which are totally overlapping its territory and more than 100 LAU located at the border with the neighbouring relief units. For the current analysis, out of the border localities, the authors took into the consideration the LAU with more than 50% built-up area included within the Romanian plain limits, that is 762 LAU (67 urban LAU and nearly 695 rural LAU) (Fig. 1).

Establishing the cities of influence. For the urban-rural relationships analysis, several areas were selected, evenly distributed throughout the Romanian Plain, so as to better reflect the spatial influence of the cities in the development of rural localities

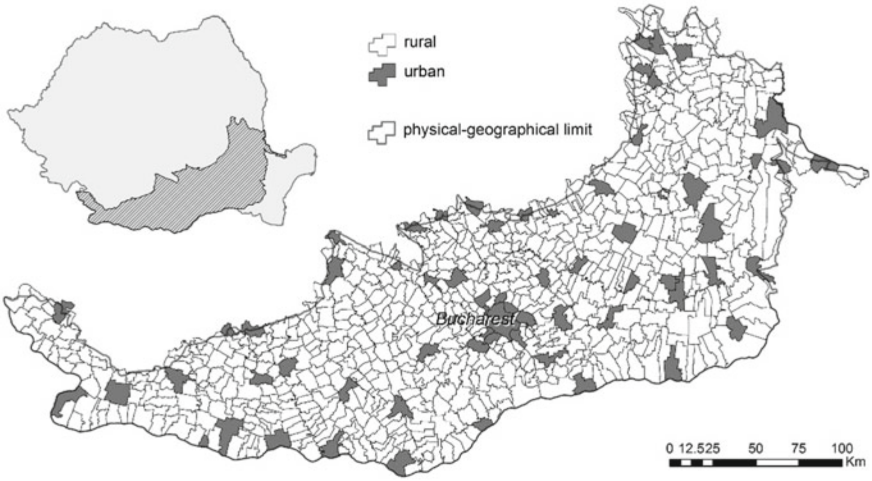

Fig. 1 The local administrative units (LAU level) included in the Romanian plain

in their surrounding territory. Thus, out of a total of 71 cities located in the Romanian Plain, 34 were considered to be cities of influence, territorially significant in terms of demographic size and functional profile (Table 1).

Establishing the areas of influence. In order to identify and assess the influence of the urban areas on the neighbouring rural territory, the authors delineated the area of influence (rural LAU) for the selected cities. Given that, in geographical terms, the spatial extent of urban-rural relationships refers to commuting and time-travel distances and socio-economic interactions, they require either spatial adjacency or accessibility provided through the transport infrastructure (Zasada et al. 2013). The analysis of the location of the rural territorial units and their transport-wise accessibility to urban centres within the differentiated administrative settlement hierarchy is an important component in delineating rural areas under the urban influence (Bański and Mazur 2016). As a result, the areas of influence were set based on the degree of accessibility, calculated as the distance between the city of influence and each rural locality in the surrounding area. Thus, based on this criterion, the inclusion of rural LAU in the area of influence was made as follows: ≤15 km distance from the influence cities with less than 100,000 inhabitants, ≤30 km distance from the influence cities with a population of 100,000–400,000 inhabitants and ≤45 km distance from the influence cities with over 400,000 inhabitants. The rural LAU included in the

Table 1 Ranking the selected cities according to their demographic size and functional profile. Number of localities included in the influence area

Name	Demographic size	Functional profile	No. of rural LAU2 included in the influence area
BUCHAREST	>400,000	industrial and services	72
GALAȚI	200,000-400,000	industrial and services	13
CRAIOVA	200,000-400,000	industrial and services	11
PLOIEȘTI	200,000-400,000	industrial and services	29
BRĂILA	200,000-400,000	industrial and services	11
BUZĂU	100,000-200,000	industrial and services	18
PITEȘTI	100,000-200,000	industrial and services	7
FOCȘANI	50,000-100,000	industrial and services	13
TÂRGOVIȘTE	50,000-100,000	industrial and services	6
SLATINA	50,000-100,000	industrial and services	2
CALARAȘI	50,000-100,000	industrial and services	5
ALEXANDRIA	50,000-100,000	industrial and services	9
SLOBOZIA	50,000-100,000	mixed	7
BAILEȘTI	<50,000	mixed	7
CALAFAT	<50,000	industrial and services	3
CARACAL	<50,000	industrial and services	7
FETEȘTI	<50,000	services and industrial	3
GIURGIU	<50,000	industrial and services	5
OLTENIȚA	<50,000	industrial and services	5
RÂMNICU SĂRAT	<50,000	industrial and services	7
ROȘIORI DE VEDE	<50,000	industrial and services	8
TECUCI	<50,000	mixed	7
TURNU MĂGURELE	<50,000	industrial and services	7
URZICENI	<50,000	industrial and services	12
BECHET	<50,000	agricultural mixed	4
GAEȘTI	<50,000	industrial and services	5
ÎNSURAȚEI	<50,000	agricultural mixed	3
ISACCEA	<50,000	mixed	1
LEHLIU GARĂ	<50,000	mixed	6
POGOANELE	<50,000	mixed	3
TITU	<50,000	industrial and services	9
VÂNJU MARE	<50,000	mixed	4
VIDELE	<50,000	mixed	6
ZIMNICEA	<50,000	mixed	3

influence area of each city based on this criterion is shown in Table 1. Thus, of the 318 rural LAU (Fig. 2), the majority are located in the influence area of Bucharest (72), Ploiești (29), Buzău (18), Galaţi (13), Focşani (13) and Urziceni (12).

Statistical analysis. Based on data availability, several indicators (dependent and independent variables) resulting from statistical and spatial data processing have been considered (Table 2).

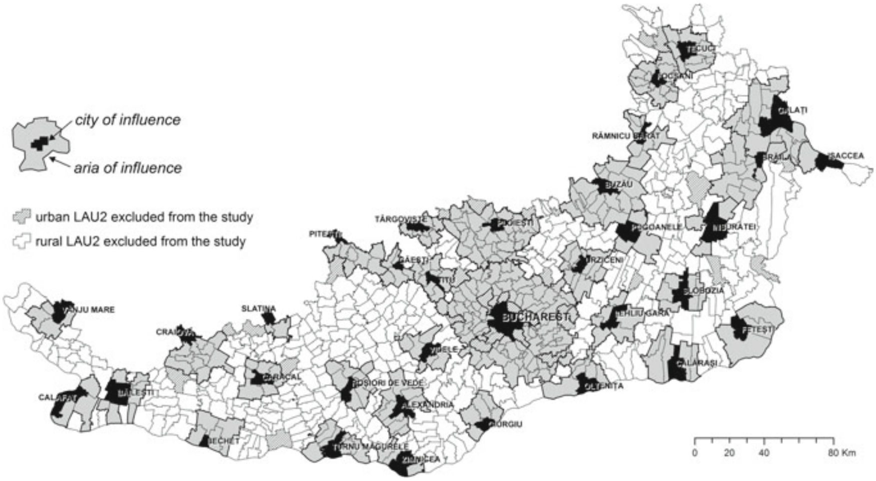

Fig. 2 The cities and their influence area established based on the connectivity criterion

Table 2 Dependent and independent variables included in regression models to assess urban-rural relationships in the Romanian Plain

Dependent variable	Explanation	Processed based on
Y_1	Built-up areas dynamics (1990–2015)	LANDSAT satellite images
Y_2	Living floor space dynamics (1992–2011)	NIS
Y_3	Population growth dynamics (1992–2011)	NIS
Y_4	Age dependency ratio dynamics (1992–2011)	NIS
Y_5	Migratory balance dynamics (1992–2011)	NIS
Y_6	Unemployment rate trend (1992–2011)	NIS
Y_7	Economic dependency index trend (1992–2011)	NIS
Y_8	Water supply network trend (1992–2011)	NIS
Independent variable		
X_1	Functional profile hierarchization (1992)	NIS
X_2	Demographic hierarchization (1992)	NIS
X_3	Connectivity (by roads)	Google maps

The dependent variables were used to assess the level of socio-economic development in the area of influence of each town.

Built-up areas dynamics. The existing built-up space is more likely to trigger further development with similar or different land use functions (e.g. residential, commercial). For the current research, the thematic layers containing built-up areas extracted using visual interpretation of Landsat 4/5 TM and Landsat 8 OLI_TIRS images were quantified and analysed.

Living floor space. This variable refers to the total amount of living rooms surface measured by the interior dimensions at floor level.[3] This indicator is associated with built-up areas dynamics, mainly triggering suburban residential areas (residential suburbanisation) which, in time, is more likely to attract better-educated population with high incomes (Sýkora and Ourednicek 2007), but also residential segregation and exclusion (Soós and Ignits 2003).

Population growth dynamics, considered as the average annual rate of population change during a specified period, is generated by the positive birth rates and migration. In relation to the influence of the urban centre over the neighbouring rural territory, it is mainly caused by urban-rural migration or vice versa. During the early stages of suburbanisation, the outward moving of population brings in infrastructure and new functions, generally influencing higher land consumption (Frenkel and Ashkenazi 2008). Hence, higher population growth rates trigger increased spatial changes, especially built-up areas expansion, resulting in the spatial redistribution of the population inside metropolitan areas under residential deconcentration (Sýkora and Ourednicek 2007).

Age dependency ratio (% of the working-age population) is the ratio between the elderly population (65 + years) and the working age (15–64 years) population.[4] Regularly, this indicator has a negative meaning with respect to the socio-economic progress of rural areas (Bański and Mazur 2016) which, in time, reflects itself in the economic dependency of population.

Migratory balance. Rural–urban migration lessens population pressure in rural areas, helping improve economic conditions and reduce poverty. However, disparities between urban and rural areas in terms of income, employment and the availability of basic infrastructure and services still remain (Sheng 2002). Also, under urban-rural migration, new suburban areas are experiencing an influx of well-educated, affluent and demanding urban residents which claim services, commerce and infrastructure (Bański 2014).

Unemployment rate in suburban areas is an important indicator which expresses the labour functional relationships with urban areas. Thus, higher unemployment rates in urban areas lead to the shift of population in the suburbs where land resources are more accessible (‘suburbanisation of poverty’) (Hochstenbach and Musterd 2017). In addition, the relocation of businesses in the suburbs attracts the available workforce from the city—‘job suburbanisation’ or ‘job sprawl’ (Raphael and Stoll 2010).

[3] http://statistici.insse.ro/shop/index.jsp?page=tempo3&lang=en&ind=LOC103B.

[4] https://data.oecd.org/pop/elderly-population.htm.

Economic dependency index, defined as employee's upkeep of another person who does not carry out a remunerative activity, is calculated as the number of non-occupied persons (inactive and unemployed)/100 occupied persons (Simion 2000). This indicator influences the socio-economic development of the rural areas, generally leading to migration flows to more developed regions.

Water supply network (the length of water supply network at LAU level) mainly relates to the built-up areas dynamics and the migratory balance in terms of the increased demand for the development of technical infrastructure (Bański and Mazur 2016) under the expanding urban influence over the rural surroundings.

The independent variables have been set to categorise each selected town according to the functional profile, demographic size and accessibility.

The *functional profile* and *demographic size* of the influence cities are important in explaining their effects on the surrounding rural LAU, thus determining the degree of urban influence and the types of relationships that might be developed. Furthermore, the accessibility was considered assuming that better connectivity to the influence cities can increase the development degree of the nearby rural LAU. This was calculated as road distance between each rural locality included in the area of influence and its influence city. The *connectivity* (accessibility degree) was essential for the initial selection of influence cities/towns given that the physical distance has a significant impact on the urban-rural relationships: the closer the rural areas are to the cities, the stronger their interaction is. In this way, the role of the city is essential in reducing the 'rurality' degree (Pascariu and Czischke 2015), as well as in quantifying the driving time necessary for the population of a region to reach a populated centre (Dijkstra and Ruiz 2010).

Regression models. Urban-rural relationships were carried out using regression models in order to identify and evaluate the interactions between the (*influence*) determinants and the degree of development of the rural LAU in the area of influence, as reflected into a series of socio-economic and demographic indicators. *Multiple linear regression* (MLR) and *binary logistic regression* (BLR) estimated for eight sets of variable combination were applied (Fig. 3). Thus, based on the resulted regression

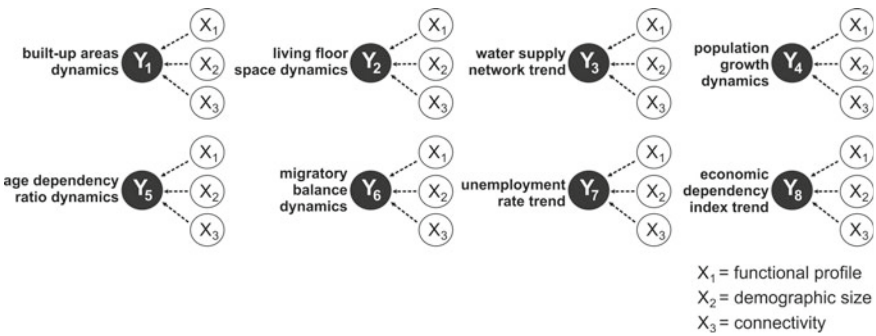

Fig. 3 The sets of variables combination included in regression models

Table 3 The classification (coding) of the dependent variables to apply BLR

Dependent variables	Classes	
Built-up areas dynamics	<50 ha	≥50 ha
Living floor space dynamics	<50 m^2	≥50 m^2
Water supply network dynamics	<1,000 m	≥1,000 m
Population growth dynamics	Negative	Positive
Age dependency ratio dynamics	Negative	Positive
Migratory balance dynamics	Negative	Positive
Unemployment rate dynamics	Negative	Positive
Economic dependency index	Negative	Positive
Code	0	1

coefficients, the factors that contributed to the development of the rural areas near the selected towns were identified, compared and ranked.

Using MLR, the influence of each explanatory factor was investigated. For this, the categorical independent variables, i.e. functional profile, was classified as continuous data from 1 to 4 considering their importance in the development of the region: agricultural mixed (1), industrial and services (2), mixed (3), services and industrial (4). Before developing the MLR models, all variables were normalised into the range 0–1 by *Min–Max linear transformation*, to achieve similar data range. Furthermore, in order to assess the influence of each explanatory factor's classes on the independent variables against the established reference category, the BLR was used. Thus, each dependent variable was divided into two classes (Table 3) in order to show the magnitude of the process (low–high, negative–positive). Additionally, each considering continuous explanatory factor was classified and prepared as categorical (Table 4).

Results and Discussions

The relative contribution of the explanatory variables was evaluated using the corresponding coefficients in the regression models. In the case of MLR, the relative contribution of the explanatory factors was assessed using the standardised estimated coefficients β (Table 5). Significant differences have resulted between values, suggesting that the explanatory factors have different effects on the considering dependent variables. The highest positive values indicate that the demographic size is the best predictor mainly for the Y_1–Y_3. This means that the probability of built-up areas, living floor space and population growth to increase occurs if the demographic size in the influence cities increases. Furthermore, the negative β values resulted for Y_4–Y_6 indicates a significant influence of the demographic size and connectivity in the negative dynamics of age dependency ratio, migratory balance and unemployment rate dynamics. The influence of connectivity on the degree of development of the rural

Table 4 The categorical data obtained by classification of the continuous explanatory factors. The established reference category

Explanatory factors	Category				
Functional profile	Agricultural mixed	Industrial and services	services and industrial	Mixed	–
Demographic size	Very small (<50,000 inh.)	Small (50,000–100,00 inh.)	Medium-sized (100,000–200,000 inh.)	Large (200,000–400,000 inh.)	Very large (>400,000 inh.)
Connectivity	Very weak (>40 km)	Weak (30–40 km)	Average (20–30 km)	Good (10–20 km)	Very good (>10 km)
Code	1 (reference)	2	3	4	5

Table 5 Standardized estimated coefficients *(β)* for the multiple linear regression models

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
Functional profile	0.034	0.061	0.016	−0.058	−0.027	−0.159	0.015	0.029
Demographic size	0.870	0.707	0.704	−0.123	−0.195	−0.142	0.045	0.142
Connectivity	0.473	0.471	0.480	−0.053	−0.169	−0.074	−0.121	0.114

LAU included in the area of influence is also evident, the regression coefficients showing important contribution mainly to Y_3, Y_1 and Y_2. It means that better roads connectivity (decrease in distance) will trigger population growth, built-up areas and living floor space expansion due to better accessibility to the influence cities. Also, the β coefficients for Y_5 (−0.169) and Y_6 (−0.074) indicate that migratory balance and unemployment rate decrease when the connectivity to influence cities is very good.

The regression models pinpoint that the functional profile has low significance in the socio-economic indicators dynamics after 1990 compared to demographic size and connectivity. However, the β coefficients show that unemployment rate has negative dynamics and built-up areas and living floor space positive dynamics when the functional profile of the influence cities grows in importance. Furthermore, the water supply network is more developed when the functional profile of the influenced cities increases in importance.

In case of the BLR, ranking the classes of each explanatory factor compared to the established reference category was evaluated using the corresponding β coefficients (Table 6). First, for the functional profile, the positive β values show that *industrial services* and *mixed* profile have the most important contribution mainly to built-up areas expansion and population growth, compared to the *agricultural mixed* profile (reference category). On the other hand, the negative β values indicate that the *industrial and services*, *mixed* and *services and industrial* profiles contribute more to the negative dynamics of age dependency ratio, unemployment rate and economic dependency index than the *agricultural mixed* profile. In case of the demographic size, the influence to the built-up areas expansion, living floor space dynamics, population growth and water supply network extension is more evident in the rural LAU situated near the largest cities than in the rural LAU near the smallest cities. Furthermore, the negative dynamics of age dependency ratio and migratory balance is also more evident in the rural LAU situated close to the cities with more than 100,000 inh. In terms of connectivity, it is also obvious the contribution of the very good connectivity between rural LAU and influence cities mainly to population growth, built-up areas and living floor positive dynamics comparing to the influence of the very low connectivity. Hence, the negative dynamics of the age dependency ratio and unemployment rate are better explained for the rural LAU located closer to the influence cities.

In addition, the *Nagelkerke R Square* indicator (Table 6) shows how socio-economic development of the rural LAU is differently explained by the analysed explanatory factors together. Thus, the highest values (0.437 for Y_1 and 0.40 for Y_3)

Table 6 Estimated β coefficients for the logistic regression models. *Nagelkerke R Square* values

		Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
Functional profile	Agricultural mixed[a]								
	Industrial and services	18.059	0.212	19.175	−19.723	19.781	−2.984	−2.700	−1.316
	Services and Industrial	−0.014	1.603	−0.014	−21.897	−0.023	−22.118	−22.993	−21.487
	Mixed	19.107	−0.093	18.551	−19.732	19.616	−3.639	−2.366	−0.428
Demographic size	Very small[a]								
	Small	1.073	1.366	1.644	−0.977	−0.128	1.043	0.474	−0.014
	Medium-sized	2.472	2.542	2.568	−0.737	0.178	−1.317	−0.291	0.314
	Large	2.290	1.040	2.045	−1.290	−0.451	1.500	0.676	0.598
	Very large	6.179	3.529	5.247	−3.618	−0.339	−0.564	−0.037	0.815
Connectivity	Very weak[a]								
	Weak	0.288	0.916	−0.709	−1.179	−1.743	0.633	0.633	−0.470
	Average	2.406	1.575	0.534	−1.727	−1.688	−0.174	1.129	0.336
	Good	3.929	2.975	2.911	−2.690	−0.657	−0.435	1.226	0.503
	Very good	4.212	3.222	19.175	−3.135	−0.194	−0.824	0.929	0.423
Negelkerke R square		0.437	0.254	0.400	0.267	0.088	0.223	0.102	0.057

[a]Reference category

indicate that functional profile, demographic size and connectivity explain 44% of the built-up areas expansion and 40% of the increase in population in the influence area.

On the other hand, the lowest values for Y_8, Y_5 and Y_7 indicate that the water supply network extension, negative dynamics of migratory balance and economic dependency index could be better explained by other explanatory factors of the influence city, as well as by local drivers (e.g. investments, entrepreneurial initiatives, development projects, external migration) which were not included in the present study.

Conclusions

Assessing the relationships between urban areas and the surrounding rural territory is essential in understanding the dimension of the spatial and functional linkages between the two types of settings. Spatial and statistical analyses, in particular can provide quantitative upshots on the types and variety of connections developed between cities/towns and their rural surrounding territory.

In Romania, urban-rural relationships have been addressed at different spatial scales and focused on a variety of linkages (e.g. spatial, functional). The dimension and the complexity of the urban-rural relationships is highly influenced by the size and functions of the urban area, thus county seats, large and medium-sized towns trigger a wider diversity of linkages than the small towns. Thus, the complex relationships between these two types of settings (urban and rural) are better understood using a combination of statistical and spatial analysis methods, providing two- or three-dimensional image of the spatial phenomena taking place in the surrounding of cities. As a result, in order to reflect the degree of rural development, the urban-rural relationships assessment were performed as the interaction between three independent variables (demographic size, functional profile and connectivity) of the selected urban LAU and eight socio-economic dependent variables (population growth, living floor, age dependency, economic dependency, built-up areas expansion, water supply, migratory balance, unemployment rate) of the rural LAU. The estimated coefficients of the regression models indicate that after the 1990 the socio-economic development in the Romanian Plain's rural LAU has been mainly triggered by the demographic size and connectivity to the influence cities. Their effect is more visible on the population increase, built-up areas and living floor space expansion in the surroundings of Bucharest, Pitești, Galați, Craiova, Ploiești, Brăila, as well as in the decline of the migratory phenomena and unemployment in the surroundings of Bucharest, Pitești, Buzău, Călarași. Moreover, the spatial and statistical analysis shows a reduced influence of the functional profile in the socio-economic development degree. Thus, it can be assumed that the future socio-economic development of the rural LAU in the study area is more likely to occur near larger cities, with good connectivity, as well as characterised by mixed and industrial and services functional profiles (e.g. Bucharest, Ploiești, Galați, Brăila, Craiova). Conversely, a low development degree of the rural LAU is mainly expected in the influence area of the small towns characterised by a dominant rural–agricultural profile and industrial decline (e.g. Însurăței, Bechet, Fetești, Vânju Mare, Titu, Zimnicea, Videle). Overall, the current results help in identifying areas with different rural development potential and better understand the urban-rural interactions.

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Dynamics of the Internal Structure and Habitation Conditions of the Ghettoized Urban Structure of Harman Mahala Quarter—Plovdiv, Bulgaria (Through Combined Application of Remote Sensing and Field Research Methods)

Nadezhda Ilieva, Krasimir Asenov, Boris Kazakov and Todor Lubenov

Abstract Post-communist societies are facing numerous challenges leading to complex structural changes. New models of socio-spatial polarization of the cities have emerged. In recent decades, Bulgaria has seen a clear trend of growing number of Roma people residing in cities. In the majority of cases, the Roma settle either in already existing Roma quarters, or the new settlers form completely new Roma quarters. The swift explanation of the Roma quarters in both horizontal (spatially) and vertical (height) aspect, makes it difficult to trace the changes. Considering that most buildings are illegal, they are not present on cadastral maps and urban spatial plans. The serious difficulties which Bulgaria has been encountering regarding the integration of its Roma population, together with the increased ghettoization of the Roma living in cities and the eventual threats of social cataclysms, determine the necessity of carrying out this study. Its main objective is to analyze the spatial development trends and the internal structure of the Roma quarters, based on the case study of the Roma-inhabited Harman Mahala quarter in the city of Plovdiv, applying remote sensing and field research methods.

Keywords Spatial segregation · Ghettoized urban structure · Harman Mahala quarter—Plovdiv · Roma population

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Introduction

Spatial segregation has attracted the attention of geographers and sociologists for more than a century. Their research focuses on the analysis of spatial segregation patterns, the causes of their occurrence, their development and of course—the consequences. The proximity of ethnic groups determines patterns of social interaction and spatial access to social services: ethnic groups living apart from one another are unlikely to interact with each other and use the same social institutions (healthcare, educational institutions, parks, social centers, etc.). As the spatial proximity increases, the probability and degree of social interaction increases too.

In the United States, the concept of segregation is mainly perceived through indicators related to ethnic or racial affinities of the individuals, whereas in Europe—mostly to socioeconomic status, education level, housing quality—as Van Kempen and Özuekren (1998), Musterd and Ostendorf (1998), Friedrichs (1998), Johnston et al. (2002), Maloutas (2007), Van Kempen (2007) and other authors reveal. The above-mentioned researchers emphasize the growth of spatial segregation in the cities of most countries, pointing out as main factors the immigration flows, the "withdrawal" of the "social state", the housing market, the unequal distribution of council housing, the ethno-cultural specifics of the minority groups, etc. Overall, the level of spatial segregation in Southern European cities has been deemed lower compared to that of the Western European ones. Malheiros (2002) highlights that the nature of the existing spatial segregation in Southern European cities is determined by four features: (1) poorer housing conditions; (2) high levels of informality; (3) more complex housing distribution patterns; and (4) a higher degree of suburbanization. At present, scientists point out that the above-mentioned processes have become one of the main features of cities across post-communist countries of Europe as well. Although there are significant differences between the former communist countries themselves, it can be argued that their cities are characterized by a lower degree of segregation compared to the rest of Europe. Eastern European authors such as Szelenyi (1983), Marcińczak (2007), Toušek (2009) explain the lower degree of spatial segregation with the political agenda during the communist period, aimed at social equality. The post-communist socioeconomic transformation, as well as the introduction of the neoliberal model of state development, however, triggered a process of sociospatial polarization, with the explicit clarification that the segregation processes are valid for all social groups of people, especially for those who identify themselves as Roma. The above-mentioned authors state that the different forms of spatial segregation are related to the spatial concentration of representatives of the Roma ethnic group. Despite the great interest in that ethnic community, especially during the so-called "Decade of Roma inclusion", the empirical studies of the Roma neighborhoods and the place they hold in the urban area are relatively scarce in Bulgaria.

Categories and Methodology of the Research

The structural analysis of the changes occurring in urban neighborhoods, housing differentiation and the concomitant processes of spatial segregation and concentration, originated in the Chicago School of Sociology (see, for example, Burgess 1925; McKenzie 1925). Various spatial patterns of the cities exist, usually involving concentric zones—Burgess (1925), specific sectors (Hoyt 1939) or multiple nuclei (Harris and Ullman 1945). The spatial aspects of the social processes are theorized in the pioneering works of Harvey (1973, 1982) and Castells (1972). Each object or subject demands space. Since no object/entity can occupy the same space simultaneously with another one, space becomes divided, which is its basic physical characteristic (Harvey 2006; Simmel 1997). The same authors claim that space is never purely physical (absolute) or mathematical (geometric), but it is always also social. Space is defined by Bourdieu (1989) as a "system of relations", and Massey (2005) defines space as a "product of relationships".

It is hard to find a clear and common definition of *spatial segregation* in scientific literature. There are different ways to perceive and address the problem. The definition of the term *segregation* in the Dictionary of Human Geography is brief, describing spatial segregation as *a division of a particular community into subgroups throughout the area of residence* (Johnston et al. 1986). Despite the seemingly simple definition of spatial segregation, the term remains relatively unclear. Van Kempen and Özüekren (1998) believe that the essence of spatial segregation is expressed in the concentration of a particular group in some areas, compared to others where the same group is represented to a lesser extent. Closely related to spatial segregation is the theory of *spatial assimilation* (Massey and Denton 1988; Massey 2005), according to which the levels of acclimatization and integration determine the concentration of certain groups in a given territory. Spatial assimilation is the result of two opposing spatial forces: (1) concentration—that leads to ethnic segregation and (2) dispersion—where ethnic assimilation of given ethnic groups occurs. According to Van Kempen and Özüekren (1998), the opposite process of spatial segregation is the formation of the so-called *mixed residential areas*, defined as a situation where representatives of all ethnic groups live together.

In most definitions, spatial segregation is regarded as residential segregation, but it may also refer to the formation of separate groups in schools, at work, during leisure activities, etc. Research has shown that almost every criterion (social status, material status, ethnicity, mother tongue, race, religious beliefs, etc.) differentiating individuals and groups of individuals can become the basis for physical separation. A special feature of the Roma ethnic group is that spatial segregation, in that case, is not just ethnic and social, but also economic, cultural, and so forth. Depending on the spatial scale, different forms of segregation are observed: for example—segregation between the cities and their suburban belts; between individual neighborhoods within the city itself; between blocks of flats in a given neighborhood and even on a vertical scale (between the floors in a residential building).

The study of spatial segregation by urban geography in recent decades has been strongly influenced by the metaphor of the "dual city," which in its essence describes the trends of polarization of urban societies. The relationships between individuals, the way they interact, the differences that exist between them, are at the basis of the concept of the *dual city*—a concept formulated by Marcuse (1989, 1993), Mollenkopf and Castells (1991) and Sassen (1991), or the *divided city* of Fainstein et al. (1992). Van Kempen (2007) on the other hand makes the connection between the divided society and the divided city: if a society is divided, the city space will also be divided. Closely related to the theory of the divided city is the formation of various spatial urban structures such as *ghettos, ethnic enclaves*, etc., that are the product of the processes of spatial segregation. Marcuse (1995, 1997, 2005) suggests that the term *ghetto*, therefore, should be replaced by the term *ethnic enclave*. Marcuse distinguishes the *enclave* from the *ghetto* in the way those two form: according to that author, the formation of the ghetto is the result of the application of force, whereas in the case of the enclave that element is missing. Another major difference, according to Marcuse, is that in the case of the enclave it is the inhabitants who set the boundaries of the enclave, that is—it is generated "from the inside", while in the case of the ghetto, the dividing line is imposed "from the outside". Wirth (1998) refer to such areas (enclaves) as to *voluntary ghettos*—quarters which are formed in order to strengthen a shared (ethnic) identity.

Closely related to the study of the various urban spatial structures is the term *quarter*. There is no commonly accepted definition in the literature: Van Kempen (2007) distinguishes three approaches to defining the *quarter*. The first approach, adopted by Megbolugbe et al. (1996), considers the neighborhood as a homogeneous area with common demographic and residential characteristics. In this case, however, some areas are unlikely to be included in any quarters, given that many urban areas are characterized exactly by their heterogeneity. According to the second approach, adopted by Galster (2001), the boundaries of the quarter are outlined by the inhabitants themselves—on the basis of the shared identity or the way they perceive the quarter, i.e., based on the formed *sense of place*. Van Kempen (2007) points out that this approach, just like the first one, also excludes some areas, especially at a time when individualism is in its heyday. Van Kempen (2007) perceives the so-called *functional approach*, according to which urban space is divided into statistically defined areas whose boundaries are administratively imposed. This approach, the author points out, eliminates the possibility of some parts of the city not being included in the urban space. In the present study, the boundaries of Harman Mahala quarter of the city of Plovdiv, Bulgaria, are outlined on the basis of the ethnic homogeneity, the morphological structure and the urban planning characteristics of the neighborhood. In this study, the term *ghettoized urban structure* (GUS) is used. In defining that term, along with ethnicity, social and economic criteria are also used, such as unemployment rates, poverty level, infant mortality rate, the share of gray economy employment rate, vocational and educational level, etc. Another distinctive feature of the studied quarter is the long-term accumulation of interrelated problems of various natures: economic, social, urban, ecological, etc. The spatial range of a GUS can vary greatly: it can cover a whole neighborhood, part of it or just a group of adjacent residential buildings. In infrastructural terms, the GUSs are characterized by deteriorated housing, poor technical and social infrastructure, poor public transport access, chaotic planning of the housing units and so forth.

Urban geography is open to various research methodologies. In the tracing of in the transformation trends of Plovdiv's urban space, orthophoto images (1952, 1965, 1975, 1982, 1989, 2005), cadastral plans (2010), the Integrated Plan for Urban Regeneration and Development of the city (2013) and its Spatial Development Concept (2015) were used, as well as unmanned aerial vehicle images (2018). Those images were georeferenced and digitized in GIS environment. GIS technologies were used to trace, visualize and analyze changes in the urban space's structure and to calculate building intensity ratios, the height of buildings, etc. data, which were later attached as attribute information to the corresponding ArcGIS layer. The studied area has been photographed by an unmanned aerial vehicle (UAV) from a low altitude—90–120 m, with precision instruments for capturing and recording data in the visible spectrum. Detailed maps of the actual state of the buildings—their outline, height, construction density, surface area, etc., have been elaborated on the basis of subsequent processing of the data obtained from aerial photo shooting, as well as the application of appropriate methods and algorithms. The values of some basic urban planning indicators—such as the construction density index and the percentage of landscaping—have also been established. Spatial data have been combined with field studies data, through quantitative and qualitative methods of gathering information, which all complement the characteristics of the living environment of the residents of Harman Mahala quarter. According to Bryman (2006), the choice of a research strategy of this kind provides authors with "data richness," considering that quality methods of collecting information are used to understand the relationships previously identified through quantitative research. The quantitative survey involved 500 inhabitants of Harman Mahala: through the developed questionnaire, empirical information has been collected about some ethno-demographic indicators, economic and housing conditions, degree of satisfaction with the quarter the respondents live in, social networks, etc. The purpose of the interviews was to collect quality data about the preferences and desires of the inhabitants, and to find out about the reasons behind the results of the survey. By applying the above-mentioned methods of data collecting, it was intended to give a complete picture of the situation of the Roma ethnic group, whose study normally is seriously hampered by the lack of data.

Tracing the Trends, the Origin and the Development of the GUS of Harman Mahala

Historically, four Roma quarters have emerged in the city of Plovdiv. Among those, it is only Hadji Hasan Mahala quarter (9 ha), which is located in the central part of the city—at the foot of the "Ancient Plovdiv" architectural reserve. All other Roma quarters are located on the outskirts of the city, as in the case of Stolipinovo (formally "Izgrev")—situated in the eastern administrative region of the city over an area of 54 ha. The historical data show that the neighborhood was formed in the beginning of the last century, around 1910–1915. "Sheker Mahala" or "Todor Kableshkov"(10 ha), on the other hand, is situated in the northern administrative region of the city. After the great flooding of Harman Mahala quarter in the 1950s, people were massively relocated to what is now Sheker Mahala quarter, for which purpose the government built massive, single-storey houses for the newly settled residents. Harman Mahala quarter (5 ha, formally known as "Hadzhi Dimitar") is also located in the northern administrative region of the city, next to the northern industrial zone of Plovdiv, and is the most densely populated GUS in the city. Since the beginning of the so-called transitional period, as a result of the intra-migratory movements and the concentration of Roma in urban settlements, the micro-quarters of Shumen and Kanala Kar emerged in the immediate vicinity of Stolipinovo quarter, becoming part of that ethnic megastructure. The total area of all Roma quarters in Plovdiv combined is 80 hectares, which constitute 2.3% of the total residential area of the city (Fig. 1).

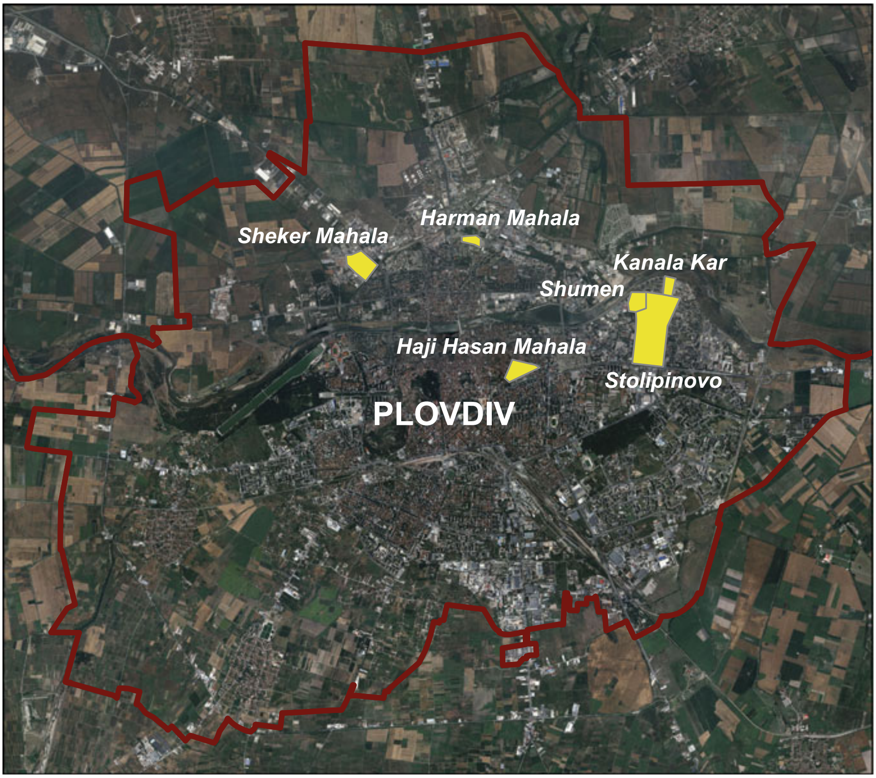

Fig. 1 Location of the ghettoized urban structures (Roma quarters) in the city of Plovdiv

Harman Mahala is located in the Karshiyaka suburb of Plovdiv—until the beginning of the twentieth century—beyond the urbanized part of the city, which facilitated the adaptation of most of the migrants arriving from villages around Plovdiv. Asenov (2018) states that "although we have no reliable information about this, we can assume that at the end of the nineteenth and in the early twentieth century, there is a "Roma" neighborhood in the Harmanite locality outside the city. Asenov justifies his assumption with conversations he had in the early 1990s with elderly inhabitants of the quarter, when those residents were already 75–80 years old and, when asked about their place of birth, declared Harman Mahala as their birthplace. This suggests that by 1910–1915, the neighborhood already existed. Asenov further states that on the basis of the information gathered from archives, it is safe to say that in the second half of the nineteenth century, an ethnically distinct neighborhood was formed in the block formed between "Eledzhik", "Nikola Belovezhdov", "Velyu voyvoda" and "Belozem" streets. For the formation of the quarter some natural phenomena also played a role: after the great earthquake of 1928, a large part of Plovdiv was affected, as many buildings were destroyed, especially in the densely built city center. Families who became homeless—mainly Roma and Turks residing by that time in the city center—moved to Harman Mahala, where there were available lots. The Roma residents were forced to leave the central, nicer areas of the city, and were driven to the outskirts—to more disadvantaged areas, in the obedience of a local authorities' resolution. Initially, those areas were beyond the administrative limits of the city, but due to its territorial expansion, the two neighborhoods were gradually "swallowed" by the city. Another natural disaster which played an important role in the formation of the studied neighborhood was the great flooding of 1957, which destroyed most of the houses located in the eastern part of the quarter. The government and the local authorities, together with voluntary work on behalf of the victims of the flooding, built 140 one-family, one-storey houses in Todor Kableshkov (Sheker Mahala) district of Plovdiv, which lead to the formation of that new Roma quarter. Based on the information provided by the respondents, it turns out that the majority of the flooding victims were not locals residing in Harman Mahala, but were migrant Roma who came to the neighborhood in the 1940s and the 1950s. By relocating some of the residents of Harman Mahala to the newly emerged Sheker Mahala, the vacated space was quickly "captured" by their relatives, who until the flooding lived outside the neighborhood. In fact, that natural disaster lead to the formation of the final ethnic profile of the population of Harman Mahala, apart from the Bulgarian families who were gradually moving out of the quarter until the beginning of the twenty-first century. The spatial development of Harman Mahala in the following decades was a consequence of several components: migration into the neighborhood, demographic growth and availability of vacant municipal lots. During the period between the two mappings—the one of 1965 and that of 1987 (Figs. 2 and 3) the following changes are worth mentioning: (1) the construction of the Textile Technical School, which limited the spatial expansion of the quarter to the south; (2) the construction of the block of flats known as "The Small Giant", just outside the southwestern corner of the quarter, where part of the Roma families were later accommodated. However,

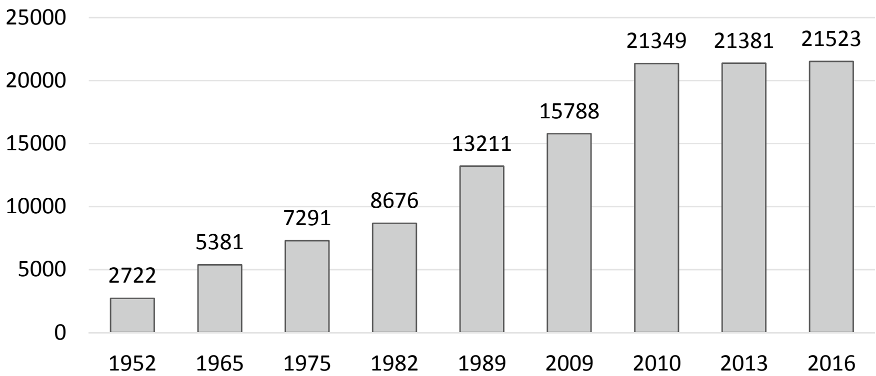

Fig. 2 Dynamics of the built-up area of Harman Mahala in the 1952–2018 period

some of the owners (of Roma origin) sold out their apartments and rebuilt their either rickety or more solid homes on the expropriated municipal (council) lots.

After the second half of the 1990s there has been a trend which remains hidden for numerous institutions, researchers and the macro-society, namely—the trend of mass construction and reconstruction of new residential buildings, both within the neighborhood itself and on newly acquired municipal lots. What is the current state of Harman Mahala in terms of space: significant expansion in vertical direction and continuing construction of homes on any space available even through acquiring parts from the street network and the pavement areas. The desire to maximize every space available often creates severe conflicts between neighbors, although the vast majority of the homes existing homes, as well as the ones about to be built are on municipal lots—i.e., not even owned by their inhabitants. The allowed legal construction requirements make no sense in the neighborhood and, therefore, those are completely overlooked by the residents. The result is both sad and comical: a 60-cm-wide street; a balcony almost entering the neighbors' bedroom; windows of two neighboring buildings standing at 50 cm from each other; a 4 m^2-room etc., etc. The main current spatial trend of the structural development of the neighborhood involves vertical growth of the existing building stock. Despite the intensified control over the last few years, aimed at prevention of illegal construction, the ongoing trends for horizontal expansion of the neighborhood in almost all directions (north, east, and southeast) continue as well (Fig. 3).

As it is seen from Figs. 2 and 3, the major part (76%) of the housing stock in the studied quarter was built after the socio-political changes following 1989: the first decade of the twenty-first century marked the highest peak in construction as 34% of the buildings in the quarter were built in that period. Compared to the city of Plovdiv as a whole, exactly the opposite situation is observed—74% of the building stock was erected before 1989, 12% in the 1990s and 14% after 2000.

The spatial data enables the visualization of the continuous horizontal, and, due to the existing limitations, vertical expansion of Harman Mahala quarter in recent years.

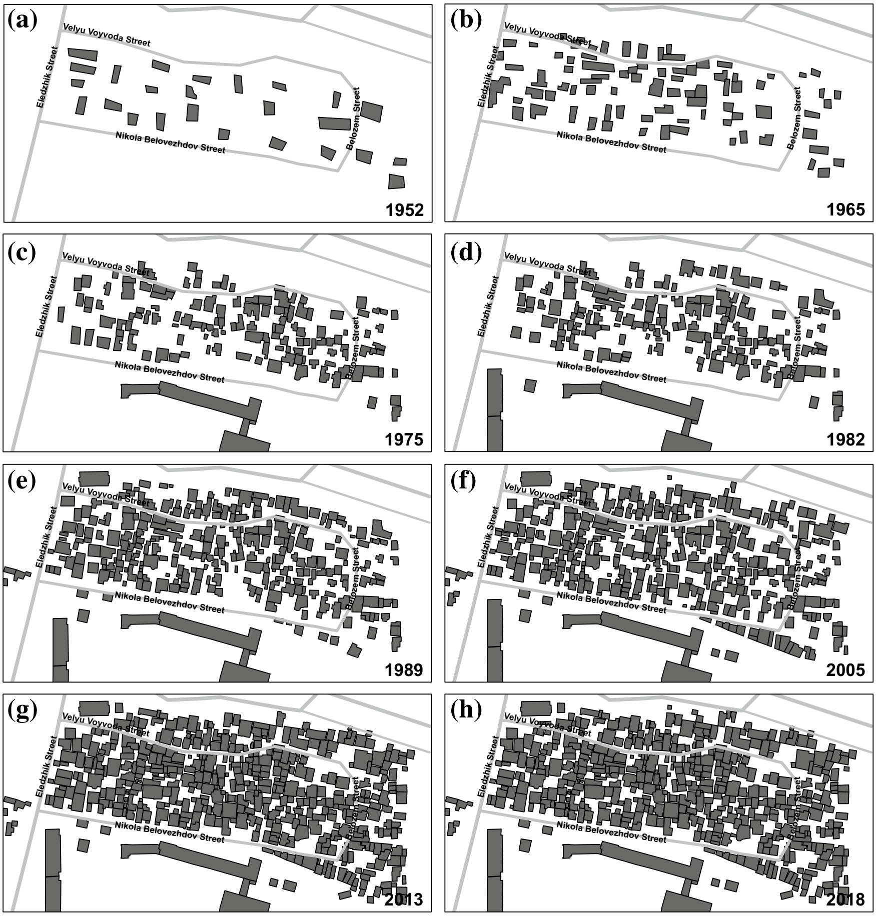

Fig. 3 Spatial expansion of Harman Mahala in the 1952–2018 period—**a** 1952, **b** 1965, **c** 1975, **d** 1982, **e** 1985, **f** 2005, **g** 2013, **h** 2018

Space has become the most valuable asset in the neighborhood. As it is seen from Fig. 3 the building density rose from 13% in 1952, to 63% in 1982, and over 95% in 2018. The street network is inadequate and in an extremely poor condition—the streets are narrow, sometimes to a point where two people can barely pass through. In many places, the area represents a construction site. No urban planning regulations apply here: who is going to build and where—are all matters solved by internal arrangements within the community. The degree of proximity between the individual families is crucial, as each family negotiates and decides whether a certain family is "ours" or not so much. The only laws applicable are the internal community laws. The recent removal of an electric pole by the municipal authorities, for example, caused serious problems and provoked protests among the local population, since any action to eradicate even illegal life-threatening constructions, is perceived by the residents as a personal encroachment on their identity. No green spaces exist in the quarter. The service infrastructure is only represented by primitive shops for essential everyday products.

Even though Harman Mahala is relatively small and it has been in existence for more than a century, governments and local authorities have failed in dealing with its dissolution and spatial assimilation. An accumulation of incoherent and mediocre policies has been observed, which unfortunately have been unable to cope with the expansion (both horizontally and vertically) of the Roma quarter. The only attempt to eliminate the unwanted spatial concentration of the Roma population dates back from the 1960s and the 1970s when a decision was made by the local authorities to expel the Roma from their neighborhoods and settle them in other districts of the city, mainly in the then newly built residential complex of "Trakia". That attempt however failed and the reason for that failure was the fact that when it comes to cohabitation in ethnically mixed neighborhoods, the Roma feel insecure and eventually they return to the Roma neighborhoods, thus expanding the range of segregated spaces. That process has been intensified since the early 1990s, i.e., after the fall of the communist regime in Bulgaria.

In recent years, local authorities have been obliged to develop anti-segregation plans and urban development projects, which, however, often remain merely on paper, since there are no sanctions whenever those plans and projects are not applied. Spatial inequalities, therefore, have deepened and, combined with other forms of social and ethnic exclusion, have created a seemingly indestructible "vicious circle", leading to an increase of the existing social gap. The impossibility of solving the problems eventually has brought actions to a halt. The partial demolition of Harman Mahala quarter caused serious local residents' discontent, which they expressed through massive public protests. Apart from the apparent result of the partial demolition of the quarter in 2018, there has also been an increase in the sense of fear and uncertainty about the future of the inhabitants' dwellings. The above-mentioned local authorities' actions were actually taken due to investing interests in the area. The Spatial Development Concept of Plovdiv Municipality states that "incorrectly implemented integration programs—starting from displacement to construction of alien to their (of the Roma) ethnic culture housing units—have not improved their (of the residents) condition. It has become clear that neither displacement nor housing construction can solve the problems, but rather the implementation of micromanagement measures so as to achieve a certain community standard, consistent with the local residents' cultural identity. In case of possible future actions such as the construction of housing for the Roma communities, apart from all parameters such as social status, building requirements, income levels, etc., it is necessary to carefully consider the so-called *family factor*, the family relations and the inter-family relations. The effect of the numerous projects aimed at solving the GUS's problems has been insufficient, and unless the government intervenes (at the national level) and initiates the elaboration of a strategic action plan for solving the problems of ethnic minorities, the socioeconomic disparities in the Bulgarian society will increase and the consequences in the near future can lead to serious political and social shocks and upheavals.

Demographic Characteristics, Habitation Conditions, and Structure of the Housing Stock

The total number of Roma people in the city of Plovdiv according to the official statistics is 9,438 (as of February 2011), or just 3.1% of the city's population. According to unofficial data, however, around 45–50,000 Roma reside in Stolipinovo quarter alone, another 5000–6000 in Sheker Mahala, some 3000–4000 in Hadji Hasan Mahala quarter, and in Harman Mahala—1800 residents. The Roma in the city of Plovdiv thus accounts for approximately 20% of the city's population and about 10% of the total (unofficial) number of Roma in Bulgaria (750,000 according to the so-called expert assessment).

The quantitative surveys show that 75.8% of the population in Harman Mahala identifies themselves as *Turks, 19.8% as Roma* from the *burgudzhi* subgroup, who inhabit the western zone of the neighborhood, and *4.5%* identify themselves as *Bulgarian*. There is a clear distinction between the three ethnic communities.

Since the accession of Bulgaria to the EU (2007) there has been a gradual increase of emigration abroad of Roma people. As a result of the quantitative surveys and according to the data from the local administration, it has been estimated that about one-third of the permanent residents of Harman Mahala have indicated a foreign country address as their current place of residence. Resettlement to other parts of the city is normally not observed, apart from a trend where wealthier representatives of the Roma ethnic group from other quarters, buy houses and lots in Hadji Hasan Mahala quarter because of the higher social status of its residents, together with its better geographic location within the city center.

Along with the population number and the age structure of Harman Mahala quarter's population, the structure of the households is yet another important feature. The average size of a household in the neighborhood is 5,4 members. According to the survey, extended families constitute 68% of all households, given the fact that in many cases two or three generations share the same home. Nuclear families, on the other hand, account for 32% of all households. Over 90% of the married children stay with their parents—sharing one home, one yard, or in the immediate proximity. Thus, younger families wish to have more autonomy, but the parents stay nearby or even in the same house. The elderly (the grandparents) do not wish to be an obstacle to the young, but they still prefer being nearby or living in something like a semi-detached house. In order to solve the housing problems, outbuildings are made mostly, or new houses are built in place of the old houses. If possible—if the housing conditions permit this—married sons normally remain with their parents (and if the parents can afford it, they provide shelter for their married daughters as well). In cases where housing conditions do not allow that, outbuildings are built in the yard, reconstructions of old buildings are made, or collecting of funds comes into practice: all members of the household are involved, and the old buildings are torn down, while new houses are built and in their place. The new house of course is higher, larger, taking areas away from the yard, the street or the neighboring lot.

Housing conditions are mainly the result of the interconnection between household resources, household preferences and how affordable the dwellings are in terms of prices. This interaction does not take place in a vacuum—it occurs in the context of demographic, economic, political, and ethno-cultural characteristics. An important determinant of the housing situation in one household is the situation of the working-age members on the labor market—whether they are employed, and, the size and structure of the income in particular. The residents of any GUS are forced to live in such areas mainly due to lack of sufficient or any income, low educational level (or no education at all) and lack of professional qualifications so as to meet the labor market's demand. It is these deficiencies which actually restrict the access to other urban residential areas.

Prior to the socioeconomic transformations in the early 1990s, one of the most important positive features was the nearly full employment of the working-age Roma population. Most of the residents of Harman Mahala for example used to work in the textile factory nearby. After the restructuring of the economy in the early 1990s, however, there has been a huge decrease of jobs for low-skilled workers such as the vast majority of the Roma. Thus, in the first years of the so-called transitional period, many households became dependent on social welfare. Since the beginning of the twenty-first century, however, there has been a clear trend of decreasing number of families dependent social welfare, which is evidenced by the results of the quantitative survey—only 7.3% of the families actually rely on social welfare. After the "withdrawal" of the state, the Roma started looking for a solution to their daily domestic problems on their own, leading to increasing numbers of those involved in the so-called gray (or informal) economy. The Roma started taking advantage of newly emerged opportunities which the gray economy provides, such as the so-called "suitcase trade" (retailing of products bought at a cheaper price across the border with a neighboring country), production of illegal alcohol, etc. Along with all that, entirely legal activities, such as establishing companies that provide jobs in the field of construction, for example, were also initiated. The "opening of the borders" after Bulgaria's accession to the EU in 2007 provided opportunity for the Roma to legally work abroad: according to the survey 44.8% rely on income generated by relatives who work abroad, 56.3% declare that a member of the family has worked at some point, or is currently working abroad. With the income increase which has been observed, apart from the vertical expansion of the neighborhood, there has also been an increase of the purchasing of apartments in the block of flats next to the quarter—a building known by the nickname "The Small Giant". It is interesting to mention that the prices of the apartments located on the side of that building facing the quarter itself, and of the apartments on the lower floors, are by some 100–150 euros per square meter cheaper than those apartments located in the opposite side of that same building.

The ethnic grouping into a certain city area (quarter) reduces the solitude of the members by supporting those who are of the same ethnic origin, through developed internal social networks, which provides safe living space and helps solving everyday problems. The "hostility" of the majority has generated individualism and isolation among the ethnic minority representatives, who fear contact with others. On the other hand, the acute need for solidarity and social support at the collective level, also serves as a shield against discrimination by the majority and even provides certain advantages of economic (creation of specific livelihood strategies and alternative economic structures), cultural (the ability to maintain and unite common cultural patterns), social (linking to social support networks), and political nature (creation of alternative political institutions) (Boal 1981; Marcuse 1997). The Roma in Harman Mahala, therefore, most often (75.5%) refuse to live outside that neighborhood.

When talking about a sustainable urban environment, it is necessary to take into account not only the objective indicators characterizing the neighborhood, but also other factors, such as the sense of security which Roma people have about the neighborhood they inhabit. Many of the Roma live in constant fear (15.5%) that they will be evicted, but on the other hand, the authorities themselves are afraid to evict them, because there is nowhere to move those people. Residents strongly refuse to leave their homes and move to social housing (86.2%), despite the fact that most of their homes are overcrowded, because they would feel even more insecure if they moved to live in council houses. The feeling of insecurity appears not so much from the fact that they would have to pay a rent, but that they would not live in their current environment, where they feel relaxed and more secure. These processes lead to the ever-greater isolation and to growth of the invisible wall that exists between the quarter and the surrounding urban environment. Thus, a self-contained structure emerges, becoming increasingly remote and less reliant on the state, while at the same time the role of the internal social networks, the loyalty to the place, the long-standing coexistence—for more than a century now, the internal rules and "laws", become increasingly stronger. According to the survey, the residents define their neighborly relations as good (97.4%), while only 22.3% of the respondents declare that they would like to live in another residential area (67% of the respondents, however, mean the adjacent area of their current quarter, the city center, and in particular—Haji Hasan Mahala—29%), being aware that these parts of the city are inaccessible considering their current economic (income) situation. The fact is that most of the residents of the studied quarter know each other (77.5% declare that they know everybody, 5.3% know at least 50% of the residents, etc.) and actually live together with their neighbors (73.8% hang out together on a daily basis) for several reasons, such as sharing food, heating, talk and entertainment, strengthening social networks, etc. The most important topics the respondents discuss with their neighbors and friends are the topic of finding work (47%) and money (42.4%), but also in cases of illness or death (49%) and house repairing (31.1%).

In terms of availability of basic housing infrastructure, however, things are much better—90% of the dwellings have an internal water supply and 94% of the buildings are connected to public sewerage. The housing itself is diverse, represented by different construction approaches which basically reflect the different construction periods, while solid buildings are the predominant type. Nearly 90% of all dwellings are built of bricks and were erected in the period following the political changes in 1989. Only 4% of the houses are built of adobe and represent the housing stock from the earliest construction period of the quarter—the early 1900s.

Given the specific situation which Harman Mahala is in, traditional urban planning tools are in most cases not applicable. The interference of local authorities is hampered by the fact that four to five consecutive generations of Roma have been residing in the neighborhood, which has lead to a strong sense of belonging to the place. This is a factor that appears to be yet another additional obstacle to the implementation of new urban measures. Regardless of the worsened urban development characteristics, Harman Mahala stands out with better overall conditions compared to most other Roma quarters, given its relatively good household provision as it is evident from the Fig. 4.

The housing situation of the ethnic communities can serve as an indicator of the level of integration and as an assessment of the integration processes. As it was mentioned earlier, the housing in the GUS normally does not meet any urban planning standards and regulations. Only three of the houses have a legal ownership document, while 97% of the buildings were built on municipal (council) lots. The above-mentioned increase of emigration flows and the improvement of the economic capacity of the population imply an increase of population dispersion processes, but such processes are not observed in the studied neighborhood. The massive reconstruction of old houses and the construction of new multi-storey houses in the scanty space of the ghettoized structure is a new trend among those who work in Western Europe (mainly in Germany). As a result, the building density has reached over 95%. Dwellings with three (39%) and four (28%) rooms make up two-third of all dwellings in the neighborhood. Sixty-three percent of the houses are three-storey buildings, 30% are two-storey buildings and just 7% are one-storey or ground floor houses, being at the same time the oldest. The increase of the population number is the reason for the extremely high values of the gross habitation density, which in 2018 reached about 370 people/ha. The prevailing dwelling size in the studied neighborhood (51% of all homes) is 60–89 m^2, while for the city of Plovdiv as a

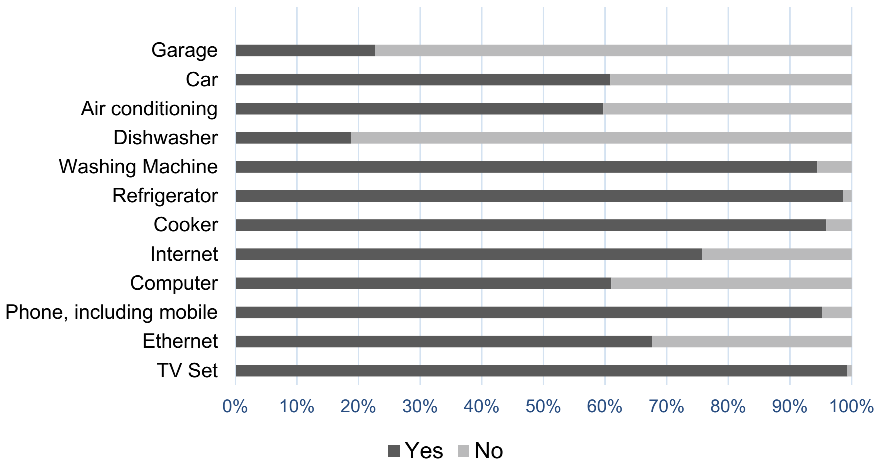

Fig. 4 Household provision in Harman Mahala

whole, the prevailing dwelling size is 30–60 m^2 (62% of all dwellings). However, considering the number of household members and the structure of the households, a significant imbalance is observed: a dwelling in Harman Mahala is inhabited by 5,2 people on the average, as opposed to 2,4 people for the city of Plovdiv. In the case of Harman Mahala there are 12 m^2 of built-up area per inhabitant, while for the city as a whole that area is 24 m^2 or twice higher. Almost half of the population of the studied quarter (47%) gets between 10 and 20 m^2 of built-up area, and if we add the population with less than 10 m^2 of living area, the percentage rises to 77%.

Conclusion

GUSs in Bulgaria usually exhibit existence and development over a long period of time. The degradation of certain urban structure elements, therefore, should not be seen as a static phenomenon, but as a cycle. By defining and analyzing the different steps and stages of the evolution of a GUS such as Harman Mahala, the emergence of new GUSs can be avoided in the future.

Over the last two decades, there has been a significant expansion of the existing GUSs, accompanied by the emergence of new ones. In most cases, the urban problems faced by the GUSs' population in Bulgaria and not just, are absolutely identical to those outlined in the description of other "ghettos" located in various cities throughout the country. A specific social model of the GUSs is observed, which can be conceptualized according to their spatial and social dimensions.

The methodology developed for the purposes of this study can be applied in the study of other ghettoized urban structures, which would not only help reveal the current internal changes in the construction and the infrastructure of the Roma quarters but will also help follow the trends and eventually avoid the emergence of future problems.

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Policies and Measures for Roma Integration—The European Experience

Georgi Bardarov and Kaloyan Tsvetkov

Abstract The Roma ethnic group has been present for centuries on the European continent. Although there are many unclear moments about their origin, the most common version suggests that they came from the Indian subcontinent, settled in Europe during the Middle Ages, through the Ottoman Empire, Egypt, and Spain. Quickly, due to its nomadic character and easy adaptability, the Roma people managed to disperse almost all over the continent. The distinctive character of this community, its specifics, and definitely Indian ethno-psychology, along with the nomadic way of life, have always created difficulties for them to integrate into European societies and value system. The Roma people have been subjected to serious persecution throughout the continent and even to genocide, as in the time of the Holy Inquisition in Catholic Europe, and the Nazi regime in Germany in the twentieth century. However, there are many positive examples of integration policies undertaken across the continent toward the Gypsies, as one of the most successful in the eighteenth century in Bohemia is held by Queen Maria Theresa. Since the beginning of the twenty-first century, in Bulgaria, the question about the difficult integration of the Roma ethnic group has been raised more often despite the considerable amount of money devoted to it. Considering that because of the demographic crisis and trends in Bulgaria, by the middle of the century, the Roma people are expected to account for about 22–23% of the Bulgarian population. We must inevitably seek adequate measures and policies for their integration into the Bulgarian society. Moreover, with the current shortage on the Bulgarian labor market, the Roma people with their young age structure can be an excellent labor reserve, of course, only with a sharp increase in their educational level. In this report, we have reviewed and analyzed the successful integration policies toward the Roma ethnic group in Europe and we have determined on this basis which of them can be adapted and implemented successfully in Bulgaria.

Keywords Gypsies · Traditions and culture of gypsies · European values system · Successful integration policies for gypsies

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Introduction

The distinctive character of the Roma community, their specific Indian-based ethnopsychology, and the nomadic way of living have always created difficulties in the integration into European societies. The Roma people have been subjected to serious persecution throughout the continent, and even genocide, as in the time of the Holy Inquisition in Catholic Europe, and the Nazi regime in Germany during the twentieth century (CERD General Recommendation XXVII 2000).

However, there are many positive examples of integration policies conducted in the continent over the Roma people in the past, as one of the most successful is held by Queen Maria Theresa in the eighteenth century in Bohemia.

Since the beginning of the twenty-first century, the problem of difficult integration of the Roma ethnic group is increasingly being raised in Bulgaria despite the considerable amount of money devoted to it. Considering that as a result of the demographic crisis and trends in the country, by the middle of the twenty-first century, the Roma ethnic group is expected to account for about 22–23% of Bulgaria's population (Ilieva 2013), appropriate measures and policies for their normal integration in the Bulgarian society must be inevitably sought. Moreover, with the current acute labor shortage on the Bulgarian labor market, the Roma people with their young age structure can be an excellent labor reserve, of course only with a sharp increase in their educational level.

Two issues stand out when it comes to the difficult integration of the Roma. The first is that they are usually referred to by heart, in theory, without knowing the characteristics of this group. In fact, they are very complexly stratified, by origin, clans, crafts, by the territory from which they come, social status, and so on. Often within a village there are several Roma neighborhoods; the people in them are from different groups, sometimes they do not even understand their language and have difficulties to communicate (Van Kempen and Özüekren 1998).

We should immediately make it clear that Romani language has no writing, at the same time it has many dialects and many borrowings (words and phrases) from the language of the ethnic group on whose territory they live. Some of the Roma are strictly endogamous, meaning they only carry marriages inside their own group (Wirth 1998).

Categories and Methodology of the Research

The Roma ethnic group, which is the subject of this study, has been present for centuries on European territory. Although there are many unclear moments about their origin, the most common version comes from the Indian subcontinent (Belton 2013). They settled in Europe during the Middle Ages, through the Ottoman Empire, Egypt, and Spain. Quickly, due to their nomadic nature and easy adaptability, Roma people managed to disperse almost all over the continent (Fig. 1).

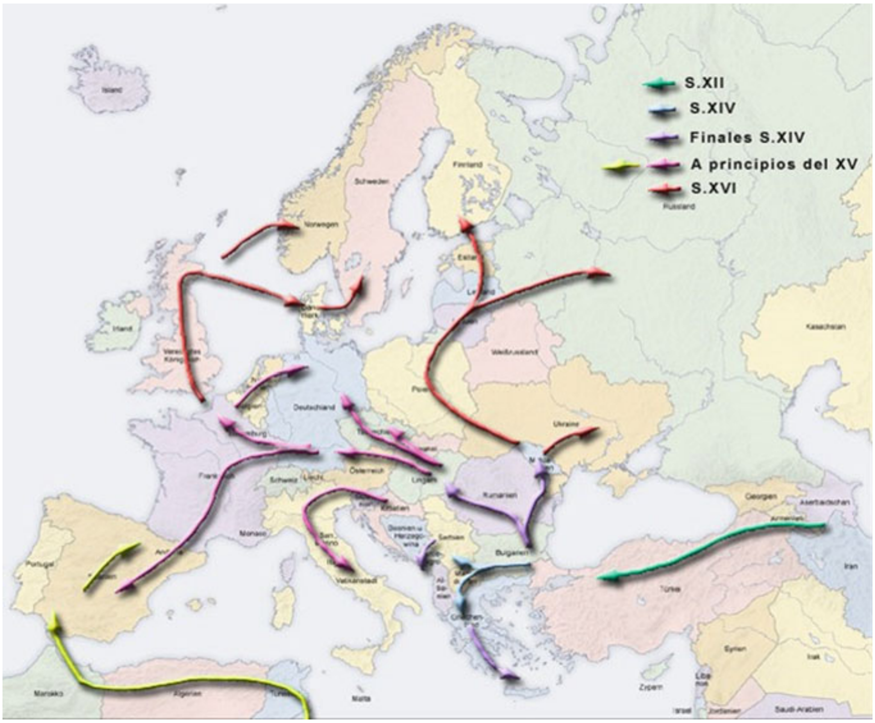

Fig. 1 The settlement of Roma people (twelfth–sixteenth century)

The aim of this study is to clarify the reasons for the difficulties faced by Europeans in their attempts to integrate the Roma into their cultural and value system. Another important research problem of the paper is to present and analyze successful integration policies for Roma from different parts of Europe that can be applied elsewhere (Sasse 2008).

The difficulties in researching this community are mostly related to their self-identification and their extremely complex stratification. Roma people have the so-called "preferential ethnic consciousness" and very often they identify themselves through the ethnicity and the religious affiliation of the territory they live in. The methodology used in the study includes critical analysis, scientific synthesis, chronological and chorological method, mathematical, statistical, and descriptive method (Bardarov and Ilieva 2018).

In the most common, generalized plan Gypsy people in Bulgaria are divided into "Yerlii" (from Turkish Yerlii-settled) which are divided into Bulgarian gypsies (Gypsy Christians or "Dasikane Roma") and Turkish gypsies (Roma Horohane) who are Muslims, "Kalderash" (romanes Calderar-coppersmith), former nomads, called Vlach Gypsies who are strictly endogamous, Orthodox Christians and the richest Roma stratum, "Rudari" or "Ludari" who identify themselves as Vlachs, Romanians or Bulgarians who distinguished themselves from the Roma, and according to their craft they are divided into: “Ursari” (bear-trainer and monkeys-trainers) and “Lingurari” (copanari—wooden spoons). There are, of course, many more groups, subgroups, and clusters.

When studying Roma people, we always face a number of myths, stereotypes, and prejudices related to them and their way of life. In general, stereotypes about the Roma can be divided into two groups: positive (musical, liberal, skillful, resourceful, loyal to their people) and negative (thieving, lazy, dirty, wild, aggressive, vengeful, malicious). One of the most important myths about them in Bulgaria is the so-called “learned helplessness” by which they burden the state, the society, the institutions to take care of them as if they are obliged to, but it is also the fault of the state itself, which abdicated from the solution of the Roma issue, allowing the creation and maintenance of ghettos, which are literally “state in the state” (Pamporov 2014).

As we have already mentioned, one of the most difficult questions about the Roma is to determine their number, because of the so-called “Preferential ethnic consciousness”. In Bulgaria, for example, there are 324,377 people or 4.5% of the country’s population, but according to experts (Ilieva, Tomova, Pamporov), it ranges from 700,000 to 800,000, or over 10% of the total population. A similar problem exists in Europe and the rest of the world, with the total number of Roma being between 10 and 20 million, but they are certainly more. In Europe, the highest number is in Turkey—over 2.5 million, in Romania around 1.8 million, in Russia and Spain at around 800,000, in Hungary 750,000, in Serbia 600,000, in Slovakia 500,000 people, and others (Merlino 2006). They have different ethnonyms; the most commonly used are Roma people and Gypsy people—“gypsies” are associated with the hypothesis of their Egyptian origin (Johnston 1986).

European Successful Integration Politics for Roma Ethnic Group

The successful integration policies that we examined and analyzed in the survey are from Bulgaria, Hungary, and Finland.

Hungary is a country with a significant Roma minority, which, according to official data, is more than 300,000, but the actual number is over 700,000. There is an interesting experiment at the Gandhi School in the town of Pécs. The training is done in bush language (a variety of Romanes language), which leads to a sharp increase in the success rate of Roma students, but this is done through compulsory study and very good command of Hungarian. The school library is one of the best-kept with books in the country; at the same time, it records a record number of visits and book-taking in recent years. The experience from Pécs shows that multilingualism is the key to success. Apart from that, the children are also engaged in a multitude of extracurricular activities tailored to their culture, which also enhances their interest in the school. These activities are a dance club, gardening, cooking, which also give them practical skills that will help them in life. Every Thursday a doctor conducts lectures to students on their health, sexual, and hygienic culture (Fig. 2).

Other successful projects for the integration of Roma in Hungary are the Zsámbék project for preparation of Roma teachers, the Roma dormitory system for children who are studying in other settlements in order to feel protected, and the Centennial School Literacy Project for adults, wherein extracurricular activities for children and parents are taught together.

Very important for the success of integration is also the Roma National Academy "Kaliy Yag", where parents and children together study mathematics, history, languages, and computer literacy.

There is another very successful practice from Hungary which could be conditionally named: "When the state is in place". It is related with Laszlo Bogdan, the mayor of Cherdi village, southwest Hungary (2006–present). The village has almost 100% Roma population, and Bogdan himself is of such ethnic origin. When he took over as mayor, the village had 430 Roma residents, with very high levels of unemployment, illiteracy, and crime, with other hallmarks of this kind of places such as dirt and disease. After two mandates of governing, we can see a village with well-kept houses and yards, working population, and accelerated decrease in the levels of crime.

What is Lasko Bogdan doing? The steps are several and consecutive. In the first place is the drastic cut in social benefits and the elimination of the effect of "learned helplessness". Bogdan also believes that the good and bad examples are very important, as he takes parents and children first into prisons, where there are many Roma, in order to see the conditions there and what awaits them if they go on the crime road,

Fig. 2 Gandhi School in Pécs

and then leads them to a university, to see what other future they may have. Under national programs, he provided over 100 new jobs in agriculture. The municipality encourages and supports the building of bathrooms in Roma houses with financial resources and labor force. He also provides parents with a job when there is an active participation of their children in the educational process. He also establishes a municipal police force, including Roma leaders who guard agricultural production. And it achieves amazing results for just two managerial mandates.

Finland is a country with less high percentage of gypsy minority, but with similar problems as other European countries. To solve these problems in Finland people rely on desegregated schools and scholarships for Roma university students. According to the Finns, it is very important to teach Romanes for teachers, because in this way an educated and integrated Roma person becomes a role model for the young people and their interest in the learning process is increased significantly. The state also provides tax benefits for employers who hire Roma people for permanent employment. Social enterprises are also being developed and social entrepreneurship is stimulated when it is oriented toward the employment and realization of Roma and the improvement of their social living conditions (Sobotka and Vermeersch 2012).

The latter example is from Bulgaria and is very indicative. The example is from the city of Straldzha, Yambol district, where the Bulgarian/Roma ratio is already almost 50–50%. During the 2017–2018 academic year in "St. Cyril and Methodius" school, where 100% of the students are Roma, the "Icelandic Model" was applied to cope with the aggression and the dropout from the learning process.

What is the "Icelandic model" and how can it be applied precisely in the Roma neighborhoods, provided that there is no Roma minority in Iceland? In the early 1990s, in Iceland it is found that there is a big problem with the use of alcohol and drugs among schoolchildren as well as a problem with school aggression. The government invited the American professor psychologist Milkman to formulate and implement the "Youth in Iceland" model. A sociological survey is conducted among all pupils about what kind of sport or art they are interested in. The state then encompasses 100% of the students in such extracurricular activities, and the only condition for them is that the activity should be team-based rather than individual. The state is committed to build infrastructure needed to pay the salaries of coaches and instructors and to assist financially distressed families in order to have their children attend these classes. At the end of each school year, monitoring is carried out, and again through a sociological inquiry it is established whether the child is in the right place or it should be redirected to another type of occupation. For over 15 years, alcohol and drug use among Icelandic youths has fallen over 20%. Mass sport leads to great sports successes of the small nation, like the successful participation of Iceland at the European and World Cups in 2016 and 2018.

In the 2017–2018 school year, the mayor's office in Straldzha decided to apply this model to the St. Cyril and Methodius school, with 100% of the students covered in extracurricular activities (like football and boxing for boys, volleyball and cheerleaders for girls/playing guitar and percussion instruments for boys and folk dances for girls). The only condition for children to be allowed to attend these community-funded activities is to have attended classes from the first to the last period. If they have escaped or have not come to school they are not allowed in. In addition, the municipality appoints and pays salaries to six Roma mediators who monitor and support the learning process. All this costs the municipality about 10,000 BGN for one year!

And the result is striking: the attendance of Roma children in school for only one year has increased with 40%, as the school director Nedka Parusheva notes with delight. What does the Straldzha experience show us? It shows that there are no impossible things, as long as we think and work in the right direction, with heart and desire and the state is in place. In the village of Cherdi people say that a miracle has happened for the two mandates of Mayor Laszlo Bogdan, but Bogdan himself answers: “What is the miracle in Roma people working and living normally in a developed, modern European country?”

Really, where is the miracle here? We need a serious change in the way we think; otherwise successful results for the integration of Roma in Europe are fully achievable!

Conclusion

The issue of Roma integration in Europe and Bulgaria has many different points of view. We believe that, in the context of the global population shifts in the twenty-first century, the unification of cultures and the aging population in the continent, the problem with Roma integration is extremely important. If Roma have their appropriate high level of education, they could be an excellent reserve on the labor market. There is no way in the developed world uneducated population to be realized on the labor market, even for low-skilled positions.

In this regard, we believe that the successful integration of Gypsies necessarily passes through raising the level of education and reduction of ghettos, because ghettos reproduce negative patterns and isolate the community from social, economic, and political processes.

The examples that we have given in this report from three different countries—northern European Finland, central European Hungary, and Eastern Europe show that the problems are similar everywhere and the same mechanisms lead to positive results everywhere. So, it is important that specialists who work with Roma be well known with the specifics of this community, and it is imperative that these experts work in Roma neighborhoods and ghettos.

The successful experiment with the “Icelandic Model” in Straldzha, Bulgaria is a real proof of this. We are absolutely convinced that the clichés and stereotypes of the twentieth century are no longer working, and in an open, globalizing, and technological world, the change in thinking and focus can lead to very successful models and policies. The issue with Roma integration is a major challenge, but at the same time, it is a possible solution for some of the worst demographic problems, especially in countries, such as Bulgaria and Hungary.

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School Segregation of the Roma Ethnic Group: A Case Study of Harman Mahala Roma Quarter, Plovdiv

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Abstract School segregation among minority groups represents a serious social and educational problem in a number of countries across Europe, including Bulgaria. While in some countries this problem arises on the basis of social stratification or concerns both local minority communities and immigrant communities, in Bulgaria—as in other Eastern and Central European countries—school segregation is mainly associated with the Roma ethnic group. Education of Roma children is almost entirely provided in segregated schools located in or near the Roma quarters, regardless of the efforts by the governments to implement measures for overcoming the problem. The paper analyzes the specifics and the trends of the Roma school segregation in Bulgaria, based on the example of the Roma children from Harman Mahala quarter in the city of Plovdiv.

Keywords Segregation · Educational integration · Roma ethnic group · Harman Mahala

Introduction

The Roma are one of the most stigmatized, marginalized, and discriminated ethnic groups in Bulgaria, the Balkans, and across Europe (Makaveeva et al. 2013). In recent decades, the issues related to segregation and integration of ethnic minorities have been of growing importance for a number of countries across Europe, including

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Bulgaria. The legislation of the Republic of Bulgaria sets the institutional framework of the policies for ethnic issues and integration processes and defines the responsibilities and tasks of ministries, non-governmental organizations, the business, and all bodies dealing with ethnic and integration issues. The overall state policy in that aspect is administered by the National Council for Cooperation on Ethnic and Integration Issues at the Council of Ministers, established in 2004. Regardless of the established legal framework, the measures and programs developed and implemented by both the state and non-governmental organizations, the desegregation and the integration of minorities at this stage have not achieved the expected results—the Roma in Bulgaria still have the lowest educational level compared to all other ethnic groups in the country. According to the last population census in Bulgaria (February, 2011), the combined share of Roma people with high school and university level of education is just 7.2%, while the level of illiteracy among the same ethnic group is considerably higher than the national average and has actually increased by 50.0% in the period between the last two censuses (2001–2011). All that eventually hinders the overall integration of Roma people, since some 17% of the Roma aged 16–25 (young working age) are unable to read or write, unlike Roma people in older age groups, where the illiteracy share is lower.

Data and Methodology

In order to achieve the objectives of the study, scientific analysis of literary and web-based sources, reports, and documents has been applied, combined with field studies and survey conduct. The target groups of the survey were students, teachers, and school principals in two typical segregated schools in the city of Plovdiv—"Panayot Volov" and "Yordan Yovkov" primary schools. The analysis was based on the answers of a total of 118 respondents—106 students aged 12–17, 10 teachers, and 2 school principals. Three separate questionnaires were designed and disseminated among students, teachers, and school principals. The student questionnaire contained 51 questions, the one designed for teachers—27 and the one for school principals—41 questions. All questionnaires consisted of both open and closed questions in order to facilitate the obtaining of substantial data on the attitudes, opinions, and facts. The questionnaires were aiming to establish the following:

- the level of social (including educational) integration/segregation of the Roma;
- the main factors for school segregation;
- the attitude of the Roma children towards the need for education;
- the attitude of the Roma children towards their future personality development and social realization;
- the problems accompanying the Roma integration and the reasons for the lack of desired effect of school integration policies so far;
- the main reasons for Roma children school dropout.

The survey encountered a number of constraints related to the inaccuracy of the information filled in by the Roma students, the voluntary nature of answering each question (leading to numerous unanswered questions), the limited information that school principals and teachers shared with regard to the implemented integration policy and its results.

What Is School Segregation and Why Is It a Problem to the Society?

Segregation, in general, is a phenomenon which can occur in various if not all spheres of social life. The definition of the term *segregation* in the "Dictionary of Human Geography" is brief, describing spatial segregation as a division of a particular community into subgroups throughout the area of residence (Derek et al. 1986). Shortly, it represents a process of physical separation of certain individuals from the rest of the population in terms of residence (spatial segregation), school attending (educational or school segregation), healthcare, labor market, etc. Most often segregation affects members of marginalized groups (ethnic, religious, etc.) from members of non-marginalized groups (the so-called macro-society, or the ethnic or religious majority). Ultimately, segregation results in unequal access to mainstream, inclusive, and high-quality services. In other words—facilities in segregated settings provide lower quality services, despite the qualities of the education (school) infrastructure itself.

Various definitions of *school segregation* exist, however, they all define segregation as a process of concentrating pupils from a particular group (ethnic, racial, or other) in a particular school or classes in educational establishments. According to Grekova (2012), a process of *secondary segregation* is also present in Bulgaria, which is defined as a process of newly emerging segregated "Roma schools" outside the Roma neighborhoods as a result of the withdrawal of Bulgarian students from them, which in turn is caused on the one hand by poorly implemented policy of desegregation of Roma schools in Roma neighborhoods, and on the other—by the traditional refusal of Bulgarians to mix with the Roma at any level if possible. There is a direct connection between spatial (residential) and school segregation: while residential segregation is not the only factor causing school segregation, but also has an undeniable impact on the concentration of children from vulnerable groups in specific schools. If school districts coincide with neighborhoods with a high concentration of persons from disadvantaged groups, it is very likely that schooling will reproduce the high levels of residential segregation.

Since Bulgaria is not a country of any immigrant minority worth mentioning, school segregation mostly applies for the Roma children. According to a survey conducted in 2016 (EU Fundamental Rights Agency, "Second European Union Minorities and Discrimination Survey (EU-MIDIS II) Roma—Selected findings" 2017), one-third of the Roma children in the countries included in the survey attend predominantly Roma schools, while 13% of the Roma children attend entirely "Roma schools". In 2015, the European Commission once again called for an end to school segregation, noted that Hungary had a higher percentage of marginalized Romani children in segregated classes (45%) than Bulgaria (29%), the Czech Republic (33%), and Romania (26%) (Rorke 2017).

Studies indicate that school segregation has negative implications not only for minority or vulnerable students themselves but also jeopardizes the overall performance of education. Tackling school segregation is therefore not only necessary to safeguard the right to education and equality in the education systems—which directly concerns the affected by segregation, but is also key to improving the effectiveness and performance of the education system as a whole (Fighting school segregation in Europe through inclusive education: a position paper 2017), which in terms concerns the whole society and is not just an issue of human rights, as in the first case. Educational segregation leads to a number of socioeconomic problems not only among the Roma population but also for the whole population of the country—deepening inequality between people, increasing the number of people below the poverty line, difficulties in finding work and rising unemployment rates.

As of 2011, nearly 40% of the Roma in Bulgaria were under 20 years old, as opposed to 22.4% of the Turkish ethnic group and 15.5% of the Bulgarians. By 2050, the Roma will account for about 10–11% of the population aged 15–64 in the country (according to the official data), and 20–24% according to the expert assessment. Thus, given that the negative educational trends among Roma children remain, Bulgaria is about to end up with a significant share of working-aged citizens with too low an educational level, which would compromise the overall socioeconomic performance of the country as a whole.

School Segregation in Bulgaria

Over the last couple of decades, segregation, social and economic integration of the Roma in Bulgaria have been research topics for a number of experts in the field of sociology, human geography, anthropology, etc., such as Tomova (2005, 1995, 2009a, b, 2010), Tomova and Nikolova (2011), Ilieva (2011, 2012, 2013), Ilieva M (2012), Popova (2012a, b), Simeonova and Tsenov (2003), Kyuchukov (2006), Metodieva et al. (2008), Marushiakova and Popov (1993), Pamporov and Topalova (2007), Grekova (2007, 2012), Nunev (2002, 2006), Asenov (2017, 2018). The Roma issue has been also addressed in a large number of non-governmental organizations' reports. Authors such as Pamporov (2008, 2009, 2010), Marushiakova (1991), Popov (1991) and Hyuseinov (2014, 2016) also explore wider Roma-related topics, such as the origin and identity of Roma, their peculiarities, etc., as well the implemented social integration policies, housing conditions, employment, etc.

School segregation in Bulgaria is a relatively new phenomenon, since during the so-called Communist era, compulsory enrolment in integrated school catchment areas was practiced in the country (Farkas 2017). Prior to the socioeconomic transformations of the early 1990s, one of the most important positive features of the then system was the nearly full employment of the working-age Roma population of Bulgaria.

Considering the growing number, and more importantly—share of Roma children in schools all over the country, the issues of education of the Roma are becoming increasingly important. Given that in numerous settlements across the country the Roma children are the vast majority of the students, the issue of education of the Roma in Bulgaria is a prime issue of the education system in the country in general. The reasons for school segregation in Bulgaria are of various nature. In our opinion, the main groups of factors leading to the emergence of school segregation are cultural, political, economic and psychological. According to a European Commission report on school segregation (Fighting school segregation in Europe through inclusive education: a position paper 2017) the following processes play a crucial role in fuelling school segregation:

- Strong vested interests (decision-makers, schools, parents) and inappropriate financial arrangements;
- Inadequate regulation of school admission; wide margin of discretion by schools to select children, including based on discriminatory grounds;
- Prejudices and rejection towards certain groups of children;
- Reduced funding for education (in the case of Bulgaria—especially in the years following the sociopolitical and economic changes of the early 1990s);
- Along with the above, we consider that in the case of Bulgaria, the following factors also play a significant role in segregation of Roma children in particular;
- The process of Roma ghettoization—residential segregation is a major, in many cases—the most important school segregation factor;
- The right of personal choice—parents have the right to enlist their children in a school of their own choice;
- Lack of access and or parents' desire of pre-school education for their children;
- "Secondary segregation"—the process of turning originally mixed schools into entirely segregated schools as a result of "white flight" processes (Bulgarian parents replacing their children into schools with no or just few Roma children. Avoiding "Roma schools" by Bulgarian parents is sometimes a factor for emigration—in cases of smaller settlements, where the only school available is a "Roma" school, parents prefer to move to another settlement (usually a large city), rather than having their children go to a "Roma school".

Depending on the share of Bulgarian and Roma children, various combinations of schools are formed in the country. According to Popova (2012b), the Roma children in Bulgaria actually go to **five different types of schools** regarding the ethnic composition of the students:

- "Bulgarian schools"—the share of Roma pupils is insignificant, somewhere between 5 and 10% of all;
- "Mixed schools"—the share of Roma pupils varies between one-third and one-fourth of all students—the educational process in such schools is relatively good;

such schools exhibit exposure to the macro-society, easier integration of the Roma children, the problem with Bulgarian language conduct is not so sharp (p. 23);

- "Roma schools"—the Roma represent the vast majority (often 100%) of the students. Such schools account for **more than one-fifth of all schools in Bulgaria.** What is more important, some **40% of all schools in the country have a share of Roma students over one-third**—such schools easily "turn" into "Roma schools" because of the subsequent process of "white flight"—the Bulgarian parents' withdrawal of their children from such schools, considering them not good enough for their children.
- "Rural schools"—found in villages and small towns; the ethnic composition of the students' body varies. In many cases, rural schools only exist because of the Roma children, for they are the majority of children in the area. Having said that, it should be noted that the Roma children actually play a positive role by keeping the school in existence, and thus providing jobs for teachers in rural areas. On the other hand, however, it is such schools which are usually avoided by Bulgarian parents through emigration to a larger settlement.
- Schools for mentally disabled children—some 50% of the pupils in such schools are Roma, which is considered as overrepresentation of that ethnic group in such schools misleading.

The training of Roma children in segregated schools leads to a number of negative consequences linked, on the one hand, to a lower quality of the education received compared to schools where children of Bulgarian origin predominate. On the other hand, going to a segregated school strengthens the relations between Roma children and deepens their social and economic exclusion from the Bulgarian macro-society.

Roma Population of Plovdiv: Survey Results on School Segregation of the Roma Children from Harman Mahala Quarter

A Brief Overview of the Number of Roma in Bulgaria and the Issue of Estimating the Actual Number of Roma

According to the latest population census of 2011, the Roma ethnic community in Bulgaria accounts for 3.7% of the population in the country (Demographic and social characteristics 2012), showing that their total number had decreased compared to the previous (of 2001) census data. According to the so-called expert assessment of the number of Roma in Bulgaria, however, the official census data is misleading and not presenting the actual situation. As an important reason for the recorded decrease of Roma by the official census data, Ilieva (2013) highlights the increased emigration of Roma to other EU Member States, following Bulgaria's accession to the EU in 2007. Another important factor is the widespread phenomenon of "preferred ethnic

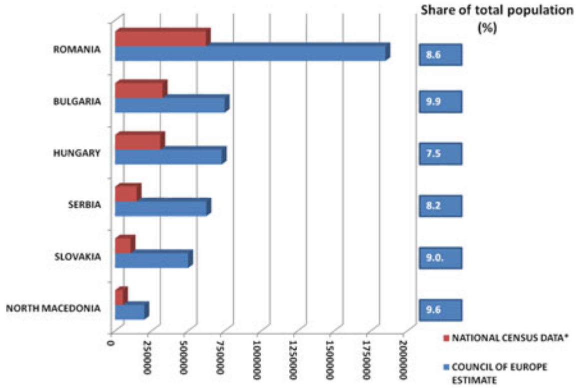

Fig. 1 Official and estimated number of Roma in selected countries in Southeast and Central Europe (*All census data for 2011, except for North Macedonia-2002). *Source* Author's adaptation from: https://www.economist.com/europe/2015/06/04/left-behind

identity" (the public declaration of another, non-Roma ethnicity (Marushiakova and Popov 1993) by a certain share of the Roma (not just in Bulgaria)—a voluntary act of declaring ethnic affiliation to the ethnic majority (Bulgarians), or to another ethnic minority group on the basis of sharing common language and/or religion (Turks). Another possible reason for the preferred identity phenomenon among Roma is the sense of growing ill-treatment by the macro-society, which makes them "afraid to openly declare their Roma identity" (Equal access of Roma … 2007, p. 12). Whatever the reason, the declaration of any preferred ethnicity by leads to distorting the actual picture and to a much lesser official number of Roma than the actual one—a common problem in all countries with a significant Roma population. As much as the right of ethnic self-identification is politically correct, it seriously hampers the scientific analysis of the Roma communities. Estimates from research and international organizations put the number of Roma as high as 800,000 in Bulgaria, 300,000 in the Czech Republic, 600,000 in Hungary, 2,500,000 in Romania and 550,000 in Slovakia (Ten Years After: A History of Roma School Desegregation in Central and Eastern Europe 2012) (Fig. 1).

The Roma Population of Plovdiv and Harman Mahala Quarter as a Sample Study Area

The official number of Roma in the city of Plovdiv as of February 2011 was 9438 or just 3.1% of the city's total population (National Statistical Institute 2011). At the same time, Asenov (2017) points out that according to the so-called expert assessment the number of Roma in the four Roma quarters of Plovdiv is much higher and there is a "significant discrepancy between the official number and the estimated number" of some 50,000 (p. 114). The number of the population residing in Harman Mahala quarter as of 2016 was 1790 people, of which only 10% actually identify themselves as Roma, some 0.5%—as Bulgarians, and the rest 89.5%—as Turks or *millet* (Asenov 2017). The Roma quarter of Harman Mahala emerged in the beginning of the twentieth century, when the city's authorities forced the Roma population residing at that time in the central parts of the city to move to the outskirts. As a result, two Roma quarters were formed—Harman Mahala and Stolipinovo (the largest Roma quarter in Bulgaria, the Balkans and presumably in Europe, with population of some 45–50,000 people. Harman Mahala quarter has been selected as a study area for practical reasons, since it is the smallest Roma quarter in Plovdiv and as such, more representative samples could be achieved during the survey. Access to the quarter and dissemination of questionnaires among school children was facilitated by the Municipality of Plovdiv (the Northern Administrative Region administration).

Results from the Survey

Main Findings from the Analysis of the Teachers' and School Principals' Questionnaire

The results of the survey indicate that the Roma respondents residing in Harman Mahala have been attending typical segregated schools, which is due to many reasons of various natures. Among the most significant ones are: the geographical location of the schools in close proximity to the selected study area of compact Roma population; the Roma's psychological attitudes; the delineation of the schools' catchment areas for enlisting first-graders, etc. A major factor in choosing a school for any Roma children is the geographic proximity of the school and the family preference, rather than the type of school itself—in terms of professional profile, quality of teaching, etc., as is generally the case of the Bulgarian ethnic majority when it comes to a school choice.

According to the teachers, many Roma children do not speak Bulgarian well (or at all) at the time of their enrolment in first grade, given that at home they speak their mother tongue (Turkish in that particular case) and do not feel the need to learn Bulgarian language. Along with the lack of motivation for learning and appropriate parents' attitude towards education, **insufficient knowledge of Bulgarian language is the most important and serious problem** in teaching Roma children. Communication with parents is also difficult, but in that case not because the language barrier: teachers often need to visit the children's home so that can establish any communication with the parents. Very few of the latter are actually interested in the school matters of their children or try to support the teachers and the school management. We believe that in order to achieve good results in the educational integration of the Roma it is necessary to take measures to improve the communication between parents, students and teachers. The Roma parents need to be constantly educated themselves (by the school mediators) about the need for education and their support in the educational process. The teachers' opinion on the question exactly how well the Roma children speak and write in Bulgarian is exactly the opposite of that of the students.

On the matter of **school attendance**, teachers declare that some students do attend classes regularly, while others are barely seen in class or don't show up at all. The younger the pupils the more they attend class and are interested in the school subjects. That trend is valid until 5–6th grade at the most. Around 7th grade (12–13 years of age), students start losing interest in what is taught and the number of students who skip classes grows significantly. At the stage when children do attend classes and show interest in what they are taught in class, teaching is seriously hampered by insufficient Bulgarian language conduct.

The surveyed teachers point out the following as the main reasons for low learning performance of their students:

- lack of sufficient knowledge in Bulgarian language (spoken only in school);
- lack of sufficient parents' interest;
- to some teachers—insufficient class attendance (regardless of the certain number of students who do not skip classes);
- lack of concentration for too long/difficulties in staying in the classroom from the first to the last study hour.

As main dropout reasons, the teachers and principals' point out the following:

- parents' lack of interest and cooperation/family environment;
- lack of motivation;
- early marriages;
- learning difficulties;
- involvement in raising younger siblings;
- parents' unemployment/low income;
- giving birth;
- insufficient coordination between institutions.

On the question of how to improve learning performance, the teachers suggest the following measures:

- Effective and harsh penalties for the parents whose children skip classes;
- Better coordination between the institutions;
- Police station in the neighborhood;
- Employment opportunities for the parents;
- Equal obedience to law;
- Early marriages prevention;
- Mandatory pre-schooling;
- Opening of a healthcare center in the neighborhood;
- Free textbooks.

As a result of the implementation of different regulations and the policy of linking social benefits with school attendance (including at pre-school stage), the number of Roma children enrolled in the educational system has been increasing, while the dropout rate has been decreasing. In both schools subjected to the survey, the share of Roma children enrolled in elementary and primary school classes is high—between 95 and 100%. The low social status of the family, the parental disinterest, the negative impact of the home environment, the difficulties in learning, the need of looking after younger siblings, the early marriages and the insufficient coordination between different institutions at the local level, are among the main reasons for dropout cases among Roma children. Regardless of the observed trend of dropout reduction and decrease of the share of those who have never attended school, the process is still exhibited widely across the country. In 2016/2017 academic year, the dropout rate at primary level in both schools under survey was between 0.9 and 2.7%. Pre-school education is regarded as a crucial factor for reducing the number of students who do not attend school or leave the educational system at some point. Pre-schooling leads to the acquisition of cultural, social, including educational habits and skills and, on the other hand, to increasing the children's motivation to acquire new knowledge for the future. The analysis of the survey results reveals that half of the surveyed students had attended nursery and/or kindergarten, which could be considered as a positive element in the educational integration of the Roma population, especially compared to previous years: in 1997 for example, only 5% of Roma children aged 3–6 attended kindergarten, while by 2001 that share had grown up (to the still "humble") 16%.

Main Findings from the Analysis of the Students' Questionnaire

The survey among children shows that only a relatively small part of the students wants to get a higher education—some 26% (Fig. 2). The reasons for that relatively low percentage are of various nature, including lack of clear comprehension of the need to acquire a higher education, the low educational level of the parents

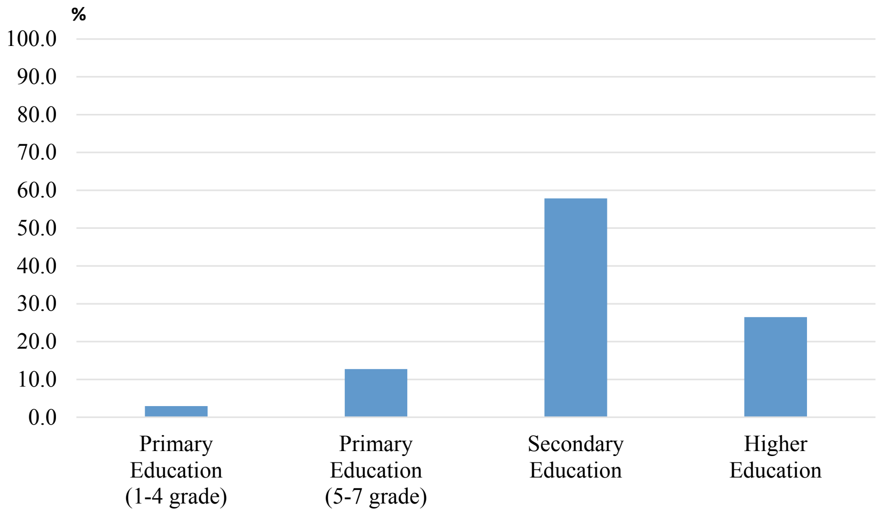

Fig. 2 If it was up to your personal preferences and desires, what education would you like to have?

themselves, the accumulated years of labor market isolation and parental disinterest (Fig. 3).

Unlike the teachers' opinion regarding the level of overall conduct of Bulgarian language, 83% of the students-respondents indicate that they speak Bulgarian and have no problems with their speaking and writing abilities. Approximately 45% of the children find writing in Bulgarian easy, 34%—very easy, while 17% find it difficult, and only 4% say they have great writing difficulties. Nonetheless, Bulgarian language as a school subject is listed among Mathematics and English as a subject they encounter the greatest difficulties with, which, especially taking in consideration the teachers' opinion, makes us believe that the children's opinion may be considered subjective and not presenting the reality to a hundred percent.

On the matter of their future development as adults and parents, it is interesting to note that 54.3% of the surveyed students believe that the most suitable age for marriage is between 20 and 24 years, but still, a relatively high share—22% of them—say they would like to marry aged between 17 and 19. Some one-fourth of all students included in the survey indicate that they only go to school because it is mandatory. To the question of why they actually go to school, one-third of the children answered that they did that in order to be able to get a job later. Naturally, especially among younger students, the reason "to learn new things" is pointed out as a main reason to go to school by 36% of all, while some 6% do declare that they attend school mainly to meet friends.

It comes as a nice surprise (although it is something which cannot be taken at face value) that only 22% of the surveyed students declare they never do homework, while

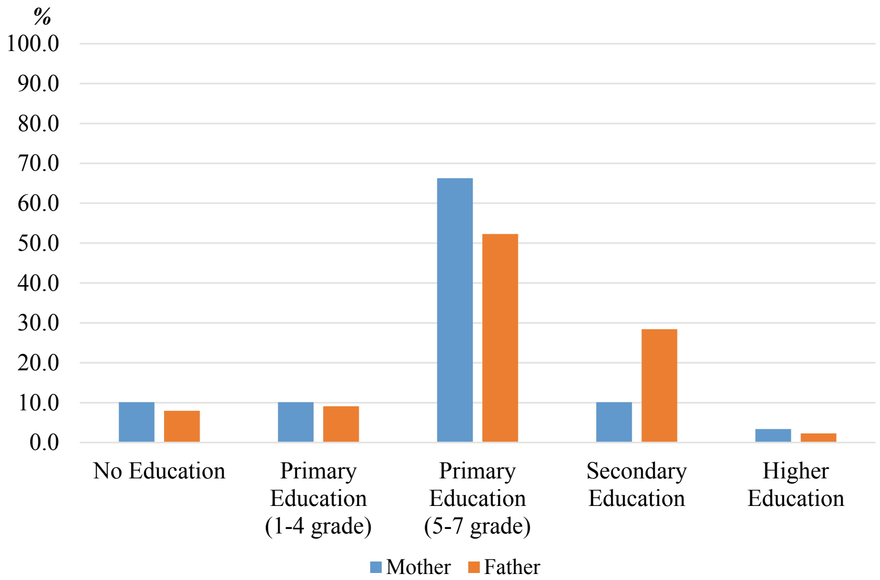

Fig. 3 Educational level of the surveyed students' parents

37% state they do homework for over an hour a day. This result should be related in future surveys to the learning performance of the students so as to establish the actual situation on the one hand, and on the other—whether students who actually do homework show better results in the classroom.

Not surprisingly, students rarely visit the school library, while 57% of the respondents declare they never visit it.

As far as the survey results are concerned, the surveyed children point out various things they like about the schools they go to, starting from "everything" (two-third of the respondents) to "the teachers" (18%), "the subjects" (11%) and "the classmates" (7%), the latter coming as a surprise, considering the cultural features of the Roma ethnic community. Generally, the Roma students do like, however, the interior design and the furniture in their school, as well as the teachers' attitude towards them and the discipline.

As for the question of what they would like to have as a job, a large number of the children declare their will to do jobs requiring a lower level of education: 70% of the children state they want to work in the service sector (hairdressers, barbers, beauticians, chefs, restaurateurs, tailors, and drivers), while the rest state they want to become fitters, car mechanics, builders and musicians. The share of students preferring to do in the future jobs such as lawyers, doctors, policemen, or firefighters is relatively low—some 14%. The vast majority, if not all, of the parents of the surveyed students, who are actually employed, are employed in low-qualification or no qualification jobs such as vendors, drivers, janitors, cooks, agricultural workers, etc., which certainly has effect on the children's cultural and values system, but also—on the children's material status. Being asked how they see themselves in 10 years, most of the students say they see themselves married, with two children, lots of money and an expensive (nice) car.

The following main conclusion can be drawn by the students' responses:

- insufficient awareness of the need for higher education is observed, "inherited" by the parents in most cases;
- the majority of students claim they speak Bulgarian which contradicts the staff's observations—a problem which can easily be solved by a simple Bulgarian language test during additional surveys in the future;
- students point out different things they do not like in school such as short breaks, lack of textbooks, noise during classes, etc., but are generally satisfied with the teachers and the overall school environment, which proves that learning difficulties arise from other factors, outside the school itself;
- the majority of students consider the age between 20 and 24 most appropriate for marriage, which can be considered as a sign of cultural shift among the Roma under survey, but needs further comparative analysis with previous similar surveys in order such shift to be actually proven.

Conclusion

The education of Roma children in segregated schools has led to a number of negative consequences related one the one hand to lower education quality compared to "Bulgarian schools", or ones with a small share of Roma students. On the other hand, going to segregated schools strengthens the bond between Roma children and deepens their marginalization, social and economic exclusion in the future. The results of the research can help the development of differentiated policies and measures for solving the problems of the individual Roma groups according to their specific features, which problems are not really problems of that ethnic group alone, but problems of the Bulgarian society as a whole. Although the idea of desegregation of Roma education in Eastern Europe supposedly originated in Bulgaria (Ten Years After: A History of Roma School Desegregation in Central and Eastern Europe 2012), overcoming the problem is hampered by various factors. The Bulgarian parents, on the one hand, oppose integration because they are concerned that it will have a negative impact on the quality of education their children receive. Because of this opposition, integrationist efforts may result in cascading white flight (a phenomenon observed in Bulgaria) whereby a classroom with a few Roma students soon becomes an exclusively Roma classroom. On the other hand, Roma parents in some cases are concerned about their children going to a predominantly Bulgarian school where they may have problems being a minority. In other words, it appears both groups of parents prefer segregation to the alternative, despite the negative consequences of segregation for the society as a whole. In addition, teachers sometimes also oppose integration because they believe that Roma children pose a discipline problem, disrupting their teaching in the classroom. They argue that this compromises the overall quality of education for all students. Last, but not least, segregation has a political side to it—politicians frequently either oppose integration or lack the political will to effectively promote it, considering that the Roma, in general, are considered key electorate and a complete disregard of their opinion and attitudes is not something politicians at a local and national level can "afford". Along with the above, entirely racist arguments are commonly heard by those seeking justification for continued segregation: (a) Roma do not want to integrate (a widely held view in Greece); and (b) Roma are incapable of integrating (Education on the Edge: Roma Segregation in the Schools of Five EU Member States 2012).

In our opinion, reduction, if not eradication, of school segregation in Bulgaria will require, among other measures, long-term efforts related to "education" of both groups of parents—Bulgarian parents need to become more aware of the threat which school segregation represents to the society as a whole, while Roma parents need to realize the importance of education in general.

The low territorial level at which the survey was conducted (a city quarter) contributes, on the one hand, to a clearer and deeper insight into the school segregation phenomenon. On the other hand, by analyzing the results from the survey among a specific minority group, will help the development of differentiated policies and measures for solving the problems of the individual Roma groups according to their specific features, which are also problems of the Bulgarian society as a whole. Despite the still serious and ongoing negative processes related to school segregation in Bulgaria, the Roma students exhibit positive trends related to adaptivity, openness to changes, changes of attitude towards their values and moral orientation.

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Orania—24 Years After Apartheid: The Sociopolitical Reanimation of a Small Rural Town in South Africa

Nico Kotze, Ruan Schoeman, Sanet Carow and Peter Schmitz

Abstract The small rural town of Orania was established in 1963 as a result of the Orange River Water Scheme. Its purpose was to accommodate the workers of this large water project during the canal construction phase. It underwent further development to provide for the services and needs of the construction workers. However, subsequent to the completion of the project in 1989, when the Department of Water Affairs abandoned it, it became a ghost town. The town was put up for sale by tender and was bought by the Afrikanervryheidstigting (AVSTIG) (the Afrikaner Freedom Foundation) in 1991, and was envisaged as the first homeland for the Afrikaans-speaking white population. A mixed-methods methodology was used to obtain information about the development and the current developmental potential of the town. At this stage, it was clear that the Apartheid ideology was reaching its demise in South Africa. The town went through three economic phases. The first was as an economic phase during construction in the early 1960s, when large water projects were initiated by the South African government. Subsequently, during the early 1990s, it served as a political-economic base; and finally, in 1994, when the farm adjacent to the town was bought and subdivided into smallholdings, it entered an agricultural economic phase. This development brought about steady growth in the town's population from 1997 to 2011, with the 2011 census showing a growth of approximately 49%, with a significant increase in the age group younger than 20 years. Twenty-four (24) years after Apartheid, on account of the authority wielded by the village council to act as gatekeeper, Orania still has a whites-only population.

Keywords Orania · Apartheid · South Africa · Economic phases · Population growth

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Introduction

Internationally, small rural towns are undergoing rapid economic change (Halseth and Meiklejohn 2009) and most of these towns and their rural communities are being 'threatened by a number of unique challenges owing to globalisation and economic reorganisation, and community destruction as a result of service withdrawals' (Gibb and Nel 2007: 71). Owing to these challenges, the local economies of these towns are declining and local businesses are failing; employment in the agricultural sector is decreasing; and populations are dwindling on account of the emigration of the rural population to larger urban centres in search of employment (Gibb and Nel 2007; Halseth and Meiklejohn 2009).

However, there is proof from countries of the Global North such as those in the United States of America (see Aldrich and Kusmin 1997), Canada (see Biggs et al. 1993), United Kingdom and Australia, that some rural communities are showing that they are able to prevent this urban decline by focusing their economies on the service sector: that is as long as they are, by and large, located close to larger urban areas or major transport networks, their populations are generally well educated, and they are located in a favourable environment (Gibb and Nel 2007; Nel et al. 2011). Additionally, it is also evident that in Australia, for instance, some of the small towns have remarkably stable populations or are even experiencing an increase in the number of residents, and that they also have sustainable economies, that could be attributed only to economic development initiatives by the local government, as well as favourable local conditions that are specific to the area. Urban push factors and small-scale flexible industries also contribute to the prosperity of these stable populations (Toerien 2018). Even in 1964, it was claimed that if small towns want to remain relevant and vibrant, they will have to provide more employment opportunities, with wages matching those of the bigger cities (Watts 1964).

Growth in small towns has more recently been associated with what Mayer and Knox (2010) describe as the 'second modernity' in small towns, which refers to a range of variables that are associated with tourism and the provision of retirement facilities in the post-industrial era, with the focus also being on leisure time activities (Nel et al. 2011). Phrases such as 'transition towns' and 'slow cities', telecommuting, counter-urbanisation (in reaction to urban congestion in the large cities), and lifestyle choices are some of the axioms used as the main driving forces behind small-town development (Powe and Hart 2008; Cromartie and Nelson 2009; Nel et al. 2011). Furthermore, according to Morén-Alegret et al. (2018), even the EU has placed emphasis on the importance of people-centred rural development to maintain sustainable food production.

In many cases, such small towns have had to reinvent themselves as significant components in the new era because it is recognised that their future potential most probably does not rest totally in the provision of services for their rural surroundings, and that they have to market themselves for new types of investment, as well as introduce settlement characteristics suitable for the post-industrial era. In these towns, the quality of life has become a much more important factor in individuals' lives (Courtney and Erirington 2003; Johnson 2006; Nel et al. 2011), and creative leadership plays an important role in attracting creative facilities and enterprises to these towns (see Sorenson and Epps 1996; Knox and Mayer 2009).

Contrary to these phenomena, it has also been found that some development towns in Israel have never reached their full growth potential and also not reached the phase of rapid and sustainable growth (the take-off point). Furthermore, the population growth remains slow, with employment and welfare lagging behind other towns in the country (Portnov 2004; Toerien 2018). These new rural towns were primarily developed for geopolitical and ideological reasons to mitigate security risks in the sparsely populated areas. Initially, these towns were sustainable on account of government investment, but their fortunes changed in tandem with the change in governmental policy in the early 70s (Portnov 2004; also see Weiner 1981).

In South Africa, as is the case internationally, the largest proportion of urban studies has focused on larger urban areas with very little attention being given to smaller centres that are facing more significant challenges (Van Niekerk and Marais 2008). In the late 1990s, studies on small towns in South Africa, to name but a few, focused on the changing demographic trends (Krige 1995; Nel and Hill 1998) and the challenges of service delivery when the primary activities were terminated (Marais et al. 2005). However, in their study conducted on smaller rural towns in the arid Karoo region of South Africa, Nel and Hill (2008) found that these small-town service centres are losing their service facilities and are only surviving economically on account of the welfare systems that were introduced in the country after 1994.

This chapter is divided into five sections. The first is the introduction and looks at the impact of economic activities and urban development on small rural towns; the second section looks at the location and development of Orania in the central arid region of South Africa, as well as the methodology used. The third section covers the population change in this small rural town and the possible political and economic factors that could have had an impact on these changes. In its turn, the fourth presents a discussion of the changes in the economic bases or phases that have had an impact on the economic transformation of this community. The final section offers recommendations for the continued growth of the population, and concluding remarks.

Location and Development of Orania

The small rural town of Orania was founded more than half a century ago in 1963 as a consequence of the Orange River Water Scheme. This project envisaged the development of three dams, only two of which were constructed, namely the Gariep (the former H F Verwoerd Dam) and the Vanderkloof dams (P K le Roux Dam), as well as canals and tunnels to redistribute the water in the drought-stricken region of central South Africa (Du Plessis 1998; Kotze 2003; Steyn 2004; Delvecki and Greiner 2014). The purpose behind the founding of this town was to provide housing for the workforce during the phase in which the canals of the project were being constructed. Orania was further developed to provide for the services and needs of the construction cohort (see Fig. 1 for the location of the town).

Subsequent to the completion of the project in 1989, when the Department of Water Affairs withdrew, Orania became a ghost town, costing the government R33 000 (approximately €2100) per month for maintenance during the late 1980s (Du Plessis 1998; Kotze 2003; Steyn 2004; Veracini 2011; Delvecki and Greiner 2014).

Orania was never proclaimed as a town, was put up for sale by tender in 1991, and was bought by the private company, Orania Bestuursdienste (Pty) Ltd. The owners of this company envisaged Orania as the first town in a homeland for the Afrikaans-speaking white population. At this stage, it was clear that the Apartheid ideology in South Africa was reaching its termination in the country (Boshoff 1998; Hagen 2013). This ideology was adopted by the National Party government that had been in power since 1948 and that insisted on separation along the lines of racial groups as its foundation. More than 52 acts were passed, including the Group Areas Act of 1950 (Act 41 of 1950), to enforce the physical separation of the different racial groups in the country (SA History online 2019). Homelands were created for the different Black population groups for them to engage in some form of self-determination (SA History online 2011).

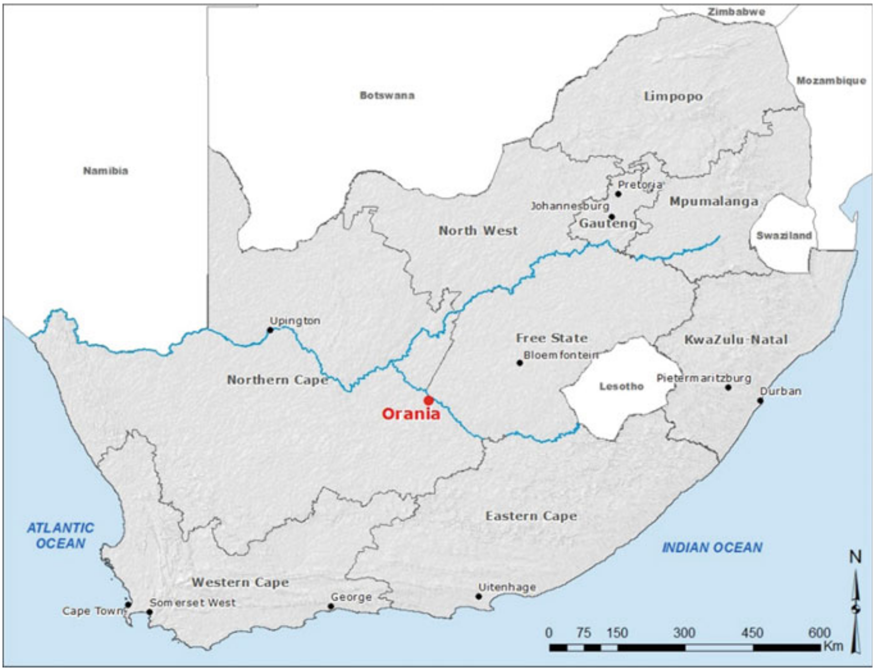

Fig. 1 Location of Orania in South Africa

Orania is unique and differs from all other urban areas in South Africa since it is privately owned and unequivocally defines itself as an emerging Afrikaner homeland in this space and at this time (Kirchick 2008). According to Steyn (2004), the vision of this ideo-structure was to partially recover Afrikaner freedom in a self-governing 'republic' with Christian values. As in the case of South Tirol in Europe, where the German-nationalist communities are called upon to cultivate their German identity and wherever possible to isolate themselves from any alien influences, in the same vein, the population of Orania is striving to maintain its Afrikaans heritage (Weidinger 2014). In the case of Orania, the point of departure of this ideology could be classified as Christian Nationalist and based on a capitalistic concept (Steyn 2004).

Additionally, owing to the autocratic nature of the Orania Management Services Company, control over the management and maintenance of the town was and is still being performed by the holding company, with virtually no assistance from the National Government (Steyn 2004).

A mixed-methods methodology was followed in this study. The historical development of Orania was established through a desktop study of the available data and of publications in the public domain (i.e. census data), while more current information was obtained through interviews with spokespersons from the Orania Movement, who are responsible for media communication.

Economic and Business Development of Orania

The town went through three economic phases, namely as a construction economic base during the early 1960s, when large water projects were initiated by the South African government, but forfeited this economic base when the project was completed. Subsequently, during the early 1990s, when the town was sold to Orania Bestuursdienste and it served as a political-economic base, it was perceived as the first town to be established in an Afrikaans Homeland. However, this idea was abandoned when the newly elected African National Congress (ANC) government in South Africa scrapped the homeland ideology of separate development.

However, with due consideration of this governmental stance of rejecting separate development, and of Section 235 of the Constitution of South Africa, 1996, it became clear, according to De Villiers (2014), that the constitution does, in fact, allow for cultural self-determination, albeit non-territorial. This means that the constitution promotes cultural autonomy but that this autonomy is not linked to a specific geographical region. As such, should the cultural autonomy be linked to a specific region, it must be legislated. In fact, Section 235 allows for the establishment of cultural councils that have public legal powers (De Villiers 2014).

From the authors' discussions with the Orania Movement, it seems that that is the path that Orania followed within the ambit of the South African Constitution (Senekal and Krige 2018).

A new phase of development was initiated when the farm Vluytjeskraal 272 adjacent to the town was bought in 1994 and subdivided into smallholdings (see

Fig. 2). This Afrikaner settlement then entered an agricultural economic phase (Kotze 2003; Hagen 2013).

The subsequent agricultural projects introduced in Orania proved to be substantial, with the production of almonds, olives, peaches and alfalfa as local cash crops. However, the planting of more than 20 000 pecan trees has proved to be the most important agricultural enterprise in the area, with only white migrant labourers being employed during the harvesting season (Delvecki and Greiner 2014). It is important to note, however, that Dalla Via et al. (2013) concluded that such an economic base,

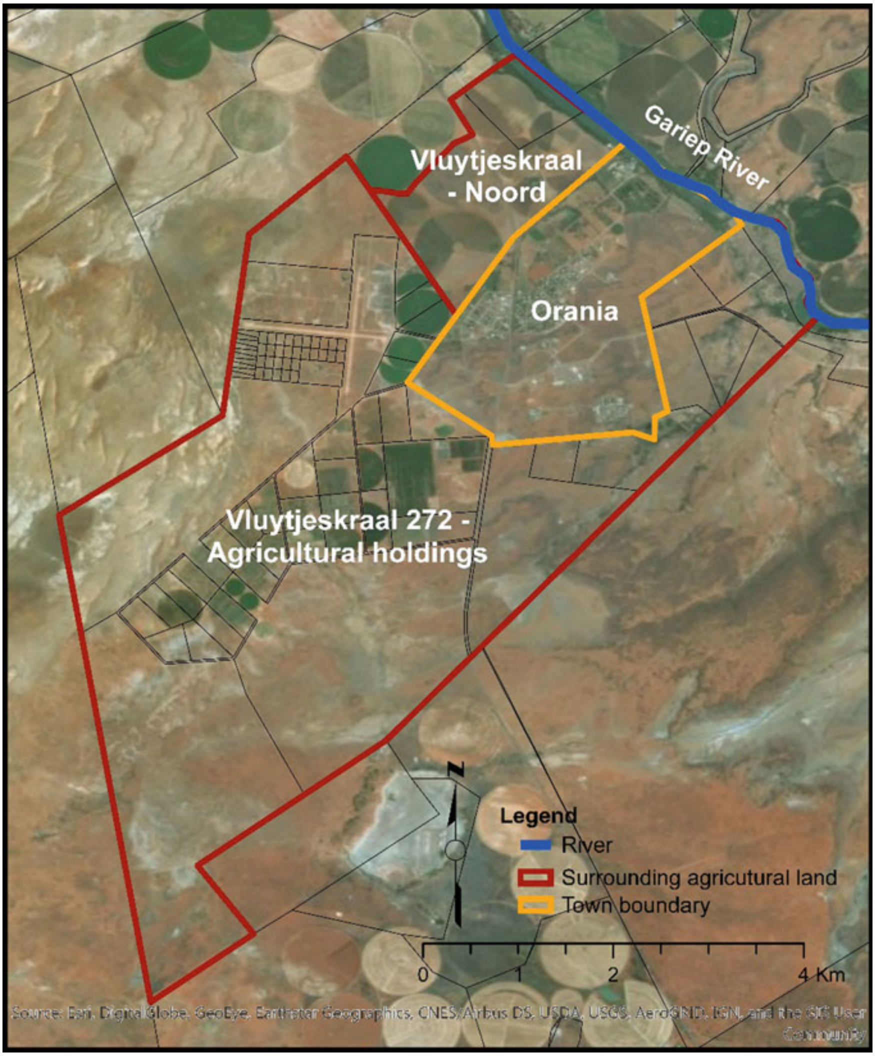

Fig. 2 The area under the jurisdiction of Orania

although currently successful, can continue to be so only as long as the contributing agronomists are properly trained and have the knowledge concerning their selected crop types.

A further contributing factor to the success of the agricultural sector in this area is that Orania is located on the banks of the Garieb (Orange) River. This river is one of the larger perennial rivers in South Africa and its water is used for irrigation purposes (see Fig. 2). This source of water is vital, since Orania is located in an arid environment, with temperatures ranging from –9 °C in winter to 50 °C in summer.

The main aims of the agricultural development in Orania, according to De Klerk (2014), are to:

- contribute to economic development and create opportunities for employment in the town;
- establish a base from which secondary industries and services can develop;
- develop and grow an export base and create foreign currency (meaning South African currency) for the town;
- ensure food security and self-reliance for the community (De Klerk 2014).

According to Porter (2004) and Markey et al. (2006), rural and small-town restructuring in the Global North is related to effective adjustments and changes to the primary sector activities, thus allowing for a wide range of transformation that would by nature be accompanied by reforms in such areas as 'transport networks, global markets, commodity prices, regulatory controls, property rights, and competing land use types' (Halseth and Meiklejohn 2009: 294). However, such reforms and opportunities have not generally been available in the restructuring of Orania.

In 2017, when the Orania Chamber of Commerce conducted a survey of the commercial activities in the town, it was established that there were 161 registered businesses at the time. The majority, 45 (27.9%) were in the retail and wholesale sector. Twenty-one (13%) of the businesses were classified as general services, while 15 (9.3%) were categorised as those servicing the tourism and hospitality sectors (see Fig. 3). In fact, as many as 600–700 tourists visit the town on an annual basis. Most of the first-time, tourists visit Orania out of a sense of curiosity and then return to enjoy the tranquillity of the environment. Following close on the previous category, 14 (8.7%) of the registered businesses were in the construction industry, while enterprises constituting the fifth-largest category of businesses included vehicle, as well as financial services, with eight (8) each. These top six business categories accounted for 68.9% of all the industries in Orania.

These 161 businesses created 549 permanent and temporary or seasonal employment opportunities during 2017. It is also worth noting that in 2018 there were eight chartered accountants living in Orania, most of whom were operating their businesses via the internet with their clients located outside the town. Furthermore, the variety of services accounted for 208 (37.9%) of the total number of work opportunities created within Orania during 2017 (Orania Dorpsraad 2017). From this information, it is clear that the economic strategies of the town's economic visionaries have moved away from large-scale projects to smaller, practically home-based economic enterprises.

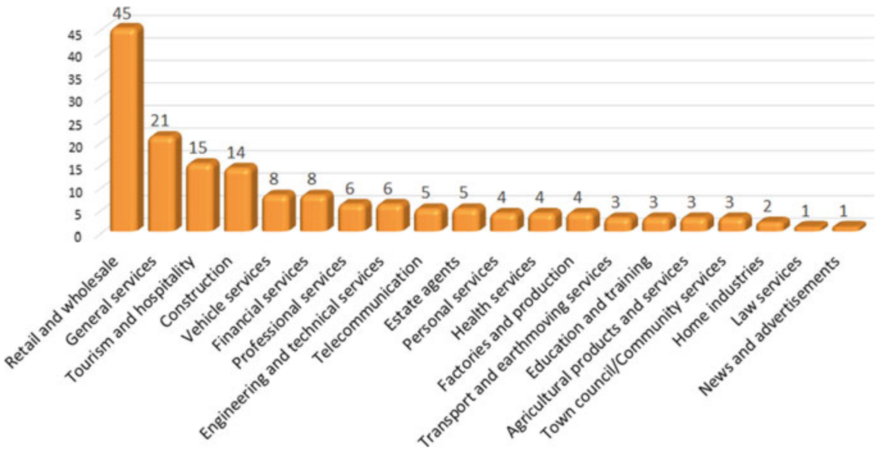

Fig. 3 Businesses in Orania. *Source* Orania Dorpsraad (2017)

Orania has also developed its own currency called the Ora. (see Fig. 4)—the preferred currency in the town—allowing locals to spend their money here instead of in the surrounding areas. Labourers are paid in Ora with the opportunity to exchange their money to ZARs. The Ora is linked to the South African currency with an exchange rate of ZAR1 equals 1 Ora. However, should a person exchange Ora back to ZAR, a commission of five percent would be payable. A further novelty is that the Ora provides for advertising space on the banknote. The income generated from the commission paid on exchanging the currencies and on the advertising space is ploughed back into the local economy by contributing to projects such as the upgrading of roads, the creation of jobs, and the provision of housing to newcomers, or is further invested to generate an income. Orania also has an e-Ora (similar to the bitcoin). Finally, if preferred or necessitated, the Orania Bestuursdienste (Pty) Ltd could also delink the e-Ora from the ZAR and link up to any other stronger currency

Fig. 4 The 10 Ora currency of Orania

such as the US Dollar. This could put Orania in a potentially stronger economic position than the rest of South Africa (Krige 2018; Senekal 2018).

Despite all the success stories, Orania still has some challenges regarding services that need to be delivered. Although a paramedic is available to attend to patients, the town has no medical doctor. For a medical doctor to run a successful practice, a minimum of 5 000 residents should live in a town. The town provides basic medical services and a medical specialist visits the town on a regular basis. There are currently also no medical emergency services available such as an ambulance (Krige 2018; Senekal 2018).

The Population of Orania

The Orania development brought about steady growth in the town's population from 1997 to 2011, with the 2011 census showing a population growth of approximately 49%, which included a significant increase in the age group younger than 20 years (see Fig. 5). This population growth is most probably due to the economic meltdown and the Affirmative Action policies that have been introduced by the ANC government in South Africa that favour people of colour in securing employment in the country. This notion is also verbalised by commentators such as Hermann (2006), as well as Kotze and Senekal (2018), who attribute the population growth in Orania to the Afrikaans population's sense of marginalisation in terms of affirmative action and their lack of access to significant political power, the crime factor, as well as the incompatible dogmatic views expounded by political leaders, resulting in doubts as to the viability of the notion of a Rainbow Nation in South Africa.

Something of an anomaly in the context of the larger South African context then is that 24 years after Apartheid, on account of the authority wielded by the village council to act as gatekeeper, Orania still has a whites-only population. No property

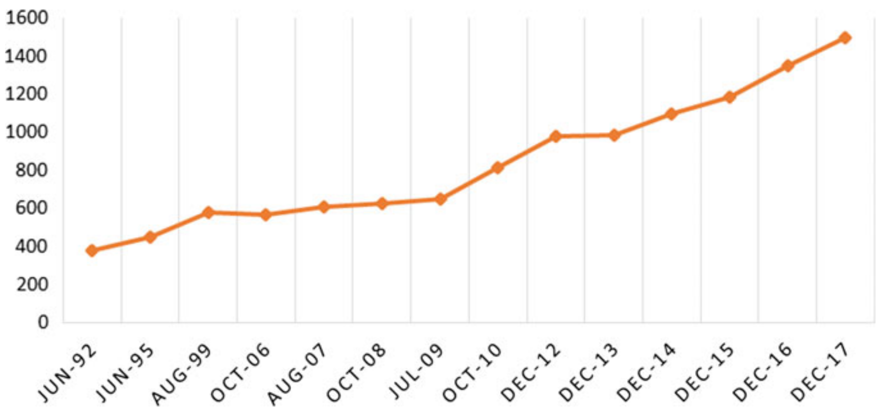

Fig. 5 Population growth 1992–2017. *Source* Orania Sakekamer (2017)

within the area can be sold to a potential buyer without authorisation by the town council. In their 2014 study, Delvecki and Greiner (2014) describe life in Orania as seemingly bleak for teenagers and young people in their early twenties in terms of employment opportunities and entertainment. However, in the same study, Delvecki and Greiner (2014) also state that the inhabitants of Orania noted the crime factor and the lack of opportunities in South Africa as the main motivation to move to Orania. They even went so far as to proclaim that the younger inhabitants are bound to the town on account of their fears for conditions on the outside.

Related to this, the residents of Orania have implemented a culture of zero tolerance towards any criminal activities. Although the entire town is equipped with cameras, it is regarded as the responsibility of each person to ensure the safety of the town and report any suspicious activities to the security services. The Orania Dorpsraad (town council) has the authority to expel a person from town or hand him/her over to the South African Police Services should they be found guilty of any misconduct. According to the studies by Krige (2018) and Senekal (2018), this safe environment attracts many families to raise their young children here. See Fig. 6 for the portrayal of a safe environment with road signs to warn drivers that children may be playing in the streets.

Fig. 6 Child-friendly road signs in Orania

When the gender composition of Orania is scrutinised, it becomes clear that the results are not in line with those for the general population of South Africa. Looking at the 1999 data, as well as the 2011 general census of South Africa, it is evident that the percentage of male inhabitants in Orania has increased to more than 60%. This can possibly be attributed to the policy of Affirmative Action, that was introduced in the country once the ANC government came into power in 1994, and that strongly promotes the appointment of people of colour and has a negative impact on work opportunities for white males. This could result in the relocation of white South African males to Orania in the hope of securing employment and an income in the town.

From Table 1, it is also clear that the population of Orania is getting younger, with more than 30% of the inhabitants classified into the 20 years and younger age category. This is a substantial change from the 1999 dataset that showed only four percent in this age group. This could be attributed to younger families moving to the town and the relocation of young white males who were unable to find work in the rest of South Africa. This should also be regarded against the backdrop of the gender distribution in the town.

Table 1 Socio-economic profile of inhabitants of Orania

Variables	1999 data (%)	2011 census (%)
Gender: Males	59	60.1
Females	41	39.9
Age: ≤20 years	4	30.2
21–30 years	13	14.2
31–40 years	15	9.4
41–50 years	21	10.4
51–60 years	16	11.2
61–70 years	17	13.0
>70 years	14	11.6
Marital status: Married	75	51.6
Widow/widower	7	4.5
Divorced	4	6.3
Separated	1	0
Never married	13	37.6
Academic qualification: ≤Gr 10	17	40.5
Gr 10 and 12	24	45.6
Tertiary qualification	57	13.9
Tertiary qualification: Diploma and certificates	27	40.5
BA/BSc	6	28.4
BA (Hons)	9	19.9
Masters and doctorates	58	9.5

When the academic qualifications for the 1999 and 2011 datasets for Orania are compared, it is clear that there has been a decline in the percentage of people with tertiary qualifications, from 57% to less than four percent. Furthermore, an examination of the tertiary qualifications of the residents of the town reveals that the large number of people with postgraduate qualifications in the 1999 data set had decreased dramatically by 2011. What should be considered is that the size of the population was still small in 1999, when Orania was considered to be the first town in an Afrikaner homeland. If the change in the age composition is considered, with 31% of the population being older than 60 years, it should be expected that these two variables could have impacted upon each other and that the highly qualified population could have died out or moved out of Orania.

Concluding Remarks

Orania is not an example typical of the majority of small rural towns in South Africa. The majority of these towns in the country are on a steady downhill slope of decline on account of the loss of services and of economic relevancy. However, in the case of Orania, there are sure signs that this small town has reinvented itself. This is clearly evident from its having passed through a number of developmental phases in order to ensure its growth and development.

Orania, a growing town based on an Afrikaner ideology, has created a safe haven for a population in a country which is renowned for its high incidence of violent crime. This segment of the population felt themselves to be increasingly ostracised in South Africa at large, on account of the political change that has taken place over the past decades.

Furthermore, the Orania economy is now based on smaller home-based industries, seemingly a successful formula for the town. It also appears that the economy of Orania has found its niche, especially in the services, tourism and hospitality sectors, and that it is growing steadily. This is in contrast to other small towns in South Africa that are mostly declining and accommodating an ageing population. Furthermore, these small-scale enterprises have created employment opportunities in the town. The Ora currency of the town may be considered to be a novelty by some observers. However, to date, it is contributing to economic growth and investment opportunities in Orania.

What is clear from this study is that the population of this once ghost town is growing slowly and that the population is becoming younger, while new economic activities are being added to what was previously available in the town. From the interviews conducted with spokespersons during this exploratory research project, it is clear that the planners and managers of Orania are constantly looking at new ways and methods to make this small town a workable option.

Whether you agree with the underlying Afikaner ideology or not, you have to agree that Orania may become a ‘small’ success story catering for a disillusioned minority in the larger Rainbow Nation of South Africa.

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Socio-geographic Assessment of the Quality of Life in North Central Bulgaria

Dimitar Simeonov, Desislava Simeonova and Petya Kancheva

Abstract The geographical science has an original approach to studying the concept of "quality of life of the population". Each geographic study suggests conducting science-based and planned research over a certain territory. In our case, this is North Central Bulgaria, which covers the areas of Pleven, Lovech, Veliko Tarnovo, Gabrovo, and Ruse. The life quality of the population is quantified, which allows the assessment of a certain territory and its differentiation against individual factors. In the proposed model for assessing the quality of life of the population the conscious rejection for using subjective criteria has been accepted; thus, our choice centers upon current, accurate and comparable indicators publicly available and adopted from the National Statistical Institute. Obviously, the individual components have unequal measurability so it is necessary to apply the linear scale method. The final indices for the quality of life of the population in Northern Central Bulgaria have been cartographically visualized.

Keywords Quality of life · Systematic approach · Settlements · Sociological methods · Region · Communities · Indices

Introduction

The current stage of community development is marked by the ongoing discussion of the appropriateness and legitimacy of changes in the concept of quality of life for the population and its assessment of the perspective of social development. Quality of life has become one of the most significant social phenomena of modern times.

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The emergence of quality of life issues in economic and philosophical literature is an element of the theory of economic well-being. The term “quality of life” appears for the first time in 1960 in the book by American economist J. Gilbert—”Public Abundance”. In the political vocabulary, this concept was introduced by US President J. Kennedy in the 1963 Report on the Situation of the Nation. Kennedy develops the thesis that “the quality of life of Americans must keep up with the amount of American goods produced” (Nagimova 2010). As a result of succession, New President L. Johnson states that the goal of American society “can not be in measuring our bank deposits, but in the quality of life of our population” (McCall 1975).

In our country, “quality of life” is defined as the main objective of regional planning. It is in all planning and strategic documents at state, regional, district and municipal level.

Different sciences have interest in the different aspects of quality of life, all of which use elements of the geographic approach to explore and characterize it in detail. It helps to reveal the regional differences of macro, meso, and microlevel, their dynamics, determines causal relations, isolates a range of problems and provides concrete practical solutions for improving the quality of life.

In the context of the global trends in the concept of quality of life, the view is that human resources are becoming a key source of economic growth with their various qualitative characteristics.

For us, the quality of life objectively is geographically diverse and even more geographically determined. The acceptance of geographic determination of quality-of-life indicators necessitates the use of a spatial-temporal approach to the analysis of this public phenomenon. Considering the territory of North Central Bulgaria as an object of analysis, we can assume it as a specific socio-geographic system reproducing the quality of life. The territorial choice of Northern Central Bulgaria covers five districts (Pleven, Lovech, Gabrovo, Veliko Tarnovo, and Rousse) and 41 municipalities. For us, this is the most compact and complex geographic subject.

The geographical interpretation of the territorial differentiation of processes for the quality of life of the population builds horizontal and vertical links. Higher scientific value is the study of vertical relationships formed by the coordination of processes and mechanisms that shape the quality of life at national, regional, and local levels. Vertical slice is directed from the higher taxonomic levels to the lower ones (in our case—to the municipalities).

Theoretical Aspects of the Study

The study of quality of life implies conducting a scientifically based and well-planned analysis of heterogeneous statistical information, which is primarily systematized as socio-geographic indicators.

In the current European version, following the EurLIFE database to the European Foundation for the Improvement of Living and Working Conditions, 12 “life domains” are: (1) health, (2) education, (3) employment, (4, 5) social participation (social relations, communication); (6) transport; (7) housing; (8) family; (9) recreation; (10) the environment; (11) security; (12) life satisfaction.

The European Social Indicators System (ESSI) offers 14 "key indicators" for life domain: (1) population, (2) socioeconomic status and subjective class identification, (3) labor market and working conditions, (4) income and distribution of income, (5) consumption and supply, (6) transport, (7) housing, household and family, (8) health, (9) education and vocational training, (10) civic activity), (11) environment, (12) public security, etc., accessibility, (13) leisure and media consumption, (14) common indicators of development (GDP).

In the definition of the World Bank, "quality of life" is "the overall well-being of people," including "the quality of the environment, national security, personal security and safety, political and economic freedoms."

According to the approach used, researchers are divided into two directions: objective and subjective. The subjective approach to quality of life is based on established values and experiences. Components in the structure of quality of life are self-esteem, life satisfaction, happiness (or a combination of them) (Diener 1994).

The objective approach limits its analysis to components such as housing, living space, nutrition, education, health care, and this is the approach we have chosen to analyze the territory of Northern Central Bulgaria. Geographical views have the following manifestations of the properties of the term "quality of life":

- the quality of life of the population is viewed from the point of the complex and systemic approach and is defined as an integrated concept taking into account the territorial differences at individual taxonomic levels (countries and regions, districts and municipalities, urban and rural) as well as global, regional and local level;
- quality of life is an evaluation category that characterizes the degree of development of the studied territorial settlement system, located in time and space;
- the quality of life of the population is objective and subjective, reflecting the objective picture of the conditions and processes of the life activity, as well as the subjective assessment of the people studying the trends of development for the quality of life on a given territory;
- objectivity in the quality of life emphasizes the positioning of the territorial factor as a leader.

The analysis of all the above-mentioned manifestations allows the formulation of a definition of the quality of life of the population in a given territory as follows: a socio-geographical category formed as a set of vital values, needs and activities that are necessary for the human being (people's satisfaction of life and environment) that provide an opportunity for individual personality development, taking into account the impact of processes related to the balanced socioeconomic development of the particular territory (Simeonov 2010).

It is important to note that one of the first attempts in Bulgaria to use an integrated assessment at regional and municipal level is through the synthetic Human Development Index (HDI) introduced by the UN in 1990 (Human Development Report 2016). This is also the first attempt to realistically assess the quality of life in the country. The HDI itself is a combined measure and is based on the use of three important dimensions of human development: a prolonged and healthy lifestyle, the level of education (judged by the literacy rate of adults and the total of student enrollment ratio I2); and a living standard.

In our view, focusing on just these three indicators of the HDI does not reveal the overall quality of life. In the case of objective reflection, it is necessary to take into account further individual elements of the methodologies of: the World Bank, the International Society for Quality of Life Studies, the World Health Organization, etc.

Data Processing by Municipalities and Tracing the Trends

Designing the arguments set out above on the territory of North Central Bulgaria, we tried to assess the quality of life of the population at the level of municipalities in 2016. We use the methodology developed by the Laboratory of Mathematical Methods for Political Analysis and Forecasting at the Faculty of Political Science at the Moscow State University, MV Lomonosov, with Akhremenko and Eutushenko (2010). The main feature of the proposed model is the deliberate denial of the use of subjective criteria for quality of life. The selected indicators are conventionally labeled and are arranged in the following order:

A—Useful living area by municipality (square meters)
B—Residents by municipality (number of persons)
C—Unemployment rate by municipalities (%)
D—Available health establishments by municipality (number)
E—Doctors by municipality (total number)
F—Places for accommodation by municipalities (number)
G—Schools total in school year 2016–2017 (number)
H—Kindergartens by municipalities (number)
I—Crime committed by municipalities (number).

Of course, it is possible to enrich the palette of indicators with others but in general the content aspects of the applied research methodology will not change.

The annual quality of life index of each municipality is a linear function of the sum of the 9 indicators divided by 9.

$$\mathrm{IQL} = \frac{\mathrm{A} + \mathrm{B} + \mathrm{C} + \mathrm{D} + \mathrm{E} + \mathrm{F} + \mathrm{G} + \mathrm{H} + \mathrm{I}}{9}$$

Obviously, the individual components have unequal measurability. In order to form the general municipal index it is necessary to bring the data in a comparable form that's why we have to apply the linear scale method

$$X_{i/a} = \frac{X_i}{X_{max} - X_{min}}$$

The essence of linear scaling is rooted in the fact that for each indicator first is found the difference between the highest and the lowest value. Then it remains averaged basis in proportion with each specific value by municipality and the result is rounded to three decimal places after the decimal point. If this recalculation is not done, the data will be dynamically incomparable.

There are various issues in each integrated assessment, one of which is how to determine the significance of the individual components that impact on the quality of life. These indicators, which are directly measurable but negatively related to the quality of life of the population (for example, the higher unemployment rate and the higher number of committed crimes), are subject to recalculation by the linear inversion formula

$$X_{i/a} = 1 - \frac{X_i - X_{min}}{X_{max} - X_{min}}$$

This has been applied by us in both indicators B and I where the size of the value is inversely proportional.

The final version of the quality of life index of the municipalities is mapped—Fig. 1. There may be outlined at least five key areas for the quality of life index in Northern Central Bulgaria. First, significantly outstripping the others are the municipalities of Veliko Tarnovo, Ruse, Pleven. The second zone includes two municipal-

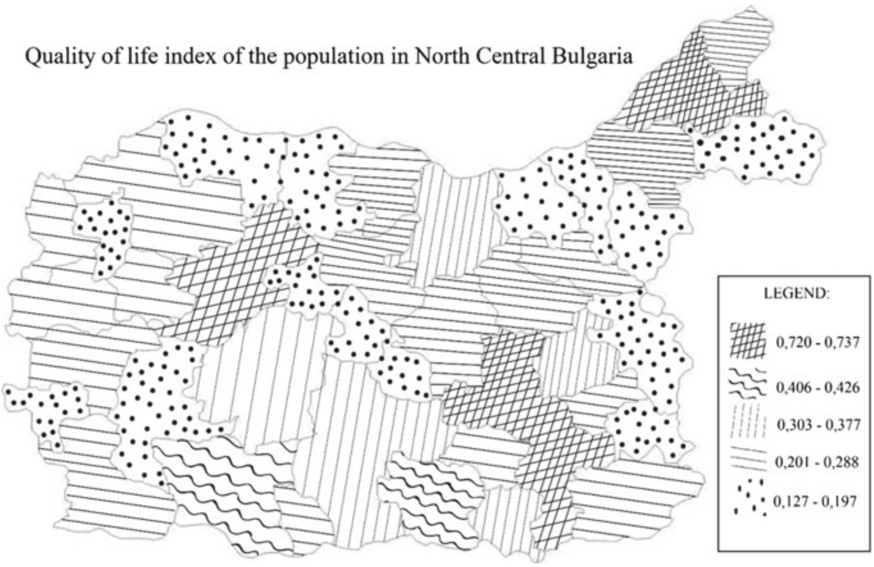

Fig. 1 Quality of life of the population

ities—Gabrovo and Troyan. The third group includes five municipalities: Lovech, Gorna Oryahovitsa, Sevlievo, Svishtov, and Tryavna, whose quality of life index is twice lower than the leading municipalities. The fourth group covers the largest number of municipalities—17. With the lower values are 14 municipalities (fifth zone), from which the last is a municipality of Ugarchin.

From the study an expected conclusion is drawn that there are district centers with high quality of life and a vast periphery of municipalities with predominantly lower values and degraded conditions. The situational analysis gives us reason to summarize that the levels of health and educational status are significantly differentiated on the "village-city-municipality" axis.

Conclusion

The quality of life of the population is an important indicator for all institutions and people and especially for the new paradigms in the social geography that has developed in our country in recent years.

The applied methodology for assessing the quality of life of the population reveals the internal differences at the municipal level. It is generally applicable and open to comments and discussion, both in content and procedural terms. Possible corrections in the choice of indicators are an integral part of such research. Adding or removing of indicators would not change the positions of leading municipalities.

The established geographic model for studying the quality of life is adapted to the opportunities for current, accessible, and relevant (comparable) statistical information with specific localization—41 municipalities from Northern Central Bulgaria.

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The Innovative Approaches for the Development of Smart Cities

Antonina Atanasova and Kliment Naydenov

Abstract The growing problems in the cities, caused by the overpopulation, increased economic growth, the loss of natural resources, are creating the necessity of decision-making referring to the different economic, social and environmental issues. In the twenty-first century, the world faces such challenges, which has made people and city governances more concerned about ensuring the high quality of life and sustainable development of the urban systems. There are different definitions for smart cities, but the universal one is that a smart city is the city which satisfies the needs of people and meets different challenges. The 'smart cities' is a new concept and it measures not how smart the city is, but the city's efforts to make itself smart—sustainable development, sound economic growth, and when the urban system adapts itself to the users' needs. The smart city concept incorporates good urban planning, use of digital technologies, networks of technologies, networks of people who work together well, a change in the way of thinking, the transformation of the city governments for successful smart cities and applying the participatory approach. That's why in order for to make a city smart, it is necessary to apply different innovative approaches and solutions and to use information and communication technologies. Smart cities utilize IoT (Internet of Things) sensors, actors and technologies to connect different components across the city from the air to the streets, to the underground. Cities have similar problems—traffic-stricken streets, poor public transport, air pollution, etc., but some of them are successfully managed to solve these problems. In this report, we will discuss good practices and experiences from different cities, which use technologies and communications to become smart, such as sensors for free parking spots, smart traffic lights, the use of energy-saving solutions, online platforms for creating solutions, bicycle lanes, smart waste management. The city will be considered as a living laboratory for experiments, some of them successful, other necessary and yet other still looking too abstract at the moment. The reason will be sought how some cities can use new technologies

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to make them look more efficient, competitive, functional and livable for citizens. This report is presented in 4 sections, including the foregoing introduction. Section "What is the concept for Smart Cities?" introduces the concepts for smart city innovations. Section "Good practices for Smart Cities" exposes the cases of development of smart cities in Barcelona and others. Section 3 discovers how some cities can elaborate and develop innovative approaches for a smart city, but others cannot. This section will reveal incentives and tools for the development of smart cities. Section 4 is for conclusion and aims to show how policy makers, NGO and citizens to identify cities which can be developed as smart cities and different solutions and practices how cities can become smarter through appropriate tools.

Keywords Smart cities · Innovations · Urban planning

Introduction

In the prehistoric period, people were hunters and they travelled a lot, therefore they never lived only in one place. When people began to lead a sedentary lifestyle and started to grow crops, small villages emerged.

Historically early cities arose in a number of regions in the ancient world—Mesopotamia, Eridu, Uruk and Ur. After Mesopotamia, this culture was transferred to Syria and Asia Minor. Although sometimes it is claimed that there is no Urbanism in ancient Egypt, several types of urban settlements were discovered in ancient times. For example, in the ancient world in Harappa, sewage for irrigation was used. In this period, the residents of the cities were generals and aristocrats. Cities became centres of commerce. Another reason for the emergence of cities was that they were well fortified.

In the Middle Ages, large cities were Rome, Constantinople, Venice, Genoa, Pisa, Paris. Cities then often grew on the site of defensive fortifications (castles, fortresses, etc.) and around them. In the nineteenth century, Bagdad and London were with a population of over 1 million. Urban population during the Industrial Age was only 3%.

The growth of modern industry since the late eighteenth century has led to mass urbanization and the rise of new big cities, first in Europe and then in other regions, with new opportunities attracting a huge number of migrants from rural communities in urban areas.

When the railways were invented, large production centres began to emerge. But in this period, cities were not good places to live in, because of air pollution, distribution of health diseases and high level of unemployment. During the Industrial Revolution, many people left their farms and moved to the cities. In this way, cities started to become more and more crowded.

Nowadays cities are attractive places because they offer many job opportunities, they are cultural and educational centres, there is public transport in them and also many things to do in your free time.

Today, more than half of the world's population lives in cities and this gives rise to new social, economic, environmental and political challenges. Today, one out of five people worldwide lives in a city with more than 1 million residents (www.un.org).

Cities are producing 80% of the Global Gross Domestic Product (GDP), consuming two-thirds of the world's energy and spewing more than 70% of the global greenhouse gas emissions (Fig. 1) (www.worldbank.org).

It is foreseen that in 2050, the global population will increase to 9.8 billion. It is expected that over the same period of time, the population living in cities will reach 6.3 billion or approximately 68% (Bellisent 2010) of the world population (United Nations). Even though cities are only 2% of the world land area, population in them consumes more than three quarters of the natural resources (Nam and Pardo 2011), 60–80% of energy. Only in Europe, 75% of the population lives in urban areas and is expected to reach 80% by 2020.

Overpopulation in the urban areas gives rise to a different social, economic, political and environmental problems and challenges, which makes cities unhealthy places to live in. Industries, transportation network, cars and overcrowded cities are polluting both the air and the water. This leads to the distribution of different health diseases—cancer, hepatitis, etc. At rush hours, cities become packed with cars, waste that people throw away is burned, there are problems with landfills, lack of places for recreation, criminality. Social problems are the other problem which cities face—unemployment, especially among young people, drugs, poverty, multiethnic challenges, etc.

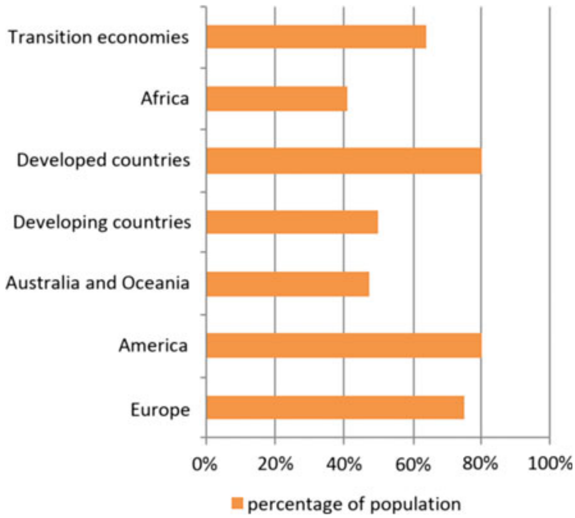

Fig. 1 Urban population by a group of economies 2016 (%). *Source* UNCTAD (2017)

It is expected that the world population will be growing in the next years and the urban population will increase more and more. That is precisely why these problems require a smart decision and smart initiatives in order to be solved.

What Is the Concept for Smart Cities?

In the last few years, the concept of smart city appeared, countless definitions exist in scientific literature so there is not one specific and unique definition.

The first time the term 'smart city' was used was in the 1990s by the California Institute for Smart Communities. The focus is on how communities could be smart and how cities could be designed to implement information technologies (Albino et al. 2015).

A few years later, the Centre on Governance in the University of Ottawa criticized smart cities for being technologically oriented. In fact, in the scientific literature, we can find the terms 'intelligent city', 'digital city', 'information city', 'knowledge city', but the focus is putting information and communication technologies in the centre or to use technology in urban areas.

In the following paragraphs, different definitions about smart cities will be given.

According to Bakıcı (2012) (Almirall and Wareham 2012), a smart city is a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce and an increased life quality.

Caragliu (2011), says that a city is smart when investments in human and social capital, and the traditional (transport) and modern (ICT) communication infrastructure support sustainable economic growth and the high quality of life, with a wise management of the natural resources, through participation in the governance (Caragliu et al. 2011).

Giffinger (2007) a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. A smart city generally refers to the search and identification of intelligent solutions which allows modern cities to enhance the quality of the services provided to citizens (Giffinger et al. 2007).

Hall (2000) A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, one which can optimize its resources in a better way, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens (Hall 2000).

Harrison (2010) A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure and the business infrastructure to leverage the collective intelligence of the city (Harrison et al. 2010).

But to summarize all definitions for smart cities, we could say that the keywords for smart cities include data, system, service, urban, network, technology, sensor, environment, citizen, public, social, mobility, sustainable, life, open, knowledge, policy, integration, decision and local (Lim et al. 2017).

According to Lim and Maglio smart cities also involve various application areas: ‘smart device’, ‘smart environment’ ‘smart home’, ‘smart energy’, ‘smart building’, ‘smart transportation’, ‘smart logistics’, ‘smart farming’, ‘smart security’, ‘smart health’, ‘smart hospitality’ and ‘smart education’.

But why smart cities (Lim et al. 2017)?

What makes a city smart? Everything, which emerges as means to make cities more efficient and sustainable. Cities are smart when they enable us to monitor, analyse and plan urban infrastructure in real time. We achieve this with the development of ICT (information and communication technology). In order for cities to be smart, it is necessary for urban territories to involve and support social cohesion, environmental sustainability, economic competitiveness and achieve a better quality of life.

This paper focuses not only on definitions for smart cities, but also on innovative approaches for how cities are becoming smart. These approaches are different just as the top-down and bottom-up initiatives, IoT (Internet of Things), sensors, measuring the information, and making infallible decisions that will autonomously optimize and regulate all the critical resources of the city.

We can learn from technologies in order to plan better and more efficient transportation infrastructure, improve street lighting, establish clean-water supplies, integrate distributed and renewable sources of energy and install sewage networks (Stimmel 2015).

Technologies are necessary to make cities more liveable. They help us to monitor each move in the urban environment, to analyse and predict different scenarios, to ensure safety and security in urban areas, well-functioning infrastructure, green space, green economy, good health economics, good connectivity in each point in the city, low-energy consumption, clean environment.

Nowadays, technologies are in our lives in bus stops, smart parking spot systems, Wi-Fi across the city, collecting and reporting information in real time, smart traffic lights, smart walkway, etc.

We can think about smart cities as a system of services, the body is the environment, where we live, work, the nervous system is communication infrastructure, the digestive system is the data flow that holds the smart system together; and the brain is the system centre, where the network learns and adapts to produce better outcomes (Stimmel 2015). But the most important thing is the heart of the city—the people who bring vibrancy, creativity, innovation, the life of the city. So, the smart city is not only a concept or definition, it’s a real condition of the urban areas—people, policy, infrastructure, education, health services, etc., all of these components working together. The smart city’s concept does not measure how smart the city is, but how challenges and problems can be faced and managed, and also benefits provided by adequate services and policies.

Good Practices for Smart Cities

In the rest of the article, some of the examples for successful smart cities will be presented.

Barcelona

In the past years, Barcelona has become a city of innovation more and more. In 2011, the city launched a project that aims for Barcelona to be smarter through listing sustainable use of energy, economic renewal and social renewal. Networks with different types of sensors have been installed in the city, providing real-time data for air pollution, noise, free parking spots, etc. And, this is a major reason for Barcelona to be one of the smartest cities in the world.

But why Barcelona? What is different?

Barcelona offers directly several smart cities services through IoT (Internet of things).

Air pollution

Through the use of sensors in different places in the city, information for the concentration of NO_2 and PM10 is provided in real time on the home page of Barcelona's official website. There is a map of the air quality across the city, accompanied by explanations of the sources of pollution, with a big finger pointed at the use of cars.

Another example for smart initiatives is smart street lights. They were replaced with LED lighting (they are activated when motion is detected and they also gather environmental information for the humidity, temperature, pollution and noise [https://www.vilaweb.cat/noticia/4175829/20140226/ten-reasons-why-barcelona-is-smart-city.html)] and sensors which are more energy efficient and reduce costs for energy in the city.

Barcelona's smart waste disposal system watches its citizens dispose of their household waste into smart bins, which suck the waste into underground storage using vacuum (https://hub.beesmart.city/city-portraits/smart-city-portrait-barcelona).

Smart bus stops are another component of the smart city. Each bus shelter uses solar panels, which provide information for the time when the next bus will arrive and there are USB chargers for phones.

One of the sustainable and economic means of transportation which reduces air pollution, caused by cars is Bicing system. Citizens can pay an annual fee and take a Bicing card. Most of the stations are located next to other public transport stops or public parking. A Bicing app is elaborated, which allows a real-time check where the Bicing stations and locations are.

There are smart parking systems using sensors, which detect if a parking spot or a loading area is occupied. It provides information for mobility patterns through sensors.

In the year 2000, Barcelona approved a Solar Thermal ordinance, which regulates that all buildings such as hotels, hospitals, swimming pools have to produce their own domestic hot water. The heating uses steam from the incineration of urban waste and the cooling uses seawater for refrigerating, producing less fossil energy consumption and carbon emissions (https://www.vilaweb.cat/noticia/4175829/20140226/ten-reasons-why-barcelona-is-smart-city.html). This solar installation produces 550,000 kwh annually (a medium-sized household in Barcelona consumes 3350 kwh annually.

It uses the biomass from Barcelona's parks and gardens to make heat and electricity.

There are different apps for public transport and drivers in the city, such as TMB Virtual, which allows you to turn on your camera, point it in any direction and bus stop signs, lines and the distance to them in metres appear on the screen, superimposed on real-world images.

Map Barcelona + Sustainable

An interactive map with initiatives and sites of social and environmental interest in Barcelona. The map is the product of collaboration between the general public, companies, organizations and the City Council and profiles initiatives and resources to improve the urban environment, build a more equal and inclusive social structure and enrich the community and neighbourhood fabric.

The heart of the cities are people, so people also make a city smarter, not only the technology, and there are apps, in which citizens report city problems, such as broken street lights, or make suggestions, recommendations. There are apps which find out how people move, their interests, or entertainment venues. Then they can use this data to improve the logistics for future 'festes' (https://www.vilaweb.cat/noticia/4175829/20140226/ten-reasons-why-barcelona-is-smart-city.html).

Lima, Peru

We all know that people living in the urban areas are prone to various diseases such as cancer, asthma due to the polluted air. In the past years, citizens in Lima have been concerned about their health and the quality of the city air.

A billboard was built on a UTEC campus construction site in downtown Lima and is capable of purifying 3.5 million cubic feet of urban air daily, the equivalent of 1200 trees. It absorbs pollutants, filters them out using basic thermodynamic principles and yields fresh oxygen that extends up to five city blocks. The billboard is also energy efficient, running on recycled water and 2500 watts per hour. It is also specifically designed to soak up construction materials, including dust and metal particles, to improve air quality for site workers and neighbourhood residents (http://innovatedevelopment.org/2014/05/19/perus-innovative-air-purifying-billboard). This innovation is created by University of Engineering and Technology (UTEC).

Other innovations created by UTEC is a water purifying billboard that converted air moisture into 9450 l of potable water within the first three months.

Lisbon, Portugal—dance traffic light

Dance traffic light is a smart solution for pedestrians who often ignore the 'red man' in pedestrian light. The Dancing Traffic Light aims to capture the attention of people waiting to cross a road in Lisbon, Portugal, by displaying a red figure dancing to music rather than the standard static figure. The figure is a low-res representation of people dancing in a nearby booth. Individuals are able to enter the booth and choose some music. When it is time for the traffic to begin moving the music begins and the individual is instructed to begin dancing. This leads to an 81% increase of people stopping and waiting for the green light to appear (https://newatlas.com/smart-dancing-traffic-light/33849/).

Conclusion

The Smart Cities market was valued at 442.89 billion in 2017 and is expected to reach a value of USD 1226.68 billion by 2023 at a CAGR of 18.22% over the forecast period (2018–2023). So, the concept for a smart city will become more and more popular. Around the world, there are many projects and initiatives for smart cities and not everything can be presented. In this article, the development of the cities over the years was briefly reviewed, as well as a different definitions what a 'smart' city is was given and finally, some projects implemented in different countries that lead to an improvement in the urban areas and increasing people's quality of life were selected.

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Spas as a Potential for the Sustainable Functional Development—A Case Study of the East Region in the Republic of North Macedonia

Biljana Apostolovska Toshevska, Mirjanka Madjevikj and Marija Ljakoska

Abstract The settlements are places of many diverse activities expressed through the many functions that take place within their area. Its functional development is based on several factors, including the resources at their disposal. In that regard, the thermal springs of certain locations can also be emphasized and, depending on their physical–chemical properties, they can be put into function. According to the potentials and the role they can have in the sustainable development of the region, they are set aside as a subject for research in this chapter. In the first part of the chapter are emphasized the spas as natural resources. In the second part, the authors tried to make a functional symbiosis between the spas and the sustainable development of the region. In fact, the main aim of the chapter is to initiate thinking about the function of the spas and the possibility of being a pulsating point of growth and development in one region.

Keywords Spas · Functional development · Sustainability · East region

Introduction

The term "spa" is being used in areas where there are one or more types of natural and healing factors (thermo mineral water, medical gases, healing mud—peloid, climate, sea, and other natural conditions in the environment). In addition to this basic prerequisite, the spas must have organized health services, facilities, devices, equipment, and staff in order to be able to use the natural healing factors; suitable accommodation and food facilities; communal and infrastructure facilities. According to the International Spa Association—(ISPA 2007), the spas (baths) are defined as "places

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dedicated to improving the quality of life through various professional services that help recover the mind, body and the spirit." Over time, parallel to the technical and technological development and the needs of the population, spa tourism is increasingly getting a characteristic of medical wellness and regular wellness tourism, and there is always the possibility to connect with the medical tourism. Basically, the spa, the wellness, and medical tourism can be separated or combined, but the differences between them as different forms of health tourism are according to the health condition of the visitors, the motives, the purpose of the visit, the offer that is provided in the specific centers, the length of stay and the financing.

The spas have always had a health and tourism function, but are also a prerequisite for moving the development of other complementary activities. The functions cover all the economic and noneconomic activities that take place in the settlements and enable meeting the population's needs. Their promotion and diversity contribute to the functional development of the settlements (Daskalovski and Madjevikj 2009). It has a particular, specific characteristic for each settlement, and it is perceived through the representation of the activities and changes occurring in this regard. Through the development, the character and scope of the functions inherent in the settlements are changed, and some of them are growing into an impulse for the occurrence of new functions.

In this chapter, the term "spa" stands for an area with a registered presence of thermal waters, that is being treated as a resourceful basis, which determines the functional differentiation of the settlements where they are located. Throughout the past, they were researched by several authors, for various purposes, in an independent study or as part of more complex studies (Cvijić 1906; Leko 1922; Kossmat 1924; Nedkov 1967; Trifunoski 1970; Gjorgjieva 1996; Popovski and Popovska-Vasilevska 2004; Ljakoska et al. 2015; Popovska-Vasilevska and Armenski 2016, etc.).

The spas are an invaluable resource because, in addition to meeting certain needs of the population, at the same time they are the basis for creating a functional classification of the settlements. In such spa settlements, besides the activities related to the direct use of hydrothermal resources, the functional structure can be complemented and enriched with a wide variety of activities designed to meet the needs of the visitors. This way the complex character of the functional structure of these settlements and their influence in the space stands out.

On the territory of the Republic of North Macedonia there are eight registered spas (Katlanovska, Kumanovska, Negorska, Strumica, Kezhovica, Kochanska, Kosovrasti, and Debar spa) which, according to their characteristics are specific (Stojmilov 2011; Stojmilov and Apostolovska Toshevska 2016), each in its own way. Along with the increasing interest by some part of the population for the use of spa services, in some of the spas have been made attempts for their functional improvement. Considering that such efforts are lacking in the analyzed case study area, an interest in researching this issue has been imposed.

This topic of research imposed because the region faces an emphasized emigration, adverse demographic structure, and inadequate economic growth while on the other hand there are a numerous natural resources, including thermo mineral springs.

Considering the worldwide experiences of the use of these waters of the sustainable development of the whole regions, the main aim of the chapter is to emphasize the possibility of turning the thermo mineral springs into pulsators of the development of the settlements near which they are located, as well as the surroundings. This way, they would enable the movement of the entire demographic, social and economic development. It is also a motivation for the local communities to sponsor further research related to the identification of adequate solutions for the development of the settlements, of the micro, macro, and meso regions with an emphasis on the development of particular natural resources that exist in the concrete geographical area. In doing so, the rational use of resources and ensuring their sustainability should be taken into account. The world's scientific society has largely discussed the sustainable use of all available resources by human, and as a part of the global development goals is the sustainable development of human settlements. In the literature worldwide, can already be found definitions of sustainable development, as a development that meets the needs of the present, but at the same time does not jeopardize the possibilities of future generations to meet their needs UN (1987). Basically, when we speak about sustainability, we refer to three basic concepts: (1) the need to arrest environmental degradation and ecological imbalance, (2) the need to avoid impoverishment of future generations, and (3) the need for equity in the quality of life among present-day populations (Redclift 1987). The issue of sustainability addresses the economic, environmental, cultural and social dimension of space-based assumption that the required development must be based on efficient and responsible use of the natural and human resources.

The chapter intends to encourage thinking about a different concept of the functional definition of space, where the spa is the carrier of the development. At the same time, it should encourage the scientific society to think about the correctness of the existing territorial organization in the analyzed area, the hierarchy and the status of the settlements, for the interactions between settlements, as well as other essential issues that would be beneficial for the growth of the region.

Methodology

The research is based on an analysis of the relevant researches done so far and knowledge related to the geological past and the geothermal waters of the region in order to see the available reserves. For the purpose of this research, we considered the East—statistical planning region as one of the eight statistical planning regions according to the NUTS 3 that the territory of the Republic of North Macedonia has been divided to. The researched area is a complex territorial system according to its position, economic, and demographic areal and functional development.

In order to perceive the condition of the spas as objects with a special function in a number of settlements that have the potential for their development, an analysis of the current literature has been done, some personal observations were done as well, followed up with field research, a survey of the current and former visitors of the spa Kezhovica and others. In terms of presenting the statistical data of the spa, a limiting role has the fact that the spa Kezhovica, unlike in the past, it is currently the only entity of its kind in the region and therefore, a greater caution when displaying the data has been imposed. The visual on-site analysis of these locations is also important for understanding the relationship that exists between the object and the natural landscape elements in the immediate surroundings.

While conducting the interview with the visitors of the spas, imposed the observations for the need of modernization of the existing facilities and increasing in the number of services. Despite all the deficiencies, most of the interviewed visitors, especially those aged above 40, said that they have been visiting the spa for many years so far and feel its benefits regarding their health.

Subject and Case Study Area

The East Region is located in the east part of the Republic of North Macedonia. It is mainly a mountainous region and spreads along the Bregalnica River, over the basins of Shtip, Maleshevo and Pijanec, and the field of Kochani. The region comprises 14.2% of the total area of the Republic of North Macedonia. In this region, there are 217 settlements (8 have a status of a city: Berovo, Delchevo, Pehchevo, Vinica, Kochani, Probishtip, Makedonska Kamenica, and Shtip), allocated in 11 municipalities: Berovo, Delchevo, Pehchevo, Vinica, Kochani, Probishtip, Shtip, Zrnovci, Karbinci, Makedonska Kamenica, and Cheshinovo-Obleshevo. According to the population estimates for 2017, this area was populated by 175,616 inhabitants or 49 inhabitants/km^2, which is a density below the national average. In the period between 2002 and 2017, the population number decreased for 5,290 persons, mainly due to the low population natural increase (−488 in 2017) and emigration, mainly abroad but also toward other settlements in the country. In the period from 2005 till 2017, the emigrants from the Eastern region participated with 14.8% in the total number of immigrated persons in the capital Skopje. Even 43% were from the municipalities of Shtip and Kochani where the majority of the population of the region is located, i.e., mainly from the cities. The municipalities Probishtip, Berovo, and Delchevo due to the massive emigration abroad are facing a lack of a sufficient population development contingent (Apostolovska Toshevska et al. 2017). During the period from 1971–1981 to 2002–2013, these municipalities moved from emigration type 1 and 2 to municipalities of emigration type 4. Actually, the situation in the whole Eastern region is alarming because "its demographic indicators, net migration and population natural increase belong to type E4[1]" (Madjevikj et al. 2016) (Fig. 1).

With such a dynamic in the demographic structure, the conditions for economic revitalization of the case study area are aggravated despite the numerous natural

[1]Types of general population movements based on population natural increase and net migration by Friganović, according to a modified Web model E1—Emigration E2—Depopulation E4—Disappearing (Madjevikj et al. 2016).

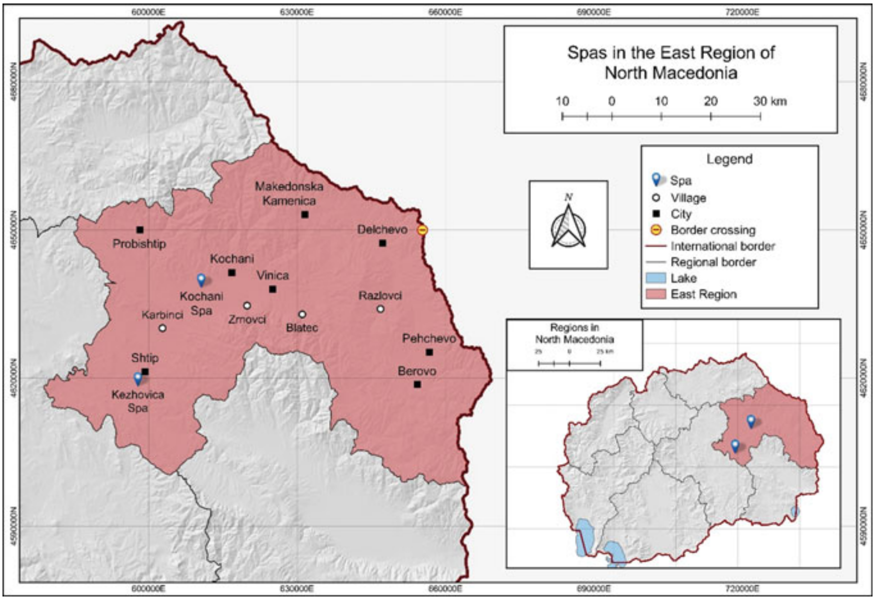

Fig. 1 Spas in the East region of North Macedonia (Author of the map: Antonio Trajkov, bachelor of geography - GIS)

resources that can contribute to overall development. Among the natural resources are also the thermo mineral springs. More precisely, a larger number of locations where thermo mineral water appears are registered. All of these springs differ in the physical–chemical properties of the water, different outflow and water temperature. Some of them are distinguished according to their characteristics and significance. Parts of them were being used in the past and some are used today as well. The extent of usage is variable throughout history depending on the capacity, the interest of using, and the ownership relations. The springs of Novo Selo and the one at the Kochani valley are of primary importance. In the Kochani valley, thermo mineral springs appear near the village of Banja, Istibanja (Trifunoski 1970), near the village of Dolni Polog and Trkanje, while under the vicinity of Novo Selo, Shtip is located the spa called Kezhovica. The springs at Dolni Podlog and Istibanja are used for heating greenhouses, while the springs of Kezhovica and the village of Banja are used for health and recreational purposes.

The spring in the village of Banja has a capacity and power of 30 l/s, and a temperature of 54 °C. The other two springs in the Kochani valley are 300 l/s and a temperature of 70–80 °C. The thermal water is of the sulfur type, with low TDS and radioactivity. It is used for curative purposes against rheumatic, skin and female ailments, inflammation of joints, muscles and veins, and stomach, gall bladder, and urinary conditions (Popovska-Vasilevska and Armenski 2016). Due to such properties, it has been used for centuries. There was a spa located here in the second and third century BC, then in the fifteenth and sixteenth centuries, it was reestablished. In recent history, the spa has been working since 1980 as a unit of the Department of Physical Medicine within the Medical Center in Kochani and functioned well with an annual visit of about 1200 patients and 500 guests until the end of 1985. In 1985 it was completely shut down and at the moment the building is ruined and out of use, although until now there were several attempts to reactivate the spa but they were all unsuccessful. So, for example, after three decades behind closed doors and not working, in 2013, the Ministry of Health is taking measures for reactivating the facility of the spa in the village of Banja, but nothing has been done to put it into function.

Kezhovica or Shtipska Banja is located on the right bank of the river Bregalnica, about 2 km southwest of the center of Shtip, at the exit of Novo Selo, which is attached to this city. The water capacity level at Kezhovica is only 4.5 l/s, the thermal water is of the chloride—hydrocarbonate type and the water temperature is 66 °C. It is used to alleviate rheumatism, joint inflammations, female ailments, some skin conditions, etc. (Georgieva and Popovski 2000). It is also the most radioactive spa in the country with 42-over units (Stojmilov 2011).

It should be noted that geothermal waters can also be used as they are, but they can also undergo some changes in temperature and by heating or cooling to reach a level suitable for a particular need. It points to the conclusion that the water temperature is significant, but should not have the role of a limiting factor for its use, and it can be adjusted to the target, of course, if it is sustainable in the first place.

Several phases can be separated in the development of the Kezhovica spa, and if we take into account the most recent history, then it is obvious that there are periods when it was not in good condition to provide quality customer services or it was improved and intensively used. Until the war, the spa was consisted of a small, low, and non-hygienic building with one general swimming pool, with two kurns (small stone basins with cooling water for washing) (Nedkov 1967). It was renovated in the 60s and the services offered were in cooperation with the health center in Shtip. A lot of resources were used in the past few years to improve the spa, it was also invested in the maintenance of the inner part of the spa, and during the direct field researches, it is concluded that today the users have a well-equipped spa with two swimming pools, shower cabins, accommodation, etc. Apart from the people who are accommodated, as users of the spa, there are people who come exclusively for the use of the water on a daily basis, and they do not accommodate within the spa. “Kezhovica” has a modest capacity of 40 beds, and not such a large number of nights spent are registered on an annual basis. Accommodation facilities are available in hotels in the city and in the private sector. In the period while the research was still on, only one spa was working, that is Kezhovica, while Kochanska Banja has been out of order for many decades so far.

The Spa as a Basis for a Functional Development

The localities where spas appear, thanks to their specific characteristics are suitable for developing settlements with a special function. Usually, the term spa settlements are used for their description. Although the primary role of the spa centers is in the field of health care utilization, the tendency is to be used at a higher level, creating a space for a wide range of developmental sustainable functions in the settlement. The possibilities for achieving this goal lies primarily in the quality of their waters, as well as in their micro and macro position in the region and beyond.

Thermo mineral waters in these settlements are some kind of liquid minerals on the ground surface and have an important economic function. They are economical generators that penetrate into many branches of the economy (Milaku 2012). By increasing consumption, (initiated by the use of thermal waters in a different form), it affects a range of economic and noneconomic activities. Thermo mineral waters are a prerequisite for the development of greenhouse production in agriculture, which can be part of the concept for the development of modern health spa tourism. Today this potential is exploited on a local level. Recently, there are certain activities for modernization of the geothermal system called "Geotherma" in Kochani. The system has been set in 1997, upgraded in 1999/2000 and fully completed in 2011. The waters are used for heating 20 ha greenhouses in Kochansko field and for heating of several public buildings (tree public schools, the Court House and the gym hall). Studies indicate that at a depth of 2000 m, geothermal waters are at a temperature of 114 °C, which has the ability to create sufficient pressure to activate turbines and to generate a current of 3.2 MW, which would be approximately the production of two small hydropower plants.

The potential for using the geothermal energy for heating greenhouses should be correlated with the development of agriculture and the need for greenhouses. In order to achieve this goal, in addition to the activities already undertaken, additional actions are needed by both, the local self-government and the Government (Strategy for the use of renewable energy sources in the Republic of Macedonia by 2020) (Ministry of ecnomy 2010). In conditions of intensive investment in health tourism and the need for cheap energy, investments of this kind would be economically justified.

The locality "Kezhovica—Ldji"—Shtip was granted under the concession of Eko Oaza—Shtip. The exploited Duplex D-1 has a capacity of 1.3 l/sek and a water temperature of 58 °C, and is used for the needs of the spa in Shtip as well as for the Physical Therapy Institute.

In the case study area, as well as at the territory of the whole country, spa is mainly understood as a place where the intention is to go and get healed. Hence, spa tourism is closely linked to the medical tourism and is under the influence of the type and shape of the health insurance. The vision of Lasak (2008) is quite true, according to which, this type of tourism will be one of the fastest-growing sectors in the tourism itself. This can be explained by the aging of European societies, the increased public awareness and the desire to take care of their own health, among young people and among adults, but also the increased property possession of some people. It is a widespread view that medical tourism, among others, in health resorts, will be one of the most dynamically growing sectors of tourism. Undoubtedly, this can be explained by the aging of the European societies, increased public awareness, and the willingness to care about one's health, both among youths and elderly people, as well as by the increasing wealth of people (Lasak 2008). The quality development of the spa areas should be followed up by the parallel dynamics of the development of the medical and the tourism sector. In a well-organized and well-thought-out spa place, apart from the health programs (which are usually in the function of healing), other tourism contents (sports-recreational, wellness) should be complemented as a single product of tourism, but also as an advantage to a particular tourist destination.

Although in Europe the idea of wellness was common practice in the 80s of the last century as a form of tourism, in the United States from the 1960s until today is a way of life. In our conditions, the modest steps are to actualize this type of tourism with the direct use of geothermal water. Regarding the current trend of tourism development, in terms of demographic changes and aging of the population (Vágner 2013) in the part relating to human health, it moves from the classic spa to the modern health tourism, which besides the medical component (preventive, curative, and rehabilitation) includes other components (wellness, sports, recreation, entertainment, healthy food, etc.) which can attract sick people for whom the state pays for the treatment and rehabilitation through the health care system, but also the healthy individuals that are aware of their own health and condition, to fund their own vacation at a spa and in climate places, in other words in destinations suitable for health tourism. Wellness itself initiates a state of mind and body in a harmonious balance, but can also be defined as a facility for the realization of procedures aimed at understanding wellness philosophy (Cathala 2007). In this context, the overall conception of space should be guided by the needs of the tourist according to Corbin's well-known conception (2002) (physical activity—to be in shape, to feel good; psychological balance—to be satisfied and optimistic; socialization—to be communicative and to enjoy society; mental state—to feel complete; esthetic experience—to be satisfied with its appearance; education—to learn something new; contact—to experience the environment and to enjoy nature). On the other hand, according to ISPA (2008, 2009), the demand for baths, spa, and wellness services is also being conceived according to the demand of users (demands by the baby boomers, wellness as a way of life, spa retreat, searching results, socialization, gender, travel experiences, detox, etc.). The quality of the spa environment and a well-designed integrated health tourism product at these locations can become the most important motive for a tourist visit to the spa areas.

This implies the necessity for a more intense connection of the medical health function of the spa complexes with sports-recreational, cultural, congressional and tourist-manifestation activities. In fact, as a special attractive destination, they should develop an original offer based on their advantages, to create and retain their own recognizable tourism product. But, the alternative development model goes on to a higher level, to create more contents and terms for intensive recreational use of the spa waters. This means a transformation into geothermal centers. It means that besides the geothermal recreation pools, a whole package of services would be offered as a hotel accommodation, restaurants, conference halls, and ski lifts. “The ultimate stage of the development of these centers consists of all-comprising, multifunctional recreational centers, referred to as “total resorts”, bringing together multiple functions at one location.” (Jarczewski et al. 2013). The recreational role of these sites can increase and attract a large number of visitors. But their success highly depends on the “geothermal resources, tradition and history, cultural trends associated with the use of hot water for recreation” (Jarczewski et al. 2013). The best form for achieving the recreational function are the aqua parks and amusement parks too, like a new type of leisure establishment. They become increasingly multifunctional by providing pool facilities in combination with entertainment, sports, relaxationm and other services, (Čuka et al. 2013). The goal is to attract a larger number of tourists from different age categories for several days. This way, they are becoming a part of the fast-growing tourism sector.

In addition, as beneficiaries of the services that have developed thanks to the spas, is not only the local population, or the population from the near surroundings, but also the population in the region and beyond. In fact, it is normal for them to generate profits from users outside of these settlements, but for that, a whole set of measures aimed at their development and affirmation is needed.

Providing multifunctional importance of these locations, in addition to the activities related to the spa, medical and wellness tourism, other types of economic and noneconomic activities will be developed, i.e., they will receive a diverse economic structure that encourages a complex development of the settlements and the region as a whole. Given the complexity and importance of the spa sites, a lot of work is needed to be done for their valorization, to increase the degree of their traffic connection, increase and modernize the accommodation capacities, improving the supply and orientation toward foreign guests. The effects of all this would be felt in several segments. The prosperity of the space created by the activities based on the potential of the thermo mineral sources in the region and other potential activities, it should inevitably lead to an increase in employment in this, but also in other complementary activities. The income generated by these activities can be used to improve the quality of life, better satisfaction of public needs, etc. Taking into account the needs of modern spatial planning, there is a fundamental need to perceive the meaning of each settlement in the surroundings, what its functional structure is and what are the economic potentials for sustainable development. In this context, the resources that the spa settlements have, are put into the function of the development of these settlements and also on a wider level development, too.

The dominant importance of the geothermal resources in several areas contributes in creating the functional specialization of the spa areas and a special functional classification based on this activity. At the same time, it is possible to identify the spatial rules and laws that appear in the distribution and the structure of the functions. However, this should further be the basis for formulating the development hypotheses for the region. Activities based on this potential can serve to improve the efficiency and increase the attractiveness of these settlements for future investment cycles (Fig. 2).

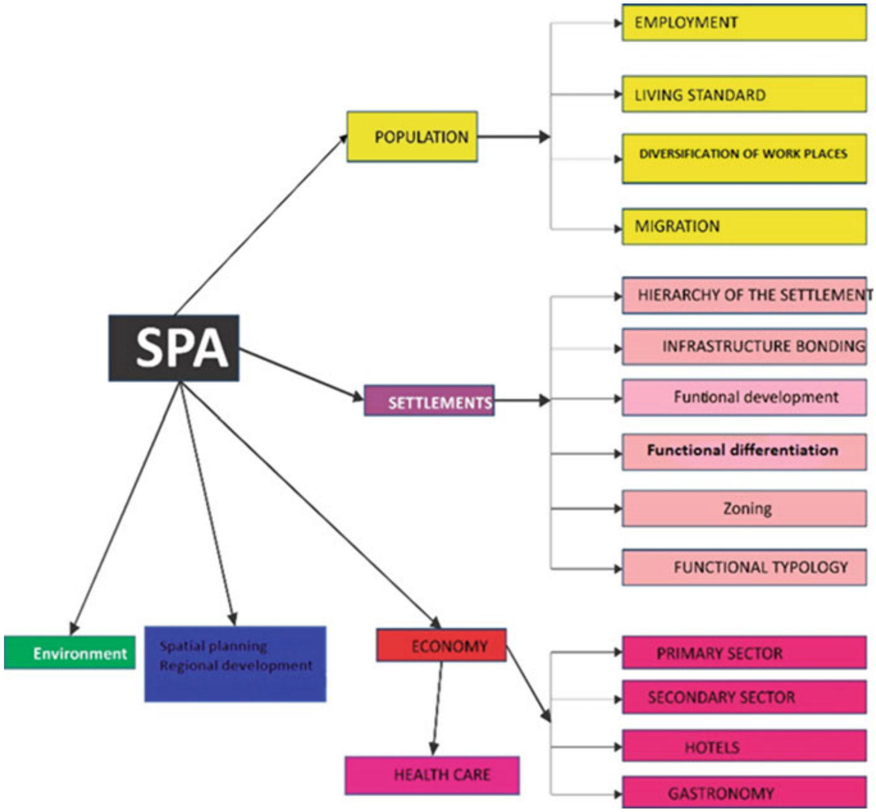

Fig. 2 The spa as a basis for a functional development

Conditions and Guidelines for Improving the Spa to a Role of a Pulsator of a Functional Development

The location of these spas is very favorable compared to the rest of the spas, which creates an adequate basis for visiting by the inhabitants of the wider surroundings. Namely, there are no other spa centers in the region. The large distance of Katlanovska spa, Kumanovska spa and Strumica spa, provides an absolute primacy to use for the population of the surrounding. At the same time, situated among the cities of Veles, Shtip, Kochani, Vinica, and Delchevo, these spas represent a great and nearby destination for recreation and rehabilitation for the inhabitants of these cities. The modern road infrastructure toward Shtip and Kochani only contributes to the possibility of more visitors. Regarding the distance of the Kezhovica spa from the city centers in the country, it can be noted that even 19 cities (of the total 34) are separated less than 100 km. Among those cities is Skopje where lives one-third of the total population in the country (Fig. 3).

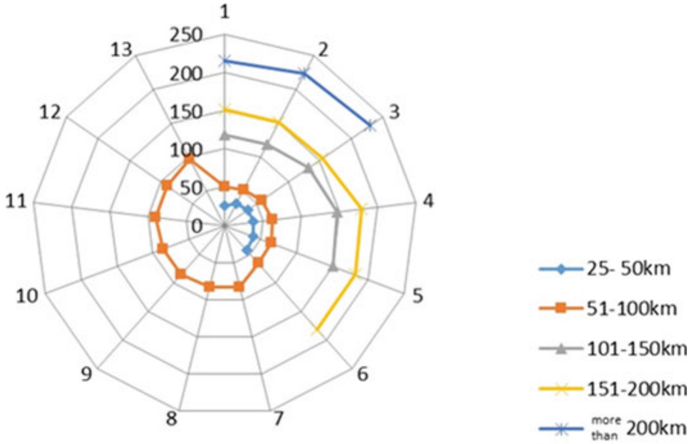

Fig. 3 The distance between Kezhovica spa and the city settlements. *Data sources* http://za.toponavi.com/101700-20332; www.amsmspi.mk

On the other hand, the location of the spa and the relatively small distance from the border crossings, especially the closeness to Bulgaria, Serbia, and Greece are very favorable for an increased attractiveness for the visitors from the neighboring countries (Table 1).

Also, the spa settlements are located near an extremely rich Bregalnica archeological site, near winter sports center, significant religious facilities, which creates a basis for the development of multipolar spa tourism.

The spa Kezhovica and Banja offers great opportunities. In order to use these thermal waters as a significant potential for the development of the region, a reconstruction is needed and also a complete renovation of the facility, its modern improvement with medical and other types of equipments too. There is the potential to form a modern spa complex for developing modern health tourism, with a modern spa center whose benefits can be enjoyed by residents from the region and beyond. If modern centers for physical medicine and rehabilitation are formed, which will be used for the geriatric and palliative care, they will create predispositions for the development of spa tourism. This could positively affect the development of the settlements of

Table 1 The distance between Kezhovica spa and the border crossings

75–100 km	101–150 km	151–200 km	More than 200 km
Tabanovce		Jazhince	Stenje
Border crossing Delchevo	Dojran	Medjitlija	Blato
Novo Selo	Blace		Kjafasan
Pelince	Bogorodica		Sveti Naum

the municipality where the spas are located and wider, in the entire Eastern region and will provide opportunities for creating new jobs in other areas. This potential in combination with other resources from the immediate surroundings can play the role of one of the impulses for the functional development of the Eastern Region. This will contribute to its affirmation and at the same time its sustainable development. Taking into account the resources available to the region, it is necessary to undertake more specific measures that will lead to greater appreciation of the spa sites, their recognition wider in the region and their wider affirmation.

In terms of the thermo mineral resources, it is necessary: to start with the inventory of all sources; providing protection of the springs and the places of use of the thermo mineral waters; monitoring the quality and quantity of waters due to the possibility of reduced outflow or quality change due to pollution; continuous monitoring of the influences of the waters to the healthy and sick people; encouraging various research for multipurpose use of water in medicine, health, the wellness tourism, pharmaceutic, and the cosmetic industry.

It is necessary to realize the appropriate line and suprastructure, appropriate professional staff and providing conditions for its settling in the area. Providing an appropriate team for planned management of the use of resources, enriching the offer. Using the experience of several European countries (e.g., Vishegrád), it is necessary to tend to maximize the economic benefits of the country from this type of tourism, increasing the volume of domestic tourism, imposing the spas as a brand for this type of tourism and connecting with certain other cultural events in the region and beyond (Matlovičová et al. 2013), as well as a common tourist offer with neighboring Bulgaria. It is certainly necessary to encourage the local community to support and develop the spa tourism, sustainable use of resources, and also building their own identity. Open opportunities for increasing the interest of foreign investors for this area and related activities.

The ambitions should be directed toward the qualification of the spas as Wellness spa, Medical spa, and gaining a Green Global Certificate. It means building spas that will grow into tools of affirmation mainly according to the concept of organization, location, facilities, design, staff, rituals, and procedures and product selection (Jovanović 2013). But, this depends largely on the investment and promotion of this type of tourism in the region. As a basis, the main question in promoting the domestic tourism of a country is connected with the purposely intended financial amount for promotion and the way of promoting. The sponsoring of those interested in the development of this business sector would surely bring in profit. On the other hand, it may be a foreign investment with respecting the principles of maintaining the resources.

In the future, conception of development of these places is the idea of a type of a "partnership" between companies and spas. Specifically, certain companies would show greater interest in cooperating with the centers for improving motivation, building relationships, encouraging creativity and working capacity among employees. In all this strategy, it is important to note another moment, which is the education for taking care of our own health from the earliest age (Table 2).

Table 2 SWOT analysis

Strengths	Weaknesses
– Relatively favorable resources of geothermal waters in quality and quantity – Location links to the surrounding cities – Location links to the other nearest spas – Proximity to other tourist motives of nature – Proximity to other tourist motives of the cultural heritage – Relatively clean environment – Tradition of using the spas during treatment	– Emigration of young population – Low population density in certain areas – Weak line infrastructure and suprastructure – Insufficient accommodation capacity in quality and quantity – Weaknesses of the public administration – Legally unresolved property issues – Insufficient service provider's network – No tradition in using thermal water for recreation – A lack of strategy for the development of spa tourism
Opportunities	**Threats**
– Spatial construction possibilities – Use of geothermal waters for different purposes (tourism, heating, electricity) – State grants for domestic investors – Attracting foreign investment – Enriching the tourist offer – Establishing strength cooperation between the relevant institutions, municipalities and the region – Access to certain funds – Standardization and gaining certificates – Possibility for interstate cooperation with Bulgaria, – Tourist promotion of the region	– Population aging and low birth rate – Uneven population distribution – Low motivation for living in the countryside's – Lack of state aid due to the replacement to the government and inconsistency in the implementation of development policies – Insufficient properly educated labor force – Unfair competition – Strong rivalry from the spas in the surrounding countries (Serbia, Bulgaria, and Greece) – Lack of funds and investments – Degradation of the environment – Nonrational use of natural resources

Conclusion

The spas in the East Region have the potential to become pulsators of the development in the region. The positive effects of their operations would enable a fully functional, sustainable development in all segments of the population and economic shaping of the region.

According to the analysis of the existing condition and despite the qualities of thermo mineral waters and the good location, the utilization is quite small. The small number of visitors, the inadequate facilities for accommodation, the realized nights spent and more are only indicating that this natural resource is not used for the sustainable functional development of the region. The idea is developing spa tourism supplemented by health and wellness tourism. It is the basis that should incite other forms of alternative tourism, connecting spa sites with other settlements in the region that have the potential to attract visitors. This way, it is possible for the services in the area to be used by people from different age groups and people with different motives for staying in the region. On the other hand, we need to compare the development with the domino effect. One investment is an inducement to another, one job is the basis for the inducement of other jobs. The activities based on this potential can contribute to improving on the efficiency and increasing the attractiveness of these settlements for the future investment cycles in these and other activities. In the future development of local spa sites, it must be ensured that they will be environmentally protected, protected from pollution, protected, and conserve from unplanned development policies.

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Landscape Ecology

Georgi Zhelezov

Tree Cover and Biomass Carbon on Agricultural Land in Mala Planina

Borislav Grigorov and Assen Assenov

Abstract Agroforestry is a neglected link in the carbon storage, and the role of trees in carbon sequestration in these systems is significantly underestimated. They can be used as a tool in climate change mitigation. Moreover, they can provide subsistence farmers with unexpected benefits, such as lower erosion levels, increased habitat and landscape diversity, cleaner air and many others. The main aims of the current investigation are to examine the presence of a tree cover on agricultural land in Mala Planina, which is located in the Western Balkan Range and to study its role in carbon collection. The maps of tree cover and biomass carbon on agricultural land in the mountain are derived from the Center for Mountain Ecosystem Studies (CMES), Kunming Institute of Botany/World Agroforestry Centre for Global Tree Cover and Biomass Carbon on Agricultural Land (http://www.worldagroforestry.org/global-tree-cover/data-download.html), provided by Zomer et al. (Sci Rep 6:29987, 2016) and processed to uncover the current status. The results of the investigation show that 3391 ha, equivalent to 33.91 km^2, of the agricultural land in Mala Planina are covered by trees, which are responsible for the storage of 1,344,135 kg C/ha.

Keywords Tree cover · Biomass carbon · Climate change mitigation

Introduction

Nowadays, climate change is one of the most discussed phenomena and scientists from around the world are racing to investigate the reasons and the consequences, regarding its occurrence. Researchers provide different measures for adaptation and/or mitigation to climate change and examine the reasons behind the storing of carbon in nature systems and the carbon cycle, as a whole. Oceans and soils are among the most acknowledged carbon sinks in our planet that are participating in global carbon budgets. At the same time, trees are known to capture carbon dioxide in the process of photosynthesis, making forests another essential link. However, trees are not only present in the vast, extensive biomes of boreal forests, temperate decid-

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uous forests and tropical rainforests, but they are becoming a more integral part of the agroforestry systems. Trees on agricultural land are a neglected link in the carbon storage and their role is significantly underestimated, as Zomer et al. (2016) argue. Erudites are well aware of the fact that the increasing population of the world will need more arable land, which will surely make an impact on the global carbon storage, as it is discussed by Bondeau et al. (2007) and Johnson et al. (2014). According to the study of Zomer et al. (2016) about the global tree cover and biomass carbon on agricultural land, 43% of this land had at least 10% tree cover in 2010 and the number has increased over the years, while at the same time, tree cover and, consequently, biomass carbon on agricultural land are being higher in humid regions. Agricultural land on the planet takes account for 45.3 PgC and trees contribute >75%. These numbers are providing an insight of the importance of tree-based carbon sequestration on agricultural land. Woody biomass has the potential to make a great contribution in the mitigation of the effect of carbon dioxide, as a major greenhouse gas (Albrecht and Kandji 2003; Nair 2012).

Trees on agricultural land do not only sequester carbon but also play an important role for farmers, dealing with subsistence agriculture (in the current case in Mala Planina). Farmers can get multiple additional benefits from tree biomass, coming from the increased landscape and habitat diversity, less erosion, less dust pollution, cleansed air, watershed conservation, and so on.

As it was previously discussed, agricultural expansion is a process that is going to continue intensively in the future decades and there are few places left in the contemporary world where this type of land use is not occurring due to the impediments of the physical geography. Agricultural production is growing extensively in the lowlands of the temperate areas, for example, but the highest rates of conversion of natural vegetation into arable land is in the tropics where around 80% of this expansion is due to the replacement of the local forests (Foley et al. 2011). As we are well aware of the fact that the expansion of agricultural land will move forward, a set of measures will be needed in order to relieve human pressure and limit the loss of forests and their ability to store carbon. One of these measures is agroforestry. In its essence it is the process of growing trees and integrating them in croplands, pastures, and so on, and ecologists have proved that these landscape systems can be more productive and healthier. Furthermore, agroforestry, with the above and below ground biomass carbon that this system stores, is becoming more recognized for its role and contribution to global carbon budgets (Schramski et al. 2015).

Important contributions on the investigated subject and especially on mapping have been by Bartholomé and Belward (2005) who present a new approach to global land cover mapping, DiMiceli et al. (2011) and Hansen et al. (2003) who work on spatial resolutions and Trabucco and Zomer (2009) who study global aridity index and global potential evapo-transpiration. At the same time, Houghton (2005) investigates forest biomass and global carbon and Alexandratos and Bruinsma (2012) discuss the problems of world agriculture that will concern future generations.

Data and Methods

The current investigation is dealing with the significance of tree cover on agricultural areas in a mountainous territory, located in the Western Balkan Range, called Mala Planina. The mountain is situated to the south of Ponor and Chepun Mts, to the west of the Iskar Gorge and to the north of Sofia Valley. This particular territory was picked out because of its proximity to the capital city of Bulgaria, thus being one of the "lungs" of Sofia and the presence of agricultural landscapes with integrated trees in them. Here we use the study of Zomer et al. (2016), where the significance of woody biomass in agroforestry systems for carbon sequestration is assessed at a global level, as a basis. In that study, the authors include three agricultural land use types from the Global Land Cover 2000 database in their "Agricultural Land" class: cultivated and managed areas (agriculture—intensive); cropland/other natural vegetation (non-trees: mosaic agriculture/degraded vegetation) and cropland/tree cover mosaic (agriculture/degraded forest). They estimate the total biomass carbon in million tons of C on agricultural land, and according to them the total agricultural area of Bulgaria is 62,433 km^2. The total biomass carbon for 2010 in this area of the country is 43 million t C with an increase by 7.4% since the year of 2000 and the average biomass carbon on agricultural areas in Bulgaria for the 2010 is 6.9 t C/ha.

Zomer et al. (2016) also provide the following six online datasets in TIFF format in geographic coordinates (GCS: WGS-84): Global Tree Cover on Agricultural Land—2000; Global Tree Cover on Agricultural Land—2010; Change in Global Tree Cover on Agricultural Land—2000–2010; Global Biomass Carbon on Agricultural Land—2000; Global Biomass Carbon on Agricultural Land—2010 and Change in Global Biomass Carbon on Agricultural Land—2000–2010. Two of them are an integral part of the current investigation: Global Tree Cover on Agricultural Land—2010 and Global Biomass Carbon on Agricultural Land—2010. Their datasets labeled with the year "2010" represent an average value of the years 2008–2010. All datasets can be acquired at the web page of the Center for Mountain Ecosystem Studies (CMES), Kunming Institute of Botany/World Agroforestry Centre for Global Tree Cover and Biomass Carbon on Agricultural Land (http://www.worldagroforestry.org/global-tree-cover/data-download.html).

Data values in the Tree Cover dataset display the percentage of tree cover and range from zero to one hundred. They are actually representing the percent of the grid cell, covered by trees. If this is to be illustrated with an example—30% tree cover of the 1 km^2 grid cell would represent 30 ha, covered by trees, 10% tree cover would represent 10 ha, covered by trees within the total number 100 ha (100 ha = 1 km^2).

Data values in the Biomass Carbon dataset are accounting for the above and below ground biomass carbon on agricultural land. Values can be acquired in the units of kg of carbon per hectare (kg C/ha) or tons of carbon per hectare (t C/ha).

Research Findings

The analysis of the results will be separated in two sections, covering data about tree cover and biomass carbon on agricultural areas in the studied area. Tables 1 and 2 present information, derived from the datasets of Zomer et al. (2016) that concerns the territory of Mala Planina, completed with the two maps in Figs. 1 and 2. These maps are further processed in order to discover the current status, showing data 10 years after the cited study.

Tree Cover on Agricultural Land in Mala Planina

Data about tree cover is displayed in Table 1 and Fig. 1. Table 1 shows the total area of a certain polygon value in the first column. As we can see, there are different ranges for the tree cover of any polygon. The authors share the opinion that the presented ranges are the best option for the analysis of the information, giving an exhaustive and comprehensive information at the same time. Taking in mind that each polygon represents a grid cell of 1 km^2, there are 221 polygons with different range of tree cover, equaled to 221 km^2. The whole territory of Mala Planina is 351.3 km^2 so they make 62.9% of it. If we take polygons, covered with woody biomass within

Table 1 Tree cover on agricultural land in Mala Planina

Tree cover on agricultural land		
Total area of each range of tree cover (km^2)	Tree cover for 1 km^2 grid cell	Total tree cover for each range within the average coverage (ha)
34	3.000000001–7 ha	170
65	7.000000001–11 ha	585
42	11.00000001–15 ha	546
28	15.00000001–19 ha	476
15	19.00000001–24 ha	322.5
16	24.00000001–28 ha	416
3	28.00000001–32 ha	90
1	32.00000001–37 ha	34.5
8	37.00000001–41 ha	312
5	41.00000001–45 ha	215
1	50.00000001–54 ha	52
2	54.00000001–58 ha	112
1	58.00000001–62 ha	60
Total tree cover on agricultural land in Mala Planina 3391 ha = 33.91 km^2		

Table 2 Biomass carbon on agricultural land in Mala Planina

Biomass carbon on agricultural land		
Total area of each category of biomass carbon (km^2)	kg C/ha for 1 km^2 grid cell	Total biomass carbon for each range within the average coverage in kg C/ha
118	4350.000001–6040	613,010
80	6040.000001–7380	536,800
18	7380.000001–8870	146,250
5	8870.000001–10,360	48,075
Total biomass carbon on agricultural land in Mala Planina 1,344,135 kg C/ha		

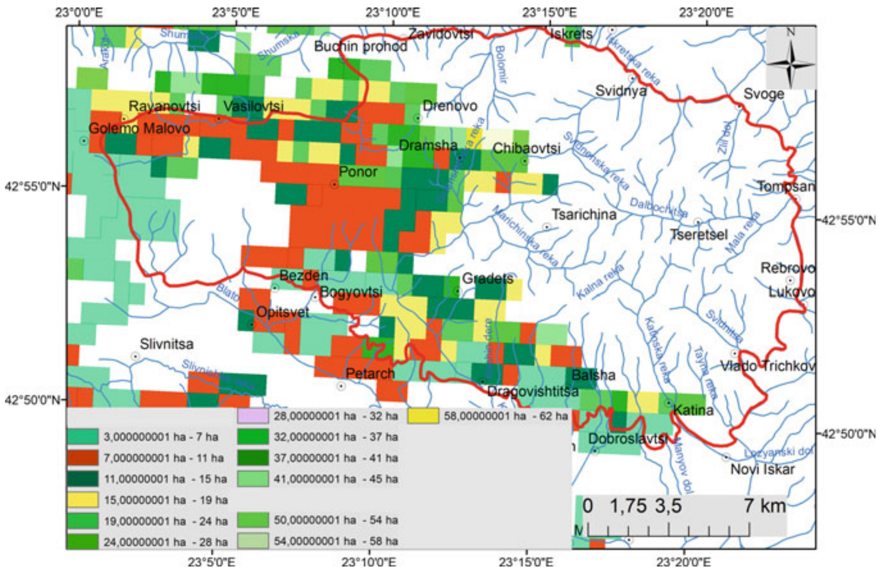

Fig. 1 A map of the tree cover on agricultural land in Mala Planina (following Zomer et al. 2016 http://www.worldagroforestry.org/global-tree-cover/data-download.html)

the lowest range between 3.000000001 and 7 ha, we will find that there are 34 of them, comprising an area of 34 km^2. It is clear that some of the polygons can have a tree cover near 3 ha and some of them near 7 ha. In order to get impression of the overall territory that is covered with wood in this agricultural area, we chose to take the average sum, which in this case is 5 ha. Moreover, a new map layer was created, using the World Imagery Basemap in ArcMap 10.1. Polygons with the current tree cover on agricultural land were shaped for all tree cover ranges and their areas were summed. Calculations show that there is only a slight, neglected difference in the total areas and in order to keep the scientific correctness, the already mentioned average sum of 5 ha was selected. So if we multiply this average number with the

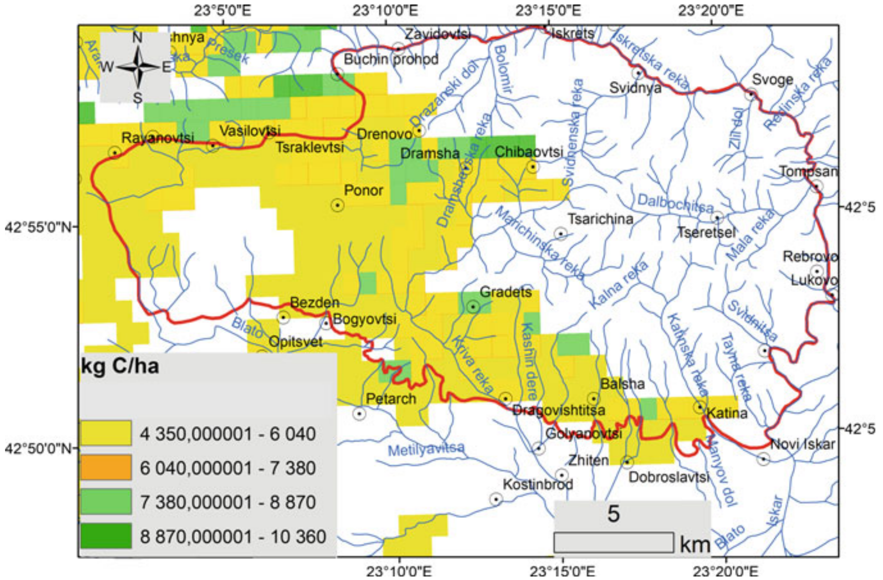

Fig. 2 A map of biomass carbon on agricultural land in Mala Planina (following Zomer et al. 2016 http://www.worldagroforestry.org/global-tree-cover/data-download.html)

total area of 34 km^2, we will find that there are around 170 ha of tree cover for this range. The same calculations are done for all other polygons, leading to the total area, covered by trees—3391 ha or 33.91 km^2. Here trees are unequally dispersed within the territory and present 15.3% of the whole agricultural land. Based on the potential of arable land, the authors think that this number can be increased, which will lead to the sequestration of more carbon. However, this should be done in a manner, preventing the loss of the main agricultural purpose of these lands.

Agricultural territories of Mala Planina, covered with trees, that are taking area between 3.000000001 and 7 ha, are located in a narrow belt from the village of Rayanovtsi, situated in the western part of the mountain, moving south near the boundary of Mala Planina and then with a few interruptions go around the villages of Bezden, Bogyovtsi, Dragovishtitsa, Balsha and Katina. They are representing the lowest range of tree cover in Mala Planina. The next place is for agricultural areas with a tree cover within the range 7.000000001–11 ha. They are situated mainly in the central to western part of the mountain between the triangle that the villages of Ponor, Bezden and Gradets form, as well as near the villages of Rayanovtsi, Vasilovtsi, Tsraklevtsi and Dramsha. These polygons are by far the most frequent in Mala Planina, taking up to 65 km^2. After them are the agricultural territories with a tree cover between 11.00000001 and 15 ha. They form a mosaic near the villages of Gradets, Dramsha, Tsraklevtsi and cover 42 km^2. All these three territories, being 63.8% of the whole agricultural areas with tree cover on agricultural lands in Mala Planina, are providing up to 38.4% of all hectares with woody biomass, which represents inequality. Although the presence and the provided services of these climate change mitigators are undisputable, the capacity of the discussed agricultural lands is not full enough and more native tree species (*Quercus* sp., *Fagus sylvatica, Carpinus betulus, Acer* sp., *Fraxinus* sp.) could be planted there in order to boost their potential as carbon collectors.

The next three ranges are between 15.00000001 and 28 ha and are covering 59 km^2 in total. They are disjunctively situated near the villages of Chibaovtsi, Dramsha, Ponor, Drenovo and Buchin prohod. The same deduction can be applied to them as well, because their potential for tree planting can also be increased. Moreover, together with the previous three ranges, they make over 90% of the mountainous area, which means that there is enough agricultural land at present.

The other polygons with tree cover on agricultural areas form a chain near the villages of Dramsha and Chibaovtsi and they can also be found around the village of Gradets. The cover with woody biomass there can reach over 62 ha, which is a bit higher value than the previously discussed. This can be used as an example of the potential that can be reached within the agricultural territories without preventing them to provide the necessary production for farmers.

By combining all polygons with a tree cover on agricultural areas in Mala Planina, we found out total cover. It is equaled to 3391 ha or 33.91 km^2. This is a quantity large enough, however, normally neglected by scientists in their investigations on climate change mitigation. Nonetheless, trees on agricultural land play their important role, as a carbon collectors and calculations in the studied mountainous territory prove that fact.

Biomass Carbon on Agricultural Land in Mala Planina

Mala Planina is a local carbon sink and this is not only proved by the presence of intact forests with native vegetation, such as those near the highest peaks like Tseria (1234 m). Another testimony is the stored biomass carbon found on agricultural land. Data about it can be acquired from Fig. 2 and Table 2.

Unlike the situation with tree cover, biomass carbon on agricultural land in Mala Planina is presented within four categories. If we compare the map, representing the biomass carbon with the one, displaying the tree cover, a certain correlation becomes obvious. The largest territories (118 km^2) hold a biomass carbon between 4350.000001 and 6040 kg C/ha and they lay within the same areas with those three ranges with the least tree cover (near the villages of Dragovishtitsa, Balsha, Bezden, Bogyovtsi, Ponor, Vasilovtsi and Rayanovtsi). The explanation is logical enough and is a piece of evidence for the great influence of trees on collecting carbon. This interrelation stands for all four categories, presenting the biomass carbon on agricultural land and the tree cover—the more tree cover, the larger quantity of biomass carbon. Another verification of this is the presence of the territories, containing the highest range of the biomass carbon, covering 5 km^2 and situated around the villages of Chibaovtsi and Dramsha. They are overlapping agricultural areas with tree cover of around 50 ha. An important moment that makes an impression is the great difference between the total area of the territories with the highest and lowest sums of biomass carbon. Areas with biomass carbon between 4350.000001 and 6040 kg C/ha are 23 times more than those that are containing near as double biomass carbon more—8870.000001–10,360 kg C/ha. However, despite the great territorial contrast between these two categories, the difference between the total biomass carbon is less than 13 times. This demonstrates that it is more essential to have a higher concentration of tree cover on agricultural territories than just vast areas with lower concentration or if it is to be said in other words—the intensive is more effective than the extensive.

The last two categories have a biomass carbon between 6040.000001–7380 kg C/ha and 7380.000001–8870 kg C/ha, being 36.2 and 8.1% of the whole agricultural area, respectively. The first category has a meridional distribution from the village of Buchin prohod to Drenovo, Dramsha, Chibaovtsi, Ponor and Dragovishtitsa. The second one can be discovered near Gradets and in the triangle between the villages of Dramsha, Drenovo and Ponor. Again agricultural areas with more tree cover contain large amount of biomass carbon, which is a demonstration for the already determined correlation.

Conclusion

The present investigation deals with a problem that is of a present day importance. The ignored tree cover on agricultural areas in global and regional calculations has proven to be an important link in the carbon pool. If tree cover is accounted for, as it should be, the total estimates for Mala Planina in collecting carbon, as a local carbon sink, are much higher than they would turn out to be when only forest landscapes are examined. Tree cover on agricultural land in Mala Planina sequesters carbon, thus having high climate change mitigation potential. Part of the arable territories has the resources for increasing the planting of wood on them, thus expanding their ability to collect carbon dioxide, but not only. Trees on agricultural land also provide more ecosystem benefits coming from less erosion, increased habitat and landscape diversity, and many more.

The whole territory of Mala Planina is 351.3 km^2 and there are 221 polygons with different range of tree cover, equaled to 221 km^2, so they make 62.9% of it. The total area covered by trees is 33.91 km^2, and trees are unequally dispersed within the territory and present 15.3% of the whole agricultural land. The villages of Drumsha, Chibaovtsi, Balsha, Kutina, Dragovishtitsa are one of those where tree cover on agricultural land may be found and the same villages can be highlighted when it comes to biomass carbon, which can be explained by the certain geographical and ecological differentiation.

The examination of agroforestry in a local territory, such as Mala Planina, presented by 3391 ha, equaling 33.91 km^2 of tree cover, taking 1,344,135 kg C/ha, proved that its significance should not be underestimated and it should be acknowledged as a technique for climate change mitigation. Data provided by Zomer et al.

(2016) were applied to a local territory. Despite the fact that it displays the tree cover 10 years ago, new calculations were set out, showing the current status and proving only a neglected difference in the values. The authors advise that agricultural territories' potential can be developed more, because they can sustain more tree cover. This should be recognized and incorporated by the farmers and the authorities—as the results confirm, the more present woody biomass, the more carbon sequestration. The plantation of the native *Quercus, Fagus, Carpinus* and *Fraxinus* species is recommendable in order to develop the best ecological conditions and to unlock the mountains' potential. Plantations should also concentrate in areas where tree cover consists of coniferous species, which are being attacked by a bark beetle and whose ecological condition is expected to decline in the near future, leading to a loss of wood biomass.

The successful outcomes of the current study can be applied in other agricultural areas in the country and they can be used for broadening this geographic prospect in the whole Western Balkan Range. As a matter of fact, the geographic perspective may be extended to the western neighboring countries of Bulgaria, due to the geographic continuality of natural units and the presence of similar problems with agricultural areas in their territories.

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Multiannual Monitoring of Heavy Metals in the Bottom Sediments of the Blagoevgrad Bistritsa River Basin

Nadezhda Nikolova

Abstract The aim of the present work is to evaluate the ecological status of the Blagoevgrad Bistritsa River and part of the Struma River Valley through long-term monitoring of the heavy metal content (Cu, Zn, Pb, Cd, Mn) in the bottom sediments. A survey was carried out between 1988 and 2018 along the two rivers in sections before and after the influx of Blagoevgrad Bistritsa. Samples were collected in background and anthropogenic areas during low tide in autumn. The following tasks were carried out in order to achieve the stated objective: to provide basic information on the concentration and distribution of heavy metals in the bottom sediments of the Blagoevgrad Bistritsa River and the middle current of the Struma River; to assess what parameters affect this distribution; and to determine the effect of the urbanization and industrial activity of Blagoevgrad on the aquatic landscapes.

Keywords Environmental status · Bottom sediments · Heavy metals · River basin · Multiannual monitoring · Anthropogenization

Introduction

Urbanization processes lead to an increasing impact of anthropogenic factors on water bodies. Small rivers are especially vulnerable if they run through urban environments. The high density of the population and the considerable industrial potential concentrated in the town of Blagoevgrad contribute to the pollution of the river system. In the process of economic activity in the region for a long period of time, the state of the drainage artery of Blagoevgrad Bistritsa River has changed. Large volumes of untreated or conditionally clean industrial water were discharged into the river.

Heavy metals are among the most common pollutants of waters, soils, and biota of natural and anthropogenic origin. These are chemical elements with a density above 5 g/cm^3 which have a negative impact on living organisms (Sparks 2005). The serious danger of heavy metals lies in their high toxicity at relatively low concentrations and

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their bioaccumulation ability. Their different migratory capacities lead to significant differences in the extent of their accumulation in the bottom sediments and in the individual stretches of the river. The majority of trace elements, especially heavy metals, cannot be in a dissolved state for a long time and are therefore present in water mainly in the form of colloidal solutions or attached to organic or mineral substances (Foster and Charlesworth 1996). In turn, the bottom sediments have a high sorption capacity (especially the fine fraction) and accumulate heavy metals as well as the entire complex of chemical elements present in the water. Therefore, they are used as the main indicator of the ecological status of the water body. The rates and volumes of bottom deposition as well as the extent of their contamination are different throughout the river basin, allowing to track both the impact of the changing anthropogenic load over time and the change in natural self-purification processes in the river (Bubb and Lester 1994).

Thus, bottom sediments reflect the specifics of migration and concentration of substances in the catchment areas and are particularly important informative objects, as practically all economic activities form and discharge wastes which contain a complex of pollutants into the river systems. Besides being a heavy metal accumulation environment, bottom sediments can, under certain conditions, become a secondary source of contamination in the small rivers (Podlasińska and Szydłowski 2017). Therefore, they were used to assess the possible anthropogenic heavy metal contamination in the Bay of Blagoevgrad Bistritsa for the period 1988–2018. The beginning of the monitoring was set by Penin in 1988 (Penin 1989) when a complete inventory of bottom sediments was carried out in the Struma River Basin and the Blagoevgrad Bistritsa River. According to the methodology, three points were tested—the estuary of the Blagoevgrad Bistritsa River after Blagoevgrad and the Struma River before and after the Blagoevgrad Bistritsa River. In 2008, as part of a project for the study of the ecological status of the Blagoevgrad Bistritsa River Basin, samples were taken for analysis from the same sites as the network was expanded by another two additional points. For the purpose of this study, 2018 samples were taken for analysis from the same sites.

Study Area

The studied area is the catchment area of Blagoevgrad Bistritsa River, which is a left tributary of the Struma River. Its catchment is formed on the territory of the Rila Mountain, and the valley occupies a central position in the southwestern part of the mountain. It divides it into two main orographic ridges: the northern Arizmanishko Ridge and southern Parangalishko Ridge (Fig. 1).

The river takes its source at an altitude of 2385 m, on the southern slope of the Golyam Mechi Peak (2617 m). It runs to the west, crosses the Bodrost resort, the village of Bistritsa, the town of Blagoevgrad, where it flows into the Struma River. With its total length of 41 km, Blagoevgrad Bistritsa River is the longest river in the southwest Rila Mountain. The total area of the catchment area is 208 km^2, with the

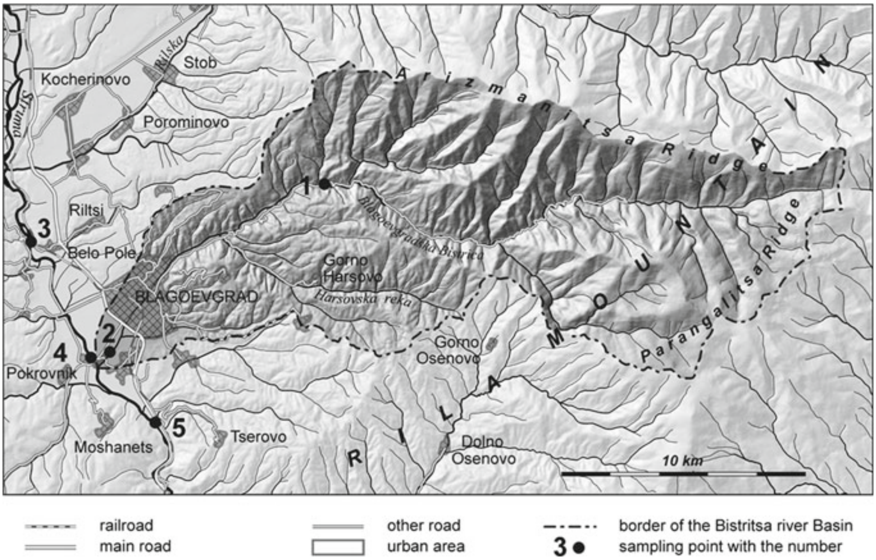

Fig. 1 The catchment area of Blagoevgrad Bistritsa River

highest point at Golyam Mechi Peak (2617 m) and the lowest point at the town of Blagoevgrad (380 m above sea level). The average rate of its riverbed is 51.8%. The average altitude of the catchment area is 1467 m and the average incline is 0.442%.

The steep incline of the midstream network creates conditions under certain climatic and hydrological circumstances to form a large surface runoff with strong transport power and rate of erosion processes. The Blagoevgrad Bistritsa River is characterized by rainy and snow-fed nourishment with marked spring high water and summer–autumn low water. The average annual runoff is about 3 m^3/s and the average annual turbidity is 1200 g/m^3 (Hristova Hristova 2012).

The main source of pollution in the river basin is the administrative and industrial center—Blagoevgrad with a population of 69,417 people (NSI 2017). From a nineteenth-century tobacco warehouse and woodworking craft trade center, it grew as an important industrial center in the mid-twentieth century. Traditional tobacco processing, fermentation, and cigarette production prevail over other industries. Among the structurally identifying branches is the machine industry. In 1961, the first enterprise for speakers, microphones, and linguistic studies was built. After that, the plant for measuring instruments and appliances was built—the only one in the country that is still in operation. Then, the plant for building elements of the communication equipment and the plant for metal constructions and the radio-electronics industry were also built. In 1962, a large cotton plant was put into operation with an annual capacity of 36 million meters of fabrics. In this period, the plants for mechanical constructions as well as for the equipment and nonstandard technological equipment were created. The shoe industry is a relatively new branch in the city, which was found in the 1980s. Also during this period (1982), the PCB plant (Printed Circuit Board) was built. Near the Blagoevgrad Bistritsa River, there is a meat factory with a slaughterhouse and a sausage workshop. There is also production of liquor, dairy products, beer, etc.

Since 1989, a number of enterprises have been privatized, some have ceased to operate, and others have significantly shrank the volume and range of their production. Today, some of the old plants, albeit with reduced capacity, are still in operation. A number of new, small- and medium-sized enterprises with specialization in the production of accurate metal parts, furniture, cash registers, fiscal printers, POS terminals, packaging, foils, plastic bags, vacuum packing lines, etc. have emerged. Most of them were found in the 1990s and others are brand new. All these companies have discharged and still discharge their wastewaters into the Blagoevgrad Bistritsa River, from where they flow into the cross-border Struma River.

Materials and Methods

Field Studies

For the purpose of the study, areas which are relatively unaffected by anthropogenic activities as well as those areas with a high anthropogenic load on the part of the industrial and communal activities have been tested. The samples were collected during the summer–autumn season during the low water level at certain points of the Blagoevgrad Bistritsa River Basin and part of the Struma River, before and after the influx of the Blagoevgrad Bistritsa River (Fig. 1). By applying the screening method, the fraction less than 1 mm is separated. In order to correlate the samples with different mechanical composition, the fraction of less than 0.020 mm was used, with a prevalence of the clay fraction. In this way, the samples collected in different rivers are reduced to "common denominator" and the anthropogenic load is estimated by the degree of saturation of heavy metals in the clayey fraction of the bottom sediments.

Laboratory Methods

We analyzed the content of heavy metals (Cu, Zn, Mn, Cd, Pb) in river bottom deposits. Sample preparation consists of acid digestion of 0.5 g samples of the bottom sediments, sieved through a 2 mm sieve and flooded with aqua regia extracted, i.e., mixture of nitric acid and hydrochloric acid (ISO 11466) in microwave-transparent vessels via a microwave-accelerated reagent system (microwave oven)—MARS

Xpress model, in two stages at different temperatures: first stage at a temperature from 0 to 165 °C and a second stage from 0 to 175 °C (Cools and De Vos 2016). Samples are left for about 16 h at room temperature to allow slow oxidation of the organic matter in the sample.

After dilution with distilled water, the samples are made equal to 50 ml and fed to an ICP-OES spectrophotometer (ICP-OES), a 40.68 MHz ICP JY ULTIMA 2 (JOBIN YVON, FRANCE) ICP spectrometer. Thus, the heavy metal content in them was determined in 2018. In 1988 and 2008, their concentration was retrieved through extraction of aqua regia through the method of flame and electrothermal absorption spectrometry using Perkin Elmer AAS apparatus.

In the study of the geochemical features in the Blagoevgrad Bistritsa River Basin, two coefficients are applied, namely, average data for different background areas and normative standards. In order to determine the degree of pollution in the Blagoevgrad Bistritsa Valley, the concentration coefficient (Kc) is used, which characterizes the degree of accumulation of a chemical element in relation to the local geochemical background.

To track the dynamics in the state of the river system over a period of 30 years, a time factor has been calculated. This coefficient is used to reveal the degree of contamination of bottom sediments over time. The content of the heavy metals studied in the bottom sediments from 1988 was taken as the basis, and the denominator was the content of the elements in the bottom sediments in 2008 and 2018.

$$\mathrm{Kc} = \frac{\mathrm{Ci}\ (1988)}{\mathrm{Cf}(2008\ \text{or}\ 2018)}$$

The proposed coefficient allows for a long-term monitoring of the state of bottom sediments and the degree of their heavy metal contamination to track changes in the impact of anthropogenic load on aquatic landscapes during the periods studied.

Results and Discussions

The copper content during the study period varied within a wide range of 2.7–150 mg/kg for different parts of the area under study (Table 1; Fig. 2). Its excesses in the outflow of the Blagoevgrad Bistritsa River compared to the local geochemical background for 2008 are over 1.5 times and in 2018 over 10.5 times. The lead content also ranges from 3.4 mg to 80 mg/kg, with the value of the concentration coefficient in relation with the local background being 1.2–2.2 times. With the largest deviations from the local background is zinc with a content of 31.2 mg/kg in the background sample №1 to 500 mg/kg at the outflow of the Blagoevgrad Bistritsa River—point №2 (Table 1; Fig. 3). The values of the concentration coefficient in the outflow of the Blagoevgrad Bistritsa River are 2.2–3.6 times for the period 2008–2018. The cadmium recorded in the second half of the study ranges from 0.1 mg to 2.8 mg/kg, with its excess in the lower course of the river 2.5 times higher than the local background.

Table 1 Heavy metal concentrations in the studied bottom sediments (mg/kg)

Point	Location	Cu			Pb			Zn			Mn			Cd		
		1988	2008	2018	1988	2008	2018	1988	2008	2018	1988	2008	2018	1988	2008	2018
1.Blagoevgrad Bistritsa River around the village of Bistritsa	23° 18′ 40″94 42° 05′ 36″ 51 529.06 м.н.в		29.2	2.7		19.3	3.4		67	31.2		373	252.8		0.1	0.9
2. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River	23° 07′ 51″ 91 41° 99′ 34″ 50 286.69 м.н.в	150	45.4	27.5	80	23.7	7.8	500	150.7	112.7	800	300.4	387.6			2.3
3. Struma River near the village of Byalo Pole	23° 03′ 74″ 58 42° 03′ 48″ 60 291.56 м.н.в	30	42.9	29.8	50	20.5	25.4	120	109.6	125.5	500	728	397.2			1.1
4. Struma River on the way to the village of Pokrovnik	23° 06′ 68″ 99 41° 99′ 09″ 07 276.35 м.н.в		36.9	35.3		22.2	34.3		118	130.4		388	712.1			2.8
5. Struma River after the Urban Water Treatment Plant	23° 09′ 68″ 91 41° 96′ 67″ 67 278.66 м.н.в	50	56	19.2	50	29	17.3	200	168	94.5	600	471.9	196.2		0.5	1.3

Of the studied heavy metals, only the concentration of manganese has been around background values in the Blagoevgrad Bistritsa Valley and exceeds the background in the Struma River Valley (Table 1).

As criteria for the assessment of the heavy metal content in the bottom sediments, the comparisons with their background content in the bottom sediments of the rivers in Europe (DeVos et al. 2006) and Bulgaria (Penin 2003) have been used, as well as the threshold effect concentrations (TEC) and the significant probable effect concentrations (PEC) determined by the United States Environmental Protection Agency (US EPA, MacDonald and Ingersoll 2002) for sedimentation in freshwater ecosystems (Table 2). The use of data from the US Environmental Protection Agency is due to the fact that in Bulgaria no norms have yet been set for pollutants in sediments. Because of the absence of Mn norms in them, the ones designated for the sediment quality assessment in Ontario, Canada (Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach 2008) have been used.

The comparative analysis of the average heavy metals content in the bottom sediments of the rivers of Europe shows higher values in the downstream of the Blagoevgrad Bistritsa River after passing through the town of Blagoevgrad and at the Struma River where the Blagoevgrad Bistritsa River flows into it (Figs. 2, 3, 4 and 5). They are the highest in the 1988–2008 period and, compared with the US EPA threshold, they mark zinc and lead as the most significant threat to the living organisms in the aquatic landscapes in this period. The 2008–2018 period is characterized by values below the threshold effect concentrations (TEC) and close to the background values in the country. Depending on the background areas in Bulgaria, the heavy metals in the bottom sediments of the area under consideration are concentrated in the following way: Kc = Zn (5.3) > Cu (3.33) > Pb (3.2) > Cd (2.00) (1.02).

The concentration coefficient (Kc) for Europe's rivers arranges the elements in the following geochemical order: Cd (10) > Cu (8.82) > Zn (7.04) > Pb (3.90) > Mn (1.00).

Table 2 Comparative data of heavy metal contents (mg/kg) in the bottom sediments of rivers in Bulgarian and European background regions, and threshold (TEC) and probable effect concentrations (PEC), (US EPA)

	Cu	Zn	Pb	Mn	Cd
Rivers in Europe, De Vos et al. (2006)	17.0	71.0	20.5	790	0.28
Background areas, Penin (2003)	45.0	94.0	25	777	1.0
Threshold concentrations (TEC), MacDonald and Ingersoll (2002)	31.6	121	35.8	460	9.79
Probable effect concentrations, (PEC), MacDonald and Ingersoll (2002)	149.0	459	128	1100	33.0

The geochemistry of bottom sediments in the downstream of Blagoevgrad Bistritsa River is determined by the industrial specialization of Blagoevgrad. According to data from other authors, in 1988, the concentration coefficient arranged the studied elements in the following order: Zn (6) > Pb (5) > Cu (3) (Perelman and Kasimov 1999). These elements indicate the specialization of Blagoevgrad in the development of instrumentation, electrical engineering, and textile and food industries.

The main quantities of heavy metals come from the untreated industrial and domestic wastewaters discharged into the Blagoevgrad Bistritsa River. From there, they flow into the Struma River, where other industrial activities are also covered in the upper part of the catchment, which influence the increased concentrations of heavy metals in the studied area.

One of the main sources of pollution in the recent past was the steel plant in Pernik, currently owned by Stomana Industry AD. For the period 2007–2010, the plant discharged in the river 159 kg of Pb, Cd—1 kg, Ni—84 kg, and Zn—113 kg (E-PRTR 2015). This is also one of the reasons for the higher values of lead, zinc, and cadmium at two of the three points of the Struma River before the influx of the Blagoevgrad Bistritsa River (Figs. 3 and 4). After the influx of the Blagoevgrad Bistritsa River, the pollution effect at point 5 (Figs. 2, 3, and 4) was intensified, especially in the period 1988–2008, when most of the aforementioned enterprises operated with full capacity but there was still no urban purification plant built. It was put into operation only in 2009 and today it operates according to the European environmental legislation.

According to other authors, the Blagoevgrad Bistritsa River water after the town of Blagoevgrad is also estimated to be heavily polluted on the basis of a set of quantitative microbiological indicators, especially during the summer–autumn low tide in the period 1979–1988. The actual data of RIEW Blagoevgrad on the physico-chemical status of the river in its downstream until 1997 also characterize it as strongly anthropogenically influenced (Sakelarieva and Yaneva 2006).

The dynamics of the change in the content of heavy metals expressed by the time concentration coefficient (Figs. 6 and 7) shows that the influx of the Blagoevgrad Bistritsa River was polluted with zinc, lead, and copper in the initial period of the study. Their concentrations at the influx of the river—point 2 exceeds 3–4 times those of 2008 and 5–10 times those of 2018. For the Struma River Valley at point 3, such large variations in the concentration ratio are not observed. They are characteristic for the Struma River, point 5, after the purification plant in the last period of the study, where a decrease in the concentrations of the copper and zinc elements has been registered.

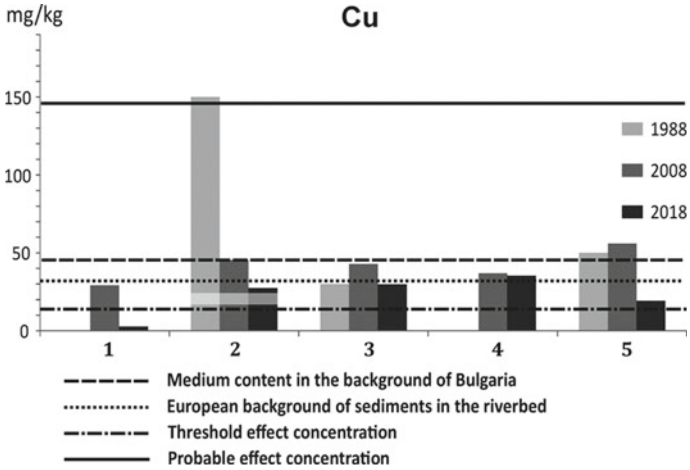

Fig. 2 Variation of Cu, Pb, Zn, and Mn content in the bottom sediments of the Blagoevgrad Bistritsa and Struma Rivers in five selected sampling locations. 1. Blagoevgrad Bistritsa River around the village of Bistritsa. 2. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 3. Struma River near the village of Byalo Pole. 4. Struma River on the way to the village of Pokrovnik. 5. Struma River after the Urban Waste Water Treatment Plant

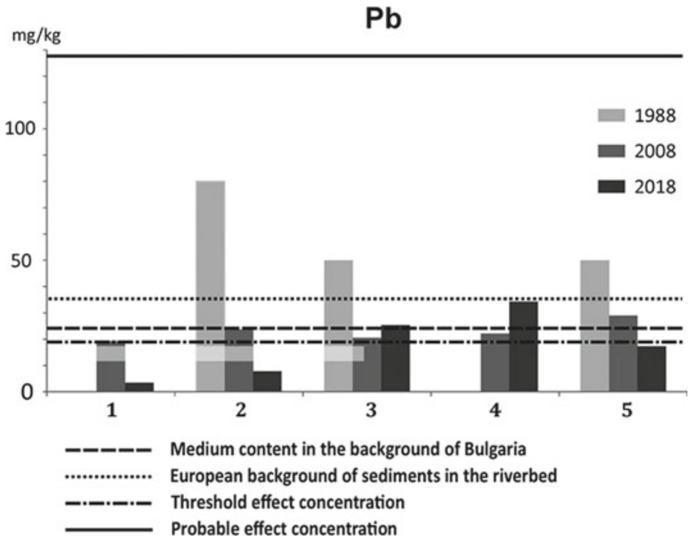

Fig. 3 Variation of Cu, Pb, Zn, and Mn content in the bottom sediments of the Blagoevgrad Bistritsa and Struma Rivers in five selected sampling locations. 1. Blagoevgrad Bistritsa River around the village of Bistritsa. 2. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 3. Struma River near the village of Byalo Pole. 4. Struma River on the way to the village of Pokrovnik. 5. Struma River after the Urban Waste Water Treatment Plant

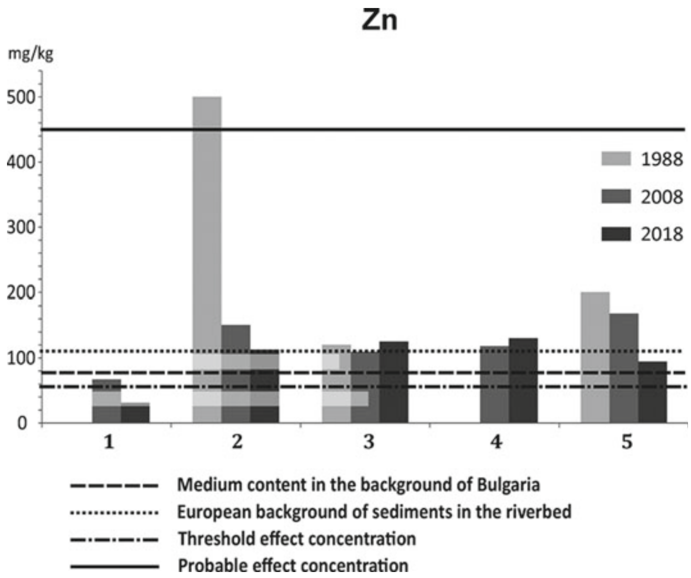

Fig. 4 Variation of Cu, Pb, Zn, and Mn content in the bottom sediments of the Blagoevgrad Bistritsa and Struma Rivers in five selected sampling locations. 1. Blagoevgrad Bistritsa River around the village of Bistritsa. 2. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 3. Struma River near the village of Byalo Pole. 4. Struma River on the way to the village of Pokrovnik. 5. Struma River after the Urban Waste Water Treatment Plant

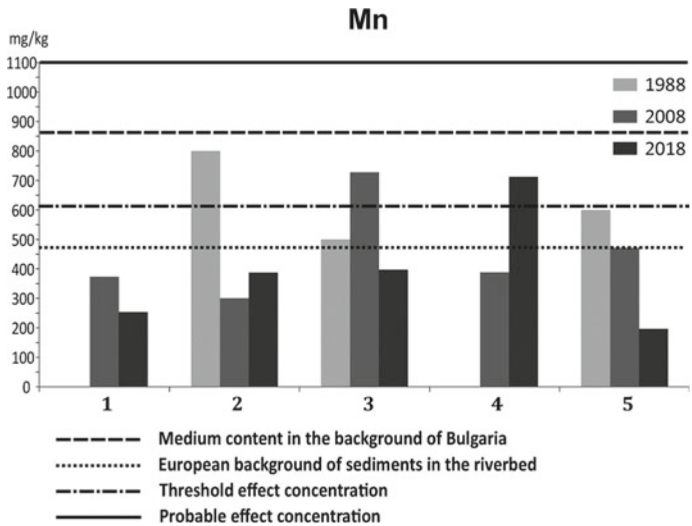

Fig. 5 Variation of Cu, Pb, Zn, and Mn content in the bottom sediments of the Blagoevgrad Bistritsa and Struma Rivers in five selected sampling locations. 1. Blagoevgrad Bistritsa River around the village of Bistritsa. 2. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 3. Struma River near the village of Byalo Pole. 4. Struma River on the way to the village of Pokrovnik. 5. Struma River after the Urban Waste Water Treatment Plant

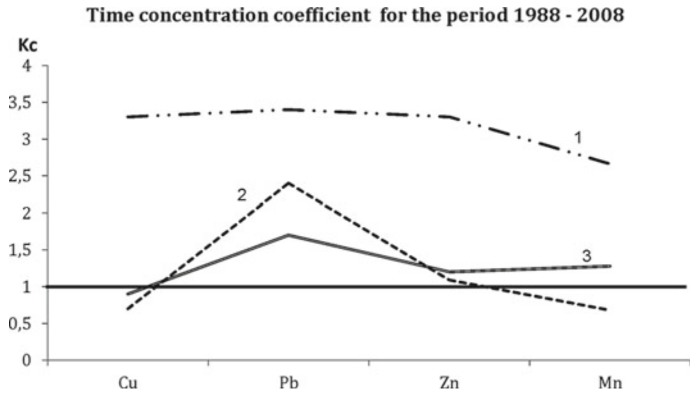

Fig. 6 Time concentrations coefficient for the period 1988–2008. 1. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 2. Struma River near the village of Byalo Pole. 3. Struma River after the Urban Waste Water Treatment Plant

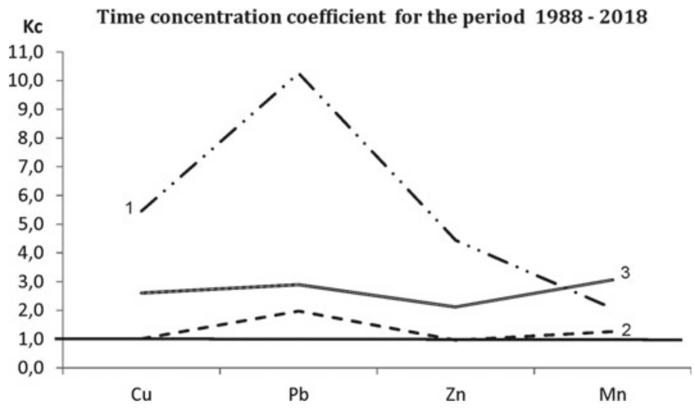

Fig. 7 Time concentrations coefficient for the period 2008–2018. 1. The estuary of the Blagoevgrad Bistritsa River before the inflow and in Struma River. 2. Struma River near the village of Byalo Pole. 3. Struma River after the Urban Waste Water Treatment Plant

Conclusion

With regard to the local background, zinc and cadmium have the highest rate of exceedance.

For the entire study period, the downstream of the Blagoevgrad Bistritsa River has higher concentrations of heavy metals compared to the upper and middle streams. There is a relatively strong techno-geochemical effect during the first period of the survey by the industrial capacities, which are located in a wide range in the south-western part of Blagoevgrad. In 1980s, the downstream of the river was heavily polluted with zinc, lead, and copper. Zinc pollution is due to the dyes and paints used in the footwear, garment, and leather haberdashery industries. Lead and copper pollution in the period 1988–2008 could be due to the PCB plant, Ltd., producing copper, tin, lead, silver, palladium, and gold products. The importance of the utility sector, whose impact on pollution is decisive in the second stage of the study, is also essential. In the third stage, the decrease in the concentrations of the heavy metals studied was observed in almost all the points, but mostly in the Struma River after the purification plant. Only after the active water purification of the river after 2009 and the reduction of the pollution from the Blagoevgrad Bistritsa River, the self-cleaning of the bottom sediments starts, and so in 2018 their concentrations get near the background ones in the country and in Europe.

The time concentration coefficient indicates that small rivers experience the most powerful techno-geochemical load. In the case of the Blagoevgrad Bistritsa River, 30 years later, in the reduction and even stopping of many industrial enterprises and the construction of wastewater purification plants, in some of them there was a sharp decrease in the concentrations of the heavy metals studied.

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Structure and Peculiarities of the Karst Landscapes in the Besaparski Ridges

Ilia Tamburadzhiev and Zornitza Cholakova

Abstract The study is focused on the karst landscapes within the scope of the Besaparski ridges. The specifics concerning the part of the ridges are studied, which are characterized by the presence and running of karst processes. An analysis of the natural components in the investigated territory was made. The role of natural components in landscape differentiation is assessed. The specifics and degrees of anthropogenic load and the different types of anthropogenic activity have been taken into account. A classification and map of the karst landscapes of the Besaparski ridges were compiled. The investigation is based on the landscape-ecological approach. Morphometric, landscape-geophysical and landscape-geochemical characterization of the karst landscapes was made. Laboratory, terrain, analytical and cartographic methods are applied. Sampling of the soil cover and the bedrock was done for geochemical analysis of karst landscapes and for the presence of macro-elements contents like Ca, Mg and of CO_2. With the help of terrestrial and remote databases integrated into GIS, a map of the karst landscapes was created. The analysis of the horizontal, vertical and geochemical structure of the karst landscapes in the studied area of the Besaparski ridges, as well as the realization of complex characterization of the different types of landscapes, is an original unique study of the specific territory.

Keywords Contemporary karst landscapes · Landscape-ecological analysis · Mapping

Introduction

The karst landscapes are the widely distributed azonal type in all landscape regions in the territory of Bulgaria. They have specific geomorphological, hydrogeological, geochemical and many other peculiarities that distinguish them from the non-karst natural complexes. Specifics are their subsurface and superficial vertical structure.

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Many authors explain the karst and the karst processes. Gvozdetsky (1972, 1988) summarizes that to the karst phenomenon are related all relief forms, developed in rocks that are soluble in natural waters: in limestones, dolomites and the transitional between them carbonate rocks, chalk and sometimes chalk-like marls, marbles, and also in gypsum, anhydrite, halite and potassium salt, potassium-magnesium and other salts. According to Ford and Williams (2007), the karst can be defined as a territory with distinctive hydrology and relief that originates from the combination of highly soluble rocks and well-developed secondary (cracked) porosity. Such areas are characterized by losing streams below the ground surface, rivers, caves, enclosed negative forms, furrowed rock surfaces and impetuous springs. Velchev (2014) points out that the carbonate rocks, running water and carbon dioxide are needed to pass the karstification process. The peculiarities of the relief and its elements, the hydrogeological peculiarities and the soil-climatic conditions of the region are also very important.

Besaparski ridges are a separate natural geographic unit with specific natural geographic features. Owing to the specificity of the lithological, hydro-climatic and soil-biogenic conditions of the ridges, the authors of the present study perceive this particular territory as a separate landscape unit composed of a certain spectrum of landscape varieties. A landscape analysis is carried out for that part of the hills where karst natural and natural-anthropogenic complexes are widely spread. Regarding the vertical structure of the karst geosystems, only their superficial subsystem is considered. In an equivalent sense, the concepts of "karst landscape", "karst geosystem" and "karst nature complexes" are used.

The main aims of the research are classification of the landscapes of Besaparski ridges, analysis of the peculiarities of their horizontal and vertical structure, as well as the processes of karstification as a major factor in the differentiation of the contemporary landscapes within the scope of the studied region. The map compilation of the horizontal structure of the contemporary karst landscapes of the Besaparski ridges, reflecting the degree of their anthropogenic transformation, is another purpose of the study.

Materials and Methods

The karst rocks create specific conditions for formation of natural or natural-anthropogenic complexes that have their own appearance and azonal character—karst landscapes. Gvozdetsky (1988) points out that the karst territory is a particular geographic landscape in a typological sense, which is, above all, distinguished by its geomorphological features. The different surface karst forms are distinctive elements of the karst landscape. The negative surface forms also prevail.

The karst landscape differs from the non-karst landscape on the "peculiarities of the relief, the hydrographic network, the soils, the biocenoses, has a more complex structural organization and a higher degree of differentiation". It is distinguished by "different mechanisms of the substantial-energetic relations, with peculiar regime of functioning and dynamics" (Andreichuk 2007, pp. 3–4). It has a subsurface and superficial vertical structure, which is very closely interrelated. Unlike the non-karst landscape, the karst has a powerful underground structure that includes cavities and caves. They are relatively individual natural sites, also called subsurface landscapes (Gvozdetsky 1954; in: Andreichuk 2007). The superficial and subsurface parts of the karst landscape are two structural subsystems.

The research is based on the landscape-ecological approach. Laboratory, terrain, analytical and cartographic methods are applied. Geographic information systems are at the root of creating a map of the horizontal structure of the karst landscapes. The horizontal structure of the karst landscape resembles that of the non-karst. By its nature, it is also complex. Its elements are elementary landscapes, the formation of which the most important are the lithologic-tectonic and the morphological factors related to the variety of positive and negative karst forms (Andreichuk 2007).

The landscape-typological classification of Bulgaria and the classification of the karst landscapes according to the morphogenetic types of karst—covered, bald, turfed, semi-turfed, and so on—proposed by Gvozdetsky (1972, 1988) and used by A. Velchev, author of the classification scheme of the landscapes in Bulgaria (1989) and the classification of the karst landscapes (2016a) are main methodical basis of the current research.

The taxa used are: class, type, subtype, genus, subgenus, group and variety landscapes. The class of landscapes is separated by the indicators for the macro-relief of the territory. The Besaparski ridges fall into the class of "foothill-hilly landscapes". Type of landscapes is separated according to the peculiarities of the hydro-climatic conditions, which are the main factor for the formation of the vegetation. In the studied area, the landscapes are of the type "hilly semi-arid landscapes". Minor signs regarding the combination of climate-predominant vegetation make it possible to separate the taxon subtype landscapes "steppe and submediterranean shrublands (šibljak)". The predominant genetic type of relief is leading factor in separating the taxon "genus landscapes". In the concrete case, this is the karst relief.

The following taxonomic levels combine the peculiarities of the karst relief and the degree of anthropogenization. Taxon "subgenus" is separated according to the morphogenetic types of karst. On the territory of the Besaparski ridges there is separated subgenus "semi-turfed karst landscapes". This group of karst landscapes depends on the peculiarities of the mesorelief and the leading morpho-dynamic processes. Thus, karst landscapes are divided into three groups based on the area: erosion-denudation (slopes), denudation (crests) and accumulative (saddle).

The greatest variety is in the types of karst landscapes. For their separation, a scale is used for the degree of anthropogenization of the territory, similar to that applied in previous developments by Velchev and Todorov (1990), Todorov (1997), Cholakova et al. (2012) and others. Natural and slightly anthropogenized, medium anthropogenized and highly anthropogenized karst landscapes have been separated. The classification is supported by the available data for the land cover classes from the Corine Land Cover 2012 project. The final formulation for a variety of karst landscape is based on the rock base and soil type factors.

Creating of the map of the horizontal structure of the contemporary karst landscapes has been done through the creation of GIS databases. Analysis in GIS environments involves several stages. The first is determining the boundaries of the studied region and generating layers of the topographic surface, the lithological substrate, the soils and the earth cover. The data used for the land cover is from the Corine Land Cover 2012. The second stage involves the use of a specific GIS tools to "cross" the respective layers and combine them into a single layer. The new layer is edited according to the classification used, expressing the varieties of contemporary landscapes on the territory of the Besaparski ridges. The editing is expressed by merging similar characteristics of individual polygons into the attribute table of the layer and, respectively, merging separate polygons on the map that have the same attributes in the attribute table and in fact do not represent different varieties of landscapes. The merging of some similar features associated with similar types of land use has been achieved because these features are not of fundamental importance for the differentiation of individual varieties of landscapes at the appropriate scale of the study. An example of this above mentioned merging of similar features with their type of land use may be the polygons of the land cover into common polygons called "agricultural", "industrial", and so on. Some additional specific features of the individual landscapes associated with the types of land use have been added. The generation of the landscape map ends with the composition of a legend that reflects not only the typological levels of the classification system but also the degree of anthropogenization of the landscapes. On the map are also added symbols depicting other terrain features, such as forms of karst relief, for example.

Mappings are implemented in landscape sites of four key sections: Ognyanovo-Sinitevski ridge, Kapitandimitrievski ridge, Novoselski ridge and the south, bordering the Kapitandimitrievski pluton, part of the Besaparski ridges. Relatively uniform spatial representation for the different parts of the ridges has been achieved. Within the Novoselski and Kapitandimitrievski ridge are mapped three landscape sites, respectively, from the foot of slope, slope and crest of the hills. In the Ognyanovo-Sinitevski ridge, the mapping is carried out at the foot of slope and the slope, and in the fourth section mapping is carried out only on the slope surface due to the specificity of the local relief peculiarities. The main components of the karst landscapes have been sampled—rock foundation, soil cover and dominant vegetation types. The samples were subjected to chemical analysis for the presence of macro-elements contents like Ca, Mg, of CO_2, and of the trace elements Zn, Pb, Cr, Ni, Co, Mn, Cd. The chemical analyses of the samples were performed at the Geochemistry Laboratory of the Faculty of Geology and Geography of Sofia University "St. Kliment Ohridski". The contents of the elements are analyzed using the atomic absorption spectrometry method. Most of these results will be analyzed and summarized in the next publication.

Discussion

Natural and Socio-economic Features

The present study of the karst complexes was carried out in the Besaparski ridges, which represent a territory of the West- and the Middle-Rhodope landscape region in Bulgaria (Velchev et al. 2011). The area of the territory investigated is 53 km^2. The ridges bordering the Maritza river and Pazardzhik-Plovdiv area of the Upper Thracian Lowland (Upper Thracian-Tundzha Landscape region) to the north, and to the south of the valley of Stara Reka river come and go through the northeastern branches of the Batashka Mountain, a part of the northern macro-slope of the Western Rhodopes (Western and Central Rhodopes landscape region). In their territory, the following parts are included: Ognyanovo-Sinitevski ridge to the north, Glavinitsa ridge to the north-west, Trivoditsi ridge to the north-east, Kapitandimitrievski ridge to the south-west and Novoselski ridge to the east.

The contemporary landscapes of the Besaparski ridges have been formed to a great extent under the influence of the karstification process. The Besaparski ridges are built by the lower part of the Dobrostan marble strata (with suppositional Late Cretaceous or Paleogene age), which is represented by marbles containing different thickness of layers of amphibolites, mica schist, kyanite-garnet schist, calc schist and muscovite gneiss. The thickness of this group reaches up to about 500 m (Kozhuharov et al. 1992).

The process of karstification of the carbonate rocks is widespread. It is related to the formation of varied form and origin karren and karrenfelds on the surface of the crest of the ridges. Different by form and size, sinkholes are spread. The widened sinkholes (valogs) and uvalas are located between the different ridges. The highest peak of the ridges is Elenski peak—535.4 m. According to A. Baltakova (2011), the negative shapes between the ridges represent corrosion valogs formed by tectonic cracks that develop in dry valleys, and large uvalas are formed between the hills, filled with shallow-lake deposits, on which are accumulated diluvium materials from the surrounding hills.

In addition to karstification, erosion is observed as a part of the contemporary morphogenetic processes at the foot of slope parts—accumulation. As a result of the sheet wash, the erosion and the transportation of weathering material from the crest and the slope surfaces to the foot, diluvium materials are accumulated. The current soil cover is developed on the diluvium materials. The diluvium processes are particularly active during the rainfall. In the crest landscapes, the denudation is better expressed.

The karst processes in the Besaparski ridges develop under the conditions of a transitional climate. The average January temperature is about 0 °C and the average July temperature is about 22–24 °C. The annual rainfall is around 500 mm. The maximum rainfall is in the spring—May.

Regarding the hydrological peculiarities of the studied territory, the absence of a constant surface runoff is its characteristic. It is formed only during rainfalls, and even more rarely during snowfall. Baltakova (2011) notes that “both surface and underground runoff gravitates to the Maritsa river. The presence of bald and covered karst causes percolation of some of the surface and rain waters, which by means of underground flow run off to the Maritsa river through the pressure karst springs Trivoditsi in the village of the same name”.

The soils within the studied territory are shallow—humus-carbonate/rendzinas (rendzik Leptosols, LPk, FAO). Mapping found that the thickness of their soil profile reaches 15–20 cm at the foot of slope parts of the ridges and 5–10 cm on the slope and crest areas. The pH of the soil solution is predominantly low-alkaline to neutral (pH = 7.7–6.5), the Ca content varies between 15 and 1%, and Mg is found only in some of the profiles, and it is low—up to 0.02%. Through CO_2 experimental data, the $CaCO_3$ content is also theoretically determined. It varies between 43 and 9%. It is important to note that the soil cover is directly dependent on the carbonate rocks. They create specific conditions for the formation of natural or natural-anthropogenic karst complexes. The content of Ca in the karts marbles found at the soil-forming rock base changes from 38 to 41% and the Mg content is below 1%. The concentration of the basic mineral that builds the rocks, $CaCO_3$, is in the range of 95–99%.

Typical for Besaparski hills are the calcareous and basophilic grasslands: Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi. In some places the pseudo-steppes with wheat and annual plants predominate. East-Mediterranean dry grass communities, *Quercus pubescens*, *Carpinus orientalis* and shrub vegetation, mainly represented by *Paliurusspina-christi*, *Rosa canina*, *Juniperus oxycedrus* and others are also found.

No settlements are located in the area of Besaparski hills. Insignificant by area, the territories of the villages Kapitan-Dimitrievo and Novo Selo comprised the present study. They touch the peripheral parts of the slopes. In a direct proximity of the ridges are located the villages of Sinitovo, Ognyanovo, Trivoditsi, Isperihovo, Byaga and Glavinitsa. The proximity of these settlements, which are characterized by a predominantly agricultural economic profile, determines to a great extent the specifics of the land use in the scope of the ridges. Livestock, vine growing and the cultivation of annual cereal and technical crops are well developed, but only on land not included in the Natura 2000 ecological network. The production of limestone from the quarries in the Ognyanovo-Sinitevski and the Kapitandimitrievski ridges is of national significance.

Landscape-Ecological Analysis

As have been already mentioned, the classifications of Velchev et al. (1989) and Velchev (2016a) were used for the purpose of the present research, and some additions and clarifications were made according to the specifics in the present study. The landscape classification used consists of 1 class, 1 type, 1 subtype, 1 genus, 1 subgenus, 3 groups and 17 varieties of landscapes. The additional specifications which were made are related to the subgenus landscapes, the landscape groups and landscape kinds, taking into account their degree of anthropogenic transformation.

The landscapes of Besaparski hills are referred to a class of foothill-hilly landscapes, type of hilly semi-arid landscapes, subtype of steppe and sub-Mediterranean shrublands (šibljak) landscapes, and genus of karst landscapes. Velchev (2016a, b) points out that the species differentiation is particularly made with great difficulty in the case of the partially-turfed, semi-turfed and turfed landscape subgenus. Differentiation of them is based primarily on the percentage of the soil cover (Velchev 2016a, b). On the basis of field observations, it has been established that, to a considerable extent, the karst landscapes within the Besaparski ridges can be characterized as semi-turfed. The discovery of the karst forms is between 30 and 70%, and in some places more; in particular, in landscapes. In the lower areas, as well as in the saddles, the revealing of the karst forms is on a smaller area than the landscapes situated in the higher parts of the slopes and on the crests. Therefore, a subgenus of semi-turfed karst landscapes was identified. For its part, the subgenus of landscapes is divided into three groups: erosion-denudation, denudation and accumulation (saddle) landscapes. Erosion-denuding landscapes are the landscapes of the slope surfaces. Denudation landscapes are the landscapes of the crest parts of the ridges, and the accumulation (saddle) landscapes are located in saddle depressions between the particular ridges of the hills. Each of the three groups of landscapes is divided into kinds of landscapes that reflect the anthropogenic specificity of the territory. The different kinds of landscapes are grouped into three extents of categories according to the extent of their anthropogenic load—natural and slightly modified landscapes, medium modified landscapes and heavily modified landscapes, respectively. To the natural and slightly modified landscapes of the Besaparski ridges fall mainly xerothermic grass formations and areas of rare woody vegetation of *Quercus pubescens* and *Quercus virgiliana* or with Mediterranean elements and forests of *Carpinus orientalis* and *Paliurus spina-christi*. To the medium modified landscapes fall agricultural areas and vineyards. To the heavily modified landscapes fall industrial sites and settlements. The differentiation of the landscapes of the Besaparski ridges, based on the interrelationships and interaction between the main natural components and the role of the anthropogenic activity as a landscape-forming factor forms the horizontal landscape structure, reflected on the map of contemporary landscapes, shown in Fig. 1. Figure 2 represents the landscape varieties by % of the total area of the investigated territory.

The landscape-ecological research has been conducted within four key areas.

Within the scope of Novoselski ridge three landscape-ecological mappings were made: at the foot of slope, the slope and the crest, respectively. The slope landscape mapping is carried out on a slope with northern exposure. The field investigations were made in that part of the ridge, located south of the road of Novo selo village—Isperihovo village. All the three field mappings were performed in the range of xerothermic grass formations on marbles and rendzinas from the classification of the contemporary landscapes of the Besaparski ridges. In the lower parts of the studied area of the Novoselski ridge, more significant turf and covering of the karst forms of the relief are observed. The soil layer at the foot of slopes is characterized by about 5–10 cm greater thickness than the thickness of the soil layer in the slope

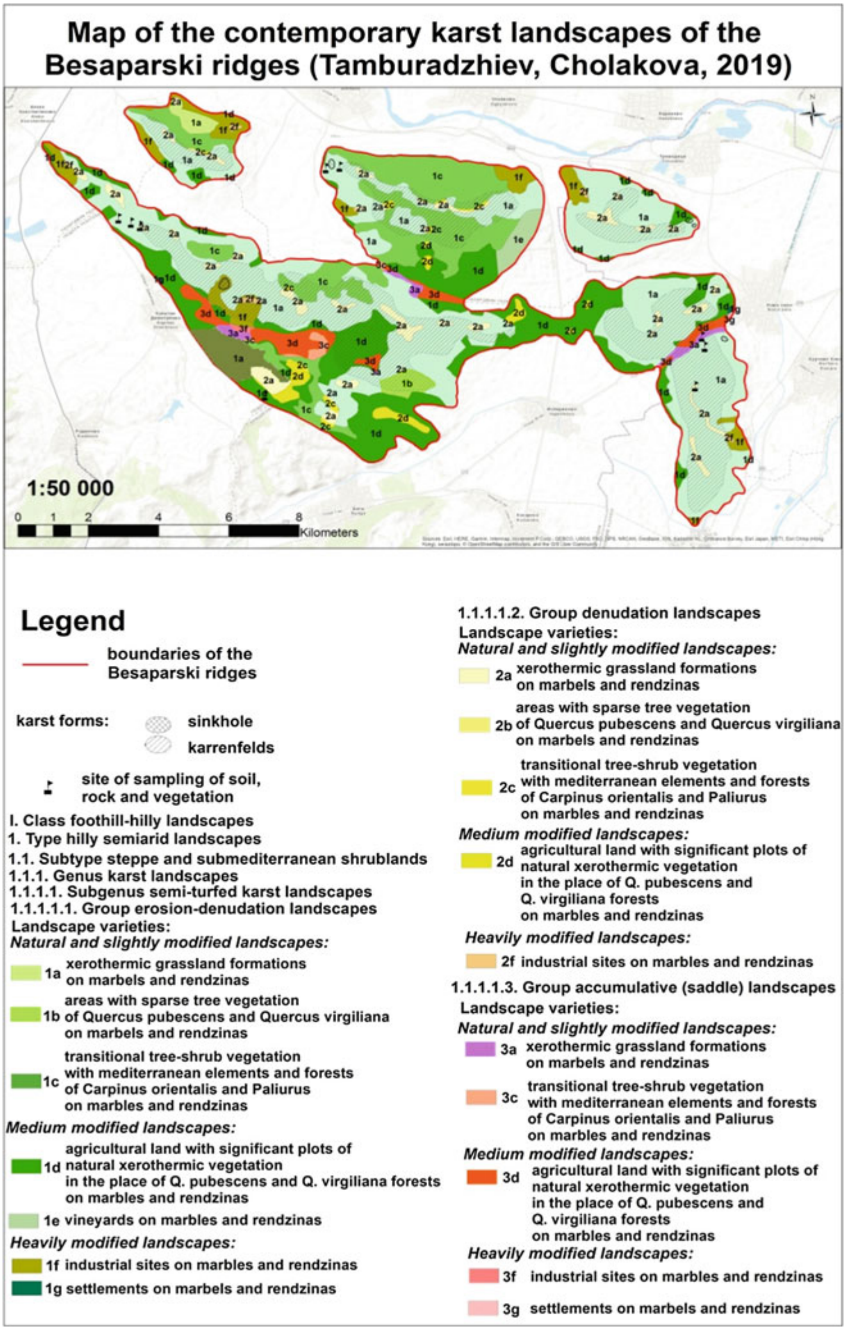

Fig. 1 Map of the contemporary karst landscapes of the Besaparski ridges

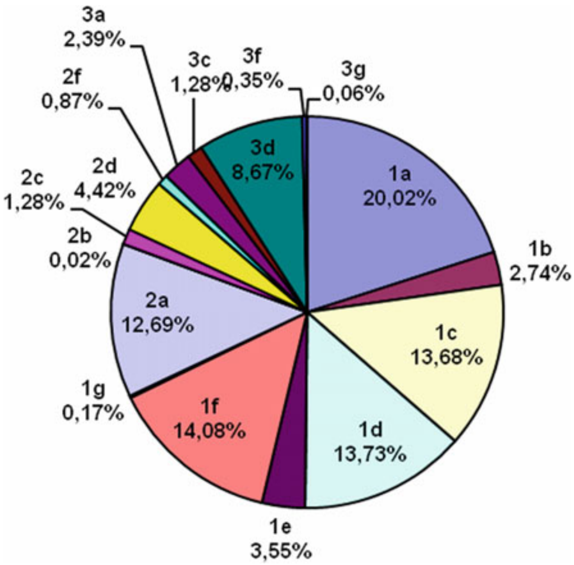

Fig. 2 The landscape varieties by % of the total area of the investigated territory

and on crest parts. Only rendzina soils, characterized by a yellow-brown color, sandy mechanical composition, significant nodules and high stoniness, are observed. Roots are observed to a small extent in the soil profile, and the soil moisture is negligible. The rock base is ubiquitously represented by karst marbles. A karst relief is observed, represented by karrenfelds. For its part, they are formed of clints and furrows, as well as separate, unsymmetrical and sporadic karren structures. Karren within the scope of the investigated key area genetically fall in the group of formed under soil-vegetation cover and subsequently pre-stuffed karren (Velchev 2014). On the basis of their form and the way of formation in the Besaparski ridges, cracked, welled, bowled, furrowed and, relatively less often than other varieties, meshed karren structures are observed. The length of the particular karren ribs ranges from 2–3 to 5 m. Fragmentation of the karren structures is observed. There is no equal direction of spreading. There is no unified consolidation of the karren structures in terms of their spatial layout. Presence of weathering material between the particular fragments and cracked karren structures are observed. Regarding the shape, both oblong karren ribs and distinct karren structures with irregular shape and outline are found. Extremely characteristics are distinct, single or situated in small groups of different size of rock fragments, located fragmentarily within the karrenfelds. These fragments have been formed as a result of the destruction of the inter-karren ribs; thereby a weathering cover is formed, favoring the presence of single representatives of the shrub vegetation. The coverage area of the karrenfelds is greatest in the high slopes and on the crest. The sod structures are 60–70% at the foot of the slopes, and up to 30% in the crests. In the Novoselski ridge sinkholes are found in particular places, which have small size and irregular shape. Their shape is elliptical. Their depth is up to 2 m and the diameter is up to 5 m. The sides of the sinkhole are relatively steep, particularly in places where they are perpendicular to the bottom of the sinkhole. The bottom part of most of the sinkholes within the scope of the surveyed area are silted up and covered with rendzina soils, and the soil layer has a small thickness of 5–10 up to 20 cm. Some shrub species such as *Juniperus oxycedrus* are found at the bottom of some of the sinkholes. In some places, *Juniperus oxycedrus* is also observed on the walls of the sinkhole. No ponors are present. In most cases, the sides of the sinkholes are mostly bare rocks with no grass cover. In some places, the slopes of the sinkholes are covered with grassy sods of calcareous vegetation, lichens and mosses. The northern sides of the observed sinkholes are aligned with the slope surface, giving them an incomplete appearance. The humidity in the Novoselski ridge is of atmospheric type and has a low degree of expression. The xerothermic grassland formations predominate, represented by calcareous and basophilic grass communities. Among the calcareous communities, those of *Dichantieta ischaemi*, *Chrysopogoneta grylli*, *Poaeta bulbosae* and *Ephemereta* are predominant. In the higher parts of the slopes, as well as on the crests, individual representatives of *Juniperus oxycedrus* are found. In the Novoselski ridge of the Besaparski ridges natural distribution of tree species is not observed, and also there are hardly even individual tree representatives found. The main anthropogenic activity observed in the area of Novoselski ridge is the agriculture. At the foot of slope and in the lower parts of slope, separate parcels of agro-landscapes are spread. In many places, specific characteristics of pasture activity have been identified.

In the Kapitandimitrievski ridge, mappings were carried out at the foot of slope, western slope and crest. Unlike the Novoselski ridge, in the Kapitandimitrievski ridge almost no differences in the structure of the landscapes from the foot of slope, the slope and the crest parts are observed. In this part of the Besaparski ridges, all the specifics of the landscapes of the Novoselski ridge regarding the landscape forming factors are characteristic. There is also established and more significant turn of the karren structures, which is reaching up to 70% coverage both at the foot of slope, in the slope and on the crest parts of the ridge. In some places single sinkholes are observed, which have similar characteristics to the sinkholes within the scope of the Novoselski ridge. The lavender agro-landscapes are characteristic for the foot of slope parts of the Kapitandimitrievski ridge, and in some places vineyards are also found. In the low slope parts of the Kapitandimitrievski ridge, karren ribs are observed, which have the appearance of rocky swaths with a rectangular shape. These structures occur mainly at the boundary between the slopes and the foot of slopes. Their length exceeds 50 m.

Within the scope of the Ognyanovo-Sinitevski ridge of the hills, mappings of its foot of slope and slope part with southwestern exposure are made. The natural conditions on the western and southern slopes of this ridge do not differ significantly from those in the Kapitan-Dimitrievo ridge and the Novoselski ridge. The landscape diversity of the Ognyanovo-Sinitevski ridge is similar to the landscape diversity in the other two ridges of the hills. As a distinctive specific peculiarity of the landscapes of the Ognyanovo-Sinitevski ridge, it can be stated that the northern slope of the ridge differs significantly in terms of afforestation with tree and shrub species from the other parts of the hills, which predetermines the different landscape structure in this part of the research area. There, the communities of *Quercus pubescens* and *Carpinus orientalis* are found, mixed with deciduous and coniferous species such as *Quercus cerris, Quercus virgiliana* and *Pinus nigra*. The tree communities are concentrated mostly at the bottom of dry valleys and in the slopes of the northern part of the ridge. More significant presence of tree communities is also observed in the structural decreases between the Ognyanovo-Sinitevski ridge and the Kapitandimitrievski ridge, where the species mentioned above are found. Much of the forest formations have anthropogenic origin. On the northern slopes of the Ognyanovo-Sinitevski ridge the "plant endemic of the Upper Thracian biogeographical region" (Asenov 2006) grows—the *Gypsophilatekirae*. This plant occurs only on the Besaparski ridges, and on that particular ridge. A distinctive feature of the low slope parts of the Ognyanovo-Sinitevski ridge is the presence of small-sized (about 5 m in diameter) anthropogenic excavations, created by the quarrying of rock material from this part of the ridges. In the northeastern part of the ridge, as well as on the territory of its neighboring Trivoditsi ridge, there are large amount of marble quarries within the scope of the Besaparski ridges. The diameter of the quarry on the territory of the Ognyanovo-Sinitevski ridge is about 650 m. The natural landscapes in this part of the ridge are completely destroyed. Qualitatively new technogenic landscapes have been created as a result of the intense and irreversible anthropogenic transformation of the vertical and horizontal landscape structure.

In the southern part of Besaparski hills, a landscape mapping was carried out in the contact zone between the carbonate rocks and the Kapitandimitrievski pluton. The mapping is done from the north side of the road of Byaga village to Kapitan-Dimitrievo village. Granodiorites in contact with karst marbles are found. The soil cover is mostly represented by rendzina soils characterized by relatively higher thickness of the soil layer (more than 30 cm), compared to the thickness of the soil layer in the rest of the Besaparski ridges. Characteristic of the soils in this part of the ridges is the presence of fragmentary situated and different by thickness of the soil layer soil areas, mainly in the falls, characterized by a high degree of stoniness. This is probably explained by the existence of an active contact zone between the carbonate and magma lithological substrate. In this part of the studied area, as well as on the northern slope of the Ognyanovo-Sinitevski ridge, a highest concentration of tree-shrub vegetation is observed. In particular landscapes, the coverage area of tree-shrub vegetation is over 50% of the area of the landscape unit. The vegetation is represented by xerothermic grass communities and individual shrub and tree representatives. The shrubs are represented by *Paliurus spina-christi* and *Rosa canina*, which predominate, and the tree species are represented by *Quercus pubescens* and *Carpinus orientalis*. In some places, the tree species are consolidated in small forests, and the shrubs are located mainly around the road, the carter's roads and the headlands between the arable lands. The landscapes in this part of the ridges are characterized by a specific structure and peculiarities influenced by the interaction between different genesis geocomponents. But also in this part of the ridges, the karst processes are fundamental in the differentiation of the landscapes and in determining the specifics of their functioning, dynamics and development. Owing to the greater thickness of the soil layer in the southern part of the Besaparski ridges, in some places agro-landscapes with annual plantations are located, as well as orchards and vineyards. On the basis of the more expressed agricultural activity, more—such as area distribution—and a wider spectrum—such as species diversity—of anthropogenic landscapes are observed.

Conclusion

The present study successfully implements and refines a classification system of the contemporary landscapes in the Besaparski ridges, suitable for investigating the landscapes and other karst areas. The fundamental role of the karstification processes and the resulting karst forms of the relief in the formation of the peculiarities of the landscapes in the study area are substantiated.

Based on the field and the cartographic investigations, it can be concluded that the largest distribution in the Besaparski ridges have the karst landscape varieties with predominance of xerothermic grass formations on marbles and rendzinas (1a); have landscapes of agricultural lands with significant plots of natural xerothermic vegetation in the place of *Quercus pubescens* and *Quercus virgiliana* forests on marbles and rendzinas (1d) and have transitional tree-shrub vegetation with Mediterranean elements and forests of *Carpinus orientalis* and *Paliurus spina-christi* on marbles and rendzinas (1c). Type 1a landscapes are widespread within the scope of the Besaparski ridges, but mostly on the slopes. Type 1d landscapes are situated mainly on the low slope parts and at the foot of the slopes of the ridges. Type 1c landscapes are predominantly spread along the northern slopes of the Ognyanovo-Sinitevski ridge, the Glavinitsa ridge, as well as in the low slopes between the Ognyanovo-Sinitevski ridge and the Kapitandimitrievski ridge. Generally, landscapes dominated by grasslands prevail and, to a lesser extent, with the presence of transitional tree-shrub vegetation. The deforestation of the terrain is mainly due to the features of the lithological substrate, combined with the processes of karstification and the specifics of the hydro-climatic and the soil conditions within the ridges. Exactly the karstification processes play a major role in determining the specifics and the presence of the intersystem interactions and interdependencies between the components of the karst landscapes. Regarding the degree of anthropogenization, the most affected by anthropogenic transformations are the landscape varieties of industrial sites on marbles and rendzinas at the foot of the slopes, in the slope parts and on the crests of the ridges, and the settlements on marbles and rendzinas at the foot of the slopes and low slope areas of the ridges. The high degree of anthropogenization of these landscapes is directly related to the intensity of the transformation of their vertical structure. In the industrial landscapes, the natural horizontal and vertical structures are completely destroyed, whereas a qualitatively new type of technogenic landscape arises.

In the process of differentiation of the contemporary landscapes of the Besaparski ridges, the interconnections and the intersystem interaction between the natural components that play a role of landscape-forming factors have been proved. The present study successfully analyzes in landscape-ecological aspect both the role of the natural components and the types of land use in the differentiation of the karst landscapes and justifies their interrelations and interactions in the karst system.

The functioning of the karst landscapes is directly related to the interaction and interconnection between the subsurface and superficial parts of the karst geosystems. The intense anthropogenic activity in the area since prehistoric times has led to lasting and irreversible transformations of the horizontal and vertical structure of the landscapes of the Besaparski ridges. The contemporary processes of anthropogenization within the scope of the ridges required their inclusion in the Natura 2000 ecological network, both under the Habitats Directive and the Birds Directive. The conservation of endemic species such as *Gypsophilatekirae* is a serious challenge to the national environmental policy and legislation. The nature conservation activity in the investigated area must be synchronized in unison with the contemporary concepts of sustainable development. In this sense, it is necessary to find a balance between the utilization of the economic landscape functions and services of the landscapes of the Besaparski ridges and the landscape functions of maintenance the unique biodiversity in this part of the country.

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Reconstruction Models of the Landscapes in Aydemirska Wetland System

Georgi Zhelezov

Abstract The wetland system is one of the most sensitive nature systems. The importance of wetland systems is determined by the fact that they provide a numbers of goods and ecosystems services. The present research observes the problems with the spatial transformations of the landscapes in Aydemirska wetland system, in north-eastern Bulgaria, which is part of the Danubian catchment. Generation of different space–time models based on old maps and aerial photos gives an opportunity for the investigation of the state and parameters of the wetland system. The reconstruction models of the landscapes are made based on these results. Investigation of the space transformation in environment historical period is a promising platform for planning of the economic activities in the region. Nature conservation will also be part of this conception, if the object has potential and nature importance.

Keywords Landscape · Wetland · Model · Reconstruction · System

Introduction

Wetlands are some of the most dynamic and fast-changing natural systems on the earth. They respond even to the smallest changes of the environment state. In this aspect they may be used as a reliable basis to determine the quality of the environment and the degree of anthropogenic transformation in a specific area. Wetlands have versatile significance:

– Wetlands contain huge water masses.
– Wetlands represent valuable fresh water reservoir.
– Wetlands take part in the water cycle.
– Wetlands support the basic living systems on the earth—their functioning, dynamics and productivity.
– Wetlands have important filtration and purification functions with regard to the drinking water globally.

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– Wetlands protect many lands from flooding.
– Wetlands are the habitat for many fish and animal species.
– Wetlands include unique landscape diversity.
– Wetlands are rich in plantation.
– Wetlands are centre of different business activities (agriculture, fishing, tourism, recreation, etc.).
– Wetlands are connected with the cultural specific and identification of many people and countries worldwide.

Research Object

Aydemirska lowland is one of the Danubian lowlands in north Bulgaria. It is situated between the river Danube on the north and Danubian plain on the south, and reaches Vetrenski hill on the west and town of Silistra on the east (Fig. 1).

The length of the lowland from the west to the east is 16.7 km, its maximum width is 2.5 km. Its area is 34 km^2, with an excess of 3–4 m above the level of the Danube river. It is found and built on the river beds. Along the Danube is built over 5 m high water dike. Drainage measures have been carried out in the lowland and an irrigation system has been built.

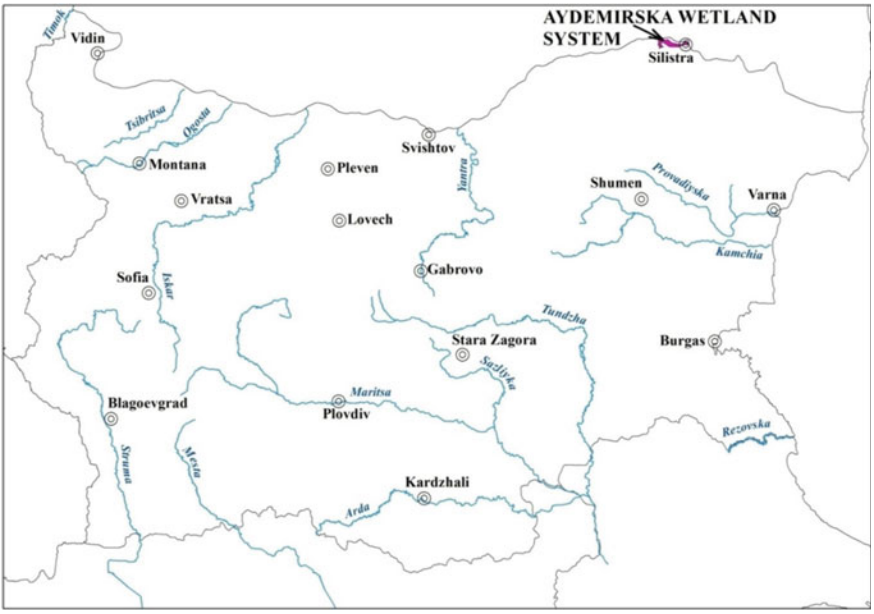

Fig. 1 Position of Aydemirska wetland system

The area of Srebarna Lake is separated from the Aydemir system of wetlands. This is determined by the fact that a self-operating system has been set up within the structure of the Danube—lake–groundwater. In the past, before the construction of the coastal dyke in 1948, the two systems have been developed as functionally connected.

Models and Modelling

Models in geographic researches are commonly based on analogies. Analogies with regard to: natural phenomena; public and economic phenomena; alphabetic–numerical images and mathematical formulas. Haggett and Chorley (1967) determined three basic groups of models—model analogies to natural systems, models of specialized systems and models of general systems.

The model is also reviewed as a part of the bilateral link "model—theory". The model is applicable upon verifying the evidence for specific theory. To be used correctly, which function is paramount and how to arrange data in order to complete a specifically assigned function must be determined. That is, an important function of the model is the theoretical interpretation in such a way that it is not identified with it, but turns the meaning of the model to the logic of the theory itself.

In this regard, Harvey (1969, 1996) identifies prior models (direct $A = B$) and posterior models (A/B). Prior models are based on building a theory. In this regard the problem of interpretation of calculations is very important. These models precede the theory from cognitive point of view. Posterior models are obtained by using formalized theories. The beginning is connected with empirical observations. These models simplify the procedure for theoretical verification. The obtained results may be transferred to the theory. If the verification proves to be successful result of modelling, then this is determined as a successful theory. In geography mainly prior models are applied. If the model is not good, then it leads to wrong (incorrect) forecasts.

According to Smyth (1998), spatial (mapping) models are reviewed as abstracts of reality. The latter contain only those features of reality that are important for the interpretation of object. The model as an abstract presents the aspects of the real world, which may be manipulated and analysed in the past, determines the present and offers opportunities for forecasts.

The condition of the systems of wetlands may be characterized theoretically through the deterministic models of Gurney and Nisbet (1998). These types of models are used upon determination of the conditions and the states of the system. The model testing is connected with the ability of the model to provide solutions.

The basic state is defined as Xt—a given state in a given model. The resulting state is defined as $Xt + \Delta t$. Ensuing from this formalistic state, it may be determined that:

$$\mathrm{Xt} + \Delta\mathrm{t} = \mathrm{f}(\mathrm{Xt})$$

The subsequent state is always a result from the impact and influence of different groups of factors. Generation of the spatial models is achieved by the application of head-up digitizing technology and direct extraction of the output mapping materials.

The reconstruction models are reviewed in this aspect. Their options give the real opportunities for restoration of the state of specific mapped objects for past periods of time and their presentation in accessible form. They provide a real platform for tracking the dynamics and the evolution of the systems in space and time. A specific research is focused on the systems of transformation and main reasons for changes of the landscapes in Aydemirska lowland.

Reconstruction Models of the Landscapes in Aydemirska Wetland System

The reconstruction models show specific states of the natural and social systems. They enable recovery of the system state in past periods of time. Another aspect of the work of the reconstruction models is the ability to track the dynamics of the system development (evolution and degradation). In combination with the potential of the spatial models, a real idea about the spatial is achieved —temporary dynamics and the processes run in the systems.

The first spatial model of Aydemirska wetland system is based on the map from 1880 (Fig. 2). It shows broad flooded area in the lowland. There is also open water body in this area. This is the oldest basic model and can be assumed to show the natural evolution of the system. This condition can be seen as a result of the interconnection between Danube river—permanent water body—and groundwater in Aydemir lowland.

The second spatial model of Aydemirska wetland system is based on the map from 1903 (Fig. 3). It shows broad flooded area and four separated water bodies. This fact determined the dynamic interaction between river Danube and flooded area in Aydemir lowland.

The third spatial model of Aydemirska wetland system is based on the map from 1910 (Fig. 4). It shows the main water body and five smaller water bodies. Three of them are situated east of the main water body, like in the model shown in Fig. 3. There are two new water bodies in the western part of the lowland. The two new water bodies mark increasing of flooding waters and underground waters in Aydemir lowland.

The fourth spatial model of Aydemirska wetland system is based on the map from 1916 (Fig. 5). The number of small water bodies is changed. There are two water bodies in the east of the main water body and one in the western part of the lowland. This fact determined the fluctuation of flooded water from river Danube to underground waters. There is data for changing of Danubian islands, which mark changes in the level of river Danube.

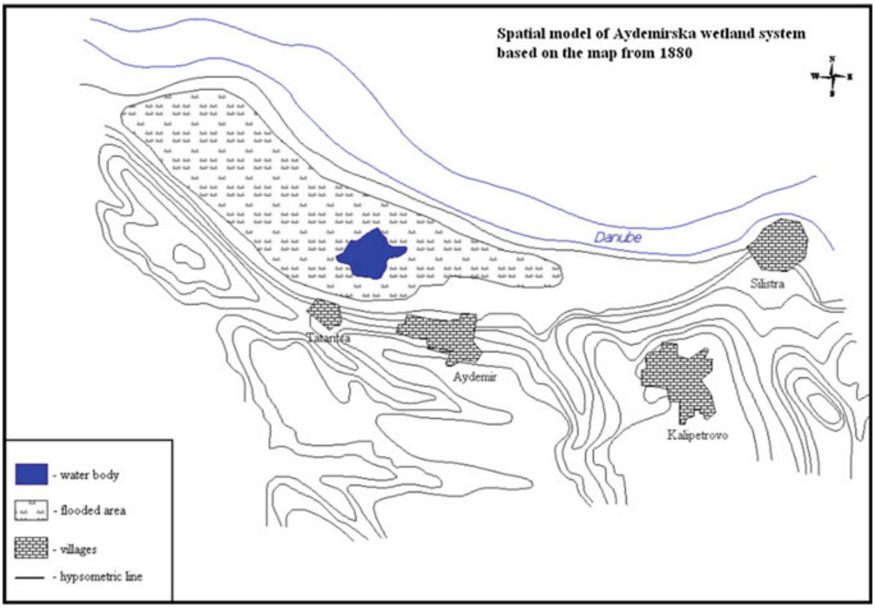

Fig. 2 Spatial model of Aydemirska wetland system based on the map from 1880

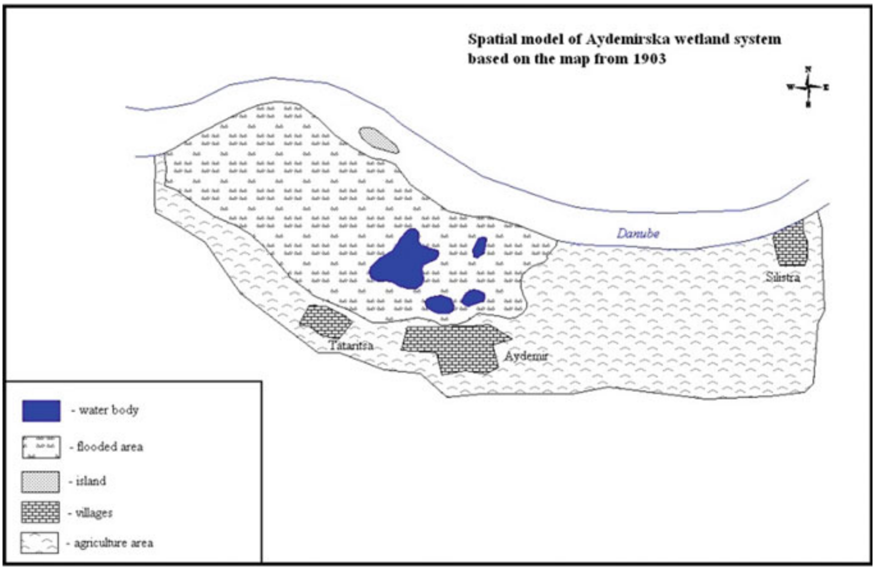

Fig. 3 Spatial model of Aydemirska wetland system based on the map from 1903

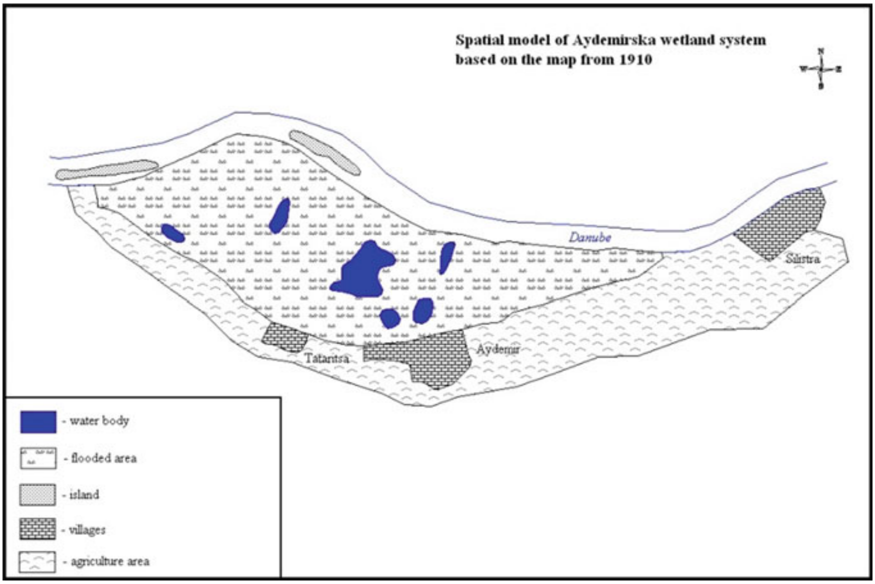

Fig. 4 Spatial model of Aydemirska wetland system based on the map from 1910

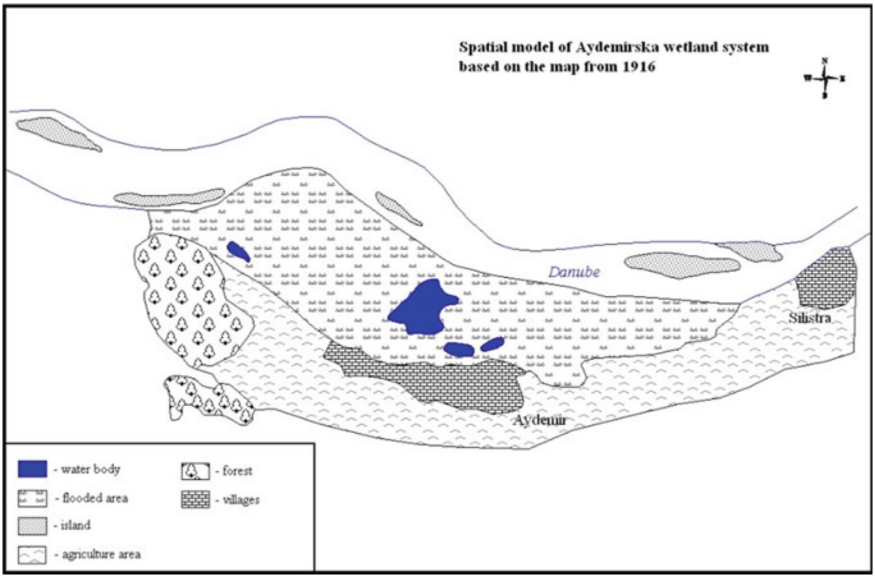

Fig. 5 Spatial model of Aydemirska wetland system based on the map from 1916

The fifth spatial model of Aydemirska wetland system is based on the map from 1920 (Fig. 6). It shows three small water bodies, which are situated east of main water body.

The sixth spatial model of Aydemirska wetland system is based on the map from 1935 (Fig. 7). It shows the main water body and two small water bodies in the western part of the lowland.

The seventh spatial model of Aydemirska wetland system is based on the map from 1940 (Fig. 8). It also shows changes in the number of the small water bodies. This can be determined as changes in functional connection between river Danube and flooded area.

The eighth spatial model of Aydemirska wetland system is based on the data from the satellite image of 2018 (Fig. 9). Part of the information for the region is collected during the field work. It shows the present situation of the landscapes in Aydemirska lowland.

There are several transformations in Aydemirska lowland as a result of anthropogenic impact:

- The protected dike along the river Danube was built.
- Industrial zone is built in the region between the village of Aydemir and the town of Silistra.
- Irrigation zone in Aydemir lowland was built.

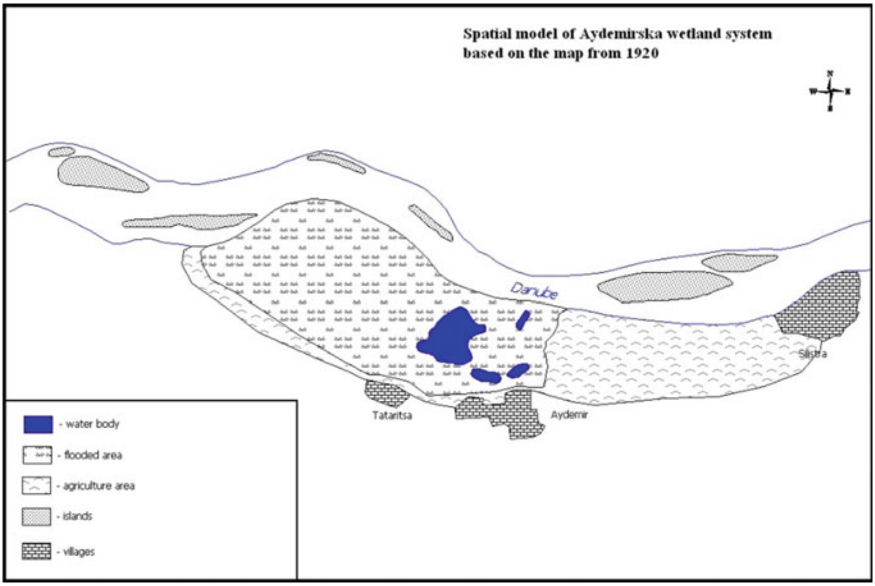

Fig. 6 Spatial model of Aydemirska wetland system based on the map from 1920

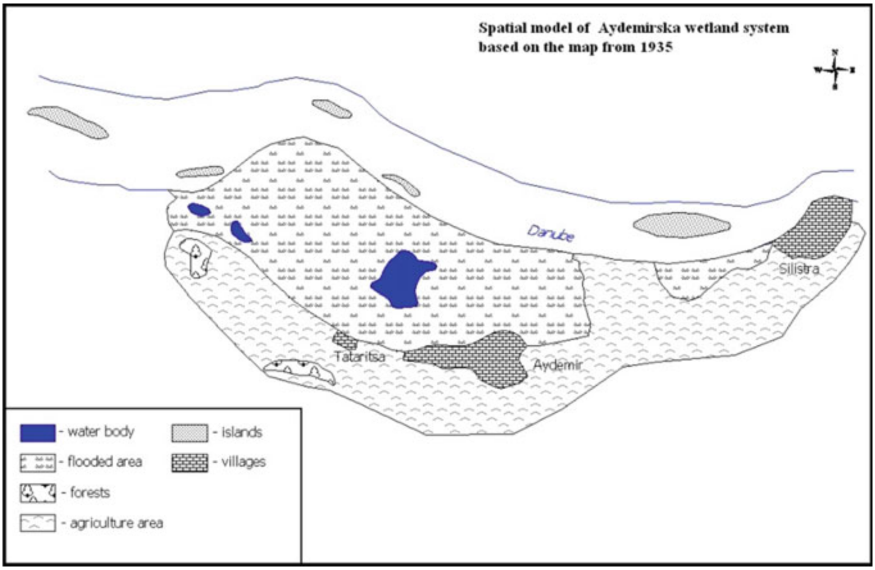

Fig. 7 Spatial model of Aydemirska wetland system based on the map from 1935

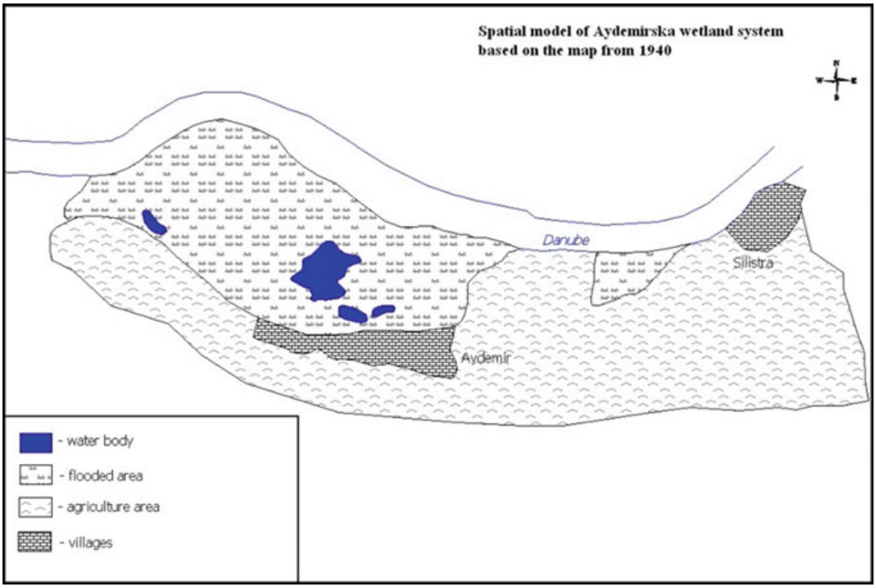

Fig. 8 Spatial model of Aydemirska wetland system based on the map from 1940

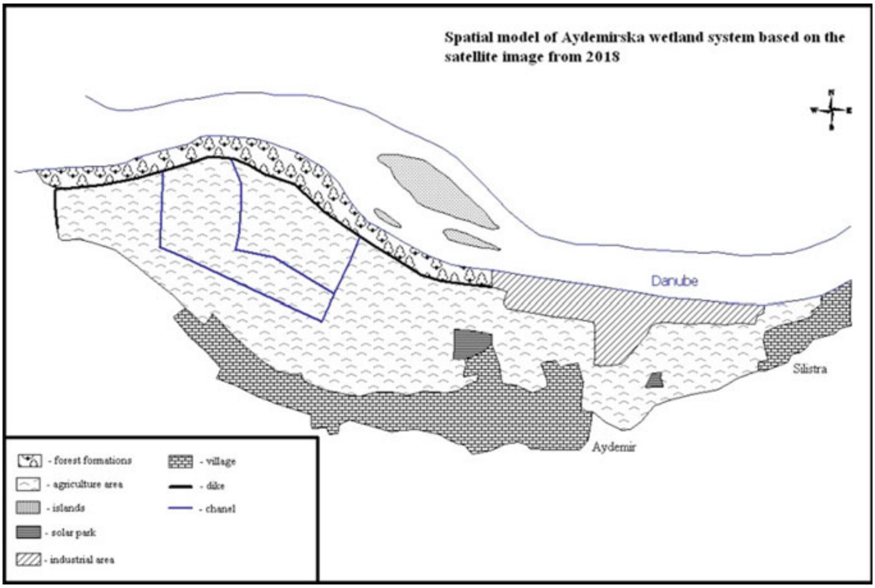

Fig. 9 Spatial model of Aydemirska wetland system based on the satellite image from 2018

– The two villages Aydemir and Tataritsa were connected.
– Two solar parks were built in the lowland.
– Forest formation along the river Danube for shore protection was developed.

The natural connection between river Danube and wetlands in the lowland is interrupted. The main water body is drained. Almost all the territory of Aydemirska lowland has been transformed into agriculture area.

Conclusion

As a result of the research, the spatial modelling and analysis are identified as considerable transformations of the landscapes in Aydemirska wetland system. The general factor for the transformations of the natural system is the anthropogenic activities.

The main part of the wetland in the valley is transformed into agriculture area.

The flooding zone and main water body are drained after 1940.

Development of the agriculture and industry in the villages of Aydemirska lowland reflected the landscape and the biological diversity of the region.

The results of the study can be used if wetland system restoration plans are developed.

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Empirical Study of the Geoecological State of Selected Landscapes in North-Central Bulgaria

Hristina Prodanova

Abstract The chapter presents the results of field research in the central segments of Stara Planina Mountain, the Predbalkan region and the Danube Plain. The study of the geoecological state was based on semi-stationary and field observations made during the summer seasons of three consecutive years. The main objective of the research was to detect and map the contemporary geoecological problems in the area. This objective has been achieved through preliminary study of literature and web-based sources, and has been verified through field studies. Cases of negative impact of human activity—the main cause of the deteriorated geoecological state of the nature-territorial complexes—were detected in some of the preliminary selected "hot spots", as well as in zones that were supposed to be relatively unspoiled, or zones of insignificant human intervention. Examples of such zones in the studied area are the unregulated clearing in the vicinity of "Pleven" hut, as well as the existing illegal landfill along the river passing by the Keryatsite hamlet of the Boazat village.

Keywords Field research · Anthropogenization · Geoecological problems · Erosion · Deforestation

Introduction

Geoecology is a relatively new interdisciplinary science which, generally put, studies the natural processes and the anthropogenic activities taking place in the contemporary landscape sphere. All living things in nature participate and function in continuous interrelation with inorganic geocomponents (rocks, air, waters), as well as soils, and together they are involved in the continuous circle of substances and energies, along with the intensive use of natural resources by human society. Depending on the different approaches to studying the "human–nature" interaction, as noted by Petrov

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(2016), geologists, geographers, geophysicists, geochemists, bioecologists, and so on, perceive geoecology in a different way.

The foundation of geoecology is related to the name of the German geographer Carl Troll, who introduced the term *landscape ecology* in 1939, replacing it with *geoecology* in the second half of the twentieth century (1966, 1968) (Petrov 2016; Pecelj et al. 2015). Troll defines geoecology as a science studying the natural complexes (landscapes) that are determined by the relationships and interactions between the biotic and the geomatic components of the natural environment.

Contemporary researchers who work in the field of geoecology are the ones such as Kvinikadze et al. (2006), who made a geoecological assessment of the environment in Georgia, Ivanov et al. (2009), Kovalchuk and Ivanov (2010), Ivanov (2014, 2015), who studied the geoecological state of mining areas in Western Ukraine, Golijanin (2015, 2017), who performed a geoecological assessment for sustainable development purposes of parts of Bosnia and Herzegovina, Gryaznov et al. (2017), who performed a geoecological zoning of industrially developed territories, Pecelj et al. (2017, 2018)—a geoecological assessment for the purposes of recreational tourism and Tandaric et al. (2018), who carried out a geoecological assessment of potentially protected areas in Croatia. In Bulgaria, a complex geoecological assessment for the needs of landscape-ecological planning of the western section of Stara Planina Mountain (the Balkan Range) was made by Avetisian and Borisova (2016).

This study aims at identifying specific geoecological problems that can serve as criteria for carrying out a complex assessment of the geoecological state of the landscapes in North-Central Bulgaria.

Materials and Methods

Study Area

The studied area is located in North-Central Bulgaria, including the parts of the central segments of Stara Planina Mountain, the Predbalkan region and the Danube Plain (Fig. 5). The north border of the studied area coincides with the one between the Predbalkan region and the Danube Plain, while the south area is limited by Stara Planina Mountain summit. The western border of the studied area runs along the Osam River, while the eastern border along the Dryanovska River and the Yantra River. The mountainous part of the studied area is represented by the highest section of Stara Planina Mountain, including the Kalofer mountain ridge with Botev Peak—the highest peak of the mountain as a whole (elevation 2376 m) and the Shipchenska mountain ridge with Ispolin peak (elevation 1523 m). The Predbalkan section of the studied area covers a variety of morphological units such as heights, ridges, plateaus, small plains and valleys. Among those are the Cherni Vrah heights (1199 m), the Chereshkite heights (1094 m), the Strazhata syncline upland (768 m), the Miskrenski heights (875 m), the Lovech heights (655 m), the Sevlievski heights (627 m), the Tarnovski heights, the Melovete ridge, the Devetashko plateau (555 m) and the Pluzhna plateau (447.4 m), as well as the Sevlievo plain.

The transitional positioning between Stara Planina Mountain and the Danube Plain makes the area attractive for landscape research. The geology of the studied area is represented by platform and fold structures of various rocks, in terms of origin and composition. The rock structure of the Predbalkan region is dominated by Early Cretaceous limestone—the main reason for the wide spread of karst relief forms in the Devetashko plateau, the Strazhata syncline upland and the Tarnovski heights. The bottoms of the river valleys are filled with thick tertiary and quaternary deposits. The rock formations of Stara Planina Mountain are diverse—the central parts (the kernels) of the anticlinals are made of Paleozoic rocks—mainly granites, granodiorites, schists, and so on, while the lateral parts are composed of limestone, dolomites, sandstone, conglomerates, and so on.

The climate of the studied area is typical temperate continental in its Predbalkan section, and mountainous in the higher parts of Stara Planina Mountain. The average annual temperature in the Predbalkan region is 10–11 °C, while in the mountainous part it varies between 8 °C in the foothills and −0.7 °C at Botev Peak (Kyuchukova 1983; Yordanova et al. 2002). The average annual precipitation increases from north to south, as the main reason for this is the increasing altitude. In the Predbalkan region the average annual precipitation is 600–700 mm, while in the higher parts of Stara Planina Mountain it reaches 700–1000 mm. Northwest winds prevail in the studied area, with wind velocity increasing from 1.3 m/s measured at Veliko Tarnovo weather station to 10 m/s at Botev Peak. Of the zonal soil types, the Luvisols and the Cambisols types dominate, while the Fluvisols, the Leptosols and the Umbrosols are the main azonal soil types. The vegetation exhibits distinct altitudinal zonation and includes oak, oak-hornbeam, beech, mixed forests, coniferous forests and high-mountain meadows.

According to the landscape division of Velchev et al. (2011), the studied area falls into two landscape classes: “Mountainous” and “Plain and foothill”. The “Mountainous” class is represented in the area by five most common landscape genera: low-, medium- and high-mountainous landscapes of oak, oak-hornbeam and beech forests, as well as sub-alpine meadows and shrubs. The most common landscape genera of the “Plain and foothill” class are the lowlands, the valleys, the heights and foothill landscapes with typical vegetation of willows, poplars and oak forests, together with widespread karst formations.

Methodology of the Research

The main objective has been achieved through preliminary study of literary and web-based sources, maps, legislative documents, and has been verified in the field. Field studies, including routing and semi-stationary observations, are the main method used for studying the geoecological state of the landscapes in the discussed area. Most of the field research was carried out in the spring, summer and autumn of

2016, 2017 and 2018, when the natural complexes are considered to be in a state of landscape stabilization. Semi-static observations have been carried out since the autumn of 2015 in relation to the spread of alien vegetation in the area of the village of Pushevo (the Melovete ridge) and in relation to the mining activities taking place in the vicinity of the villages of Skalsko and Kozi Rog—in the northern part of the Strazhata syncline upland.

The information gathered in the field was synthesized and analyzed, taking into account the factors influencing the geoecological state of the landscapes, while the identified problems were depicted on a map.

Analysis

As a result of the field research, a total of 53 geoecological problems were detected in the area (Table 1). In the subsequent processing of the collected material, those problems were systematized into three groups according to their type: (1) problems related to changes affecting the vegetation; (2) problems related to changes of the

Table 1 List of geoecological problems detected in the studied area

№	Date	Geoecological problem	Altitude (m)	№	Date	Geoecological problem	Altitude (m)
1	31.07.2017	vegetation change	565	28	11.07.2017	illegal landfil	500
2	31.07.2017	vegetation change	590	29	11.07.2017	vegetation change	425
3	31.07.2017	vegetation change	805	30	11.07.2017, 04.07.2018	vegetation change	605
4	31.07.2017	vegetation change	785	31	26.08.2017	vegetation change	1340
5	31.07.2017	vegetation change	675	32	26.08.2017	vegetation change	1185
6	31.07.2017	vegetation change	610	33	26.08.2017	relief change	1545
7	31.07.2017	vegetation change	485	34	26.08.2017	vegetation change	1610
8	31.07.2017	vegetation change	405	35	26.08.2017	vegetation change	1570
9	31.07.2017	vegetation change	460	36	19.05.2018	relief change	65
10	31.07.2017, 22.08.2018	vegetation change	445	37	19.05.2018	relief change	55
11	31.07.2017, 22.08.2018	vegetation change	690	38	23.08.2018	relief change	1540
12	31.07.2017, 22.08.2018	vegetation change	680	39	23.08.2018	vegetation change	1780
13	31.07.2017	vegetation change	1040	40	23.08.2018	vegetation change	1550
14	31.07.2017, 04.07.2018	vegetation change	465	41	23.08.2018	relief change	1889
15	01.08.2017	vegetation change	280	42	23.08.2018	vegetation change	1215
16	01.08.2017	vegetation change	240	43	23.08.2018	vegetation change	1620
17	29.10.2015, 13.08.2017	vegetation change	420	44	24.08.2018	relief change	1945
18	29.10.2015, 13.08.2017	vegetation change	340	45	24.08.2018	vegetation change	2125
19	22.08.2017	vegetation change	1405	46	24.08.2018	vegetation change	1720
20	22.08.2017	vegetation change	1490	47	25.08.2018	vegetation change	1290
21	22.08.2017	vegetation change	1590	48	30.10.2015, 22.07.2016	relief change	525
22	24.08.2017	vegetation change	1395	49	30.10.2015, 22.07.2016	relief change	485
23	24.08.2017	vegetation change	1425	50	18/25.10.2015, 06.04.2016, 18.06.2017, 19.05.2018	vegetation change	210
24	24.08.2017	vegetation change	1530	51	01.08.2018	vegetation change	370
25	11.07.2017	illegal landfil	520	52	01.08.2018	relief change	420
26	11.07.2017	vegetation change	460	53	01.08.2018	relief change	495
27	11.07.2017	vegetation change	450	-	-	-	-

relief forms and (3) problems related to emergence of illegal landfills. The largest number of registered problems goes to the vegetation-related type—41, followed by the relief-related type of problems—10 cases, and finally the unregulated landfills cases—2.

The first two groups comprise problems which vary in terms of duration, degree of impact and moment of emergence. Here we look at each of the three groups of problems by categories.

Problems Related to Changes Affecting the Vegetation

This group includes geoecological problems and processes which have a negative impact on the vegetation, and in particular—on the leading element in forest complexes—the trees. Five categories of problems were established (Fig. 1), according to the similarities between them.

Damages Concerning Individual Trees

This type of problems is related to the implementation of specific and purposeful damages to individual trees. The registered damages are located in places with episodic, but repeated human presence—along hiking trails, resting places, at the periphery of rural hamlets, and so on.

At the periphery of the Dulgodreite hamlet of the village of Boazat, Sevlievo municipality (landscape point (LP) 26), damages related to cutting down of trees and the use of metal wires to encircle private properties were registered. The above-mentioned hamlet has no permanent population, while the total population of the village of Boazat itself is 37 residents as of 31.12.2017 (National Statistical Institute 2019). The described cases are an example of anthropogenic influence of episodic nature, but with a long-lasting impact on vegetation.

Another example of individual trees damaging are the cases of tree carvings (LP11, LP12, LP22, LP42). The anthropogenic impact in this case is at an altitude in the range of 680–1200 m. The places where such tree carvings were registered are most often along hiking trails (in the vicinity of the "Pleven" hut ski run, the marked trail leading to "Tazha" hut), as well as at rest areas—the one south of Ostrets quarter of the town of Apriltsi for example, including such cases within the "Central Balkan" National Park limits (an act prohibited by law). Damage has been done to centuries-old beech trees (*Fagus sylvatica* **L.**).

Spread of Alien Vegetation

Of the numerous alien, exotic flora species that have invaded the territory of Bulgaria for various reasons, the North American acacia (*Robinia pseudoacacia* **L.**) and the

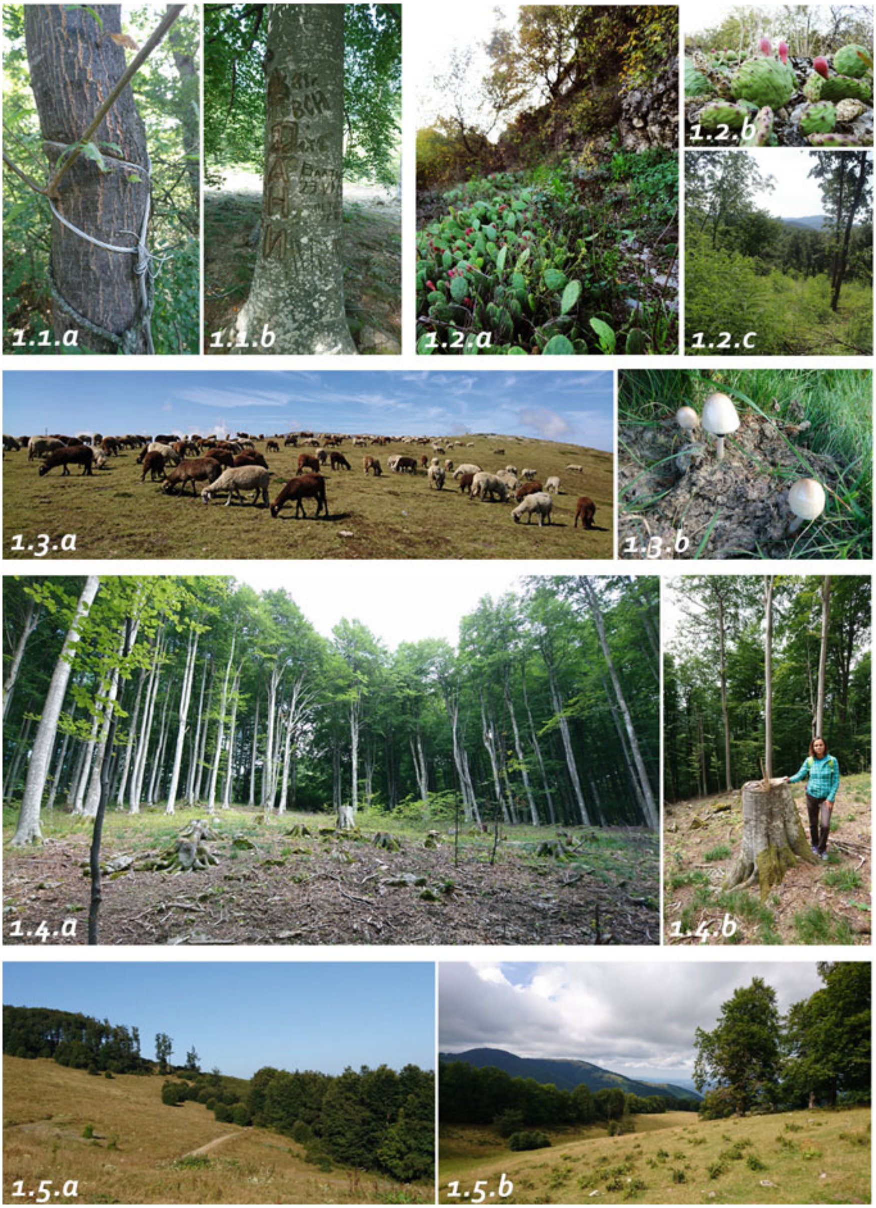

Fig. 1 Geoecological problems related to vegetation changes. 1.1. **a**, **b** Damages concerning individual trees; 1.2. Spread of alien vegetation: **a**, **b** Cactuses *Opuntia humifusa* **(Raf.) Raf.**, **c** (*Robinia pseudoacacia* **L.**); 1.3. **a**, **b** Grazing of domestic animals and the occurrence of dung fungi in the "Central Balkan" National Park; 1.4. **a**, **b** Unregulated clearings and forestry activities; 1.5. **a**, **b** Self-restoration of landscapes

Asian Tree of heaven (*Ailanthus altissima* **(Mill.) Swingle**), are found in the studied area. That group of vegetation also includes a highly unusual for Bulgaria and Europe species such as the North American cactus *Opuntia humifisa* **(Raf.) Raf**., exhibiting exceptional flexibility and resistance to cold.

Two habitats of *Opuntia humifusa* **(Raf.) Raf**. have been established in the studied area—at the periphery of the village of Pushevo (LP50) and near the entrance of the Golyama Garvanitsa cave near the village of Gorsko Slivovo (LP51). The habitat near the village of Pushevo was first described by Prodanova (2016).

The cactus field in the village of Pushevo, Veliko Tarnovo district, has an irregular funnel-like shape, occupying about 0.25 ha of the left slope of Dromuskul Dere brook. The plants have adapted to the conditions in this part of the Predbalkan region and are flourishing extremely well. Over the past 4 years, since the beginning of the Pushevo cacti monitoring, neither increase of their number has been observed, nor any indications of the cacti dying out. On the contrary, the cacti exist sustainably in the area along with local species, typical for the Predbalkan region.

The second habitat of cacti in the area has been visited relatively recently (August 2018). It is located in the area of the Devetashko plateau, near the entrance of the Golyama Garvanitsa cave (the village of Gorsko Slivovo). In that case too, as in the case of the village of Pushevo, favorable conditions for the existence of the cacti are present—limestone rocks, sufficient amount of sunshine and southern exposition of the slopes. The distance between the two habitats is relatively small—37 km as the crow flies, in NW–SE direction. Whether there is any connection between the origins of those two separate cactus fields is yet to be clarified.

Another serious problem with alien species in Bulgaria is the widespread distribution of acacia (*Robinia pseudoacacia* **L.**) throughout the Predbalkan region. This type of forest vegetation was introduced to what is now Bulgaria more than two centuries ago and today it is fully naturalized (Donchev 1968 in Panayotov et al. 2006). The so-called *white acacia* is a true scourge to the natural forest vegetation in Bulgaria. The reason is that this species spreads in an invasive way, seizing the territories of the indigenous forest vegetation, especially after logging activities. The acacia is widely spread in the Predbalkan region, the most affected areas being the Melovete ridge, the Mikrenski heights and the Devetashko plateau, at altitudes of up to 500 m. These findings coincide with Bondev's statements (1991) that the white acacia plantations occupy mostly the places of degraded (*Quercus cerris* **L.**), (*Quercus pubescens* **Willd.**), (*Ulmus minor* **Mill.**), and so on. Examples of white acacia distribution in the area can be seen around Alexander Stamboliyski reservoir (LP16) and in the area of the village of Boazat, in abandoned agricultural terrains (LP29). In both places the acacia represents the dominant tree species in the landscape.

Grazing of Domestic Animals and the Occurrence of Dung Fungi in the "Central Balkan" National Park

The problem is a result of the admittance of herds of sheep, cattle and horses within the limits of the "Central Balkan" National Park—a practice subjected to strictly defined rules stated in both the Protected Areas Act and the Park Management Plan. The main problem is related to the control of the shepherds and the free movement of grazing animals within the Park's limits, resulting in uncontrollable effects on the environment—grazing and trampling of grass areas, as well as pollution of water catchment areas with biological waste.

The pastures that fall within the studied area are located in lots of land adjacent to the town of Troyan and the village of Stokite. During the field trips in the summer of 2018, free-range herds were found in the summit part of the mountain—cattle around Maragidik (Rusalka) Peak (1 889 m, LP39) and two herds of sheep—around Yurushka Gramada Peak (2 136 m, LP45) and Paradzhika Peak (2 209 m). The distribution of dung fungi (*Panaeolus semiovatus* **(Sowerby:Fr.) S. Lundell & Nannf.** var. *Semiovatus*) (LP39 and LP46) has been reported extensively in the grazing areas of domestic animals. They are mentioned in the list of common mushrooms in the territory of the "North Dzhendem" Reserve in the "Central Balkan" National Park (Management Plan of "Central Balkan" National Park 2016–2025). The data available in the Park Management Plan makes it clear that following 2007, there was a sharp increase in both the number of grazing animals and the number of applications for permits allowing grazing: since 2010, the number of sheep in the area has been somewhere between 20 and 25,000, the number of cattle—around 5000, that of horses—about 1000. In all three cases there has been a five-fold increase of the number of grazing animals. Given this data, the problem of unregulated grazing and its impact on natural components requires a separate, more detailed study.

Unregulated Clearings and Forestry Activities

Logging in Stara Planina Mountain is a traditional economic activity with an increasing expansion in recent years. According to the WWF and some nature preservation NGOs in the country (WWF Bulgaria 2018) the annual volume of illegal logging in Bulgaria constitutes some one-third of the officially declared volume for the 2013–2017 period. The affected forests in the studied area cover both the Predbalkan region and Stara Planina Mountain, including parts of the "Central Balkan" National Park. Illegal clearings are common in the areas of Sevlievo, Gabrovo and Veliko Tarnovo. Apart from deforestation itself, additional problems related to that kind of illegal activity arise also from the use of heavy-duty machinery in inappropriate weather conditions; cutting down trees in larger areas than permitted; failure to meet certain technological requirements, and so on, which all lead to soil erosion, destruction of the existing forest roads, deterioration of the species composition of forests and their ability to reproduce. An assessment of the opportunities for logging in certain parts of the studied area (the Strazhata plateau and the Melovete ridge) was made by Prodanova (2018).

The illegal clearings given as examples in this particular study are located in the Buhalski Sredok locality (LP32) and west of "Pleven" hut (LP22) at 1500 m of altitude. The illegal clearing west "Pleven" hut (to the south of Botev Peak) involves 13 adult beech trees, the oldest one with a trunk circumference of 220 cm, while that of the other trees—of about 150 cm (Fig. 14a–b). The trees were cut at different heights above the ground—the thickest one at 1.05 m, while all the rest at about 0.3–0.7 m above the ground.

Self-restoration of Landscapes

This category represents a positive example of natural forest restoration after the end of a certain anthropogenic impact. Self-restoration of vegetation is observed ubiquitously in the studied area and the main reason for that is the depopulation of rural settlements. Restoration processes occur both in oak and beech forests at various altitudes. The process is most visible where there used to be an intensive anthropogenic activity in the past, for example—in abandoned arable lands, orchards and vineyards. Research on anthropogenization and landscape rehabilitation in the Central Predbalkan region and Stara Planina Mountain was conducted by Petrov (2007, 2009) and Petrova (2014, 2016a, 2017). Petrov uses the term "deanthropogenization" in his studies of the Predbalkan region and the Eleno-Tvardishka section of Stara Planina Mountain. Petrova uses the term "self-restoration", proving that the longer the period of lack of anthropogenic interference, the more advanced is the processes of self-restoration and the complexity of the vertical structure of the vegetation. A distinctive feature of the self-restored forest complexes, according to Petrova (2016b), is that they do not actually return to their original (natural) state: some of them are of sprout nature, exhibiting irregular vertical structure, while others are characterized by the presence of tree species, which demonstrate succession processes, such as the black locust, the aspen and the maple tree.

Examples of self-restoration are the beech forests in the "Central Balkan" National Park, in the area of "Mazalat" hut (LP31) and in the peripheral parts of the ski run at "Pleven" hut (LP22, LP23). In the Predbalkan section of the studied area, examples of self-restoration can be seen in the abandoned agricultural lands near the village of Bukovets, to the south of the Melovete ridge: the arable land in Mitsanovoto locality near the above-mentioned village was abandoned more than 10 years ago. Presently that lot of land is used for mowing hay—an anthropogenic activity that slows the self-restoration process. Nonetheless, emergence of oak trees has been observed at the periphery of the discussed piece of land. A similar example of self-restoration process is the abandoned pasture (LP18) south of the Ravnishteto locality, which has not been used for years, and the emergence of shrub phytocoenoses has been observed in the area.

Problems Related to Changes of the Relief Forms

This group of problems includes human-induced impacts through tourism and economic activities. Besides examples of negative impacts, positive, anti-erosion actions

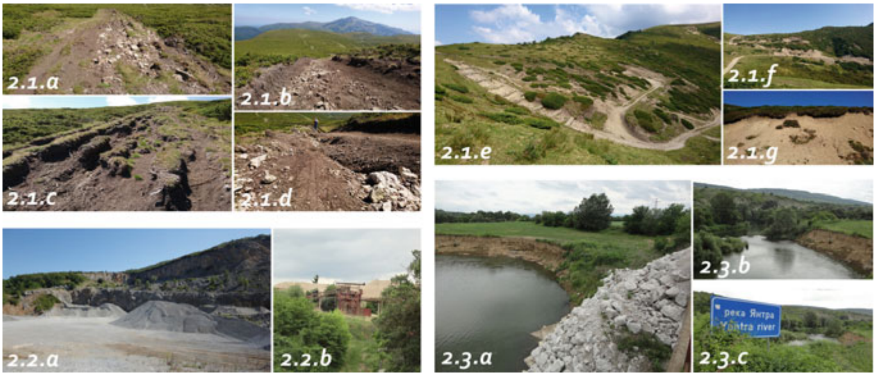

Fig. 2 Geoecological problems related to changes of relief. 2.1. Erosion of hiking trails and their adjacent areas: **a**–**d** on the eastern slope of Yurushka gramada peak, **e**–**g** in Rusaliiski pass; 2.2. Limestone and inert materials quarries: **a** Chirikovets limestone quarry, **b** Varbitsa inert materials quarry; 2.3. **a**–**c** Erosion of the Yantra River banks

and strengthening of river banks have also been recorded. Three categories of relief changes (Fig. 2) were identified.

Erosion of Hiking Trails and Their Adjacent Areas (Within the "Central Balkan" National Park Limits)

This category includes damage to soils and the rock bed caused by negative impacts of natural and anthropogenic processes. The erosion of the mountain slopes is associated primarily with the systematic movement of people and vehicles along the marked hiking trails and beyond, combined with slope steepness, lack of vegetation and as a result—water streams washing away the ruined soil cover. A survey by Ilieva and Malinov (2015) proves that more than 85.6% of the Park's territory has a very high potential risk of sheet erosion of the soil.

Examples of soil erosion can be observed on the eastern slope of Yurushka Gramada Peak (LP44) and the summit section of the Rusaliiski pass, in the area of "Tuzha" hut (LP38). The soil erosion at Yurushka Gramada Peak is caused by the casual presence of unauthorized off-road vehicles and motorbikes along the Botev Peak trail—an activity which is strictly prohibited within the Park limits. The length of the eroded stretch is over 1 km. In certain places where the grass cover is not completely destroyed, six to eight wheel ruts can be seen, 0.4–0.5 m deep and some 3–5 m wide.

In the area of the Rusaliiski pass and "Tuzha" hut, anti-erosion facilities were built (by the Park staff some five years ago, according to the hut manager's statement). Terracing was carried out at 10 levels, together with embankments of the weakest sections of the Rusaliiski pass road, while on slope areas where juniper had been missing, low hedges of branches were built for further strengthening, since in places where juniper is missing, the slope is heavily eroded.

Limestone and Inert Materials Quarries

The direct negative impacts on the landscapes arising from stone quarrying are: air pollution with dust; altered relief and land use through removing significant volumes of rock mass and destroying the vegetation; expelling animals because of the increased human presence and increased noise background; inflicting irreversible damage to wildlife habitats.

Two limestone and sandstone quarries operate in the area of the village of Kozi Rog (LP48) and the village of Skalsko (LP49), both located in the northern part of the Strazhata syncline upland. Both quarries were launched within the limits of NATURA 2000 protected areas—the "Skalsko" protected area, the "Dryanovo Monastery" protected area and the "Yantra River" protected area (Prodanova and Todorov 2016). One of the main problems arising from that is the fact that two of the above-mentioned protected areas are home to a total of 10 bat species, the future existence of which is questionable given the blastings, rock shattering, transportation and other industrial activities taking place in the area of the quarries. At the same time, the distance between the quarries and the settlements is just 1 km on average. Another example of human impact on NATURA 2000 protected area is the quarry for mining of inert materials from the Yantra River bed near the village of Varbitsa (LP36).

The problem with executing economic activities (in this case mining) in NATURA 2000 protected areas is not new to Bulgaria. There are still no clear regulations concerning those kinds of activities, and the actual conservation of habitats and birds under the two NATURA 2000 Directives is questionable in practice.

Erosion of the Yantra River Banks

This category of geoecological problems includes the failure of the left bank of the Yantra River near the village of Gorski Dolen Trambesh (LP37). Just before the bridge, the Yantra River receives the waters of the Old River. The resulting swirl, combined with the doubled force of the river waters, leads to systematic failure of the river bank, which process has been fought through periodical reinforcement with rock mass (embankments).

Problems Related to Unregulated Landfills

The unregulated landfills described here proved to be the biggest surprise during the field research stage. In both locations, waste disposal had been carried out at the outskirts of two, almost entirely depopulated, villages (Fig. 3). The first landfill is located in the gully near the Keryatsite hamlet of the village of Boazat, Sevlievo municipality (LP25). The hamlet had a population of just two residents as of the time of the visit, while the landfill is located less than 100 m from the last house.

The second landfill is located in an abandoned orchard (LP28) in the village of Dyalak (since 2013—incorporated into the village of Boazat). In that case too, the population number is insignificant—just five residents as of the time of the visit. Both examples show that the number of inhabitants alone is not a guarantee for a complete lack of geoecological problems: having no access to municipality-provided waste disposal services, leaves the local residents with few options, regardless of whether there is willingness to live ecologically or not.

Figures 4 and 5 depict the analysis of the collected data, including spatial distribution and comparison between the three types of problems described. As can be seen from Fig. 5, the largest group of geoecological problems is related to vegetation changes in the altitude range from 200 to 600 m—a total of 16, and from 1000 to 1600 m—a total of 13. Thus, two main trends of the geoecological state of the landscapes in the region can be outlined:

- The most common geoecological problems (by groups) are related to vegetation changes, observed in four out of five altitudinal belts;
- The greatest variety of geoecological problems (by categories) is observed in the low-altitude mountain ranges;
- The higher the altitude, the lesser is the number of problems (of any type and category).

In the high mountain range for example, only five vegetation-related and two relief-change-related problems were detected. Additional inspections on foot are

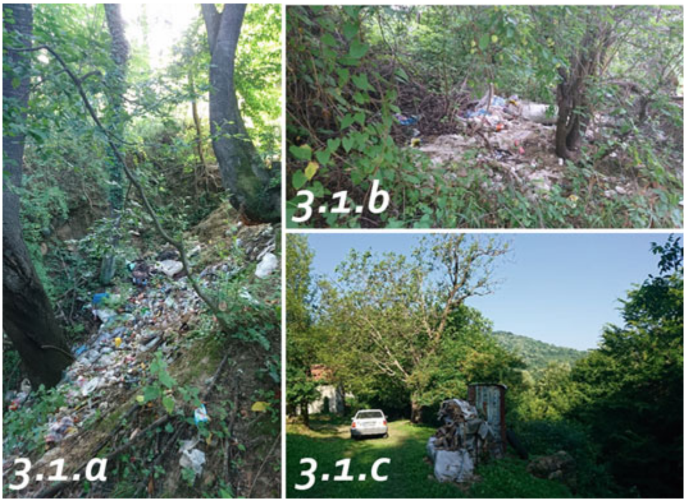

Fig. 3 Illegal landfills. 3.1. **a**, **c** Keryatsite neighborhood, Boazat village, **b** Dyalak village

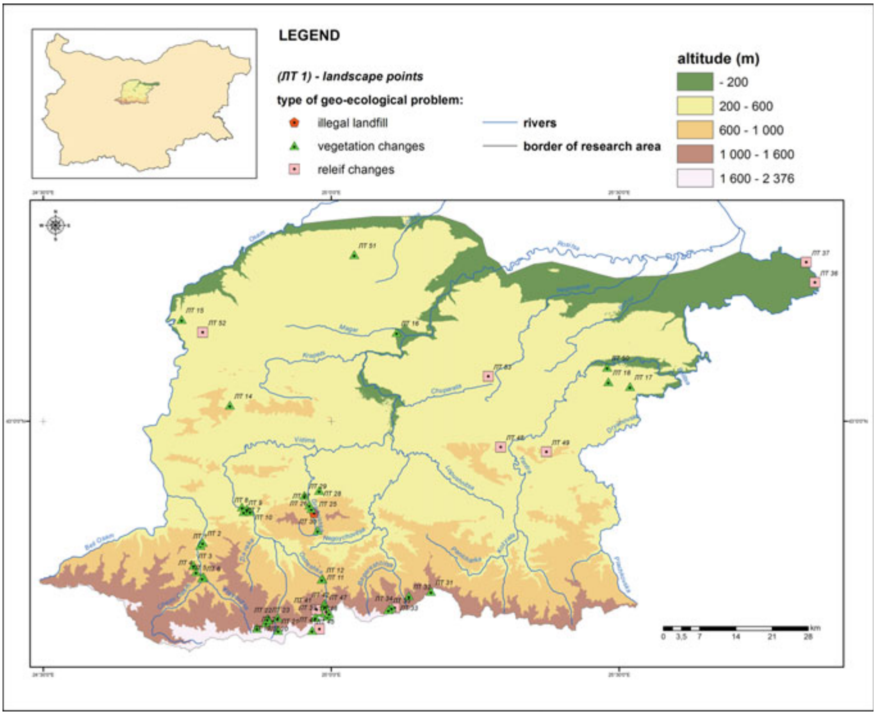

Fig. 4 Spatial distribution of observed geoecological problems by altitude

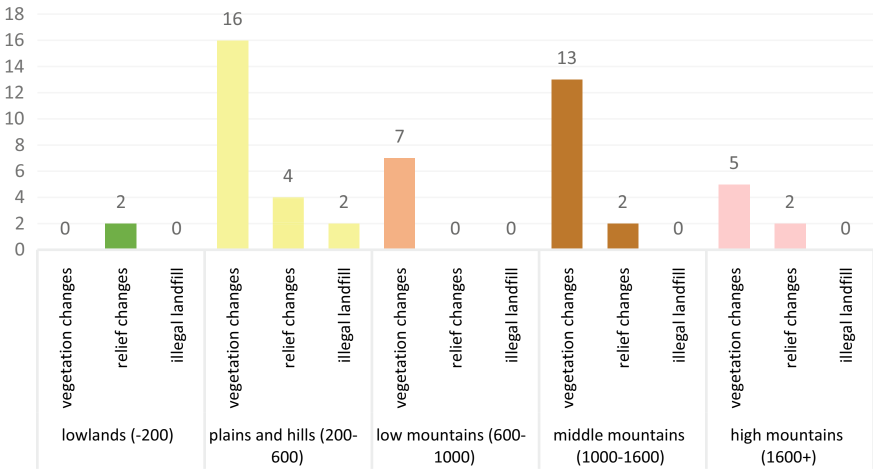

Fig. 5 Comparison of the distribution of problems by type in different altitude range

necessary in the lower part of the studied area (up to 200 m of altitude) and in the valleys of the rivers Osam, Rositsa and Negovanka, as well as in the Sevlievo plain, since the vast majority of the population and industries are located there.

Conclusion

The first evidence of human presence and economic activity in the area dates back to prehistoric times. The region is one of the longest inhabited regions in modern-day Bulgaria. As in the past, the settlement network in this area is still very dense, especially in Gabrovo district, which tops the list of administrative districts in Bulgaria by density of the settlement network. Over the last several decades, however, there has been a process of intense depopulation, which has led to reduction of the anthropogenic impact on the landscapes, accompanied by self-restoration processes. This complex picture of the studied area has been confirmed through field studies during which a total of nine categories of geoecological problems were registered, grouped into three main groups.

The majority of geoecological problems are related to changes concerning the vegetation and the relief forms. The altitudinal distribution of those problems reflects the concentration of people and their activities—predominantly in the plains and in the hilly areas, and episodic presence in the high mountain ranges. Human activities such as logging, animal grazing and tourism are traditional for the Stara Planina Mountain section of the studied area, while crops growing and mining of inert materials have been typical for the Predbalkan region.

It has to be said that at this stage of the study, we do not have enough data to make general conclusions about the geoecological state of the landscapes in the studied area. To receive accurate results we need to check the state of the landscapes in additional locations, evenly distributed across the studied area, so as to make up a whole grid of landscape point to be described. Regardless of the uneven distribution of the selected landscape points (LP), the described geoecological problems fully reveal the anthropogenic impact in the area. That impact, in combination with the ongoing natural processes, will both be used in future studies as criteria for assessing the geoecological state of the landscapes in the whole of North-Central Bulgaria.

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Ecosystem Services

Stoyan Nedkov and Steliyan Dimitrov

Climate Change and Ecosystem Services in Bulgaria, or What We Lose When We Win

Svetla Bratanova-Doncheva and Kremena Gocheva

Abstract Climate change is an increasingly important pressure which impacts on ecosystems, disturbs their functioning, provokes biodiversity loss, and reduces their ability to provide important ecosystem service such as improving water quality and regulating water flows, carbon sequestration, etc. Climate change, together with other stressors, decrease the capacity of ecosystems to buffer the impacts from extreme events like fires, floods, and storms. It is of key importance to understand the manner in which ecosystem resilience supports climate change adaptation, and put a value to the benefits and costs of policy responses that use ecosystem services to reduce climate vulnerability. The study presents the situation in Bulgaria—climate scenarios, the climate impact on the main ecosystem types, on different biodiversity levels. We combined Bulgarian vulnerability and sector analyses with EU-level data to perform a national cost–benefit analysis of the possible demand and supply of some ecosystem services relevant to climate change adaptation (mostly regulating services); we also present a case study for revealed price valuation of ecosystem services on a local project level based on EU guidelines. On both scales, we find that ecosystem-based adaptation has improved the cost–benefit ratio. The analysis is aligned with the principles of the DPSIR framework.

Keywords Climate change impact · Ecosystem integrity · Ecosystem resilience · Vulnerability · Ecosystem services · Cost–benefit analysis · Ecosystem-based-adaptation · Adaptation options

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Introduction

This chapter discusses the application of cost–benefit analysis (CBA) for assessing ecosystem services related to climate change adaptation (CCA)—both as important services that may be negatively impacted by climate change, and as a means to utilize cost-effective adaptation solutions.

The chapter presents the current situation and expected climate change impacts on biodiversity and ecosystems in Bulgaria and on ecosystem services provision. It then compares CBA's possibilities, uncertainties and limitations for assessing single ecosystem services at a national scale as used for preparing the draft Climate Change Adaptation Strategy in Bulgaria (World Bank 2018a) and on a more comprehensive regional/local scale as presented in the mental experiment of an infrastructure project (Gocheva et al. 2016).

Both applications are set in the wider context of the Bulgarian Methodological framework (Methodological framework 2017) as discussed in the Assessment of the Biodiversity and Ecosystems Sector (World Bank 2018b). The national scale study is, to our knowledge, the first for Bulgaria and its methodology allows for extending it with new services as the respective data becomes available.

On both scales, the working hypothesis is that CBA can be used to get revealed prices numeric estimates of the benefits for ecosystem service groups (bundles) based on the hypothesis presented in Fig. 1. For any cost level, e.g., C, there is a surplus of service provision that can be derived as the difference of service provision with or without the services (E–D). In terms of estimating costs, the value of ecosystem

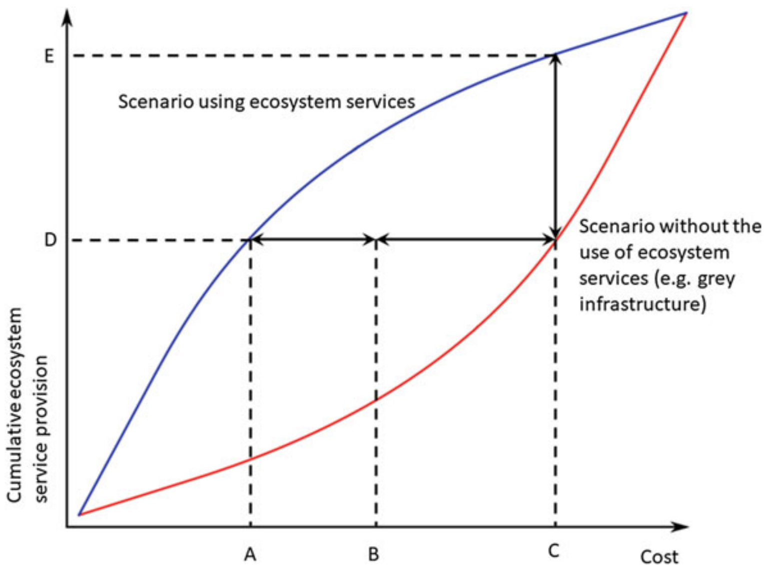

Fig. 1 Value added of using ecosystem services

services for a given level of service provision (for example, D) is derived as the cost difference of the scenarios with or without ecosystem services (C–A). The cost estimate is provided for the group of services from one or more ecosystems in a given scenario and measuring or modeling every single service may be impractical or impossible. However, in the context of a project, costs may be divided into costs attributable to a given project and accounted for by a company or group of economic actors (typically, as part of a financial analysis)—for example, C–B, and therefore the social benefits that spill over to the local community (such as climate regulation, flood protection, health, and recreational benefits), will form the difference (B–A). These transferred benefits can be estimated using economic analysis.

The principle depicted in Fig. 1 can be applied at different scales and in different contexts, from the national-level ecosystem assessment to facilitate spatial planning, down to a georeferenced local infrastructure project positioned in a specific landscape with its available ecosystems and the trade-offs in their use for a specific purpose. The exact magnitude of values would, in each given context, depend on the ecosystem type, its condition, climate resilience, and the resulting ecosystem service provision capacity over time. Cumulative ecosystem services provision refers to the way all possible (including mutually exclusive) services are used following the decision of relevant stakeholders. It often includes the trade-off between provisioning ecosystem services (such as timber or crop production) and regulating ecosystem services that are among the most relevant for CCA. The optimal cumulative service provision is subject to competing types of resource- and land-use. These parameters can be linked through the ecosystem integrity (or "whole system") approach (Müller et al. 2010), which is the basic concept in the International Long-term Ecological Research (ILTER) community and its European network (eLTER, Haase et al. 2018; Mollenhauer et al. 2018). The whole system approach also allows for easily integrating socio-ecological considerations (Dick et al. 2018; Gocheva et al. 2019). The Methodological Framework (2017) extends the LTER whole system approach in the wider context of mapping and assessment of ecosystem services in a uniform manner between the different ecosystems and find correlations to ecosystem service provision capacity. The whole system view allows taking into consideration different pressures, notably climate change, and create links between different policy areas related to climate change adaptation such as initial ecosystem condition and service assessment/stock taking, ecosystem monitoring to identify climate-related changes in service provision, identification and restoration of natural capital that is of critical importance for CCA.

Climate Change: Current Situation in Bulgaria

General Principles

Ecosystems are defined in the Convention on Biological Diversity (CBD) as “a dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit.” Biodiversity, defined as the variability among living organisms, is one of the two major traits of the ecosystems, closely interlinked with their second major structural trait—the abiotic heterogeneity, as well as the ecosystem’s water, energy, and matter balance (Müller et al. 2010). Diversity makes the ecosystem functioning more sustainable and ecosystems more resilient. Levels of ecosystem functioning and stability over time depend on biological diversity at different hierarchical levels: intrapopulation diversity (genetic and phenotypic), intraspecific (populations and ecological/morphological forms composing species), species diversity within communities, and diversity of communities and ecosystems.

It is widely accepted that at global levels, climate change is one of the main drivers of significant changes in **biodiversity and ecosystems (BD&ES)**. By affecting BD&ES, it also changes their capacity to provide ecosystem services for human well-being. Climate change can have effects both on single species and their communities, as well as the ecosystems they inhabit. Therefore, the concept of ecosystem integrity is key to understanding climate change impact on biodiversity. Ecosystem integrity is as important for the system’s resilience as a person’s good health is important for immunity to diseases. In the same manner health can affect work productivity, ecosystem integrity is closely related to the ecosystem services provision (Bratanova-Doncheva et al. 2017), which, in turn, is key to assessing the links between biodiversity and human activities in Climate Change Adaptation.

Climate change may have already provoked changes—regime-shifts—in ecosystem functioning. Both in Europe and Bulgaria, the knowledge base about the combined effects of climate change in association with other pressures on ecosystems and their service provision capacity is limited but improving. The relative importance of climate change compared with other pressures depends on the ecosystem type and biogeographical region. Climate change can facilitate the spread of IAS, which provoke changes of local flora and fauna and biodiversity loss or ecosystem state transition.

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as a function of the sensitivity of the different systems to climate change, its exposure to those changes, and its potential to adapt to them. Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change (IPCC 2007, 2014). Exposure describes the nature, magnitude, and rate of climatic and associated environmental (incl. anthropogenic) changes experienced by a species. Adaptive capacity is the potential, capability, or ability of a species, ecosystem, or social system to adjust to climate change, to moderate potential dam-

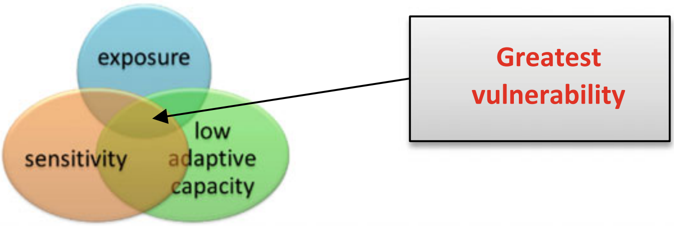

Fig. 2 The elements of vulnerability (IUCN, 2016)

age, to take advantage of opportunities, or to respond to the consequences (IPCC 2007, 2014) (Fig. 2).

Climate change vulnerability may be described at a range of different biological hierarchy levels or entities (from gene, species, populations to ecosystems) and at different spatial scales (from sites to globally), considering different biodiversity impact types (from extinction risk to declines in ecosystem function or evolutionary diversity), considering different aspects of climate change (impacts from direct climate change to indirect impacts from humans and biodiversity responding to climate change), and covering considerably different time frames (IPCC 2007, 2014).

Climate Change Risks Vulnerabilities of Biodiversity and Ecosystems in Bulgaria

All levels of biodiversity are important for maintaining ecosystem functioning and providing ecosystem services. The analysis of the main risks and opportunities arising from climate change in Bulgaria (World Bank 2018b), is summarized in Table 1.

Climate Change Impact on the Biodiversity in Bulgaria

Ecosystem functioning and its stability over time depend on biological diversity at different hierarchical levels: intrapopulation diversity (genetic and phenotypic), intraspecific (populations and ecological/morphological forms composing species), species diversity within communities, diversity of communities and ecosystems.

The main vulnerabilities concerning climate change assessed at the different levels of biodiversity in Bulgaria and summarized in World Bank (2018b) are as follows:

Table 1 Climate change risks and opportunities arising from different climate change manifestations

Risks	Opportunities
Changes in temperature (incl. heat and cold spells and heat and cold waves)	
Genetic diversity: Extinction of wild relatives, mixing with introduced species, sorts, breeds **Species**: Phenology, physiology changes, stenobiont's loss **Habitats and Populations**: Changed distribution, lifecycles changes; **Ecosystems**: Evapotranspiration, changes in functioning—primary production, biogeochemical cycles; fire risk and ESS	**BD and ES**: Longer growing season, Appearance of more heat resistant species, Increased primary productivity, Increasing adaptive capacity and biodiversity: heterogeneity, dynamics, succession Mortality of cold-sensitive pathogens Gain in primary productivity if cooler climate is stabilized and cold-resistant species enter the ES **ESS**: Surface/Groundwater for non-drinking purposes, hydrological cycle, and water flow maintenance Mass stabilization and control of erosion rates (avalanche protection)
Changes in precipitation and humidity, Droughts	
Genetic diversity, species: Decrease/loss of dry sensitive or moisture-sensitive species **Habitats and Populations**: Changed distribution; increase of IAS spread, lifecycle; disappearance of wetlands **Ecosystems**: Sparsely vegetated ecosystems, especially coastal, would be at risk; changes in functioning—decrease in primary production, increased risk of floods, erosion, landslides; increase in disservices from wetlands; decomposition of soil organic matter, salinization; fire risk	**BD&ES**: Reappearance of wetlands and increase of wetness sensitive species; better tree growth; increased BD boosts adaptability; Appearance of Dry-resistant species **ESS**: Mass stabilization and control of erosion rates, flood control; decreased fire risk Surface and Groundwater for nondrinking purposes, Bio-remediation by microorganisms, algae, plants, and animals, Decreasing of flood risk and landslides Decreasing of disservices of wetlands
Extreme events—Floods, storms, fires	
Habitats and Populations: Habitat changes and deterioration; **Ecosystems**: Ecosystem deterioration; improved conditions for pathogens; provisioning and regulating ecosystem services changes	**BD&ES**: Appearance of wetlands; **ESS**: Flood protection, Storm protection, Mass stabilization and control of erosion rates, Buffering and attenuation of mass flows, Hydrological cycle and water flow maintenance

Adapted from World Bank (2018b)

Genetic Diversity

Genetic diversity forms the basis of ecosystems' resilience to change (including climate change). The genetic diversity could insure the climate resilience and ecosystems can better tolerate disturbances caused by warmer and drier environments. For most of the ecosystem types, increasing resilience and reducing other pressures will likely be the adaptation measures of choice. Particularly vulnerable mountain habitats with rare and endangered species with low migration capability, however, may also need specific measures, such as **ex situ** preservation of species in gene banks that can be especially relevant to. The genetic diversity is being supported by the work of the National Gene Bank in Sadovo, which hosts over 60,000 gene samples from 600 plant species.

Species

Species of plants, wildlife, and fish are the target of conservation policy. Their sensitivity relates to their physiological characteristics and reproductive rates. The exposure depends on geographic location and climatic characteristics. So, the temperature-sensitive species or moisture-sensitive species could be affected by temperature increasing and moisture decreasing, especially in the south of the country. The changes in phenology rates are a reliable indicator for this kind of response on species level. In Bulgaria, phenology observations of the National Institute of Hydrology and Meteorology (NIMH) show that the phenology cycle has shifted by 10–15 days.

According to the assessment of the conservation status in Bulgaria of species with respect to the species of Annex II, the conservation status of 47.9% of all species in the continental region is "favorable", 40.2% is "unfavorable-inadequate", 4% is "unfavorable bad", 4% are rated "unknown", and 5.1% are not reported. In the Alpine region, 57.3% of the species have "favorable" conservation status, 32% have "unfavorable inadequate" status, 2.7% have "unfavorable bad" status, and for 8% of all species the conservation status is not reported. In the Black Sea region, 58% of the species have "favorable" conservation status, 23.2% have "unfavorable—inadequate" status, 7.3% have "unfavorable—bad" status, 4.3% are rated "unknown", and for 8.7% of all species the conservation status is not reported. In the marine black sea region (MBLS), 4 species from Annex II are rated "unknown". Most of these species are specialists (stenobionts)—they could exist in a narrow interval of restricted ecological conditions—unlike of the generalists (euribionts)—who survive in a large variety of conditions (ecological plasticity). Species are more sensitive to the new climate conditions may become locally extinct/deteriorate, or move in the altitudinal and latitudinal direction. Bulgaria has a high number of endemic species and rich biodiversity. It will be a significant challenge to manage this process in the future to maintain rare habitats and species and at the same time to maintain the other ecosystem services.

Most vulnerable species in Bulgaria—Rare (endemics), specialists, and endangered species with already limited distribution, especially when migration options are not possible.

Populations and Communities

The most important risk here is the interaction between species, competition for resources, the mismatch of their life cycles and loss of synchrony between species, and in results affected the species abundance and balance in the communities. It is a high probability that some species could be more competitive to other species and modify community composition. No data available in this kind of item—only sparsely investigations in our country—research needed.

Habitats

According to Volume 3 of the Red Data Book of the Republic of Bulgaria, Habitats (Biserkov et al. 2015), the country is one of the richest in Europe. Five categories (extinct, critically endangered, endangered, vulnerable, nearly threatened) of conservation status have been identified and these are based on criteria related to the main characteristics of the habitats, i.e., areas of distribution, structure, functions, sustainability, restoration capacities and resilience rehabilitation under pressure, The conservation status of Bulgaria's **166 habitats** of conservation importance have been identified. They are included in the Red Data Book and are in need of specific conservation measures. They belong to the following groups—marine habitats—11; coastal habitats—8; inland waters—21; mires, bogs, and fens—6; herbaceous communities and communities of lichens and mosses—32; shrub communities—32; forests—40; inland rock habitats—16. The habitats belong to four threat categories: critically endangered (CR)—28 habitats; endangered (ÅN)—71; vulnerable (VU)—47; nearly threatened (NT)—20.

In the Continental region, 86.3% of the habitats are in an "unfavorable inadequate" conservation status, 11% are "favorable", and 2.7% are rated "unknown". In the Alpine region, 83.6% of the habitats are "unfavorable inadequate" and 14.8% are "favorable". In the Black Sea region, 93.6% of the natural habitats are "unfavorable inadequate", 6.4% are "favorable". In the marine Black sea region (MBLS) 5 types of natural habitats are "unfavorable inadequate" and 1 is rated "unknown".

Most vulnerable habitats in Bulgaria—The possible consequence of climate change is the degradation of habitats in the 4 categories, in particular, the "unfavorable inadequate", or moving in the altitudinal and latitudinal direction. The response could be the adjustment of the protected area according to the new conditions due to the climate change. The tree line habitats have this kind of vulnerability.

Ecosystems

The ecosystem is a functional unit; therefore, the most important risk at this level are the regime-shifts in the long-term period that also influence the provision of ecosystem services. The regime-shifts' effects could be both positive or negative—increased length of the growing period could lead to increasing productivity of terrestrial ecosystems. The increasing of temperature could change the water condition of lakes and as a consequence of this—fish composition and productivity. Periods of drought could change the composition of producers in the terrestrial ecosystems and cause changes in their functioning, resulting in changes in the provision of ecosystem services. The same consequences are expected from natural disturbances on ecosystems (see Table 1). Due to these disturbances, species more adaptive for the new climate conditions could replace the formerly dominant species, change the ecosystem integrity and service provision capacity. A decrease in ecosystem services quality will directly affect may other economic sectors in the country—provisioning ES in agriculture, forestry, water sector, industry, health, regulating ES—all sectors, cultural—recreation and tourism, urban, education.

Most vulnerable ecosystems in Bulgaria are the ecosystems of inland **wetlands**, **heathland, and shrub** ecosystems (especially in **Alpine zone** in mountains) and **Coastal zone** ecosystems are the most sensitive to climate change. They are characterized by a high degree of sensitivity for all types of impacts of climate change and are further limited in area, making them particularly vulnerable. There are ongoing projects to assess the ecosystem conditions and ecosystem services in Bulgaria. In addition, a monitoring guide on ecosystem level is under development. One of the main aims of this monitoring is to follow, register, and analyze in the long term the changes in ecosystems and their services. Still, the climate changes provide good opportunities for biodiversity and ecosystems (e.g., increasing growing period). Zoning of ecosystems by the degree of vulnerability is only performed for some economically important ecosystems and the zoning for forests is presented in World Bank (2018b).

Ecosystem Services Most Relevant to Climate Change in Bulgaria

Protecting biodiversity and ecosystems may provide a powerful adaptation tool. Considering the types of projected hazards, the regulating ecosystem services are likely to have a growing importance for climate change adaptation across all ecosystem types, along with some of the provisioning services related to the provision of surface and groundwater. CICES 2018 distinguishes a total of 48 ecosystem service classes. Table 2 presents the importance of different ecosystem services for each ecosystem type—from very important (+++) to not important ():

Assessing the Value of Ecosystem Services—Case Studies of Cost–Benefit Analysis on a National and Local Scales

Deterministic and Holistic Approaches to Measuring and Valuing Ecosystem Services

Ecosystem services valuation and cost estimates are subject to cross-cutting research in the area of the ecosystem and natural capital accounting. This relatively new area is not yet incorporated in the national-level statistics of Bulgaria.

Table 2 Ecosystem services importance for adaptation (by ecosystem type)

CICES division, group	CICES class	Examples of key services	Urban	Cropland	Grassland	Marine	Freshwater	Woodland and forest	Sparsely vegetated land	Wetland	Heathland and Shrub
Provisioning—water	Surface water for drinking	Collected precipitation, abstracted surface water from rivers, lakes, and other open water bodies for drinking	+++	++	+	+	+	++		+	+
	Groundwater for drinking	Freshwater abstracted from (nonfossil) groundwater layers or through groundwater desalination for drinking	+++	++	+	+	+	+++		+	+
Regulating—mediation of waste, toxics, and other nuisances	Mediation of smell/noise/visual impacts	Visual screening of transport corridors, for example, by trees; green infrastructure to reduce noise and odor	+++	++	+	+	+	+++	+	+	+
Regulating—mediation of flows	Mass stabilization and control of erosion rates	Erosion/landslide/gravity flow protection; vegetation cover protecting/stabilizing terrestrial, coastal, and marine ecosystems, coastal wetlands, and dunes; vegetation on slopes also preventing avalanches (snow, rock)	+++	++	++	++	+	+++	++	++	++

(continued)

Table 2 (continued)

CICES division, group	CICES class	Examples of key services	Urban	Cropland	Grassland	Marine	Freshwater	Woodland and forest	Sparsely vegetated land	Wetland	Heathland and Shrub
	Buffering and attenuation of mass flows	Transport and storage of sediment by rivers, lakes, and sea	+	+	+	+++	+++	+	+	++	+
	Hydrological cycle and water flow maintenance	Capacity of maintaining baseline flows for water supply and discharge;	+	++	++	+	++	+++	+	++	+
	Flood protection	Flood protection by appropriate land coverage; coastal flood prevention (supplementary to coastal protection by wetlands and dunes)	+++	++	++	+	+	+++	+++	+++	++
	Storm protection	Natural or planted vegetation that serves as shelter belts	++	++	+	+	+	+++	+	+	+
	Ventilation and transpiration	Natural or planted vegetation that enables air ventilation	++	+	+	+	+	+++	+	+	++
Regulating—maintenance of physical, chemical, and biological conditions	Pest control	Pest and disease control including IAS	+++	++	+	++	+	+++	+	++	+

(continued)

Table 2 (continued)

CICES division, group	CICES class	Examples of key services	Urban	Cropland	Grassland	Marine	Freshwater	Woodland and forest	Sparsely vegetated land	Wetland	Heathland and Shrub
	Disease control	In cultivated and natural ecosystems and human populations	+++	++	+	++	+	+++		++	+
	Global climate regulation by reduction of GHG concentrations	Global climate regulation by GHG/carbon sequestration by terrestrial ecosystems, water columns and sediments and their biota; transport of carbon into oceans (DOCs) and so on	+++	++	++	+++	++	+++		+++	++
	Micro and regional climate regulation	Modifying T, humidity, wind fields; maintenance of rural and urban climate and air quality; and regional precipitation/T patterns	+++	++	++	+++	++	+++	+	++	+

Source World Bank (2018a)

Ecosystem service mapping in Europe defines a huge number of discrete ecosystem services (CICES 2018), and quantifies each of them using available (in many cases not very detailed) datasets and process modeling for each service's supply and use mechanisms. Georeferenced maps of the services' supply capacity and demand are then produced to derive areas with fully met, partially met or unmet demand, for example, pollination service provision is defined by pollinator habitat suitability and its proximity to pollinator-dependent crops (Valecillo et al. 2018). This approach promises clear links to EU-level ecosystem accounting and allows additive estimates for all services on every pixel of the EU-level maps; EU-level datasets are also currently the only source for national-level ecosystem service value estimates in Bulgaria and are used in our first case study. However, the modeling quality is highly dependent on reliable local data. Uncertainty is routinely not estimated/supplied with modeled EU-level layers, making it very difficult to assess the accuracy of this approach. For example, the recalculation of ESTIMAP pollination model (Zulian et al. 2013) for Bulgaria with national and local field data and a simplified conceptual schema shows difference of up to 90% to the ESTIMAP model at EU level (Zulian et al. 2017)—a finding confirmed by our GIS analysis of the EU-level pollination potential map for 2010. Despite Bulgaria's rich biodiversity, the EU-level pollination potential dataset for 2010 indicates a below-average (0–50%) potential for 54.43% of the country, above average but not excellent potential (50–60%) for 4.64% of the country and no data for the remaining 40.93% of the territory. Uncertainties in process models are added by the limited knowledge of the ecosystem services production mechanisms. Service-by-service process modeling is resource intensive and hence the number of services being modeled is small. It seems unlikely to be scalable for all CICES services even for the regular production of static maps and even less so for following climate change induced trends. Missing services strongly reduce the overall estimated ecosystem services value (especially for regulating services relevant to climate change adaptation) and doesn't account for positive externalities.

A holistic approach to the same problem is adopted in the proposed CCA options (World Bank 2018a). It envisages collaboration between national and local stakeholders in order to identify available natural capital, assess its condition and carrying capacity for different pressures, and boost the regional level climate resilience by targeted restoration, reducing other anthropogenic pressures and integrating green growth into the local economies as a way to offset losses due to climate change. Awareness and practical use of ecosystem data and knowledge by a wide range of stakeholders, ecosystem education and research are key for such an approach. One of the major institutional obstacles is the insufficient integration of ecosystem considerations, even in environmental policies such as wastewater treatment. Stakeholders, in particular, small and medium-sized enterprises, lack the capacity for understanding, accounting and reporting for statistical purposes the ecosystem services outside of the production boundary in the current system of national accounts. In our second case study we argue that CBA would hugely benefit from utilizing existing mechanisms such as the EU-level CBA Guide (EU 2015)—an approach we call modified cost–benefit analysis, or modCBA, which we believe needs minimal adaptation to be operational for the next funding period. At present, modCBA in Bulgaria cannot be linked directly to climate change adaptation due to the lack of detailed regional level climate projections and “wall-to-wall” ecosystem maps covering the entire territory.

National Scale Cost–Benefit Analysis

This case study describes the methodological foundation of cost–benefit analysis for ecosystem services prepared for (World Bank 2018a).

The analysis was based on evaluating the incremental utility of improving the provision for a total of 13 ecosystem services in three service groups: water provision, carbon sequestration, and pollination, and a total of six CCA scenarios (optimistic, pessimistic, and realistic for +2° and +4° of temperature rise). Cost data for the CBA was estimated for all adaptation options in (World Bank 2018a) using price comparison for similar projects and activities, and expert knowledge on the expected timing of different costs based on activity planning, budgetary, tendering procedures, and other time-specific considerations. Benefits data was composed of the estimated incremental benefit of using ecosystem services (beyond the direct benefits estimated in the respective other sectors) calculated from national statistics data and the estimates from other sectors using the following methods:

1. **Water provision** was estimated on the basis of GIS analysis of the JRC Water Retention Index (WRI) model dataset for 2010[1] and the coefficients for vegetation contribution to the WRI (Vandercasteele et al. 2018). We assumed targeted afforestation of half the territories with WRI below 4 (30.81% of the country’s territory), which would also cover the contribution for ecosystem restoration of 15% as per the EU Biodiversity Strategy to 2020. The incremental water provision calculated in this manner was valued using the forecast water prices from the Water sector CBA.
2. **Carbon sequestration** was estimated only for the increment of forest biomass, as approximated on the basis of the forest sector projections and the figures for the carbon content of trees (Matthews 1993) and carbon capture by forest ecosystems (Birdsey 1992).
3. **Pollination capacity** territorial scope could not be specified on a national scale due to the huge uncertainty between available datasets and the lack of means to verify the actual georeferenced values. Therefore, we used statistical data on crop production for the pollinator-dependent crops, assumed 5–10% improvement in the pollination capacity on 20% of the territory (as a result of some of the proposed adaptation options) and proposed to the CBA team to calculate incremental gains based on the coefficients in Vallecillo et al. (2018).

The estimated return on investment (RoI) for the biodiversity and ecosystems sector ranked second only to the RoI calculated for the forest sector and exceeded

[1] https://data.jrc.ec.europa.eu/dataset/06c3f085-c1e3-4228-949d-82a0899b8d7d.

the CCA RoI for all other sectors by one to two orders of magnitude, illustrating the great benefits of ecosystem-based adaptation.

At the same time, this case study illustrates the imitation of the deterministic approach, resulting in huge under-estimation of the ecosystem services value and possible further loss of ecosystem services key for adaptation due to insufficiently well-informed policies. Since the scope of (World Bank 2018a) was limited only to some economic sectors, incremental utility could be calculated for forest and partially—for cropland ecosystems, as well as the water sector, therefore leaving out other important and potentially climate-vulnerable ecosystems. We were not able to estimate the error of the predictions: climate projection scenarios have an uncertainty of their own, statistical data is not georeferenced and data limitations caused us to ignore carbon sequestration in non-forest ecosystems, notably wetlands and grasslands. We partially considered only 13 out of the 90 CICES ecosystems service classes, could not distinguish between their share in the estimated value, and were not able to estimate co-benefits and trade-offs. While implementing this approach will likely be more useful with the advancement of high-resolution satellite imagery, such additional data will not cover long time trends.

Regional to Local Application of CBA to Infrastructure Projects

Regional- and local-scale CBA presents different types of challenges, in particular, the need for—currently difficult to impossible—data integration between European, national, and local institutional and independent economic actors before the "big picture" can emerge.

We consider the benefits of extending the existing familiar cohesion funding CBA Guide approach (EU 2015). In its current form, the CBA guide applies to "major projects"—defined as projects applying for cohesion funding with eligible costs of EUR 50 Mio or above. Such projects are typically infrastructure projects in transportation, energy, environment, etc. Applicants have to perform a rigorously prescribed set of steps to provide a financial and economic analysis and risk assessment, and compare the net present value and rates of return on investment and national capital in two scenarios, referred to as Business-as-Usual (BAU) and With Project (WP). A positive funding decision is made if the project could be sustainable but needs initial investments from the cohesion funds. The BAU scenario is used as a baseline, and the WP scenario is based on the expected costs and benefits for the selected technology. However, no stipulations are made for the nature of the WP scenario and the applicants are free to propose environmentally suboptimal technologies—even for environmental projects such as wastewater treatment and waste disposal.

We propose a modification to this approach that would make receipt of funding contingent to the assessment of a scenario using fully or partly green infrastructure and ecosystem services (GI scenario)—a method referred to as modified cost–benefit analysis, or modCBA. In modCBA, applicants may be free to have more than one WP scenario as long as one of them is GI, or just include the BAU and GI scenarios. In this manner, no restrictions are posed on any technological solution and the comparison with GI will allow the applicant to make an informed decision on the relative merits of "grey" WP and GI.

Such analysis needs to be georeferenced but project and company data included in it is confidential and to our knowledge, GI solutions have so far not been introduced in any Cohesion-funded wastewater treatment project (WWTP) in Bulgaria. Therefore, we created a hypothetic case study (Gocheva et al. 2016) by "transplanting" the numeric example from the CBA Guide to the topography of the similarly sized city of Plovdiv, Bulgaria. The CBA Guide contains an example of upgrading an existing wastewater treatment plant to reduce the levels of released N and P. Plovdiv has its own WWTP with different parameters and technical solutions so we only "borrow" its local specifics: located at a big river with birds and habitats protected areas, and within the flood risk area. Plovdiv's WWTP also has limited area and its territorial extension meets significant local opposition; therefore, sludge treatment and disposal is a problem we also introduce in our case study.

In our hypothetic case study a second green–grey infrastructure (GI) scenario is introduced in which primary treatment is performed in the existing facility but the chemical N and P treatment (secondary treatment) is replaced by a number of constructed and restored wetlands. In this scenario, the project's territory becomes larger and more land would have to be purchased. However, the new wetlands would provide additional retention volume for flash flood protection, cultural services supporting outdoor recreation and bird-watching tourism, and potentially also income from carbon sequestration if such permits become tradeable.

After reproducing the BAU and WP scenarios for a 30-year period from the numeric example of EU (2015), Gocheva et al. (2016) calculate the GI scenario based on secondary treatment cost estimates from EU (2011), statistic data for land prices and tourism income and carbon prices. To estimate the necessary form, flows, basin, and vegetation structure and derive the area of the constructed wetlands for the GI scenario, we consulted relevant technical literature including Vymazal (2010), Sundaravadivel and Vigneswaran (2001), Toet et al. (2005). Correspondence between the wastewater treatment mechanisms in wetlands and CICES was established based on UN HABITAT (2008) (Table 3). To estimate carbon sequestration, we applied the figures of Agus et al. (2010) but found that the accumulation of carbon sequestering media is negligible over the project timeline of 30 years. Therefore, an approximation was made using only the Phragmites Australis reed biomass carbon (Yu et al. 2013).

The resulting calculation show very significant cost savings and, since the WWTP can now afford to lower water prices by 10% in implementing policies to support the vulnerable population—somewhat lower revenue in the GI scenario compared to the WP scenario. On balance, the GI scenario has much better financial parameters (Table 4).

Both the net present value and the much better rates of return [FRR (C) and FRR (K)] prove the financial feasibility of the GI scenario and the leverage provided by ecosystem services. In fact, the positive net present value of the GI scenario suggests

Table 3 Mapping of ecosystem functions to ecosystem services

Wastewater constituents	Removal mechanism as presented by UN-HABITAT	Correspondence to CICES ecosystem service classification
Suspended Solids	• Sedimentation • Filtration	• Maintenance and regulation by inorganic natural chemical and physical processes • Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation) • Smell reduction • Buffering and attenuation of mass movement • Decomposition and fixing processes and their effect on soil quality
Soluble organics	• Aerobic microbial degradation • Anaerobic microbial degradation	• Bio-remediation by microorganisms, algae, plants, and animals
Phosphorous	• Matrix sorption • Plant uptake	• Maintenance and regulation by inorganic natural chemical and physical processes • Bio-remediation by microorganisms, algae, plants, and animals • Filtration/sequestration/storage/ accumulation by microorganisms, algae, plants, and animals
Nitrogen	• Ammonification followed by microbial nitrification • Denitrification • Plant uptake • Matrix adsorption • Ammonia volatilization (mostly in SF system)	• Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals • Dilution by freshwater and marine ecosystems • Maintenance and regulation by inorganic natural chemical and physical processes • Regulation of the chemical condition of freshwaters by living processes • Visual screening
Metals	• Adsorption and cation exchange • Complexation • Precipitation • Plant uptake • Microbial Oxidation/reduction	• Regulation of the chemical condition of freshwaters by living processes • Filtration/sequestration/storage/accumulation by microorganisms, algae, plants, and animals • Bio-remediation by microorganisms, algae, plants, and animals • Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation)
Pathogens	• Sedimentation • Filtration • Natural die-off • Predation • UV irradiation (SF system) • Excretion of antibiotics from roots of macrophytes	• Buffering and attenuation of mass flows • Filtration/sequestration/storage/accumulation 3y microorganisms, algae, plants, and animals • Mediation by other chemical or physical means (e.g. via Filtration, sequestration, storage or accumulation) • Smell reduction • Disease control

Adapted from UN HABITAT (2008)

Table 4 Comparison of the incremental value for scenarios with and without the use of ecosystem services

WP scenario: grey infrastructure	GI scenario: green and grey infrastructure
Inflows structure, thousands EUR	*Inflows structure, thousands EUR*
Service 1: Water purification 336 466 Service 2: Energy production 6 561	Service 1: Water purification 302 819 Service 2: Energy production 6 561 Service 3: Recreational and bird watching tourism 3 913 Sales of CO_2 emission rights 3
Total revenues 343 027 Residual facility value in year 30: 4 265	Total revenues 313 296 Residual facility value in year 30: 4 265
Total inflows 347 292	Total inflows 317 561
Outflows structure, thousands EUR	*Outflows structure, thousands EUR*
Initial investment 126 531 Total operating costs 155 837 Replacement costs 22 678 Loan repayment 17 890	Initial investment 79 484 Total operating costs 133 571 Replacement costs 9 760 Loan repayment 13 012
Total outflows 322 936	Total outflows 235 828
Financial parameters	*Financial parameters*
Present value of inflows 182 745 Present value of outflows 222 120 **Net present value—39 375** Financial rate of return on the investment [FRR (C)] 1.106% Financial rate of return on the national capital [FRR (K)] 4.376%	Present value of inflows 168 443 Present value of outflows 158 583 **Net present value 9860** Financial rate of return on the investment [FRR (C)] 4,842% Financial rate of return on the national capital [FRR (K)] 9,910%

that even with reduced water prices, its implementation would be feasible by itself without any cohesion funding. This institutional paradox might, if also encountered in real-life projects, actually discourage the implementation of green solutions. In addition, the capital flow during the years is more evenly distributed, suggesting that significant economies occur during the first year of the investment when there are still no revenues (Fig. 3).

Due to the hypothetical nature of this case study, it is not possible to systematically perform all next steps that would have been produced in a real project with socioeconomic and environmental impact data, and we cannot simulate a full economic analysis and risk assessment. Nonetheless, the objective measurement of the major share of co-benefits and their attribution to ecosystem accounts could be done in a more consistent manner through following the incremental changes in the accounting of the water purification enterprise and the municipality in charge for flood protection, as demonstrated in the numeric example of Table 5. Thus, modCBA is, in fact, a variation of the revealed preferences method that can derive ecosystems service valuation directly from company accounting without the additional labor intensive and arguably less precise stated preference methods (Kahneman and Knetsch 1992; Diamond and Hausman 1994; Kahneman 1992).

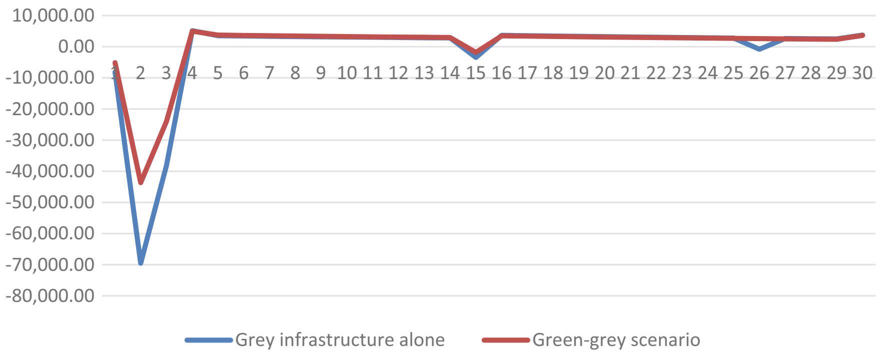

Fig. 3 Discounted net cash flows during years 1–30 of the project implementation (including 10% water price reduction)

Since a separate valuation for each and every single ecosystem service is not feasible on a company and even municipal scale and not needed in practice, the services are grouped in bundles following the principles of

- **Mutual exclusivity**: services that cannot be provided simultaneously (such as timber harvesting and carbon sequestration) should not be added to the same bundle.
- **Structural and functional production complementarity**: services provided via the same mechanism belong to the same bundle, e.g., freshwater for drinking purposes and freshwater for production purposes.
- **Final recipient**: services in a bundle should serve the same beneficiary/homogenous beneficiary group, e.g., one or more companies; a municipality; the city population.
- **By ecosystem account**: all services in a bundle should belong to the same account so their cumulative value would easily be added to it even if the single services cannot easily be valued.

The great advantage of modCBA as described in this case study is its closeness to the corporate understanding of standard business practices and their accounting. Thus, it would likely be better suited for bridging "the last mile" by setting the abstract ecosystem service concept in the day-to-day business context of estimating monetary costs and benefits. The mid-term time horizon employed in modCBA creates a baseline of continuously measuring expected value in- and outflows but also for monitoring the benefits from the green infrastructure.

The difference between predicted and actual developments could provide a way for the consequent implementation of the entire DPSIR framework rather than mostly limiting DPSIR to measuring anthropogenic pressures. By sharing impact measurement and moving part of the response from the legislative to the business context, enterprises would have economic incentives to identify and measure environmental pressures and respond to them. For example, carbon sequestration—even at the very optimistic carbon prices we expected back in 2016—is underrepresented in the

Table 5 Correspondence between project benefits, CICES ecosystem service(s), stages of the cost–benefit analysis and national accounts

Benefit	Non-discounted value, 000 EUR	CICES correspondence	Ecosystem service bundle, valuation stage	Valuation method, accounting	NCA account
Wildlife conservation: extend the habitat near NATURA 2000	Not estimated	Maintaining nursery populations and habitats (including gene pool protection)	Local project externalities (LPE); valued in the economic analysis	Not accounted; Approximation: avoided restoration costs[a]	Biodiversity satellite account
Bird-watching tourism in the restored wetland	3913	Physical and experiential interactions with natural environment Physical and experiential interactions with natural abiotic components of the environment	Additional services' utilization (ASU); Valued in the financial analysis	Sales of services over 27 years, cash flow calculated on the basis of water purification end price reduction by 10%	Outdoor recreation account
Protection from flash flooding for city residents and businesses	24,585	Hydrological cycle and water flow regulation (including flood control, and coastal protection)	LPE	Avoided municipal costs for building dykes, ditches, other flood protection infrastructure, derived from comparable flood protection tenders in Bulgaria	Service account(s), cannot be specified without a national NCA framework

(continued)

Table 5 (continued)

Benefit	Non-discounted value, 000 EUR	CICES correspondence	Ecosystem service bundle, valuation stage	Valuation method, accounting	NCA account
Carbon sequestration in Phragmites reed beds (peat formation is insignificant over 30 years)	2707	Regulation of chemical composition of atmosphere and oceans	Global project externalities (GPE)	Sales of carbon emission quota for carbon offset; estimate based on EU ETS carbon prices assuming EUR 1 annual price increase over 27 years	Carbon account
More affordable clean water for the citizens and business	33,647	Sales of services over 27 years, cash flow calculated on the basis of water purification end price reduction by 10%	LPE	Incremental direct valuation (gross revenue difference between WP and GI scenarios)	Water account

Example reference values can be seen here: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=5341

GI scenario of this case study and the operator, aiming at increasing carbon offset sales in a cost-efficient manner, may choose to add a photobioreactor, produce and sell algae fuel while also boosting the installation's climate change mitigation capacity. The impact created by such response would be captured precisely in the corporate and municipal accounts, allowing for a decentralized implementation of the DPSIR framework without the imposition of additional legislation and red tape. The exact evaluation of carbon capture in monetary terms provided by modCBA has the additional benefit of providing data for assessing the climate change mitigation and adaptation measures which are also required in the CBA Guide as part of the conditions for cohesion funding, and create a clear link to the adaptation and mitigation aspects of environmental impact assessment (EU 2013).

The modCBA case study does not at this stage deal with climate proofing of the installation according to the non-paper "Making vulnerable investments climate resilient" (EU, year unknown) since the numeric example in the CBA Guide does not mention the share of costs for such purposes. Nonetheless, positioning the new wetlands between the river and the WWTP could provide a retention volume for climate proofing the existing installation at no additional costs. As will often be the case in practice, green infrastructure does not replace grey infrastructure in the case study. Rather, the optimal service level will also require technological solutions.

Conclusions

This chapter explored the expected impacts of climate change on Bulgarian biodiversity and ecosystems, and the use of cost–benefit analysis as a support tool for valuing and weighing the gains and losses of climate change adaptation.

The two case studies we present illustrate the advantages and challenges of both the deterministic and holistic approaches to cost–benefit analysis for climate change adaptation. In practice, we expect that these two approaches will be implemented together and ecosystem-based adaptation will benefit from their respective strengths. The practical use of high and ultrahigh-resolution satellite imagery will assist the improved large scale mapping and assessment of natural capital whereas detailed ground data such as the numbers in our local scale case study can provide a cost-effective, crowdsourced ground truth verification. Together, these two sources of data could help enabling much more precise, near-real-time modeling.

Such efforts will, of course, also require a new ecosystem awareness and thinking among all stakeholders, and in particular businesses and individual volunteers who may find new opportunities in the green economy. Institutional changes, both legislative and procedural, will be necessary for successful adaptation. They should facilitate concerted action between policymakers, institutions, scientists, practitioners, and volunteers, review and reduce existing impediments. For example, the eligibility rules in the current programming period would not allow funding to be allocated to the economically much better GI scenario of our second case study, or for the installation of a photobioreactor. With the increase and streamlining of climate change funding and the development of EU-level sustainable financing rules, this is likely to change in the next programming period. The Bulgarian society will need a new appreciation for the way our ecosystems function, in order to make the most of climate change adaptation and not to lose when we win.

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Mapping and Assessment of Wetland Ecosystems Beyond Boundaries. A Pilot Demonstration in the Transboundary Nestos/Mesta River Basin

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Abstract In the context of the WetMainAreas project of the INTERREG Balkan Mediterranean Program, wetland ecosystems are considered as important biodiversity hotspots with multiple services to human well-being, which often face weak protection and are subjected to human pressures and usage conflicts. The project focuses on ecosystem connectivity beyond the boundaries of protected areas and national borders and it is linked to the result indicator 'Expansion of ecological connectivity and transnational ecosystems' integration of designated areas'. Wetlands are mapped and assessed as important landscape features that can contribute to the ecological coherence of the Natura 2000 network. A pilot demonstration is presented for the transboundary Nestos/Mesta river basin (5822.28 km^2), large parts of which are covering by Natura 2000 sites while a significant number of wetland sites are found in unprotected land. A landscape-level methodological approach is followed based on mapping products and European and national datasets. Spatial analysis and modelling techniques are applied to map the landscape's natural potential and to reveal landscape patterns of well-connected, protected or unprotected natural areas that possess high potentials to preserve biodiversity. The study tackles the lack of detailed geospatial data on wetland contribution (especially the small ones) and the lack of assessments on the contribution of wetland ecosystems in the spatial connectivity of protected networks. It demonstrates the important role of wetlands and of Natura 2000 sites in preserving biodiversity at transnational level. The study results can support policymaking and contribute to defining conservation measures.

Keywords Wetlands · Connectivity · Natura 2000 · Transboundary ecosystems

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Introduction

Wetland ecosystems constitute unique areas of high biodiversity. From the early 90s it has been stated that regional wetlands are integral parts of larger landscapes (drainage basins) and their function and values to people in these landscapes depend on extent and location (Mitsch and Gosselink 1993). Ecosystem services provided by wetland ecosystems have been characterized as vital (Costanza et al. 1997, 2014; Mitsch and Gosselink 2000; De Groot et al. 2012; McInnes 2013) and appear to be maximum in landscapes that balance nature and human enterprises (i.e. urban and agricultural areas) (Mitsch et al. 2015). Specifically, the role of wetlands as key habitats has been underlined by the need to preserve a balanced mix of ecosystem services as well as a healthy underlying level of biodiversity to sustain future services (EU FP7 OpenNESS Project Deliverable 3.1, Pérez-Soba et al. 2015). Also, it has been stated that by ensuring their conservation the required protection of processes and linkages for threatened species towards climate change in key biodiversity areas is provided (Derneği 2010). To better integrate wetland ecosystems in EU Strategies and Directives, Abdul Malak et al. (2019), highlight, as a key policy message, the ecological value of wetlands for improving connectivity despite being usually geographically scattered in the broader landscape.

The EU biodiversity strategy to 2020 amongst others, expresses concern about the increasing deterioration of wetlands. The Habitat and Birds EU Directives (the backbone of EU nature legislation), under Article 10 and Article 4, respectively, consider wetlands as important landscape features that maintain and enhance ecological connectivity amongst Natura 2000 sites and across the wider environment, in support of wildlife conservation (Kettunen et al. 2007). However, often there is lack of knowledge on areas of high biodiversity value outside protected areas and consequently, lack of conservation and management measures is given that the original goal of Natura 2000 sites did not include network's connectivity (Kettunen et al. 2007).

In this direction, the EU Green Infrastructure Initiative, which benefits environmental and territorial cohesion policies, addresses the reconnection of fragmented natural areas and the improvement of their connectivity within the wider countryside, and it promotes ecosystem services and the well-being of people (European Environment Agency 2011; European Commission 2012). Also, at global level, the Aichi Target 11 puts priorities for increasing the well-connected systems of protected areas, the area-based conservation measures and the integration of areas of importance for biodiversity and ecosystem services into the wider landscape. The demand for maintaining habitats for species has been considered as a human benefit, since it preserves natural heritage and safeguards intrinsic human values (i.e. recreation) at the same time (Knight 1997). Martínez Pastur et al. (2017), based on plant species richness, reported that biodiversity potential and ecosystem services supply (provisioning, cultural, regulating) significantly varies at the landscape level.

Similarly, the ecosystems' continuity and integration are recognized by the EU cohesion policy as one of the main challenges for the safeguard of the biodiversity of the Balkan Mediterranean territory, in support of sustainable development and improvement of citizens' quality of life. The territory shares natural environment of high biodiversity value including lake complexes, inland and coastal wetlands and riverine systems. Still, the transnational cooperation on biodiversity and ecosystem integration are very weak, nature protection and management of protected areas are insufficient, the implementation of EU directives is slow and common problems arise from inefficient use of resources, pollution and fragmentation (CP Balkan Mediterranean 2014–2020, 2014). Within this challenge, the WetMainAreas project is carrying out the mapping and assessment of wetland ecosystems as landscape features that play a significant role in the ecological connectivity of the Natura 2000 sites.

The current study presents the pilot assessment of the WetMainAreas project, for the transboundary Nestos/Mesta river basin. It tackles the need for integrated transnational assessments focusing on wetland ecosystems and the Natura 2000 network. In particular, the aims of this pilot study were as follows:

(i) map the spatial extent of wetland ecosystems
(ii) map the structurally connected natural areas of the transboundary river basin (inside and beyond the boundaries of the Natura 2000 network) that have high potential to preserve biodiversity.

Methodological Approach and Data

In the current study, a landscape-level methodological approach was followed based on mapping products and EU datasets. Spatial analysis and modelling techniques were applied to map and assess the areas of the Nestos/Mesta river basin that possess high potentials to preserve biodiversity (natural potential) and the connectivity patterns between protected and unprotected areas of high natural potential, focusing on the spatial distribution of wetlands and of Natura 2000 sites.

The transboundary Nestos/Mesta river basin (5822.28 km^2) is shared between Greece (3348.30 km^2) and Bulgaria (2473.98 km^2). The river rises from springs in Rila Mountains of Bulgaria and flows into the Aegean Sea, in Greece forming one of the most important deltaic cTransboundary Nestos/Mesta river basin shared between Greece and Bulgaria Europe (Fig. 1).

Mapping of Wetland Ecosystems Spatial Extent

To tackle the lack of detailed geospatial data on wetland contribution (especially the small ones) the latest CORINE Land Cover dataset (CLC 2018 version 20b2) that is freely available from the Copernicus Land Monitoring Service was enhanced using other thematic layers, i.e. the water and wetness detection results from analysis

Fig. 1 Study area: transboundary Nestos/Mesta river basin shared between Greece and Bulgaria

of Sentinel 2 images, the Copernicus Hydro Data for Europe and the Open Street Map Data for European countries. To accurate delineate the boundary of wetland ecosystems, photointerpretation and on-screen digitization was performed based on Google Maps hybrid while the historical image archives of Google Earth was used to justify the long-standing presence of water and of wetland vegetation.

Following recent suggestions proposed within the HORIZON 2020 research project Satellite-based Wetland Observation Service-SWOS (Abdul Malak et al. 2016; Fitoka et al. 2017), the mapping of wetland ecosystems covered the entire river basin, beyond the boundaries of administrative units and of protected areas. It encompassed all wetland types, as those are defined by the Ramsar Convention, including both natural and artificial wetlands, and even the non-wet habitats such as sand dune systems and beaches along coastal wetlands, or the deepwater habitats of lakes. Also the mapping included adjacent degraded wetlands which have lost their naturalness (dominance of wetland vegetation, water, hydromorphic soil) like

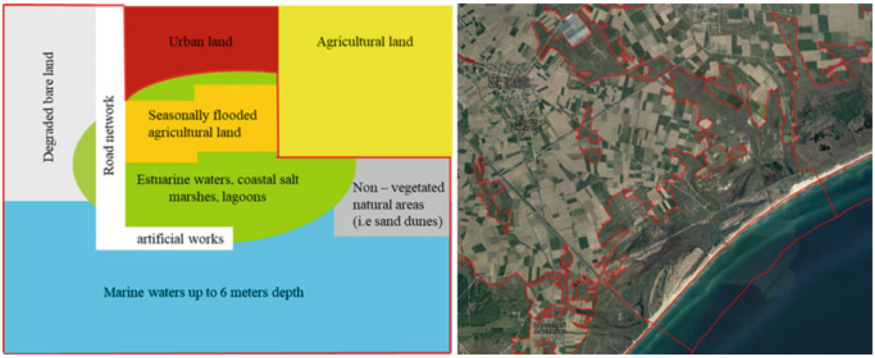

Fig. 2 Wetland ecosystem boundary (red line) (Nestos estuarine waters and Maggana Coastal lagoon, East Makedonia and Thrace, Greece)

filled wetlands that could potentially be restored (i.e. bare land), and road network or artificial works (i.e. river embankments), which may cross the wetland ecosystem (Fig. 2).

Mapping of Connected Areas that Possess High Potentials to Preserve Biodiversity

To assess the spatial (structural) connectivity of areas that possess high potentials to preserve biodiversity, we applied a methodological approach at landscape level to first map land cover areas of high potentials to preserve biodiversity and then to create a network based on the morphological spatial pattern analysis of these areas.

Based on the fact that a totally unique—undisturbed natural land cover unit, indicates absence or minimum anthropogenic impact, and that a neighbouring agricultural zone is considered more favourable to it, compared to the transition into a developed land cover unit, we applied a pattern analysis to map the dominant land cover and the degree of land cover heterogeneity. The pattern analysis was applied in the GuidosToolbox software (v. 2.8), using the Landscape Mosaic (LM) image analysis tool (Vogt and Riitters 2017). The enhanced land cover map was reclassified in three land cover classes

- Natural and seminatural: all ‘forest and semi natural areas’, ‘wetlands’ and ‘water bodies’ CLC Level 1 classes, plus the CLC Level 3 ‘artificial surfaces’ classes of ‘green urban areas’ and ‘sport and leisure activities’ and the CLC Level 3 agricultural areas classes of ‘rice fields’, ‘pastures’ and ‘agroforestry’.
- Agriculture: the remaining agricultural areas CLC classes (most intensive agriculture).
- Developed: the remaining artificial surfaces CLC classes.

For all raster analysis, we kept the cell size at 100 m, which is in compliance with the CLC 2018 linear mapping accuracy. The pattern analysis performed a tri-polar classification model at pixel level using the critical values of 10, 60 and 100% along each axis, in order to: (i) Identify the presence (10%), dominance (60%) or uniqueness (100%) of each land cover class (Natural, Agriculture and Developed) in a moving window of 9 × 9 pixels surrounding each pixel. This resulted in a window with a side of 9 × 100 = 900 m which approximately coincides with the minimum distance of 1 km for species dispersal (Saura et al. 2017). (ii) Locate interface zones of natural land cover with agriculture and/or developed (urban).

The classification resulted in a partition of the tri-polar space into 19 mosaic classes, indicating the different degrees of land cover heterogeneity. To highlight landscape mosaics within the natural background and identify human-natural interface zones (Riiters et al. 2010), we condensed the 19 classes into 6 (from all natural to not dominated by natural). This resulted in the 'Nature Dominance' map of the study area. As biodiversity itself is considered as an ecosystem service and is classified either as 'maintaining of nursery populations and habitats (Haines-Young and Potschin 2018) or as 'habitats maintenance for species' (TEEB 2010), we considered that Nature Dominance reflects the natural potential of the landscape to deliver the habitat maintenance ecosystem service.

To link the natural potential with the supply of the habitat maintenance ecosystem service we considered the presence of national designation as additional input, based on the scenario that protection measures are adequately applied and safeguard biodiversity. Additional inputs are anthropogenic contributions to ecosystem services that can act together with the natural potential and enable the identification of the spatial units within which the ecosystem service is provided (Burkhard et al. 2012; Potschin-Young et al. 2018).

Table 1 presents the rules which were applied to assess the supply of the habitat maintenance ecosystem service in five classes: no supply (0), very low (1), low (2), medium (3), high (4) and very high supply (5). If a landscape unit has some 'natural potential', the 'supply' is reduced by 'weak or no' protection, it is increased by 'strict' protection, and it is not affected when 'medium' protection exists. If it has 'no natural potential', there is 'no supply', despite any protection measures that may apply. The

Table 1 Assessment of the habitat maintenance ecosystem service supply based on Natural Potential (NP) and different protection levels

Protection	Natural potential					
	No	Very low	Low	Medium	High	Very high
Strict (high)	No supply	Low supply	Medium supply	High supply	Very high supply	Very high supply
Medium	No supply	Very low supply	Low supply	Medium supply	High supply	Very high supply
Weak/no	No supply	Very low supply	Very low supply	Low supply	Medium supply	High supply

level of protection of nationally designated areas was derived from the most recent European datasets of the Common Database on Designated Areas (CDDA) based on their IUCN management categories (Dudley 2008). It was classified as: (a) high (strict) protection for the IUCN categories Ia, Ib, II; (b) medium protection for the IUCN categories III, IV, V, VI and (c) weak/no protection for not applicable to IUCN categories, not related to nature conservation or no protection status.

As the last step, for assessing the structural connectivity of natural areas that possess medium, high and very high ecosystem service supply, a Morphological Spatial Pattern Analysis (MSPA-analysis) was applied in the GuidosToolbox software (v. 2.8), using 10 for the EdgeWidth setting. This value corresponds to a 1 km zone around each pixel, and is in compliance to the minimum 1 km distance of species dispersal applied also in the selection of the moving window for the LM computation. The MSPA was then converted to a network using the NW Component image analysis of the GuidosToolbox software (Estreguil et al. 2019). The evaluation of the network included the examination of the overall network connectivity metrics and the spatial distribution of wetlands and of Natura 2000 sites, within the network of the connected and isolated areas, as well as within the unconnected and unprotected land.

Results and Discussion

Spatial Extent and Distribution of Wetland Ecosystems in Nestos/Mesta River Basin

The wetland mapping for the Nestos/Mesta river basin resulted in a total wetland spatial extent of 15285.5 ha, 30% of which (4510.5 ha) were not included in the CORINE Land Cover dataset (CLC 2018 version 20b2) (Fig. 3).

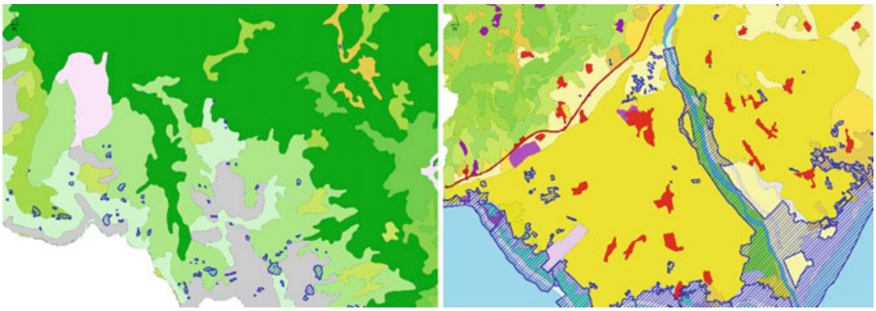

Fig. 3 Examples of the enhanced CORINE land cover dataset (filled colour polygons) with the wetland ecosystems (blue dashed polygons) from a mountainous area in Bulgaria (left) and from a lowland area in Greece (right)

The total wetland spatial extent corresponds to 2.46% of the river basin area. It is roughly below the suggestion made by Mitsch et al. (2015) that a range of 3–7% of temperate-zone watersheds should be in wetlands to provide adequate flood control and water quality values for the landscape. This result, along with the findings that 19% of the total wetland spatial extent is outside of legally protected areas, being more vulnerable in degradation or even loss, provides a scientific documentation for motivating protection and conservation measures. Considerable amount of wetland extent (21% of its total extent) is found out of the Natura 2000 sites representing the only source of habitats for aquatic species in the wider landscape of the river basin (Fig. 4). It is notable that most of these wetlands are located in areas of weak or no protection (all of Bulgarian wetlands which are outside of Natura 2000 sites and 15% of those Greek wetlands which are outside of Natura 2000 sites).

As expected, the bulk wetland spatial extent (10.397 ha) is found in the lowland coastal part of the river basin in Greece, forming by Nestos delta, the adjoining

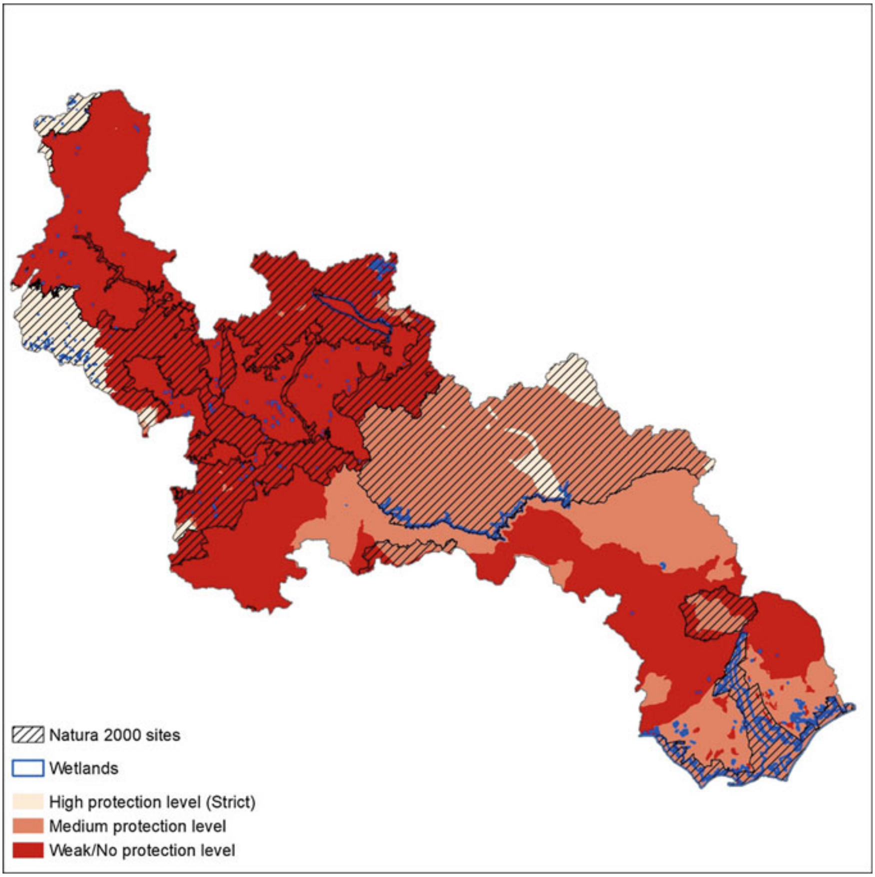

Fig. 4 Wetlands, Natura 2000 sites and protection status in Nestos/Mesta river basin

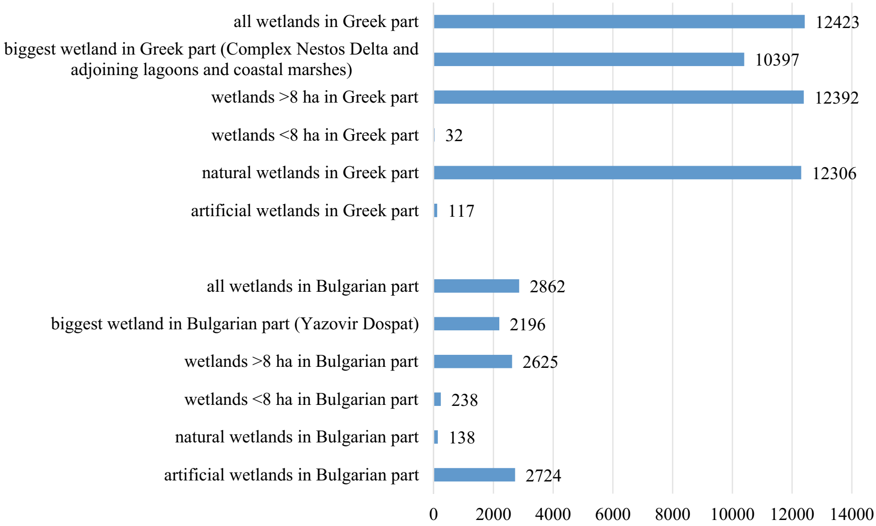

Fig. 5 Spatial extent (ha) of wetlands in Nestos/Mesta river basin

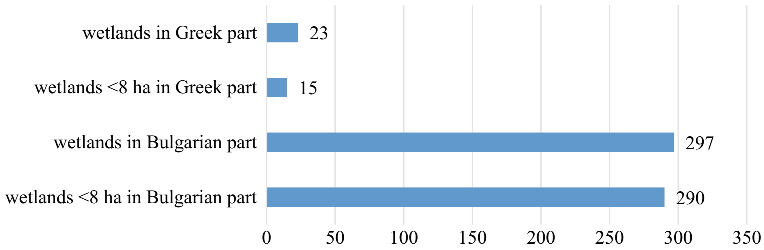

Fig. 6 Number of wetland sites in Nestos/Mesta river basin

lagoons and coastal marshes. While, in the Bulgarian part, an extremely high number of sites (297) has been mapped, from which only 7 of them are bigger than 8 ha. Also, more than half of them are artificial (168 sites) covering almost 95% of the total wetland spatial extent in the Bulgarian part. Figures 5 and 6 present areal and statistics of the wetland distribution over the transboundary river basin.

Connected Areas that Possess High Potential to Preserve Biodiversity in the Nestos/Mesta River Basin

In our study, we focused on the need for knowledge on connected areas of high value for biodiversity. As a first step, the capacity of the transboundary river basin of Nestos/Mesta to preserve biodiversity was mapped based on the degree of land cover heterogeneity and in particular on nature dominance. The dominant land cover pattern analysis resulted in 6 classes, from 'all natural' to 'not dominated by natural' (Fig. 7). The results demonstrate the natural potential of the transboundary river basin to preserve biodiversity. Natural areas ('all natural' and 'mostly natural') are quite dominant occupying 64.95% of the river basin while the areas which are not dominated by natural occupy the 24.18% of it. Mixed zones ('natural-agricultural', 'natural-developed' and 'natural-agricultural-developed') cover only 10.87% of the river basin. However, the biggest influence zone is that of the 'natural-agricultural' land that covers 10% of the study area.

Based on the scenario that the presence of national designation safeguards biodiversity, the supply of the habitat maintenance was mapped (Fig. 8). 'All natural' and 'mostly natural' areas with strict protection status reach a smaller spatial extent of the 5% of the river basin, restricting the supply of the habitat maintenance ES. The scenario of protection status revealed interesting results for the Natura 2000 sites net-

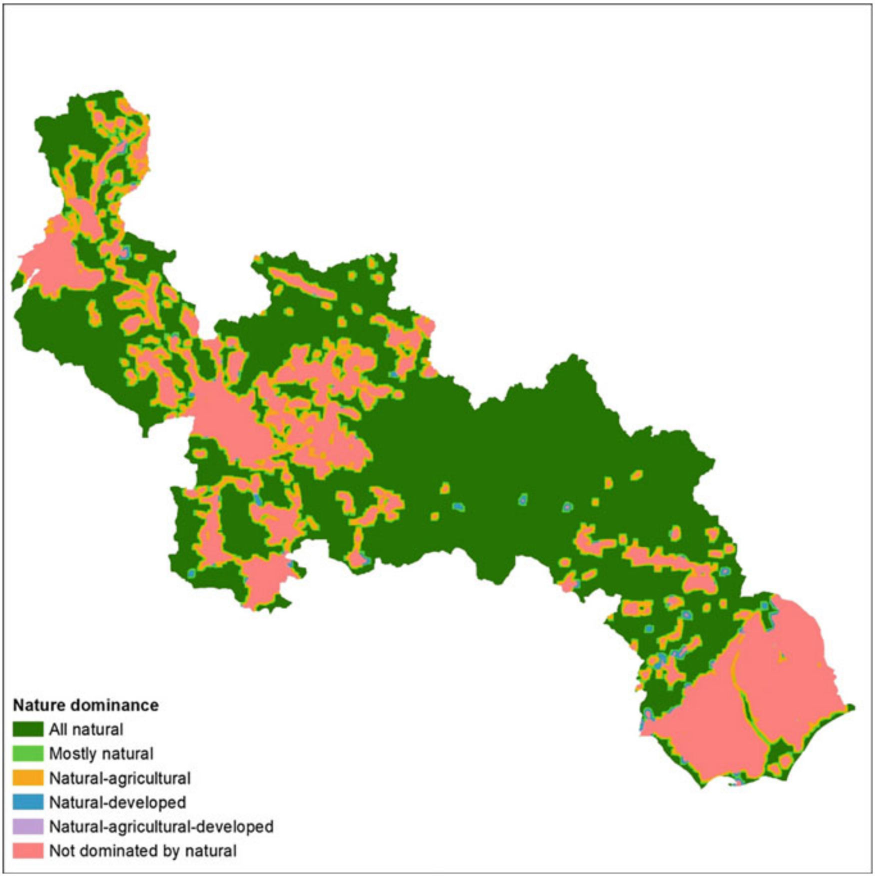

Fig. 7 Map of nature dominance in the Nestos/Mesta river basin

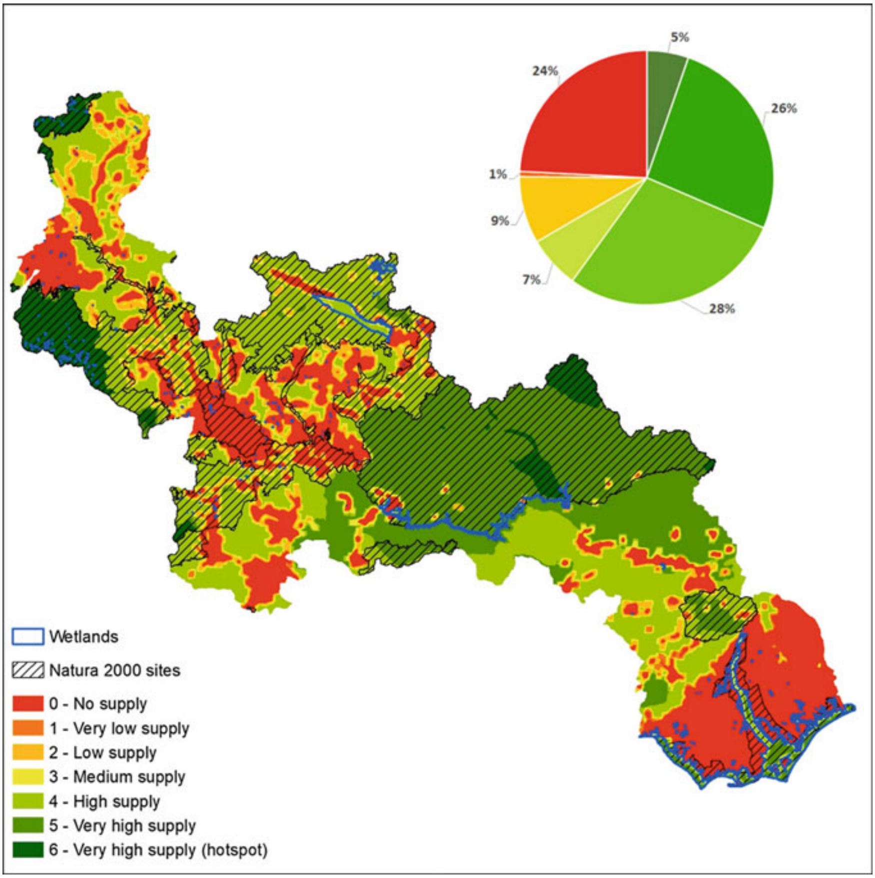

Fig. 8 Areas of different supplies of the habitat maintenance ecosystem service and their spatial relations with distribution of wetlands and Natura 2000 sites in the Nestos/Mesta river basin

work. Figure 9 shows the proportion of all ranges of the habitat maintenance supply inside and outside Natura 2000 sites. Notable is that areas with very high potential to preserve biodiversity (26% of very high supply) are found beyond the boundaries of the Natura 2000 network. Also, notable proportions of low supply (32%), very low supply (16%) or no supply (25%) are found inside Natura 2000 sites.

The Morphological Spatial Pattern Analysis (MSPA) resulted in a network consisting of sixteen (16) Network Components (NW Components) (Fig. 10). Six (6) out of the sixteen (16) NW Components, were MSPA cores with no connectors-links, hereafter called 'isolated areas'. The remaining ten (10) NW Components, were connected sets of MSPA cores and bridges (connectors-links between different MSPA cores), hereafter called 'connected areas'.

The overall network connectivity of the river basin, as expressed by the relative Equivalent Connected Area, ECA_rel, is 82%. Given that habitat connectivity greatly

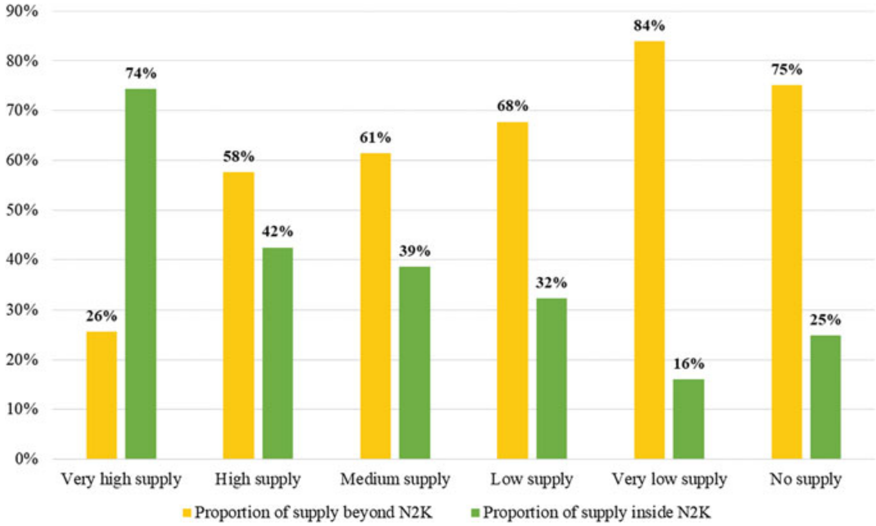

Fig. 9 Proportion of habitat maintenance supply inside and outside Natura 2000 sites

enhances the movement of species within fragmented landscapes (Gilbert-Norton et al. 2010), the connectivity result is quite promising, reflecting the percentage of reachable habitats at the river basin.

Figure 11 demonstrates the spatial distribution of the Natura 2000 sites and of wetland ecosystems over the results of the structural connectivity analysis. A significant proportion (35%) of connected land is found beyond the Natura 2000 sites network. Aichi Target 11 puts priorities for increasing the coverage of well-connected systems of protected areas. Still, a quite big portion of the Natura 2000 sites (95,623 ha) is fragmented and/or not dominated by natural habitats (16% in unconnected areas of medium, high, very high supply areas and 9% in hostile areas).

As regards wetland ecosystems, it is found that more than half of their spatial extent (59%) is scattered outside of the connected network. In particular, wetland extent of approximately 6050 ha is found in fragmented natural areas (of medium, high, very high supply) and some 2900 ha in hostile areas (no natural dominance and no protection). The biggest extent of these (4573 ha; 2371 ha, respectively) is located in the downstream area of the river basin close to the deltaic formation (in the Greek part), whereas in the mountainous zone (in the Bulgarian part) there are numerous very small isolated wetland sites. Needless to say, these wetlands should constitute top priority sites so as to get all benefits obtained by wetlands (Gibbs 2000).

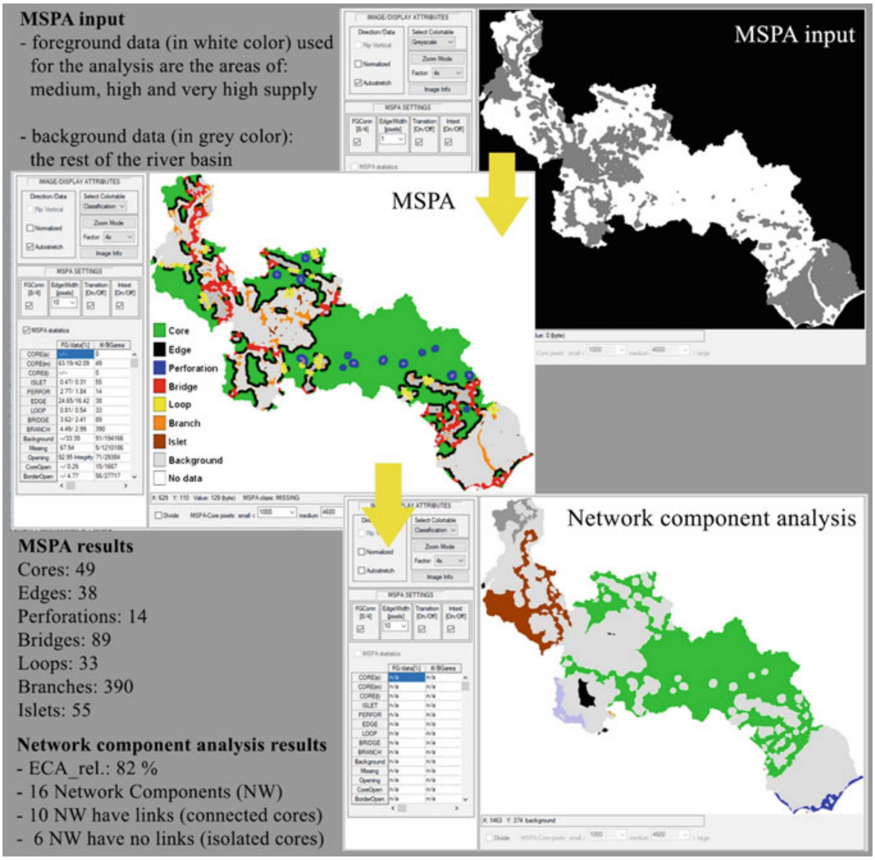

Fig. 10 Results of the structural connectivity analysis of areas of medium, high and very high supply

Conclusion

The current study demonstrated a mapping and assessment landscape approach for the Nestos/Mesta river transboundary basin. It tackled the lack of detailed geospatial data on wetland contribution (especially the small ones) and the need for integration of ecosystems at wider landscapes and beyond the boundaries of the Natura 2000 sites.

The mapping results provide baseline knowledge on connected areas of high value for biodiversity and seek to support management and conservation interventions. Three are the main elements which have been spatially documented. The first is related to those wetland ecosystems which are found to be the only source of habitat for aquatic life in fragmented and hostile areas, and thus they should be preserved as stepping stone features of the wider landscape. The second regards, the notable

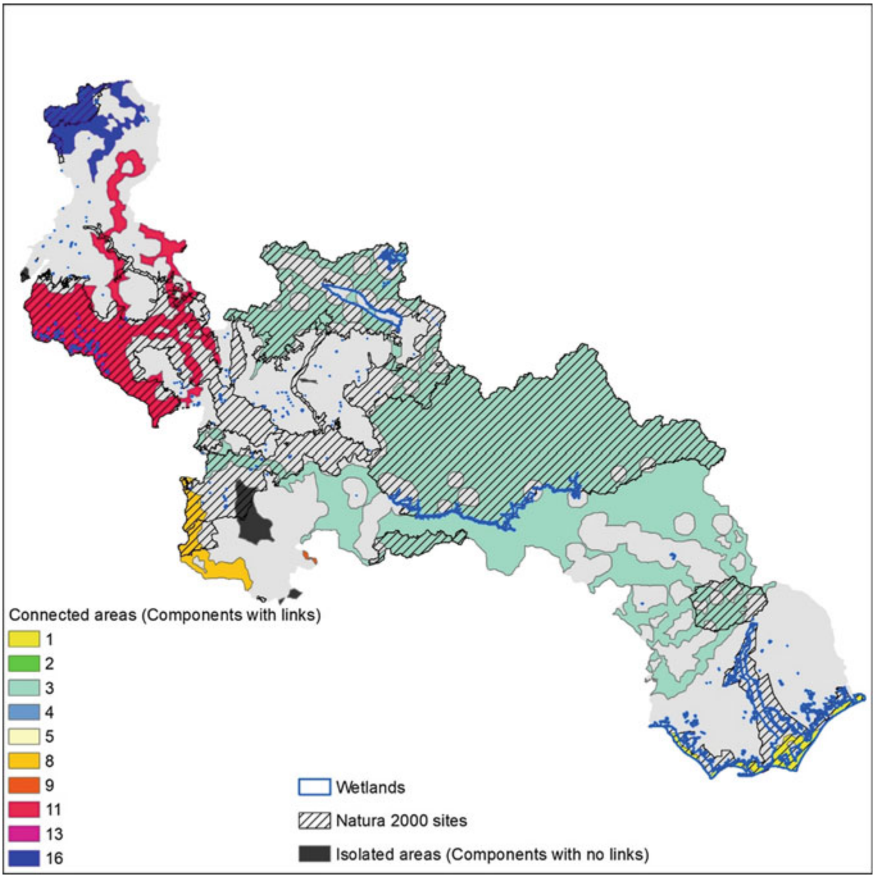

Fig. 11 Spatial relationships between wetlands, N2 K sites and connected areas

extent of connected areas with very high potential for preserving biodiversity which is extended beyond the boundaries of the Natura 2000 sites, indicating the areas with potential for species movement. The third element is related to the degraded areas (not dominated by nature and weak protection) which are found within the Natura 2000 sites, and thus provide management implications including the improvement of their protection status as well as the alteration of human interventions.

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Integrated Assessment and Modelling of the Spatially Explicit Perceptions of Social Demands for Ecosystem Services

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Abstract In the context of global environmental changes, the endeavours to reach both natural and social sustainability become more and more debated. Speaking of regional development and realization of economic intentions, the impact on the biodiversity must be considered. The local communities, however, might disregard some interventions that affect the environment when trying to reach better socio-economic status. In this paper, we intend to explore the social demands for ecosystem services in terms of the construction of an open-pit mining project in the semi-arid Southern Arizona. By conducting qualitative assessment via survey-based investigation, we couple the preferences of the ecosystem services beneficiaries (ESBs)—local environmentalists and local residents, with natural-based parameters. The research outcomes help to identify the most important ecosystem services reliant on water resources. The generated supply/demand maps reveal a spatial understanding on the ecosystem services in regards to the hypothetical judgements of the involved participants (ecosystem services beneficiaries). In addition, the importance and the application of the ecosystem services concept in nature-based solutions are highlighted.

Keywords Ecosystem services · Social perceptions · Quantitative evaluation · Stakeholders · Mapping

Introduction

Nowadays both researchers and practitioners are keen to provide smart solutions and to apply multidisciplinary explanations in the environmental research. The myriad applications of the ecosystem services (ES) concept prove its integration into the decision-making process by transforming knowledge on non-political objects such as the human–environmental interactions, and making them significant in policy and

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practice. Interestingly, throughout the communication with people having different demographic profiles and education degrees, we can define the levels of appropriation of the concept. In this research, we conducted survey-based assessment in the region southeast of Tucson (Arizona, USA), developed in the period July–December, 2016. Arizona is known as state of the 'Five C's' (cattle, cotton, copper, citrus and climate) and has leading position in extraction of minerals and copper in the USA. On the other hand, in such area, where the environmental balance is so fragile and extreme weather events occur on regular basis, the dimensions of a mining project's impact go further the socio-environmental concerns. Debates over the construction of a new copper mine (open pit) continue to present date.

In order to obtain information on the people's perception for the importance of the ecosystem services and given different scenarios for water availability, we prepared a survey questionnaire that was initially disseminated to experts from local environmental non-profit organizations, groups, centres and to state/federal service agencies. On the next stage, a second questionnaire was distributed among locals, as we believed that locals, having indigenous knowledge about the surrounding landscape, would provide truthful information. The research outcomes resulted in maps of the perceived demands for ecosystem services.

Social Demands for Ecosystem Services

'Unique Water of Arizona'

The local population in Tucson promotes year-round nature conservation activities and environmental education for a healthy Tucson community. There are number of activists and eco-movements and people convey their willingness to keep the desert landscape the way it is. The planned site for the Rosemont Copper mine is situated within the Pantano Wash watershed and encompasses the Cienega Creek (Fig. 1). That landscape is well known among the conservationists for its 'outstanding quality', where the riparian vegetation and biodiversity represents the original biodiversity in Tucson area before 1900. The Cienega Creek is recognized as 'Unique Water of Arizona' (Fonseca et al. 1990) and is an endangered cultural landscape (Pima County 2004; Sonoran Desert Conservation Plan 2004). The case study territory is dominated by grasslands with mesquite shrubs—89.03%, and in the highlands of the watershed, there are pine oak woodlands species—8.86% (Table 1). In addition, within the case study area the important wildlife corridors Coronado National Forest, Saguaro National Park and Las Cienegas National Conservation Area intersect.

In Southern Arizona and specifically the area south of Tucson, there is a rapid real estate construction and urban expansion (Schneier-Madanes et al. 2016). The development pattern projected for 2045 indicates that population and housing density in the urban fringe will increase much faster than the urban core (2045 RMAP Land Use Technical Report). Given the water resources availability and the sensitive

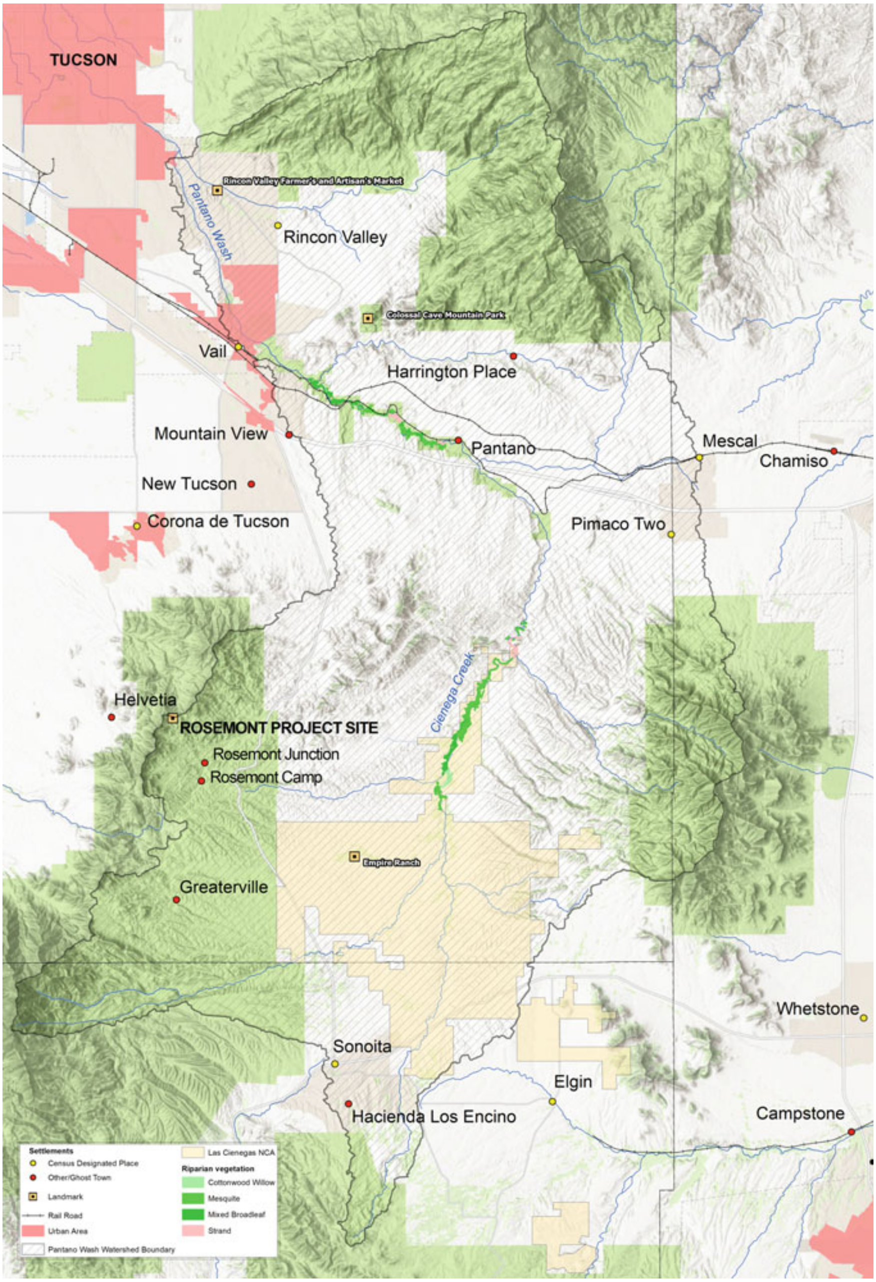

Fig. 1 Upper Pantano wash and Cienega Creek watershed—case study boundaries

Table 1 National Land Cover Dataset 2012, percentage of the watershed territory

Land cover classes	%	acres [ac]		%	acres [ac]
Open water	0.004	13.51	Mixed forest	0.17	589.76
Developed, open space	1.11	3933.06	Shrub/scrub	88.18	313019.63
Developed, low intensity	0.26	914.55	Grassland/herbaceous	0.85	3010.24
Developed, medium intensity	0.13	473.49	Pasture/hay	0.003	11.38
Developed, high intensity	0.004	12.58	Cultivated crops	0.04	143.42
Rock/sand/clay	0.22	781.70	Wetlands	0.10	341.23
Deciduous forest	0.002	8.73	Emergent herbaceous wetlands	0.07	256.88
Evergreen forest	8.86	31449.06			

ecological state of the area, the footprint over the biodiversity will be even greater. Improper ranging practices, housing development, deteriorating, land degradation, habitat fragmentation and biodiversity are some of the economic and ecological pressures that entail the concentrated efforts of scientists, government agencies, NGOs, ranchers and local residents.

Assessment and Mapping Approach

The methodological framework in the present research has been set over several investigation approaches. The ES concept lines up with a toolbox of technical methods where the socio-environmental input can be successfully integrated, as presented in Burkhard et al. (2013), Castro et al. (2015), García-Nieto et al. (2013). The human activity has twofold impact over the environment. It could be regarded at the same time as main driver for disturbances and as a structural landscape component. Therefore, the landscape is observed as the place of interactions between the humans and the environment (Bastian et al. 2012, 2014).

The qualitative assessment of the ecosystem services is widely used in both the scientific and practical domain (Burkhard et al. 2012; García-Nieto et al. 2013; Koschke et al. 2014; Sherrouse et al. 2014; van Vliet et al. 2010). Based on the expert-based assessment and strategic sampling of groups of stakeholders—ecosystem services beneficiaries (ESBs), the importance, provision and demand for ecosystem services can be identified. Later, we transferred the survey results into GIS and by means of thematic mapping and geospatial analysis tools the qualitative data was visualized into maps.

Initially, a qualitative stratification and strategic sampling of groups of ESBs were made and two different questionnaires per each group were designed (Appendices 1–2). It is important to point out that the questionnaires are anonymous, no personal data has been collected, the given answers are based on personal judgements and do not represent any institutional position. The research participants were categorized in: (1) *experts*—local environmentalist, conservationists, water managers and ecologists involved in water programmes, and (2) *locals*—the population living within the watershed. Although the applied purposive identification does not meet the requirements for statistically significant sampling, yet it is still reliable as the participants provide meaningful contributions regarding the context of the investigation (Polkinghorne 2005). Our goal was to collect as many answers as possible and for the period August–December 2016 we realized face-to-face and by telephone interviews with 29 professionals (Table 2). The questionnaire was developed in two parts: Part A—general demographic information and Part B—ecosystem services assessment. In Part B, the expert respondents were asked to assess the importance of the ecosystem services in 4-point Likert scale (1–4) and to rank them in order starting from the most important. We were also seeking for their opinion on hypothetically the most affected ecosystem services given four different water availability scenarios (no water flow, low water flow, high water flow and flood). Finally, we presented a map of the watershed and we asked the experts to identify the locations where there is a specific demand for ecosystem services, i.e. the provision of the ecosystem services does not meet the demand for them.

The questionnaire was filled by 29 experts through online and in-person meetings and/or by phone. Later on, we transferred the survey results in GIS and created maps. That approach was used in the second stage of interviewing when we aimed to approach people living in the vicinity of the proposed copper mine site. A second questionnaire was developed and disseminated in two settlements in the Pantano wash watershed—Rincon Valley (downstream; 5139 inhabitants) and Sonoita (upstream; 818 inhabitants), as considered being potentially the most affected by the open-pit mine.

Considering the unfamiliarity of the locals with the ES concept, a different approach was applied and the aim was to reach specific demographic profiles[1] of people living within the watershed. First, it was necessary to present the scientific

Table 2 Profile of ecosystem stakeholders—expert group

National/Federal (n = 8)
Nature Conservancy, BLM, US Fish & Wildlife Service, US Forest Service, National Park Service
State (n = 6)
Tucson Audubon Society, Sky Islands Alliance, Sierra Club, Center for Biological Diversity
County (n = 15)
Pima County, PAG, WRRC, University of Arizona, Sonora Institute, Save the Scenic Santa Ritas, Southwest decision resources, Friends of the San Pedro River, Watershed Management Group

[1]The demographic information is derived from the open-access public database found in http://www.city-data.com/city/Arizona3.html.

Table 3 Interviewee's demographic profile—locals (non-experts)

Sonoita (n = 9)		M	F	Rincon Valley (n = 10)		M	F
Education	Primary	–	–	Education	Primary	–	–
	High	1	2		High	3	–
	College	4	2		College	3	4
Residency	Local	2	4	Residency	Local	5	1
	Non-local	3	–		Non-local	1	3

terminology and technical language of the survey data into more recognizable form. The two settlements—Rincon Valley and Sonoita are both highly dependent on water resource availability. In such semi-arid environment and water-scarce region, water for domestic use and agriculture is delivered only from private and/or shared wells. By that mean of public participation, the local knowledge served for verification of an expertise based on scientific and practical information and can also reduce uncertainties (Grêt-Regamey et al. 2013; Presnall et al. 2014). The integration of expert judgments into spatial models can initiate dialogues for ecological and institutional changes in the process of natural resource management (Redpath et al. 2013; Cote and Nightingale 2015).

To build the demographic profile network, *gender*, *education* and *place of residence* have been considered as the socio-demographic variables that have important impact on the cognition and perceptions regarding a socio-environmental conflict (Table 3). *Gender* is related to the overall social engagement and positions of the individual in the decision-making processes (Kelemen et al. 2015; Villamor et al. 2014). *Educational level* influences the ecological knowledge, including perceptions over the climate change that people appropriate (Blayac et al. 2014; Sanogo et al. 2016; Zoderer et al. 2016). The resident's *sense of place* is recognized as a variable that affects public support for programmes concerning nature conservation and protection.

On a later stage, a map of the watershed was presented to the experts and they were asked: (1) to point out the places where, according to their personal judgements, there is a specific demand for ecosystem services and (2) to identify the services. That approach was driven by hypothetical judgements and outlined *water flow regulation*, *recreation and tourism*, *natural heritage and natural diversity* as the most threatened and most 'needed' services.

Importance of the Ecosystem Services

The approach of qualitative assessment relies on data collected through interviews. Therefore, the participants' responsiveness and the significance of the information are both essentially important and crucial for the research development. The distributed questionnaires yield results that were later used in order to allocate demands for ecosystem services. Experts outlined as the most important (Fig. 2), the ES *Freshwater provision*[2] (65.52% from the total response), *water flow regulation*[3] (62.07%), *Recreation and tourism*[4] (65.52%), and *Natural heritage and natural diversity*[5] (62.07%). Interestingly, based on the expert's judgements, there is similarity in terms of importance for provisioning and cultural services—*freshwater provision* and *recreation and tourism.* Despite the different scores, the services have been rated with, that outcome indicates areas in the watershed—ecosystem services hotspots, where special management attention is needed. Hence, the applied approach subtlest support to the nature conservation initiatives and confirms the ecological values of the Upper Pantano wash and Cienega Creek watershed.

Regarding the results obtained by interviewing locals, we notice a slight difference in the responses, but rates keep the same trend (Fig. 3). The most important ES is *freshwater provision*, having prominent number of response—85.71%. Water is a basic natural resource and in the semi-arid environment people appreciate its importance for health, thrive and for daily routine. Therefore, the ranking is followed by the ES *food from agriculture and livestock*. In this water-scarce region, ranching is a traditional and emblematic sector in the local economy and the agricultural activities need to be secured with water. On the other hand, the recreational and aesthetic values of the landscape have been also evaluated as important benefits provided by

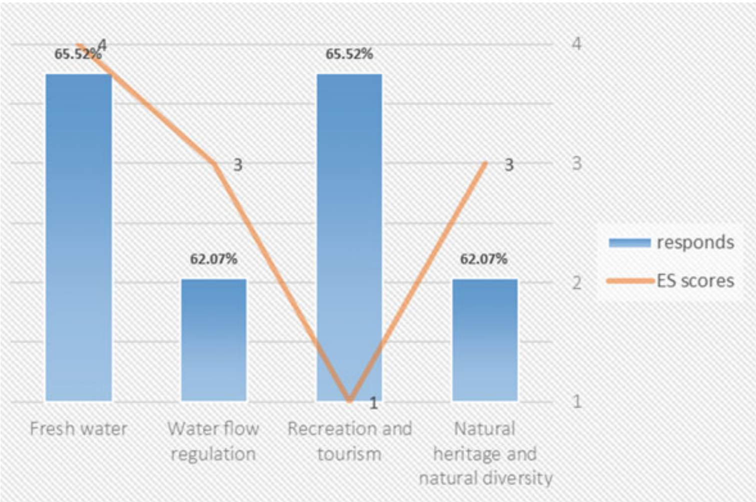

Fig. 2 The most important ES and the scores given to each service according to the experts' perceptions

[2]Freshwater provision—used freshwater for drinking, domestic use, industrial use, irrigation, etc.

[3]Water flow regulation—maintaining the water cycle features, e.g. water storage and buffer, natural drainage.

[4]Recreation and tourism—outdoor activities and tourism related to the local landscape.

[5]Natural heritage and natural diversity—the existence value of nature beyond economic benefits.

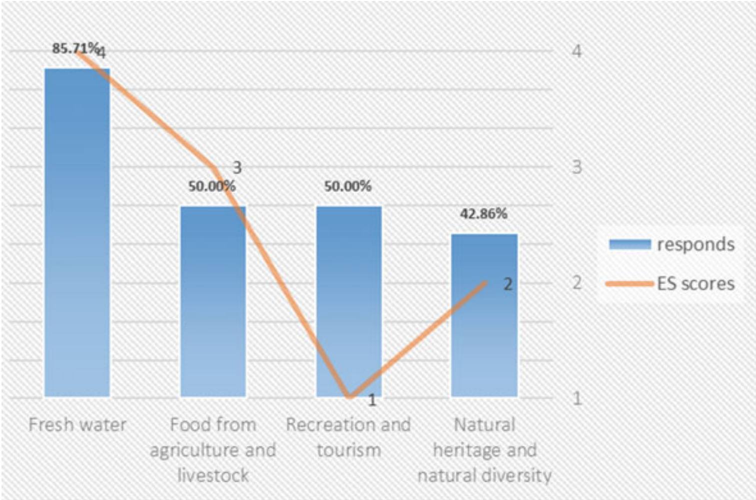

Fig. 3 The most important ES and the scores given to each service according to the locals' perceptions

nature. There is a strong relation and attachment of the local residents to the place as they can 'feed the emotional and physical health' (woman, ~60 years old), and provide 'mental relaxation' (woman, ~30 years old).

The spatial analysis approaches and tools provide information about the spatial distribution and allocation of the defined services. One of the main advantages of this method is the opportunity to represent and visualize data collected via field surveys and some empirical estimates in GIS. The data processing and the elaboration of maps were realized under ESRI ArcGIS platform. The experts' hypothetical judgements have been linked into GIS, allowing to integrate spatial data and to perform further geo-statistical analysis. That output represents robust predictions on automatically selected cells from the raster dataset. Considering the limited data (number of responses), we applied spatial interpolation using raster and feature datasets by diffusion kernel method. The resulted density map (Fig. 4a) represents the distribution of the demands for ecosystem services according to the experts' perceptions.

Given the assumption that the highest provision of the ecosystem services is allocated along the riparian area of Cienega Creek, the specific demand for ecosystem services has been outlined by the identified places where the functioning of the ecosystems bears certain disturbances. The allocation of the ecosystem services demands reveals that the southern parts of the watershed are characterized with lower scores than the northern parts, encompassed within conservation areas. The overlay analysis shows that the land cover classes underlaying the distributed services refer to grasslands, croplands, wetlands, shrubs and forests (upstream) as well as to the developed territories around Rincon Valley and Sonoita (Fig. 4b).

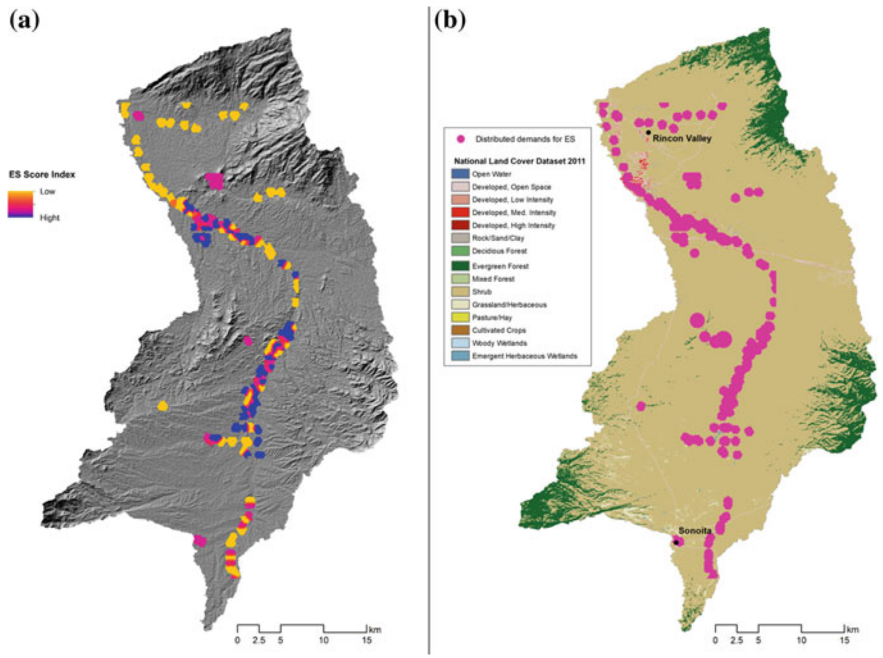

Fig. 4 Distribution of the demands for ecosystem services—**a** allocation of the demands for ES and **b** Land cover classes within the Upper Pantano Wash watershed

Conclusion

The integration of multidisciplinary approaches in a complex socio-environmental conflict requires certain flexibility and tackling between many perspectives. The traditional knowledge is considered to be a driver for collaborative work that will strengthen the community values. Such comprehensive investigation gives valuable insights over different components of public participation. However, still challenging remain the questions on how to communicate science and how to deliver information to the affected communities.

The survey questionnaire was distributed to more than 40 local environmentalists and scientists, by following the 'refer to a friend' approach. Yet, a detailed and complete analysis of the sociocultural factors that form the ESBs choices has the potential to present better understanding of peoples' preferences. An advantage of the applied questionnaire is that we managed to collect valuable insights regarding the way people perceive the ongoing investment projects southeast of Tucson. On the other hand, the research findings raised the matter of the used ES terminology that should be regarded in a more critical way as it provokes bias in the results. Both experts and non-experts have difficulties interpreting information in the framework of an abstract concept. By bringing forward the importance of smart geospatial solutions, the benefits of the application of GIS-based modelling approach, supported by the elaborated maps, have significant contribution and eases the analysis throughout the entire research process.

The complex character of a socio-environmental conflict, such as the construction of an open-pit mine in a water-scarce region, sets prerequisites for an integrated analysis when the environmental and social resilience is concerned.

A survey-based assessment conducted through interviews with ecological conservationists, biologists, hydrologists and experts involved into the watershed planning and environmental management was the approach used for qualitative assessment of the demand for ecosystem services. By integrating the public opinion in the human—nature communication, some drawbacks in the dialogue between science and practice could be highlighted. In the present research, we would also like to place focus on the 'language' of communication that was sometimes ambiguous and troubled locals when asked to provide sound insights for environmental issues.

The elaborated maps played an important role as they mediated the expert-based opinion, allowed to visualize the perceptions and allocate the demands for ES. Undoubtedly, the most important benefits provided by that sensitive landscape is *freshwater provision*, but the socio-economic benefits still play an important role in forming preferences for the area.

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Appendix 1: Questionnaire—Experts

Ecosystem Services Assessment

Assessment of the benefits provided by the **Pantano Wash and Cienega Creek watershed** (Southern Arizona) (Fig. 5) regarding different water availability scenarios.

All responses are anonymous. There is no 'right' answer, so please let us know what your opinion/perception is through this survey.

Estimated time to fill out the survey: 15 min.

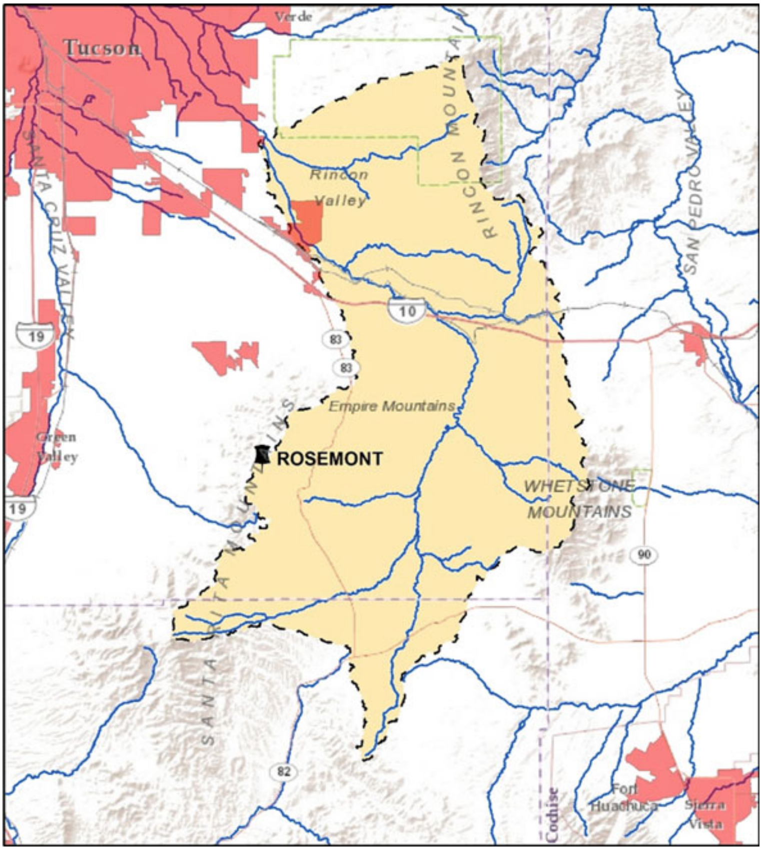

Fig. 5 Investigated area of the Pantano Wash watershed and Cienega Creek

Part A.

1. Where do you live? (city/town, state)?
   …………………………………………………………………………………………….....
2. Have you visited the Cienega Creek or Pantano Wash watershed?
   ……………………………………………………………………………………………
3. How close to the watershed do you live (area in Figure 1)?
   .…………………………………………………………………..……………………….
4. How long have you lived in the area?
   ………………………………………..…………………………………………………..…
5. What is your occupation?
   …………………………...

6. What geographic location do you identify yourself most with? (Chose only 1):
   - ☐ From your county/town
   - ☐ From Arizona
   - ☐ From USA
   - ☐ Other (please specify) …………………………
7. What is your education?
   - ☐ None
   - ☐ Primary school
   - ☐ Secondary school
   - ☐ High school
   - ☐ University/College
8. How did you receive this questionnaire? (online/in person interview)?
   ……………………………………………………………………………………………

Part B.

I. Ecosystem services perceptions

Nature provides resources from which people, directly or indirectly, benefit of and the ecosystem services are the benefits people derive from the ecosystems. These include provisioning services such as freshwater, timber, fiber, etc.; regulating services that contribute to the air quality, floods, disease control, water quality, etc.; and cultural services that represent the cultural heritage, recreational activities, spiritual benefits, etc.

1. Do you think the Pantano Wash and Cienega Creek watershed provide benefits that contribute to human wellbeing of the region? How many benefits?
   - ☐ Very little to none
   - ☐ Few
   - ☐ Many
   - ☐ Very many
2. Can you evaluate some potential benefits in the boxes below?

Which of the following do you think are the **most important** benefits and contributions (ecosystem services) for maintaining well-being or quality of life of people living or visiting Pantano Wash and Cienega Creek watershed (Fig. 5).

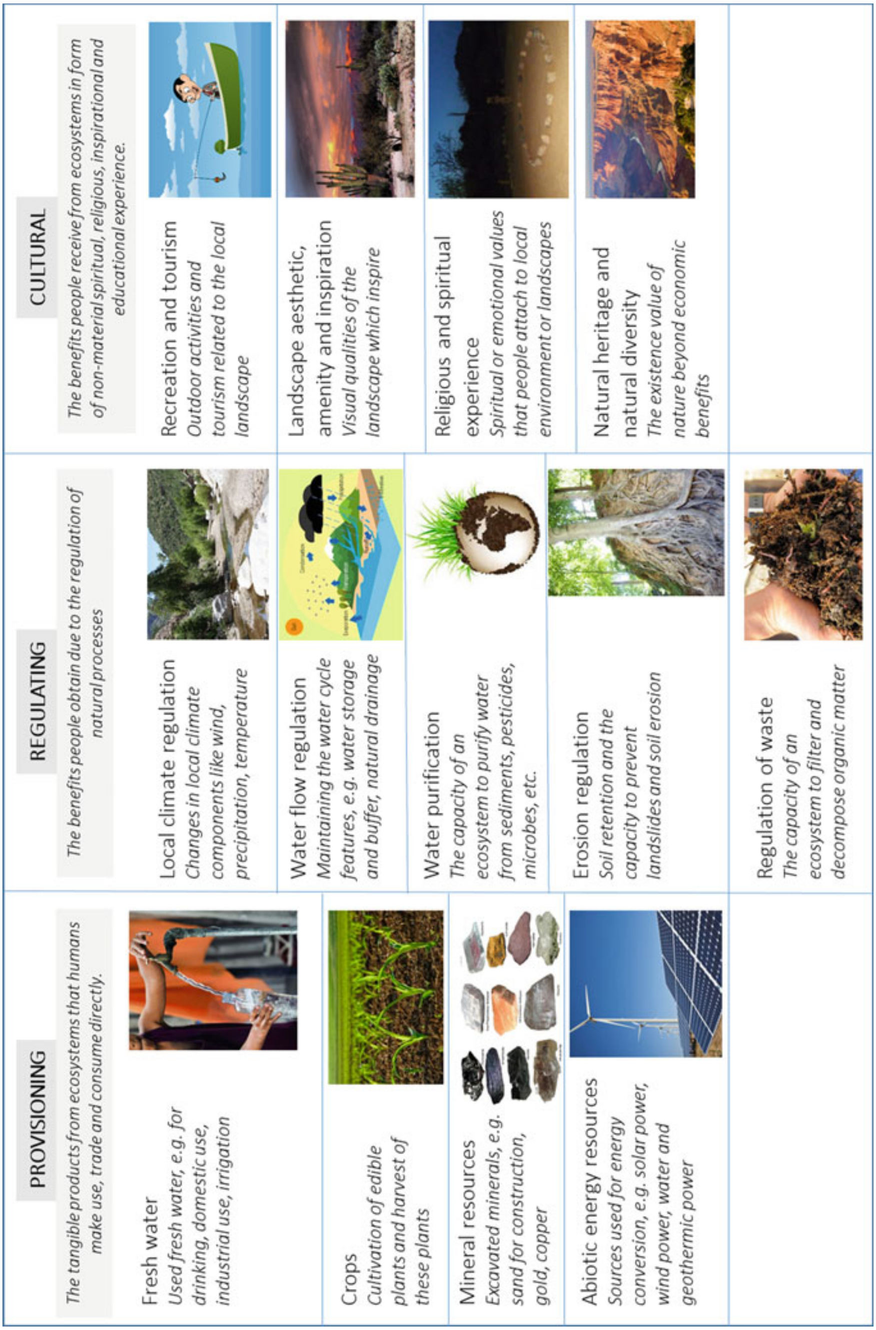

Fig. 6 Ecosystem services

Ecosystem benefits (see Fig. 6)	Choose 4 of 11 ES and rank: (1) Least important; (2) Somewhat important; (3) Very important; (4) Most important	Why are they important? (describe with 1–2 words)	Using the four ESB you chose: In the last 10 years, would you say each has (1) Decreased; (2) Remained the same; (3) Increased; (4) Don´t know
Freshwater provision (A)			
Food from agriculture and livestock (B)			
Mineral resources (C)			
Alternative energy (hydropower, windmills, etc.) (D)			
Local climate regulation (E)			
Water flow regulation (F)			
Water purification (G)			
Erosion regulation (H)			
Regulation of waste (I)			
Recreation and tourism (hiking, birdwatching, etc.) (J)			
Landscape aesthetic, amenity and inspiration (K)			
Religious and spiritual experience (L)			
Natural heritage and natural diversity (M)			

3. From the most important for you, choose **only 2** and list them in the box below. How do you think they have changed? (worse, no change, better or don't know)

Ecosystem benefits	*How has the supply of this service changed in the last 10 years?* *(worse (1), no change (2), better (3), don't know (4)*

4. Are there any other important benefits provided by this area? Which? ……………………………………………………………………………………………

II. Water Flow Perception

1. Have you heard of the Rosemont mining project? YES NO
2. (If YES) Do you think that this project will positively or negatively affect the benefits that people obtain from the water resources?
   - □ Positively
   - □ Negatively
3. Choose **only 2** benefits (ecosystem services) from the Benefits panel in the table below that you think will be most affected by the water flow availability?

Water flow	Benefits negatively affected. *Choose up to 2, if any, contributions and give them a 1 (min) to 10 (max)*	Benefits positively affected. *Choose up to 2, if any, contributions and give them a 1 (min) to 10 (max)*
		
		
		
		

Appendix 2: Questionnaire—Locals

Ecosystem Services Assessment

Assessment of the natural resources provided by the **Pantano Wash** and **Cienega Creek watershed** (area southeast of Tucson).

There is no 'right' answer.

All responses are anonymous.

Part A.

9. Where do you live? (city/town, state)?

……………………………………………………………………………………………….…

10. How long have you lived in the area?

……….………………………………………………………………………………………

11. What is your occupation?

……………………………………………………………………………………………..

12. What geographic location do you identify yourself most with? (Chose only 1):

- ☐ From your county/town
- ☐ From Arizona
- ☐ From USA
- ☐ Other (please specify) …………………………

13. What is your education?

- ☐ None
- ☐ Primary education
- ☐ High education
- ☐ University/College Major: ………………………………………………………….

Part B.

1. Thinking about that specific place (point on map), do you value it, because:

- Floods don't occur there and water is well stored

  ....

- You can go hiking, spend your free time and do other leisure activities

  ……………………………...

- Nature is diverse and unique

  ....

2. Do you agree that the contributions of the nature from the previous question are the most important (enclosed in the watershed) for the well-being?

……………………………………………………………………………...……………………

3. Would you say that you have noticed a *(1) decrease* or *(2) remained the same* or *(3) increase*, or *(4) don't know*?

- In terms of floods and water storage?
………………………………..
- In the possibilities for hiking and leisure activities?
……………………………………………………………………………….……………………..
- In terms of natural diversity?
....
- In the fresh water demand?
…………………………………………………...….………………………………...

4. Have you heard of the Rosemont mining project? YES NO
5. (If YES) Do you think that this project will positively or negatively affect the contributions of the nature and the natural resources?
Positively Negatively

Can you tell me with a few words why?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

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Flood Regulating Ecosystem Services—Mapping and Assessment Tool Based on ArcSWAT Output Data

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Abstract The ecosystem services (ES) are strongly related to the human well-being, and their mapping and assessment is among the main challenges. The regulating ecosystem services are not consumed directly by the society or the beneficiaries, but they offer important benefit. Flood regulation is such type of service which can mitigate or prevent the risk of the most frequent nature disaster in Europe. The paper presents an approach for mapping of flood regulating based on hydrological modeling and GIS tool. The tool is designed as ArcGIS script, connected with the ArcSWAT database. Three parameters derived from the hydrologic moldering results for each Hydrologic Response Unit are used as indicators to define the flood regulation capacity. The tool extracts the necessary data from the ArcSWAT results by user selected day, month and year and transforms them into qualitative estimations. The results are presented in form of maps of flood regulation ecosystem service in the case study area of Ogosta river basin.

Keywords Flood regulation · Ecosystem services · ArcSWAT · ArcMap · Mapping · Assessment · Modeling · Ogosta

Introduction

Flood protection is one of the most important regulating ecosystem services (ES) that may increase or reduce the negative effects of water-related disasters. Forests especially provide natural hazard mitigation and water regulation services by reducing flood-danger, preventing damage to infrastructure and influencing water retention capacities (de Groot et al. 2010). The human benefit of flood regulating ecosystem service provision is flood-damage mitigation and finally, the protection of human properties (Fisher et al. 2009; Boyd and Banzhaf 2007). The latter being part of the

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demand side of ecosystem services. Fisher and Turner (2008) state that ecosystem services just contribute to other flood mitigation measures based on, e.g., capital or dykes. In Chee (2004), flood regulation is based on "moderation of weather events, regulation of the hydrological cycle and maintenance of coastal and river channel stability" which all are part of the "stabilizing ecosystem services". The regulating role of wetlands, floodplains, and coastal ecosystems is usually emphasized (Ming et al. 2007; Posthumus et al. 2010) but it is also important to pay attention to the functions of other ecosystems throughout river basins which control the processes of water balance (Pert et al. 2010).

Forests, grasslands, and wetlands are ecosystems with a high capacity for regulating the water flows. The areas, where water is not properly regulated by the ecosystem (e.g., in cities, where the natural water cycle is often interrupted by impermeable surfaces), there is a much higher risk of such fluctuations, potentially leading to flooding or water shortages (Burkhard and Maes 2017). Floods are the most common natural hazard events in Europe with the potential to cause huge damages and economic losses. Therefore, the interest toward alternative and mostly cheap damage control solutions increases (Barredo 2007).

The regulating ecosystem services are not directly consumed as goods by people but they provide many direct benefits by keeping a safe and habitable environment. Unlike many provisioning ES, flood regulating ES cannot be supplied and imported from remote areas. Service providing areas (SPAs) and service benefiting areas (SBAs) need to be physically connected (e.g., by a water body or stream) or located in the same functional unit (e.g., a watershed). The "flow" of flood regulating ES takes place by spatial units that are able to capture excess water (e.g., from torrential rain) and to regulate the surface water runoff contributing to floods. Humans and their properties benefit from this regulating ES flow by lower amounts of floodwater reaching the SBA. The ES demand exceeds the supply in case of flood hazards. Land use change (e.g., afforestation) in the SPAs can help to increase flood regulating ES flows.

Therefore, it is important to understand the ecosystem processes fundamental for flood regulation ecosystem service and what the spatial characteristics and quantitative indicators are. Based on these indicators qualitative assessments are made. Using the qualitative values it is possible to assess and map the ecosystem service. However, the processes and the indicators are not identical or equally distributed through the territory, i.e., different ecosystems have different functions and therefore also different capacities to provide ecosystem services (Burkhard et al. 2009, 2012). Therefore, in order to simplify the mapping and assessment of the services only major and specific processes are selected to avoid complications.

Since these regulating ecosystem services do not provide material goods, that could be evaluated with approximately reliable values like wood production for example, the mapping of these services is based on potential of the ecosystems to providing the service. A mapping of flood regulation ecosystem service supply and demand in the SPA and SBA could be made, based on basins, subbasin, and land cover data. However there are other major factors like soil cover, slope, and aspect. Furthermore in this case for generating quantitative indicator values additional researches are required. Popular solution is the usage of specialized hydrologic models such as KINEROS (KINematic Runoff and EROSion model), SWAT (Soil and Water Assessment Tool), STREAM and hydraulic models such as HEC-RAS (Hydrologic Engineering Center) in combination with GIS-based interfaces such as AGWA (Automated Geospatial Watershed Assessment) and ArcSWAT. The models require a large amount of data in the period of significant time gape. However, they could generate the reliable parameter values for indicators like evapotranspiration, surface runoff, or water yield, which could be used for flood regulation ecosystem services assessment (Nedkov and Burkhard 2012; Stürck et al. 2014).

In this chapter, we present an approach for mapping and assessment of flood regulation ecosystem service, based on the output of the GIS-based hydrologic model ArcSWAT and a Python-based ArcGIS tool. The tool assesses scores based on indicators derived from Hydrological Respond Units (HRU), which are unique combination of land cover, soil cover slope, and location. It enables to visualize the assessments results for each flood event chosen by the user (with a selective day, month, and year, based on the ArcSWAT input data). For this purpose we put two main objectives: (1) to apply the GIS-based ArcSWAT hydrologic modeling tool in the case study area, and (2) to develop automated flood regulation ecosystem service assessment, which determinates the potential of the different Hydrologic Response Unit (HRU) to supply these service.

Materials and Methods

Study Area

The study area (Fig. 1) is a part of the Ogosta river basin, North West Bulgaria. The basin's area is around 51798.5 ha and elevation between 202 and 2009 m. The mean slope values of the rivers are between 17% (river Chiprovska) and 7.4% (downstream area of the main river Ogosta).

The climate is temperate-continental characterized by relatively warm summers and cold winters. The mean annual temperatures are between 10.1 and 11.1 °C. The annual precipitation varies with significant differences. At the North hill parts of the basin the annual precipitation values are between 600 and 800 mm. At the low mountain parts they reach 900 mm and at the high mountain parts—1000 mm. The area has a precipitation maximum during the spring–summer season and a minimum during the winter.

The soils in the Ogosta basin are presented by several soils types. The dominant soil type at the low mountain parts is Luvisols (LV, FAO, 1998). They are represented by subtype Albic Luvisols (La), Chromic Luvisols (Lc), Calcic Luvisols (Lk), and Orthic Luvisols (Lo). Rankers (U) and Lithosols (I) cover a large part of the area. Fluvisols (Eutric Fluvisols—Je, Thionic Fluvisols—Jt) covers the areas alongside river valleys (Kotsev 2003).

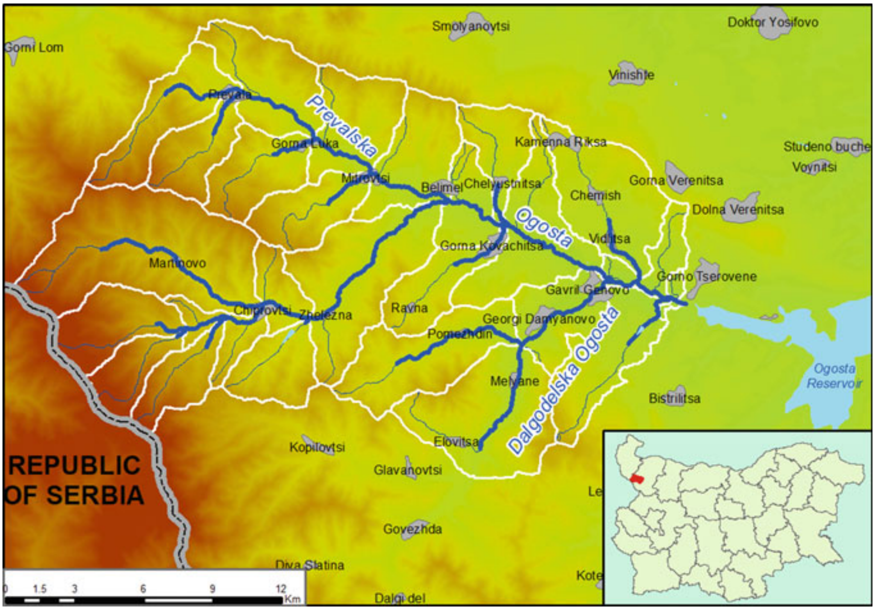

Fig. 1 Case study area Ogosta basin

Hydrological Modeling

ArcSWAT is river basin/watershed scale model developed to predict the impact of land management practices on water, sediment, or agricultural yields in large complex watersheds with varying soils, land and management conditions over long period of time. SWAT requires specific information about topography, land management practices, vegetation, soil properties, weather in the watershed. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling, etc., are directly modeled by SWAT using input data. The watershed may be partitioned into a number of subbasins. The input information for each subbasin is grouped or organized into the following categories: climate, hydrologic response units (GRUs), ponds/wethlands, groundwater, and the main channel draining the subbasin. HRUs are lumped land areas within the subbasin that are comprised of unique land cover, soil, and management combinations (Winchell et al. 2010).

The required spatial data for ArcSWAT model includes a digital elevation model (DEM), soil, and land cover data. The DEM data were required for delineating the watershed. The soil and land cover data are used with the DEM to define the HRUs. Free DEM data of 12 m resolution is obtained from ALOS PALSAR. The soil data are obtained from the Bulgarian Soil Resources agency. The land cover data are obtained from the Ministry of Agriculture and Food.

There are ten land cover classes in the case study area. The original land cover system (CORINE Land Cover—CLC) is reclassified to Land Use and Land Cover

(LULC) classification needed for running ArcSWAT simulations (Table 1). Therefore 61.6% of the case area is covered by Forests and 20.52% is under agricultural use.

The original soils data is in form of a polygon vector data, created by combination of cadastre data and United Nations Food and Agriculture Organization (FAO) data. The case area has 14 different main soil types of FAO classification (Table 2) and 34 FAO soil classes. Default ArcSWAT database includes the US soil data. Therefore, FAO data tables have been imported. Every soil unit has a unique value, referring to a specific FAO soil type in the default ArcSWAT database. For instance, if the value of a polygon is 5896, that polygon or soil mapping unit has index I-2b-5896.

Temporal data is essential for ArcSWAT simulations. In this study, daily rainfall data of 10 different rain-gauges are used for the period between 01.01.2000 and 01.01.2006. Solar radiation, temperature, wind speed, and humidity data were simulated via ArcSWAT weather generator. The highest rainfall values are in the period 07.08.2005, and the highest rainfall values of the period is on 06.08.2005, where the rainfall values of the gages are between 25 and 93 mm.

For running ArcSWAT properly it is necessary to have data for a long time period for a reliable simulation and generated data, even if the user needs a simulation for a shorter period. The accuracy of the computation is depended on the data accuracy and scale. In this case we use data for a time period between 01.01.2000 and 01.01.2006 and we ran ArcSWAT for 08.2005.

The first step is to delineate the watershed. For this purpose, ArcSWAT uses the DEM to determine the location of the streams, the flow direction, and accumulation. Watershed discretization created 29 subbasins of the case area of 37144.81 ha. In the second step, ArcSWAT defines three slope classes: 0–15, 15–35, and above 35 (Table 3). The highest slope values are located at the upper parts of the study area, while the other classes are located at the middle and low elevation sites of the area.

The third step is to input the land cover and soil cover data. After that in the fourth step using the subbasins, land cover, soil cover, and slope data ArcSWAT generates the Hydrologic Response Units—HRUs (2759 types in total). The HRUs are represented with a polygons created by the hydrologic model. The HRUs have a

Table 1 Land cover classification and area percentage

LULC code	LULC name	Percentage
AGRL	Agricultural land—Generic	20.52
FRSD	Forest deciduous	36.90
FRSE	Forest—evergreen	0.81
FRST	Forest—mixed	23.89
ORCD	Orchard	0.41
PAST	Pasture	3.34
RNGB	Range—brush	2.05
RNGE	Range—grasses	9.24
UIDU	Industrial	0.76
URML	Residential-Med/Low Density	2.09

Table 2 Soil classification and area percentage

Soil code	Soil type	Percentage
Bd	Dystric Cambisols	2.77
Be	Eutric Cambisols	8.64
Ch	Haplic Chernozems	0.66
E	Rendzinas	1.56
I	Lithosols	23.00
Je	Eutric Fluvisols	6.21
Jt	Thionic Fluvisols	2.81
La	Albic Luvisols	9.52
Lc	Chromic Luvisols	2.68
Lk	Calcic Luvisols	5.22
Lo	Orthic Luvisols	13.39
Rock	Rock	2.30
U	Rankers	19.46
We	Eutric Planosols	1.77

Table 3 Slope classification and area percentage

SLOPE class	Percentage of the study area
0–15	22.1
15–35	43.64
35–9999	35.27

unique name generated of the combination of the 1. Subbasin, 2. Land Cover Code, 3. Soil Code, and 4. Slope Value. For example HRU 17_FRSD_U3-2c-6637_35-9999 is located at Subbasin 17 and it is a combination of Deciduous Forest (LULC class FRSD), Rankers (U3-2c) and slope value above 35. The fifth step is to input the temporal data.

At the end, we ran ArcSWAT to generate result for the period between 01.08.2005 and 30.08.2005.

Indicators for Flood Regulation ES Assessment

Ecosystem service indicators are used to monitor the state or trends of ecosystems and ecosystem service delivery within a determined time interval (Burkhard and Maes 2017). For the purpose of the study we selected three indicators related to flood regulation ecosystem service: actual evapotranspiration, surface runoff, and water yield. The parameters of the indicators are generated via ArcSWAT and obtained from the model result tables.

Actual evapotranspiration in SWAT is calculated as evaporated rainfall intercepted by the plant canopy, the maximum amount of transpiration, and the maximum amount of sublimation/soil evaporation. The actual amount of sublimation and evapotranspiration from the soil is then calculated. Only when no snow is present will evapotranspiration from the soil takes place. Higher amount of evapotranspiration indicates lower capacity for flood regulation and vice versa.

Surface runoff, or overland flow, is flow that occurs along a sloping surface. Using daily rainfall amounts, SWAT simulates surface runoff volumes and peak runoff rates for each HRU. High amount of surface runoff indicates that the ecosystem retains less water through its structure, therefore the capacity for flood regulation is low.

Water yield is the net amount of water that leaves the subbasin and contributes to stream flow in the reach. High amount of water yield indicated low capacity for flood regulation and vice versa.

A Tool for Mapping and Assessment of Flood Regulation ES

Biophysical methods for the assessment of water flow regulation are based on quantification of different parameters of biotic and abiotic structures and can be divided into three main categories according to the character of the measurement and how the necessary information is extracted (Vihervaara et al. 2018). These are direct measurements, indirect measurements, and modeling methods. For this study, we apply ArcSWAT as modeling method for generating parameters needed for ecosystem services assessment. The parameter for indicator actual evapotranspiration is evaporated water per day (mm H_2O/day). The parameter for the indicator surface runoff is the amount of the water flow per day (mm H_2O/day) and the parameter for water yield is quantified in water contribution per day (mm H_2O/day). The quantitative values are used to generate qualitative estimations between 1 and 5 where: 1 stands for low relevant capacity for flood regulation, 2 for relevant, 3 for medium relevant, 4 for high relevant, and 5 for very high relevant capacity. Using this scale, the results will be more understandable and easy to represent and visualize. Based on these assessments, estimation values representing the capacity of ecosystem services are calculated. For this purpose, we use the ArcSWAT result table, regarding the HRUs. For each HRU there is information for a number of different indicators including the specified ones.

Therefore the ArcSWAT HRUs result table includes a large amount of daily information which is difficult to read and visualize. For example, if the user runs ArcSWAT for a time period of a month, the result table will have data for each HRU for each day. In this case it will generate 2759 table rows, representing the HRUs, multiplied by 28–31, representing the days of the month.

In order to simplify the assessment and mapping of flood regulating ecosystem service a tool is created, which extracts data for the specified indicators from ArcSWAT results for a user preferred date. After that the tool automatically generates the described qualitative values for the parameters and the actual flood regulating assessment. The tool is based on Python and ArcPy and it runs like a tool of the ArcCatalog with a simple dialog window (Fig. 2). There are two main steps for running the model: user operations, and model operations.

The user operations follow the steps of connecting the tool with the ArcSWAT output folder by selecting the location of the output database (option "table" in Fig. 2), choosing a preferred folder for the generated results (option "folder" in Fig. 2) and choosing a date (option "year, month, day" in Fig. 2) based on the ArcSWAT result data. The model operations have two major steps: Extracting information and Ecosystem service assessment.

At the first step, the model creates a new empty geodatabase in the selected folder. The model extracts information related to the specified indicators for the selected date only and imports it in the created geodatabase. The information is represented by a geodatabase table which could be joined with the HRUs for visualization purposes. The geodatabase table has a name representing the selected date. For example geodatabase table with a name hru200586 represents date 06.08.2005 (dd/mm/yyyy). Therefore, the user could create multiple tables for different dates in the same geodatabase without losing information.

At the second step the model runs a qualitative assessment of the flood regulating ecosystem service via biophysical method based on three indicators and their quantitative parameters:

Actual Evapotranspiration: Qualitative values between 1 and 5 are calculated automatically, where 1 represents the minimal quantitative value of the indicator and

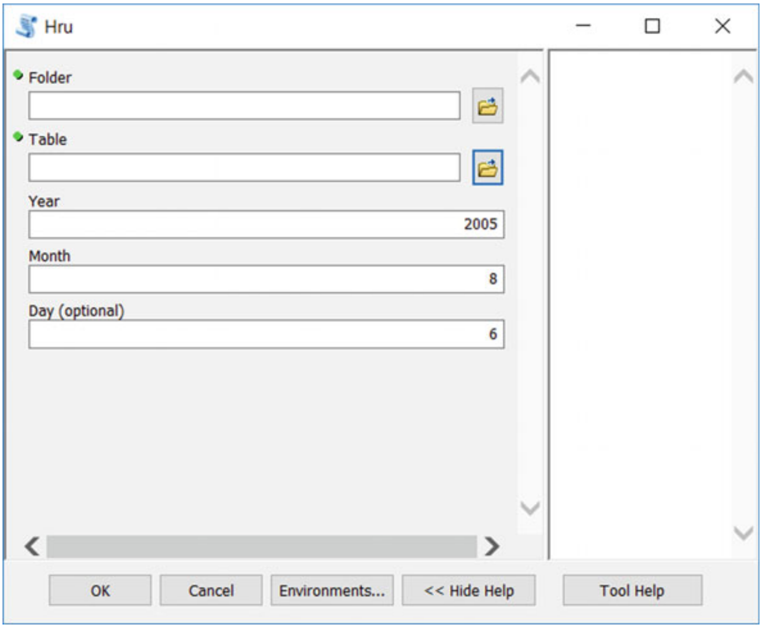

Fig. 2 Flood regulation Ecosystem service assessment tool's dialog window

5—the maximal. That is, the higher the volume of evaporated rainfall, the higher is the assessment value of the indicator. For example, Actual Evapotranspiration indicator has quantitative values between 0.13 and 0.937 mm for the HRUs for 06.08.2005 (dd/mm/yyyy). Therefore, HRUs with value between 0 and 0.1874 mm have a value of 1; between 0.1875 and 0.3748 mm have values of 2, etc.

Surface Runoff Contribution: Qualitative values between 1 and 5 are calculated automatically, where 1 represents the maximum quantitative value of the indicator and 5—the minimal. That is, the higher is the Surface runoff, the lower is the ES indicator assessment. For example Surface Runoff Contribution has quantitative values between 0 and 47.183 mm for the HRUs for 06.08.2005 (dd/mm/yyyy). Therefore HRUs with a value between 0 and 9.4366 mm have ES indicator values of 5; between 9.4367 and 18.8732 mm have qualitative value of 4, etc.

Water Yield: Qualitative values between 1 and 5 are calculated automatically, where 1 represents the maximum quantitative value of the indicator and 5—the minimal. That is, the higher the net amount of water that leaves the subbasin and contributes to stream flow in the reach, the lower is the ES indicator assessment. For example Water Yield indicator has quantitative values between 0 and 56.676 mm for the HRUs for 06.08.2005 (dd/mm/yyyy). Therefore, HRUs with value between 0 and 11.3352 mm will have qualitative value of 5; between 11.3353 and 22.6704 mm will have qualitative value of 4, etc.

The last step of the assessment is the calculation of estimated qualitative value, representing the ES assessment, calculated of the values of all selected indicators per polygon/HRU. For example if ES indicator Actual Evapotranspiration has a value of 3, Surface Runoff Contribution has a value of 4 and Water Yield has a value of 4, the final flood regulation ES has an estimated qualitative value of 4 for the specific HRU. The model generates a geodatabase table which can be joined with the HRUs and visualize the results.

Results

Results of the Hydrological Modeling

The ArcSWAT hydrologic model generated a HRU shape file with 29 subbasins and 2759 unique HRUs. The subbasins have an estimated elevation values between 275.88 and 1402.14 m. The smallest subbasin (Subbasin 10) has an area of 0.024 km^2 with just 3 HRUs. The largest subbasin (Subbasin 17) has an area of 42 km^2 which is 12% of the study area with 154 HRUs. The largest HRU has an area of 15.615 km^2 (Subbasin 17) and the smallest HRUs have an area between 155 and 158 m^2. The majorities of the HRUs (77% of all HRUs) are below 0.1 km^2 and they have a total of 44.55 km^2, which is 12% of the study area. 20% of the HRUs have an area between 0.1 and 1 km^2 and they take 171.85 km^2, which is 46.3% of the study area. At the end 3% of the HRUs have an area above 1 km^2 and they take 155.04 km^2, which is 41.7% of the study area. Therefore the described results of the flood regulation ES assessment in the next section of the paper are based on the HRUs with an area above 0.1 km^2.

The majority of the HRUs with area above 0.1 km^2 are combination between Forests or Agricultural lands (80% of the study area). The most frequent combination is with FAO soil type Rock—66 HRUs with Deciduous Forest (LULC class FRSD) and 74 HRUs with Agricultural lands (LULC class AGRL), but they have total area of 1.1 and 3.58 km^2. The most frequent slope values are 0–15 and 15–35. The largest HRUs have combinations of Deciduous Forest and Mixed Forest with Lithosols (FAO class I-2b-5896) with an area of 67.2 km^2 and Agricultural lands with Calcic Luvisols (FAO class Lk18-2a) with an area of 11.7 km^2. They have slope values of 15–35 and above 35 for the Forest areas and 0–15 for Agricultural lands.

Mapping and Assessments of Food Regulation ES

The most common estimated capacities based on the indicator actual evapotranspiration (Fig. 3a and Table 4) are relevant (score 2) and medium (score 3). The HRUs with low relevant capacity (score 1) are combinations of Urban Industrial areas (LULC

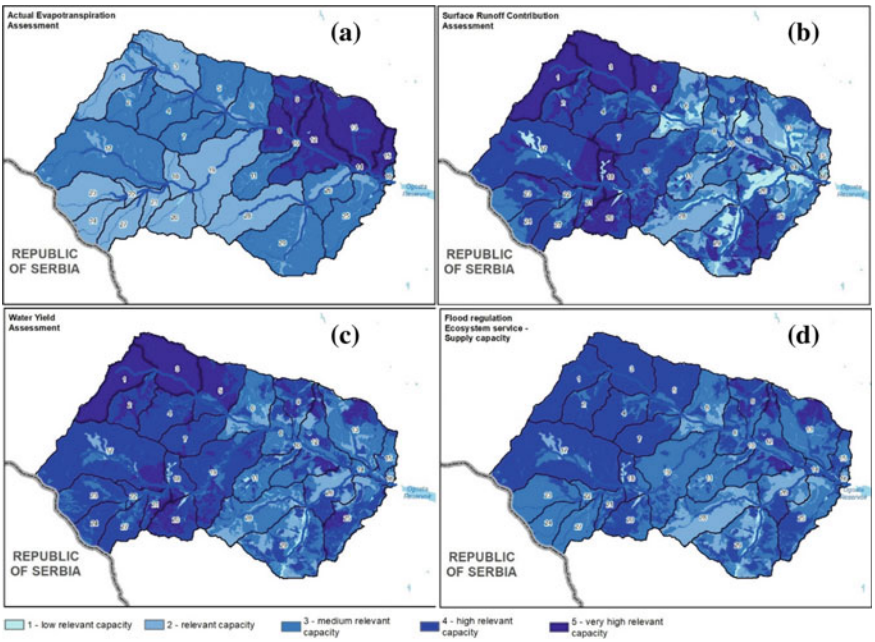

Fig. 3 Flood regulation ES capacity in Ogosta basin according the three indicators (**a**–**c**) and overall score (**d**)

Table 4 Distribution of the areas (in percentage) with different flood regulation capacity according to the three indicators

ES Indicators/capacity	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Actual evapotranspiration	0.06	38.66	43.67	4.41	13.21
Surface runoff contribution	6.30	14.93	21.44	37.21	20.12
Water yield	0.90	9.34	26.37	45.19	18.20

class UIDU—Industrial areas) with soil type Rocks (FAO class Rocks) and slope values of 15–35 and above 35. HRUs with Forest (Deciduous Forest and Mixed Forest) have relevant (score 2) and medium (score 3) capacity with combination of Cambisols, Luvisols, Lithosols and all three types of slope values. The HRUs with relevant capacity are located in subbasins 19, 20, 23, 24, 27, 28 and the HRUs with medium capacity are located at Subbasins 4, 5, 6, 7, 11, 17, 25, 26, 29. The HRUs with very high capacity (score 5) according to the results based on the indicator actual evapotranspiration have mostly Agricultural land with Fluvisols, Luvisols and slope values of 0–15 as well as Forest areas with Luvisols, slope values of 15–35.

The most frequent estimated capacity for the indicator Surface Runoff Contribution is 4 (Fig. 3b). The HRUs are represented by Forest areas (Deciduous Forest and Mixed Forest) with Lithosols, Rankers and slope values of 0–15 and 35. They are located mostly at the West and Central part of the study area while the HRUs with value of 5 are located at the North of and Central part of the study area, Subbasins 1–5, 18, 20. The HRUs have again combination of Forest areas (Deciduous, Mixed, and Evergreen Forests) with Luvisols, Cambisols and slope values of 15–35 and above 35. The HRUs with low and relevant capacity for this indicator are located in the downstream areas. They are represented predominantly by Agricultural lands with Luvisols, Fluvisols, and slope values of 0–15.

The most frequent estimated capacity value for the indicator Water Yield (Fig. 3c) is 4. The HRUs are represented by Forest areas (Deciduous Forest and Mixed Forest) with Rankers at the West, Southwest part of the study area and Lithosols at the Central part. Both have slope values of 15–35 and above 35. The areas with very high capacity according to this indicator are related to HRUs with Forest areas (Deciduous Forest and Mixed Forest), Cambisols at the North part (Subbasins 1, 3, 5), and Luvisols at the South part of the study area (Subbasin 20). The HRUs with estimated values of 1 and 2 for this indicator are located again in the downstream areas.

The overall results of the flood regulation capacity show that the HRUs with the lowest estimated ES values (1 and 2) are located downstream at the east part of the study area and the high ranked HRU's are located at the high elevated forest areas at the west part of the study area. Therefore, the qualitative estimations of the flood regulation ES show decrease of the capacity with the decrease in elevation. In between, at the central parts of the study area, are located the HRUs with an average estimated ES values of 3 (Fig. 3d).

The areas of very high capacity (score 5) show an exception of the above-mentioned rule. There are 43 HRUs with score 5 and they take ~2% of the study area

(Fig. 3). The results show that they are mainly combination of Forests (Evergreen Forest, Deciduous Forest and Mixed Forest, LULC classes FRSE, FRSD, FRST) or Shrubland (LULC class—RNGB), with Luvisoils/Fluvislols (FAO classes—Lc3, Lo44, Je78, La1) and slope values of 0–15, 15–35, and above 35. They are located on both sides of river Ogosta's downstream with elevation around 320 m, before the influx of Dalgodelska Ogosta (the second major stream in the basin), subbasin 12, West of the location where the low assessed HRUs are. These HRUs with highest flood regulation capacity are island like areas surrounded by HRUs with combination of Agricultural land, Pastures, or Shrubland with Luvisoils and Fluvisols (Thionic Fluvisols, Calcic Luvisols) and slope values between 0 and 15 with medium capacity. The HRUs with an very high capacity combined with the HRUs with high capacity (Forest areas, Luvisols, and slope values of 0–15) are a natural linear borders with small streams between agricultural lands.

A second area, where HRUs with estimated values of 5 are located, is at the North-east border of the study area, subbasins 9, 12, and 13. These HRUs have combination of Mixed Forests or Shrubland (LULC class—FRST, RNGB), Albic Luvisols (FAO class—La1) and slope values of 15–35 and above 35 at elevation between 500 and 700 m.

The majority of HRUs with an estimated value of 4 are located at the West part of the study area. Those HRUs take ~46.5% of the study area (Fig. 4). Here at subbasin 17 is located the largest HRU in the Ogosta's basin with an area of 15.615 km^2. It is a combination of a Deciduous Forest (LULC class FRSD), Rankers (U3-2c) and slope value above 35 (Unique combination 17_FRSD_U3-2c-6637_35-9999). Other large HRUs with an ecosystem service assessment of 4 in the same subbasin have a similar combination of Forests (Mixed, Deciduous and Evergreen, LULC classes FRSE, FRSD, FRST) with Rankers, Eutric Cambisols (FAO classes—U3-2c, Be1-2a) and slope values of 15–35 and above 35 and elevation between 1500 and 750 m. Below 750 m are located HRUs with similar combination of Forest areas and Luvisols (Albic, Orthic) and slope values of 15–35.

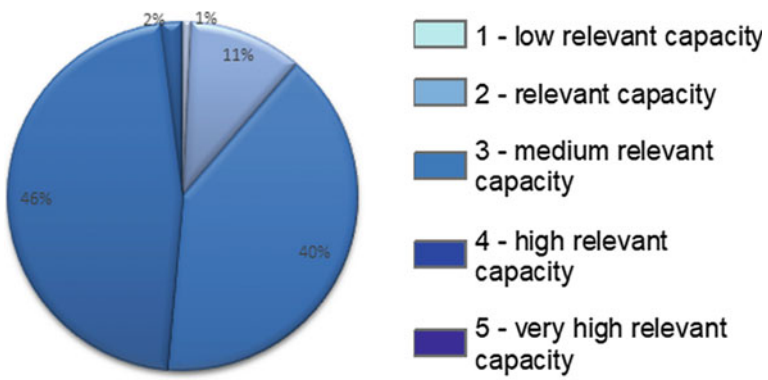

Fig. 4 Distribution of the areas (in percents) between the capacity classes in Ogosta river basin

The HRUs with medium capacity take ~40% of the study area (Fig. 4). The largest HRU has an area of 6.1033 km^2 and it is a combination of Deciduous Forest (LULC class FRSD), Lithosols (FAO class—I-2b) and slope value of above 35, located at the central part of the Ogosta's basin (subbasin 19) with unique combination—19_FRSD_I-2b-5896_35-9999. The majority of these HRUs are combination of Forests, Grasslands/Herbaceous and Agriculture (LULC classes FRSD, FRST, RNGE, AGRL) with Lithosols, Rankers, Fluvisols, Luvisols (FAO classes—I-2b, U3-2c, Jt3-2a, Je6-3a, Lk18-2a, Lo2-2b, Lo44-1b) and all types of slope values. The HRUs with LULC of Agriculture have high values of Actual Evapotranspiration (5), but low/average values of Surface Runoff Contribution and Water Yield (estimated values of 2 or 3). Forests and Grasslands/Herbaceous with Rankers have low/average Actual Evapotranspiration values (estimated values of 2 or 3) and good values (estimated values of 4) of Surface Runoff Contribution and Water Yield. With combination with other soil types Surface Runoff Contribution and Water Yield values are 2 or 3.

The HRUs with an estimated value of 2 take ~10.5% of the study area (Fig. 4). They are located at the Central and East parts of the Ogosta's basin, around the river's downstream. The majority of the HRUs are combination of Agricultural land (~36%), Forests (~35%), Pastures, and Grasslands (LULC classes—AGRL, FRST, FRSD, RNGE) with Lithosols (~30%) Fluvosols (20%), Luvisols (~16%), and Rock (10%) (FAO classes—I-2b, Jc1-2a, Je1-3a, Jt3-2a) and all three types of slope values. The highest value according to the indicator Actual Evapotranspiration is 4 and it occurs in HRUs with Agricultural land, Rocks and all three types of slope values. They are located around river Ogosta's downstream and at the North-East pars of the study area. The lowest value is 2 and it occurs in HRUs with Forests, Lithosols all three types of slope values. The highest value according to the Surface Runoff Contribution is 3 and it occurs in the HRUs with Rocks and slope value of above 35.

The HRUs with low capacity take 0.7% of the study area (Fig. 4) and they are located at the South part of Ogosta's basin. The majority of them are HRUs with combination of Agricultural land, Urban Industrial (LULC classes AGRL and UIDU), Calcaric Fluvisols (FAO class Jc1-2a) and slope values between 0 and 15.

Conclusions

The model results show that upstream areas have a medium to high flood regulation capacity values and low to relevant values at the downstream areas. The only exceptions are the some downstream located areas with very high capacity. Furthermore, HRUs with the same land use, land cover, soil type, and slope values could have different ecosystem service capacity in different subbasins. For example, the HRU with unique combination agricultural land, rocks and slope value between 15–35 (AGRL,ROCK-6694, 15–35) has low relevant capacity of in Subbasin 6, while the same combination in Subbasin 3 has high relevant capacity. This indicates that the flood regulation ecosystem service capacity is strongly dependant of the location (upstream, downstream) as well as the elevation.

The usage of ArcSWAT generated data for the purpose of mapping and assessment of flood regulation ES has some disadvantages that could impede the work in some cases. The variety and the amount of the ArcSWAT generated HRUs (majority of them with area below 0.1 km^2) complicate data analysis and pattern finding, which makes the result description more difficult. From the other hand, by extracting selective data by date and indicators, the user has a clear visualization of the results. Therefore, it is possible to understand the relationships/connection between the elements of the HRUs, the ecosystem service indicators and the generated assessment of the Flood regulation Ecosystem service capacity. The approach needs to be further tested in different basins to validate it and adjust the main elements of the procedure.

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Assessment of Pollination Ecosystem Service Provided of Urban Ecosystems in Bulgaria

Mariyana Lyubenova, Stoyan Nedkov, Miglena Zhiyanski, Georgi Popchev and Petar Petrov

Abstract The honeybee is the most important insect pollinator, and the service they provide is among the most important regulation ecosystem services. The main problem in the assessment of ecosystem services of urban habitats in Bulgaria is the lack of data from the inventory. There is only aggregated data at municipality level about the number of beehives. The main objective of this work is to present an approach for assessment of pollination service provided by urban ecosystems in Bulgaria and the results of its mapping at national scale. The approach relies on application of two spatially explicit indicators which based on parameters such as density of bee families and minimal flying coverage. Following the matrix approach for spatially explicit ecosystem service assessments suggested, pollination supply capacities were assessed for all municipalities in Bulgaria. We used statistical data for beehive holdings and colonies per municipality for the years 2010 and 2016. The results of the assessment were used to generate maps of the pollination supply capacity of urban ecosystems in Bulgaria. They provide appropriate information about the spatial distribution of this service throughout the country which can be used for the needs of regional planning. The high sensitivity of the sector, as well as its importance for the environment and the economy, requires a careful and long-term state policy.

Keywords Urban ecosystems · Pollination service · Spatially explicit index · Categorization · Assessment

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Introduction

According to Albert Einstein, “if bees disappear from Earth, mankind will survive for no longer than four years” (Eardley et al. 2016). The reason is simple—about one-third of the plants that are the source of food for humans and animals are pollinated by insects, and 80% of these insects are bees. In other words, about one-third of our food as quantity and quality depends on bees and their protection is of utmost importance. In recent years, the extinction of bees has become a serious problem for beekeepers around the world. The data on the high mortality rates of bee families are worrying not only for the producers of honey and bee products, for which it is a real blow to the business, but also to scientists and environmentalists (Eardley et al. 2016).

The world scientific community agrees upon the view that pollination, as one of the most important regulation ecosystem services (ES), takes part in keeping the life cycle, habitat and genetic resources. This function is fundamental to plant reproduction, agricultural production and the maintenance of terrestrial biodiversity. Furthermore, pollination is one of 15 ecosystem services identified as declining by the Millennium Ecosystem Assessment (MA 2005). The assessment on pollinators, pollination and food production has been carried out by experts from all regions of the world, who have analysed a large body of knowledge, including about 3000 scientific publications (Eardley et al. 2016). The state of knowledge on this issue was summarized in the accepted chapters and their executive summaries for policymakers, approved by the Plenaries of IPBES (Eardley et al. 2016; Potts et al. 2016).

The pollination is related to a wide range of benefits. More than 75% of leading food crops and almost 90% of the world’s flowering plants rely, at least in 35%, on animal pollination. Global agriculture, honey and food production, biofuels and construction are increasingly relying on pollinators. In the absence of animal pollination, crop production would decrease from 40% to 90% for different crops. Annual market value linked to pollinators is about US$ 235–577 billion (Burgett 2009; Burgett et al. 2010; Eardley et al. 2006, 2016). The pollination and bee products are also important for the medicine and for the healthy human diets of vitamins, minerals and fibres. The pollinators and pollination are sources of inspiration for art, music, literature, religion, architecture and technology. The magnificent British Expo-2015 pavilion, which looks like as human-scaled hive, and the Hive-Inspired Building Hostel in Wismar (Germany), which looks like bee habitat, can be given as examples (Eardley et al. 2016; Potts et al. 2016).

According to the published inventory data, the pollinators are from diverse taxa. Over 20,000 bee species are the dominant pollinators in most ecosystems. Flies are the second most frequent visitors to the majority of flowers with approximately 120,000 species. Some butterflies, moths, wasps, beetles, thrips, birds, bats and vertebrates also pollinate plants and crops. The best known pollinators are managed honey bees such as western honey bee (*Apis mellifera*) and eastern honey bee (*Apis cerana*) (Eardley et al. 2016; Potts et al. 2016).

There is a decline in diversity and occurrence of wild pollinators such as bees, hoverflies and butterflies in Europe and North America. About 40% of the bee species are threatened in some National lists and 9% of European bee and butterfly species are also threatened. The multiple threats to pollinators are in several groups: land-use change, intensive agricultural, pesticides, genetically modified crops, pathogens and pests, climate change, invasive alien species, species interactions in ecosystem, etc. The assessment and modelling of the pollination service are extremely important on a regional and global scale. The EU Biodiversity strategy to 2020 aims to halt the loss of biodiversity and ecosystem services in the EU and helps to stop global biodiversity loss. Action 5 of the strategy calls member states to map and assess the condition of ecosystems and their services in their national territory. The working group on Mapping and Assessment of Ecosystems and their Services (MAES) delivered a methodological framework for this process, which contains a coherent typology to be used for the different types of broad ecosystems to be considered in the assessment to ensure consistency across the member states (Maes et al. 2013). Following this framework, a methodology for mapping and assessment of urban ecosystems and their services in Bulgaria was developed. It consists of three main parts: mapping of ecosystem types; assessment of ecosystems condition; and assessment of ecosystem services (Zhiyanski et al. 2017).

Bulgarian honey production is relatively small compared to the world yields. Bulgarian honey is among the 15 agricultural commodities with the highest value of exports. In recent years, main exports are for Germany, Greece, Poland, France and Belgium. Meanwhile, high death rate had been observed for the managed bee. The reasons are poor weather conditions, lack of grazing, early interruption of eggs lying by mothers and the predominantly poor and medium-sized bee families predation. For instance, the severe winter of 2016–2017 increased the average mortality rate for the country above 40% (the average is 5–10%). Another, factor for the death of bees in Bulgaria is the usage of pesticides (herbicides, insecticides and fungicides) for crop protection or seed decontamination by the farmers.

There few works on the assessment of pollination capacity of urban habitats in Bulgaria but none of them has been published. This study is part of mapping and assessment of urban ecosystems in Bulgaria following the methodological framework developed by Zhiyanski et al. (2017). The main objective of this work is to present an approach for assessment of pollination service provided by urban ecosystems in Bulgaria and the results of its mapping at national scale.

Materials and Methods

The assessment of pollination service requires inventory data on different parameters of insect pollinators which is not available in Bulgaria. There is only aggregated data at municipality level about the number of beehives. In order to quantify and represent spatially ecosystem service, it is necessary to have a variety of information, which very often is not available to the extent required, so only a small group of potentially representative spatial variables can be used as indicators (Muller and Burkhard 2012). To represent the spatial extent of the pollination provided by urban ecosystems in Bulgaria, we developed two spatially explicit indexes: *density of bee families (IH)* and *minimal flying coverage (Is)*. The indexes are used due to several reasons: the missing information for insect pollinators in urban habitats; the honeybee is the most important insect pollinator and "pollinate" is often used to describe the services provided pollination of crops; the honeybee is one of the best pollinators due to the structure and size of limbs and body allowing them to pollinate flowers of different shapes and sizes and at last the needs of large amounts of nectar and pollen for food of larvae and adults. So, the honeybees regularly visit all flowering plants in the region during the vegetation period (Eardley et al. 2006).

The density of bee families is calculated by the formula:

$$IH = H/S(\mathrm{n/ha}) \tag{1}$$

where H is the number of bee colonies, and S—the area of municipality (ha)

The minimal flying coverage is calculated by the formula:

$$\mathrm{Is} = \mathrm{Hol} * \mathrm{s/S} \tag{2}$$

where Hol is the number of holdings, and s (km^2)—the minimal area (s = 1.5 km*1.5 km*3.14) effectively flew over from bees.

We used statistical data for beehive holdings and colonies per municipality provided by the Ministry of agriculture, food and forests. This is the only available source of data for the whole country, which enables analyses at national level. The data were provided for 255 municipalities in Bulgaria for two years 2010 and 2016. The spatial data in ESRI GIS format for municipalities in Bulgaria were obtained from the Ministry of Environment and Water database developed through the project "Study for Integrated Management of Water in Bulgaria" supported by Japan International Cooperation Agency (JICA). The statistical data about beehive holdings and colonies were integrated into the GIS layers by linking spatial and non-spatial data using relation keys.

The ecosystems have different functions that ensure ES provision which can be regarded as their capacity to ES supply. Following the matrix approach for spatially explicit ecosystem service assessments suggested by Burkhard et al. (2009, 2012), pollination supply capacities were assessed for all municipalities in Bulgaria. The density of bee families and the minimal flying coverage indexes were used as indicators for quantification of pollination supply. The capacities of the urban ecosystems at municipality level were assessed on a relative scale ranging from 0 to 5 (after Burkhard et al. 2009). A 0 value in our case indicates that there is no relevant capacity which is due to lack of data for the corresponding municipalities. The other five capacity classes are 1—very low, 2—low, 3—medium, 4—high and 5—very high.

The scores for the indexes were categorized into five intervals corresponding to these classes. Data sorting was performed using median distribution and the data which differ significantly from the other (outliers) were removed. Then, the remaining data were divided into categories using equal intervals method (Tukey 1977).

Maps of ES are made for a broad set of purposes including ecosystem assessment, decision support, priority settings, ecosystem accounting economic liability, etc. The main requirements for ES maps are reliability, accuracy, resolution and clarity, whose importance varies according to the mapping's purpose (Jacobs et al. 2017). Our main purpose for mapping urban ES in this study is decision support for the implementation of EU biodiversity strategy at the national (country), regional (district) and local (municipality) levels. According to the methodological framework (Zhiyanski et al. 2017), ES maps should be prepared for the whole country on map sheets based on EEA reference grids at a scale of 1:125 000. The main requirements for such maps are clarity and reliability (Jacobs et al. 2017). Our analyses show that they are too large for national scale decision support and that they are too coarse and not sufficiently reliable for the local scale. Therefore, we aggregated the data for urban ES into larger spatial units (municipalities and districts) to prepare small-scale maps presenting the whole country in a single map sheet that can be used for decision support at the national level.

The results of ES capacities by polygons in the GIS database were aggregated into municipalities using a summary statistics tool. The aggregation was applied by generating mean values of all ES capacity scores per municipality. Then, the mean values were assigned to municipality GIS layer. The resulting layer contains mean ES capacities of urban ecosystems in each municipality based on the pollination assessment. The value intervals of the capacity scores were defined using the natural breaks method. The conceptual scheme of the whole process of ES pollination mapping is presented in Fig. 1.

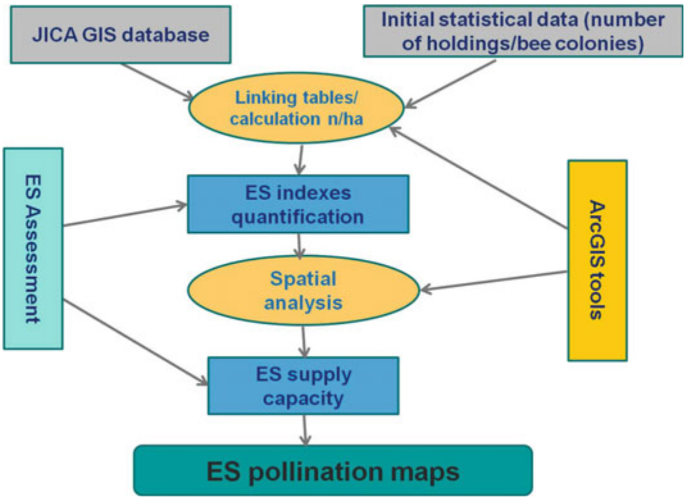

Fig. 1 Conceptual scheme of the ES pollination mapping at national level in Bulgaria

Results

The assessment was conducted for 255 municipalities in Bulgaria, which occupy a total area of 110,998.4 km^2 (Fig. 2). The highest number of evaluated municipalities is located in the south-central and south-western regions.

A total decrease in the number of honeybee holdings from 23,904 in 2010 to 16,963 in 2016 was observed (Fig. 3). This trend is most pronounced for the south-western region where the decrease is 51.36% (ranging from 31.45 to 59.86% between different municipalities) and for the southern-central region with 36.89% (from 25.22% to 45.47%). The average decline in lower in the northern part of the country: north-western by 33.55% (from 20 to 50%); north-central by 25.67% and north-eastern by 15.83%. The municipalities of Ruse, Bourgas and Yambol represent the few exceptions where the number of holdings has increased during the observed period.

In 2010, the total number of bee colonies is 586 938, while in 2016 it increases to 812,693. The analysis shows that along with the reduction of the number of holdings, the number of bee colonies increases during the observed period by 3% to 145% in

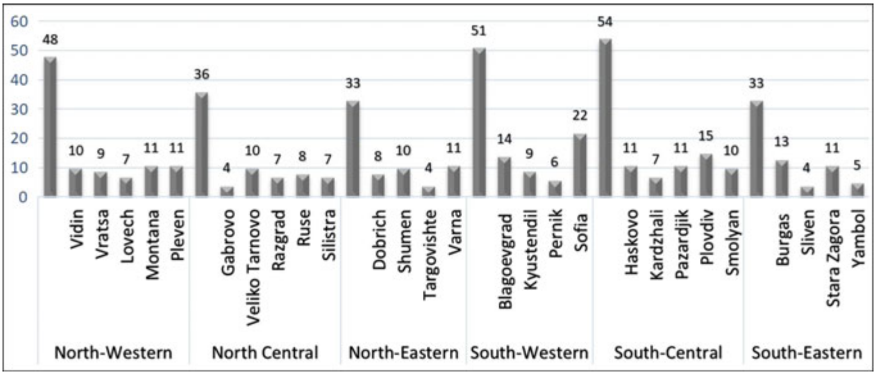

Fig. 2 Number of municipalities in Bulgaria by districts and regions

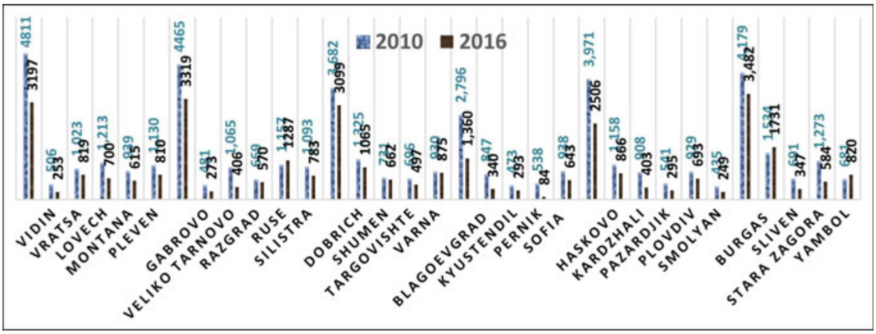

Fig. 3 Variation in number of holdings in Bulgaria by districts and regions (2010–2016)

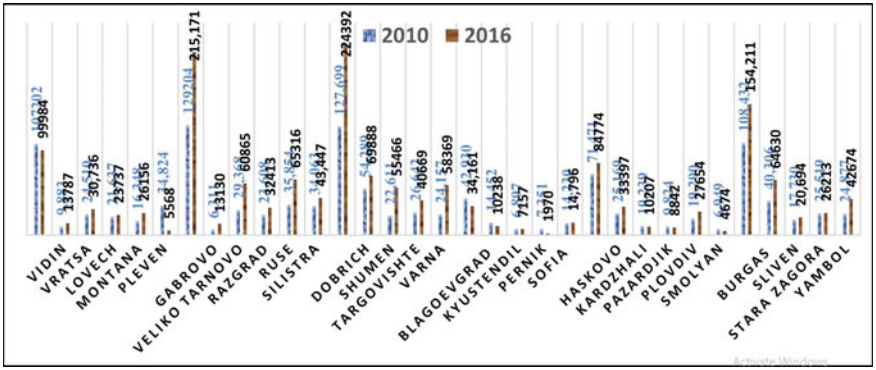

Fig. 4 Variation in number of bee colonies in Bulgaria by districts and regions (2010–2016)

different municipalities (Fig. 4). The obtained tendency for the increasing number of bee colonies in Bulgaria most likely is a result of growing funding under the Rural Development Program and national donations for the sector and the consolidation of bee colonies. However, this does not have a strong impact on honey production in the country. In opposite of the general trend, there is a decrease in the number of bee colonies farmed in six municipalities: Pleven, Blagoevgrad, Pernik, Kardzhali, Pazardjik and Smolyan.

The average value of IH for the country in 2016 is 63 n/ha. The capacity for pollination in the northern part of the country is more than three times higher than the capacity of the southern regions. The average value of *Is* is 9.5, which means that in a uniform placement of bee colonies they can cover the territory of a mean municipality about 10 times. For the northern part of the country Is is 14.4 and for the southern part 4.6. The highest pollination capacity (according to data from 2016) is observed in six municipalities: Dobrich, Rousse, Varna, Silistra, Targovishte and Shumen (Figs. 5 and 7).

The results for IH index show that for the country as a whole, there is predominantly low pollination capacity during the observed period. More than 50% of municipalities very low capacity (score 1) and another 30% have low (score 2) (Table 1). Although there is an increase in the total number of honeybee colonies during the observed period, the percentage of municipalities with medium and high capacity is decreasing (Table 1).

The maps of the pollination service of the urban ecosystems in Bulgaria according to the IH index (Figs. 6 and 7) show that the areas with highest capacity are in the north and north-eastern part of the country. The south-eastern part of the country is characterized by predominantly low capacity.

The comparison between the two maps indicates that there is a significant decrease in pollination capacity between 2010 and 2016. The areas with low capacity in the south-eastern part of the country are even more pronounced in the map of 2016, while the areas with very high and high capacity in the northern part are decreased.

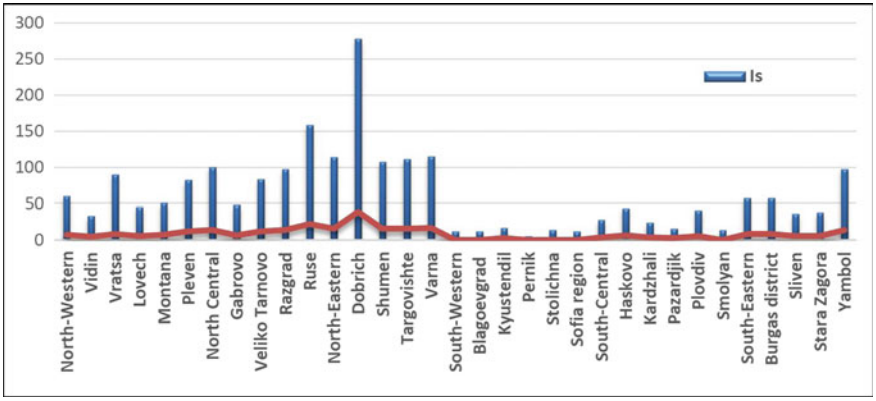

Fig. 5 Variation in IH and Is by districts and regions (2016)

Table 1 Comparative analyses of the results for IH and Is (2010–2016)

Score 2010	Capacity	Upper limit	Number of municip.	%	Score 2016	Upper limit	Number of municip.	%
I_H					I_H			
1	Very low	0.037	103	40.55	1	0.039	130	51.18
2	Low	0.064	76	29.92	2	0.073	77	30.31
3	Medium	0.091	39	15.35	3	0.107	32	12.60
4	High	0.118	17	6.69	4	0.141	11	4.33
5	Very high	0.145	19	7.48	5	0.175	4	1.57
Is					Is			
1	Very low	1.899	32	12.60	1	1.899	32	12.60
2	Low	3.430	80	31.50	2	3.430	80	31.50
3	Medium	4.960	79	31.10	3	4.961	81	31.89
4	High	6.491	41	16.14	4	6.491	39	15.35
5	Very high	8.021	22	8.66	5	8.022	22	8.66

Conclusions

The comparative analysis of the pollination capacity of the urban ecosystems in Bulgaria for the 6-year period shows predominantly very low and low according to IH index and low and moderate capacity according to the Is index. There is a positive trend in the number of colonies and a negative trend in the number of holdings. The

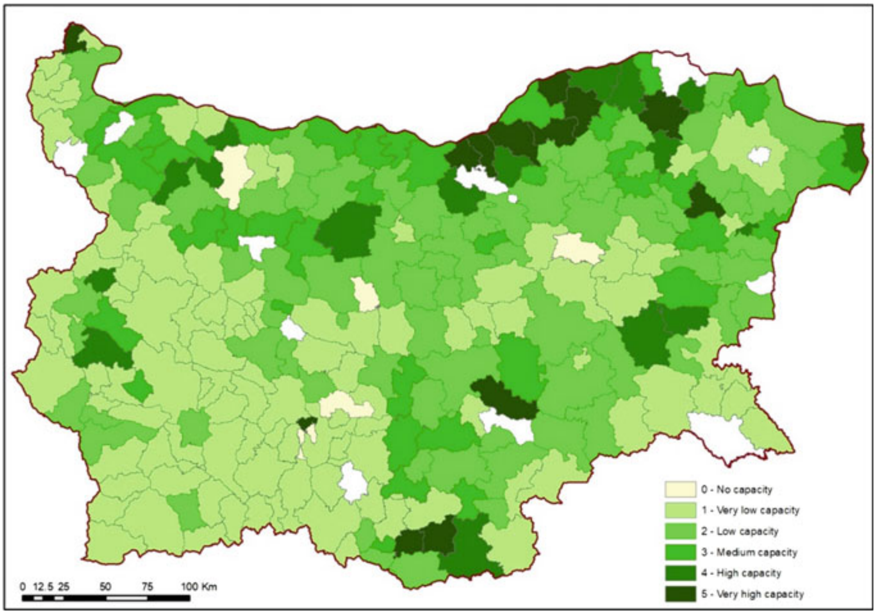

Fig. 6 Map of the pollination supply capacity of urban ecosystems in Bulgaria according to I_H index (2010)

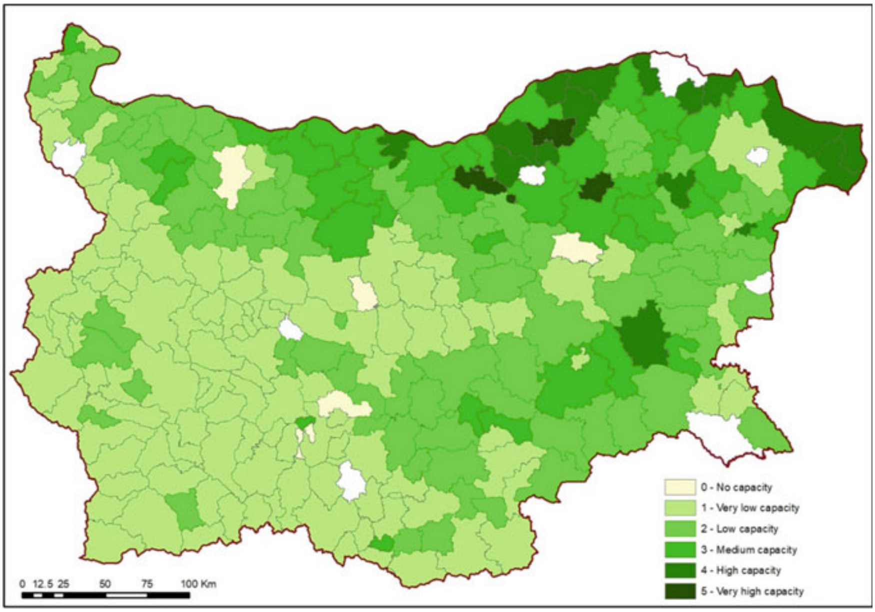

Fig. 7 Map of the pollination supply capacity of urban ecosystems in Bulgaria according to I_H index (2016)

provided service could not satisfy the demands of the communities and the environment. The honeybees' status is quite dynamic in Bulgaria and the pollination service provided is highly vulnerable due to the influence of many anthropogenic factors. Therefore, the observed trends are quite unsustainable. Essential to the sustainable provision of the pollination service is the effective legislation that regulates appropriately the interests of grain producers, tenants, beekeepers and environmentalists.

The result of the common work of institutions and the United Union of Beekeepers in Bulgaria has adopted Ordinance No 15 on the Protection of Bees and Bee Families from Poisoning. The role of the Food Safety Agency, which regulates the use of pesticides and other preparations in agriculture and livestock farming, is essential. Effective means of control need to be developed, such as the introduction of detection protocols to establish the link between dead bees and the active substance of treatments. For this purpose, a licensed laboratory is required. The laboratory at the Thracian University is in the process of being licenced, but it is still not functioning.

It is necessary to develop compensation payment schemes to beekeepers in the case of proven bearers' fault for the mass bee mortality. For now, in such cases, the court penalizes only the tenants. Restarting the business of beekeeper would cost around 155,103 BGN. The price for a new bee family is 120 BGN, and for a bee mother 24 BGN as it takes about a year for the development of new bee family.

For the state of the pollination service, provided by the managed bee in Bulgaria, an effective state policy is essential. Beekeeping has to be involved in schemes for direct payments under the EU's Common Agricultural Policy (CAP) for the period 2020–2027. This policy also includes finding markets, maintaining available markets in Europe and the US, and regulating the prices of Bulgarian honey, also restricting competition for cheap Ukrainian, Russian and Chinese honey. Farmers growing bees should be trained by conducting courses, providing the necessary literature and controlling their activities. Moreover, the construction of a colour-nectar conveyor in the regions can be considered, i.e. growing crops consistently flowering during the growing season to provide a constant feed for bees.

All these comprehensive measures will lead to the sustainable development of beekeeping in Bulgaria and the provision of pollination service by the managed bee, important for the biodiversity protection and the maintenance of agricultural production.

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Forest Ecosystems in Bulgaria Under Environmental Change—Carbon Sequestration Potential and Vulnerability Zones

Miglena Zhiyanski

Abstract Mountain forests fulfil multiple functions, including the provision of goods as timber, fuelwood, non-wood forest products, and services as regulation of flows, purification of air and water, carbon storage, protection from natural hazards, and provision of cultural services. The role of mountain forest to provide a wide range of ecosystem services is increasingly acknowledged especially in the context of environmental changes in a social aspect. Currently, there is a strong scientific interest to what extent the potential of mountain forests to store carbon could be enhanced under global environmental changes. The aim of this study is to analyse the carbon sequestration of mountain forests from different vegetation zones in Bulgaria under realistic and pessimistic scenarios of climate change using LPJ-GUESS Ecosystem Model and to define tendencies in their vulnerability and adaptive potential. The general trends are presented and vulnerability zones are defined for forest mountainous territories of Bulgaria.

Keywords Forest ecosystems · Carbon sequestration · Scenarios of climate change · Modelling · Vulnerability zones

Introduction

The changes in environmental conditions cause negative impacts on forests and the consequences expressed by reduction in their productivity, natural regeneration, and sustainability are difficult to be predicted (Kraeuchi and Xu 1995). Forests are particularly sensitive to climatic change due to the long lifespan of trees, which makes their adaptation to changes more difficult. Nowadays the vegetation cover of Bulgaria is a complex combination of primary and secondary plant communities formed under an instant anthropogenic evolution. Many changes were noticed in the zonal distribution of the forest vegetation in mountain regions of Bulgaria, expressed by replacement of native forest species with forest plantations or secondary communities (Pavlov 1998). The limited distribution of *Quercus cerris* and *Q. frainetto* on

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the loess surface in Northern Bulgaria as well as the restricted area of distribution of *Q. petraea* in some mountain region are mainly result of natural climatic changes, which are related with an extend of its xerothermal element and increase of oaks in altitude (Popov et al. 2010). This is also a reason for the extension of the area of *Q. pubescens* in the lowlands, but its development is embarrassed in areas with more continental climate. Pavlov (1998) underlined that the degradation processes of vegetation in mountain regions is strongly expressed in the altitude range between 0 and 1000 m a.s.l., which is related with unfavourable hydrothermal regime of forest habitats. Changes are recorded also for the treeline zones in different mountain areas of Europe (Cudlin et al. 2017). Therefore, forests are extremely vulnerable to environmental changes. At the same time, the interactions between above-ground vegetation and other ecosystem components impose the necessity to apply integrated approach in ecological studies on the effects of global changes on forest ecosystems in mountain regions.

Forests, from terrestrial ecosystems, have a leading role in carbon sequestration. The data show that over 600 billion tons of carbon are stored in the vegetation with the following distribution: 440–550 billion tons of forest vegetation, 20–50 billion tons of grassland, 5–15 billion tons of ponds and lakes, 10–40 billion tons of tundra and arid areas (Olson et al. 1983). A relatively small part (1–45 billion tons) of the carbon stock is related to the seas and oceans. Recent studies reported about more significant role of forests, indicating that the carbon stock in them is over 1100 billion tons (Briffa et al. 1995).

The forest territory of Bulgaria in 2017 covers 4.24 million ha or 38.2% of the country's territory, including 3.88 million ha (91.0%) of forests. The non-afforested area included is 302,000 ha. Compared to data from 2000, the total forest territory of the country has increased by about 330,000 ha (~8%). At the same time, the territory covered by forest is almost 480,000 ha (14%). The main factors driving the dynamics of this process are self-afforestation of non-forested areas and abandoned lands outside afforested areas. Notable is the lower increase in the total area compared to the increase in the afforested area, which is mainly due to the increase in forest emerging on long-uncultivated brownfield land outside wooded areas (National Forestry Accounting Plan of Bulgaria, including Forest Reference Levels for the period 2021–2025). The mean carbon stock in forest stands including aboveground biomass and soil for Bulgarian forests is 723 Mt C in 2000 (or 185 tC ha^{-1}) and increases in 2009 up to 779 Mt C (or 199.7 tC ha^{-1}). In regional context the state of forest ecosystems is of a particular interest in increasing the potential of forests as carbon sinks.

Mountain forests fulfil multiple functions, including the provision of goods as timber, fuelwood, non-wood forest products, and services as regulation of flows, purification of air and water, carbon storage, protection from natural hazards, and provision of cultural services (MAES 2013). The role of mountain forest to provide a wide range of ecosystem services is increasingly acknowledged especially in the context of environmental changes in a social aspect. Currently, there is a strong scientific interest to what extent the potential of mountain forests to store carbon could be enhanced under global environmental changes.

Maintaining carbon balance and preserving biodiversity are two of the key criteria for sustainable forest management directly linked to the problem of climate change. Within the elaborated project 'Programme of measures for adaptation of the forest in Republic of Bulgaria and mitigation the negative effect of climate change on them' completed in 2011, analysis of the state of forests, and scenarios for climate change in Bulgaria in twenty-first century were developed, based on the emission scenarios of IPCC (2007) (Raev et al. 2011). Maps of contemporary climate (1961–1990) were elaborated, as well as for 2020, 2050 and 2080. Sixteen models for change of climate elements were tested, with accepting optimistic and pessimistic scenarios for the future climate parameters in Bulgaria (Alexandrov 2011; Raev et al. 2015).

It is known that anthropogenic greenhouse gas emissions (such as CO_2, CH_4, etc.) stimulate global climate change on Earth (Houghton et al. 1992). In turn, climate change leads to changes in the distribution of vegetation (Smith et al. 1991). The biomass of temperate forests is expected to shift the boundary of the polar circle and the areas of the tree species to be changed both horizontally and vertically (Prentice et al. 1992; Cudlin et al. 2017). In this respect, predicting the dynamics of carbon stocks in mountain forest ecosystems is one of the most important tasks. The effects of climate change as well as various management options on the dynamics of forest ecosystems have been well studied using simulation modelling (Kellomäki et al. 2008; Peng 2009).

Forest ecosystems are distributed in different locations and vary according to the environmental factors, applied forestry activities and the land-use history. Carbon sequestration and storage are therefore controlled by various factors in different regions of the country. Even for a small country such as Bulgaria, depending on the altitude and other geographic parameters, global change will have a specificity that will affect the dynamics of carbon in forest ecosystems.

The main task of the present study is to analyse changes in carbon sequestration and to define vulnerable zones for forest ecosystems in Bulgaria using realistic and pessimistic climate change scenarios for 2020, 2050 and 2080 (Raev et al. 2011, 2015). Based on the scenarios of future climate change and the data for forests components, the effects of climate change on carbon sequestration in forests will be quantified, which helps to the identification of vulnerability zones. For the forests distributed in these areas some climate adaptation measures are proposed to increase their carbon storage potential.

Region and Methods

Changes in carbon stocks in different components of forest ecosystems in Bulgaria, as well as forestry dynamics, changes in species composition and age structure are analysed by modelling. Information about the developed and applied models for ecological modelling in forests, with presented details, features and significant differences, is summarized by Paulo De Melo-Abreu et al. (2010) and presented on the World Meteorological Organization's website. The aim of all developed models is to improve understanding of the role of vegetation, in particular forests, in maintaining the state of the environment and assessing impacts caused by land-use change (such as deforestation and afforestation) in relation to atmospheric composition/ quantity of greenhouse gases (GHG) and other pollutants.

Modelling offers opportunities to monitor C stocks in larger regions, but also poses a challenge for accuracy. The model system LPJ-GUESS (Smith et al. 2001) is an object-oriented modular framework for modelling the dynamics of the structure and functioning of global scale ecosystems characterized by different levels of detail. The framework includes processes based on tree physiology and biogeochemical processes occurring in different types of ecosystems and resulting from the BIOME3 model family (Haxeltine and Prentice 1996) and LPJ-DGVM (Sitch et al. 2003). In this model, vegetation can be represented at different levels of abstraction, depending on the degree of representativeness, the scope of applicability and the purpose of the work. The model also includes a statistical GETCLIM Climate Generator, which allows the system to simulate changes in climate variables both in the forest floor and in soil temperature and humidity. The abovementioned scenarios were used for modelling. For more accurate simulation of future climatic changes, the data for temperatures and precipitation were taken from the closest stations of regions, where the 31 representative sites, randomly selected and listed in Table 1, are located. These conditions are simulated for these forest ecosystems in the conditions of a contemporary climate. The simulation of the effects of changes in temperature and precipitation on the carbon dynamics in forest ecosystems was based on two scenarios—realistic (_S) with simulations of the state of forest ecosystems in 2020, 2050 and 2080 and pessimistic (_C) with a simulation of the state in 2080, described in details by Raev et al. (2015). According to the climate scenarios developed by Raev et al. (2015) and applied in this study under the current climate (1950–2000) the average annual air temperature in lowland is from 10 to 14 °C. The average annual temperature for the foothills and mountainous areas is from 4 to 1 °C, which depends mainly on the altitude and exposure of the slopes. At the optimistic scenario (_O), not included in present study, the average annual air temperature is expected to increase by 1–2 °C in lowland and 0.5–1 °C in mountainous regions in 2050. The expected increase of temperature in 2080 is about 2–3 °C in lowland and 1–2 °C in mountain areas compared with current climate. At the pessimistic scenario (_C) the increase of the air temperature is even more significant. By 2050, average temperatures rise by 3–4 °C in lowlands and by 2–3 °C in mountain areas, which is a significant increase compared to current climate. In 2080 the increase of air temperature continues—1 °C higher comparing to 2050. Assuming that by 2050 the air temperature warming in the country is expected to be around 0.75–1.5 °C (_O) and 2.5–3.5 °C (_C). Precipitation in current climate (1951–2000) increased from 450 to 500 mm in the lowlands to 1000–1100 mm in the high mountains. Precipitation in the forest climate zone from 900 to 1700 m is 720–1100 mm. At optimistic scenario in 2050–2080, no major precipitation changes are expected. At the pessimistic scenario for the same period, precipitation reduction with 100–200 mm is expected. The authors concluded that there is a change in the annual course of precipitation:

Table 1 Forest ecosystems sites studied with simulation model for climate change effect on carbon sequestration

Forest vegetation zones[a]	Forest vegetation regions in Bulgaria[a]		
	Mizia	Trakia	South border
	Geographic coordinates of sites and altitudinal diapason (m)		
I. Lower plain-hilly and hilly-foothill zone of oak forests	0–600	0–700	0–800
1.1. Subzone of floodplain and riparian forests	0–600	0–700	0–800
	1. Danube sub-region–Ruse region (43° 64′N, 25° 52′E), 39 m a.s.l. 2. Silistra region (44° 05′N, 26° 50′E), 34 m a.s.l.	3. Gorna Trakia–Plovdiv region (42° 09′N, 24° 38′E) 171 m a.s.l. 4. Yambol region (42° 20′N, 26° 33′E), 134 m a.s.l.	5. Ardino sub-region–Kardzhali region (41° 36′N, 25° 42′E), 382 m a.s.l. 6. Pirin sub-region–Strumyani region (41° 37′N, 23° 12′E), 150 m a.s.l.
1.2. Plain-hilly subzone of oak and xerothermic forests	0–400	0–500	0–600
	7. Oak forests in North Bulgaria–Pleven region (43° 05′N, 24° 33′E) 368 m a.s.l. 8. Oak forests in Ludogorie–Veliko Tarnovo region (43° 13′N, 25° 28′E) 215 m a.s.l. 9. Oak forests in Dobrudzha Black Sea coast–Suvorovo region (43° 18′N, 27° 42′E) 350 m a.s.l.	10. Oak forests in Varna-Burgas Black Sea coast–Varna region (42° 55′N, 27° 40′E), 111 m a.s.l. 11. Oak forests in Eastern Balkan–Sliven region (42° 46′N, 26° 40′E), 448 m a.s.l.	12. Deciduous xerothermic forests in Pirin sub-region–Sandanski region (41° 31′N, 23° 19′E), 190 m a.s.l. 13. Lower Maritza–Svilengrad region (41° 04′N, 26° 03′E), 133 m a.s.l. 14. Strandzha–Tzarevo region (42° 06′N, 27° 45′E), 150 m a.s.l.

(continued)

Table 1 (continued)

Forest vegetation zones[a]	Forest vegetation regions in Bulgaria[a]		
	Mizia	Trakia	South border
	Geographic coordinates of sites and altitudinal diapason (m)		
1.3. Hill-foothill subzone of mixed deciduous forests	400–600	500–700	600–800
	15. Mixed broadleaved in North Bulgaria–Gabrovo (42° 49′N, 25° 28′E) 455 m a.s.l.	16. Mixed broadleaved in Rhodopes (41° 49′N, 24° 08′E) 614 m a.s.l. 17. Mixed broadleaved in Eastern Balkan (42° 54′N, 27° 00′E) 424 m a.s.l.	18. Mixed broadleaved in Pirin (41° 45′N, 23° 30′E) 703 m a.s.l. 19. Mixed broadleaved Ardino sub-region (41° 21′N, 25° 49′E) 718 m a.s.l.
II. Middle mountain zone of beech and conifer forests	600–1800	700–2000	800–2200
2.1. Low-mountain subzone of forests of durmast, beech and fir	600–1000	700–1200	800–1500
	20. Central Balkan (42° 49′N, 24° 19′E) 803 m a.s.l. 21. Western Balkan (42° 56′N, 23° 37′E) 854 m a.s.l.	22. Rila (42° 22′N, 23° 58′E) 892 m a.s.l. 23. Rhodopes (41° 57′N, 24° 48′E) 900 m a.s.l.	24. Rhodopes (41° 35′N, 23° 36′E) 813 m a.s.l. 25. Pirin (41° 29′N, 24° 49′E) 879 m a.s.l.
2.2. Middle mountainous subzone of beech, fir and spruce forests	1000–1500	1200–1700	1500–1900
	26. Central Balkan (42° 53′N, 23° 30′E) 1014 m a.s.l.	27. Rila (42° 05′N, 23° 54′E) 1259 m a.s.l.	28. Pirin (41° 47′N, 23° 29′E) 1850 m a.s.l.
2.3. Upper alpine subzone of spruce forests	1500–1800	1700–2000	1900–2200
	29. Rila (42° 04′N, 23° 24′E) 1750 m a.s.l.		

(continued)

Table 1 (continued)

Forest vegetation zones[a]	Forest vegetation regions in Bulgaria[a]		
	Mizia	Trakia	South border
	Geographic coordinates of sites and altitudinal diapason (m)		
III. High-mountain zone	>1800		
3.1. High mountain subzone of forests of spruce and Macedonian pine/Heldreich's pine	1800–2000	2000–2200	2200–2500
	30. Pirin (41° 42′N, 23° 31′E) 2400 m a.s.l.		
3.2. High mountain subzone of single trees, dwarf pine and shrub formations	2000–2200	2200–2500	2500–2700
	31. Rila (42° 11′N, 23° 19′E) 2405 m a.s.l.		
3.3. Subzone of alpine pastures	>2200	>2500	>2700
	Not included		

[a]According Zahariev et al. (1984) and Classification scheme of forest habitat types in Republic of Bulgaria (2011)

Table 2 Plant functional types (PFTs) for Bulgaria included in the LPJ-GUESS model

BNE	Boreal needleleaved evergreen tree
BNS	Boreal needleleaved summergreen tree
BBS	Boreal broadleaved summergreen tree
TeBS	Temperate (shade-tolerant) broadleaved summergreen tree
IBS	Boreal/temperate shade-intolerant broadleaved summergreen tree
TeBE	Temperate broadleaved evergreen tree
MNE	Mediterranean summergreen or evergreen tree
C3G	Cool grass (C_3)

reduction of rainfall during the growing season and increased precipitation in the cold part of the year (Raev et al. 2015).

A total number of 124 simulations was performed to achieve the tasks.

The following parameters were taken from the Forestry Management Plans (under application in 2010) for each selected site in order to be included as input data for the model: Tree Species; Age [year]; Number of trees [1/ha]; mean height [m]; SD height; mean diameter [cm] at breast height; SD diameter [cm]. The relevant PFTs (Plant Functional Types) for forest zones in Bulgaria are considered (Table 2).

Results and Discussion

Analyses on Carbon Sequestration in Forest Ecosystems in the Lower Plain-Hilly and Hilly-Foothill Zone of Oak Forests Under Realistic Climate Change Scenario

Sub-zone of floodplain and riparian forests—the effect of climate change on carbon sequestration in floodpain and riparian forests located in the three forest vegetation regions of Bulgaria is presented in Table 3. For forests ecosystems in Mizia region developed along riverside of the Danube river and its tributaries, simulations showed a decrease in carbon accumulated in biomass. The natural vegetation developed under the modern climate conditions is formed by the plant functional types: TeBS, IBS, C3G. The modelled carbon dynamics in these systems under realistic climate change scenario showed the appearance of plant species from type TeBE, which contribution to the carbon sequestration has increasing tendency till 2080. Carbon accumulated in grass vegetation is relatively stable for the studied period due to the specifics of these habitats and the development of the tree cover. The expected increase of temperature and changes in precipitation regime will affect stronger trees from TeBS type. In soils the changes in carbon are slightly expressed but with clear tendency.

Table 3 Changes in carbon sequestration in forest ecosystems according the forest vegetation regions under realistic and pessimistic scenario

	Carbon sequestration changes (kg C/m^2) under different scenarios and year			
Forest vegetation zones	Realistic_S			Pessimistic_C
	2020	2050	2080	2080
I. Lower plain-hilly and hilly-foothill zone of oak forests				
1.1. Subzone of floodplain and riparian forests	−1.010 (±0.71)	−0.727 (±0.82)	−0.993 (±1.05)	−2.288 (±1.36)
1.2. Plain-hilly subzone of oak and xerothermic forests	−0.865 (±0.74)	−0.720 (±0.71)	−1.384 (±1.13)	−1.759 (±0.79)
1.3. Hill-foothill subzone of mixed deciduous forests	−0.708 (±0.65)	−0.395 (±0.74)	−1.190 (±0.63)	−1.881 (±0.37)
II. Middle mountain zone of beech and conifer forests				
2.1. Low-mountain subzone of forests of durmast, beech and fir	−0.461 (±1.54)	−1.522 (±2.11)	−1.186 (±1.76)	−3.134 (±0.97)
2.2. Middle mountainous subzone of beech, fir and spruce forests	−1.210	−0.429	−0.170	−4.159
2.3. Upper alpine subzone of spruce forests	1.684–2.811	1.490–3.895	5.520–2.530	0.888–2.707
III. High-mountain zone				
3.1. High mountain subzone of forests of spruce and Macedonian pine/Heldreich's pine	1.049	4.684	5.204	6.425
3.2. High mountain subzone of single trees, dwarf pine and shrub formations	1.824	3.019	4.221	13.775
3.3. Subzone of alpine pastures	Na	Na	Na	Na

Na not included in present study

Similar is the expected situation in these forests in Trakia region, where the carbon accumulation in biomass is characterized by a clear decrease. In South border region the areas of Pirin and Eastern Rhodopes are differentiated. For Eastern Rhodopes a slight increase in carbon sequestration is prognosed. The permanent appearance of plant species from MNE type, which are resistant to drought and tolerant to higher temperatures, is specific. Carbon sequestration slightly increases mainly due to the accumulation in forest litter.

Plain-hilly subzone of oak and xerothermic forests—changes in climate are expected to affect seriously the oak forests in all regions of Bulgaria. Carbon accumulated in oak forests in Northern Bulgaria modelled under realistic scenario (_S) showed low influence in the next four decades, but well-expressed negative effects in 2080. The decrease of carbon stored in aboveground biomass affects slightly the soil carbon. For forests in Ludogorie region the negative effect of changed climatic factors and expected drought is much serious. Special attention needs to be paid on forests located in Dobrudzha Black Sea coastal area, where the decrease in carbon sequestration with 1.598 kg C/m^2 is expected soon in 2020. In Mizia the participation of species of TeBE type will increase. The carbon accumulation in soils is also expected to increase till 2080. In Trakia the expected climatic changes will affect the oak forests in a lower degree. The simulations show a decrease of carbon accumulation in biomass for 2020 and 2050, while in 2080 the stabilization is a result of the permanent establishment of species from TeBE and MNE types. The prognoses indicate the appearance of more resistant and tolerant to drought and increased temperature plant species. In soil system the accumulation of carbon is stable as some fluctuations are due to the development of aboveground vegetation. In South border region the decrease of carbon is rapid, clearly expressed again in Pirin sub-region where is up to 1.915 kg C/m^2, which differs with those in forests located in Lower Maritza—1.090 kg C/m^2. Simulation models for xerothermal forests in Strandzha show risks of carbon losses under increased temperature and decrease of precipitation. In these ecosystems the participation of plants from MNE type, tolerant to drought, will increase. No clear changes in soil carbon are expected, while fluctuations are determined mainly by specifics of litter and development of aboveground vegetation cover.

Hill-foothill subzone of mixed deciduous forests—the prognoses for mixed broadleaved forests in the region of Mizia are characterized by a slight increase of carbon accumulated by tree species of TeBS in 2020, followed by a rapid and strong decrease, which reached 1.818 kg C/m^2 in 2080. In Rhodopes and in Eastern Balkan the expected decrease is 0.5–0.6 kg C/m^2. In South border region the same tendency appears in biomass carbon accumulation of these ecosystems, while in soils the carbon will be stored mainly in the forest litter. More resistant to drought plant species as well as species from MNE type will be part of the forest communities, but the carbon sequestered in biomass is mainly determined by plant species of TeBE type.

Analyses on Carbon Sequestration in Forest Ecosystems in the Middle Mountain Zone of Beech and Conifer Forests Under Realistic Climate Change Scenario

Low-mountain subzone of forests of durmast, beech and fir—the negative impact of changing climate is also expected in this zone. The decrease of carbon accumulated in the aboveground biomass is mainly due to the coniferous specie in mixed forests, while the broadleaved compensate this variation, which is related with the appearance of species from types TeBS and IBS. Never mind the sequestered carbon in these ecosystems decreases. The changes are expected to be less expressed in some ecosystems (in the region of Rila Mountain for example). For mixed forests from the region of Rhodopes, the negative effects are much expressed with sharp decrease of carbon accumulated in coniferous compensated by those in type ISB. The soils are characterized with slow increase of carbon in the superficial 0–10 cm layer related with the higher input from broadleaved and its specifics, decomposed more intensively under changed climatic factors.

Middle mountainous subzone of beech, fir and spruce forests—for these ecosystems a contrasting situation is expected. Forests in Mizia are characterized by a slight increase of carbon in biomass without well-expressed changes in the soil system. The changing climatic conditions influence positively the coniferous vegetation and in 2050 and participation of species from TeBE type could be part of the composition of these forests. In Pirin region the temperature increase provokes higher carbon accumulation in coniferous tree species and in 2080 more temperature tolerant trees and shrubs are expected to be part of ecosystems. For these forests in Rila region, a decrease of carbon stored in coniferous is prognosed.

Upper alpine subzone of spruce forests—the temperature increase and changes in precipitation in vertical diapason under realistic scenario (_S) have positive effect on carbon accumulation in spruce forests. The prognoses scenarios suppose the appearance of new functional plant types. In soils the variations are more expressed, but a sustainable trend after 2020 is established.

Analyses on Carbon Sequestration in Forest Ecosystems from the High-Mountain Zone Under Realistic Climate Change Scenario

Very well-expressed positive effect of climate changes is prognosed for forests of spruce and Macedonian pine/Heldreich's pine in high-mountain zone regarding carbon sequestration under realistic scenario. Expected changes in carbon accumulation are significant. In this zone the role of coniferous species and shrubs is essential. In soils the changes are also related to the carbon accumulation in forest litter and superficial layers.

In the high mountain subzone of single trees, dwarf pine and shrub formations the effect of changes under realistic scenario is related with increased accumulation of carbon in shrubs and trees, while the participation of grasses stays relatively stable. This positive effect is expected very soon in 2020.

In soils the tendency in increased carbon accumulation could be explained by more favourable microclimatic conditions for microorganisms as well as with the quantity and composition of input plant materials. It is necessary to be underlined that for simulation the effects of changes on the dynamics of soil organic matter under natural development of ecosystems longer time-periods are needed. Changes in soil organic matter are strongly dependent on aboveground components, which are the main source of litter as well as the anthropogenic impacts, which are expressed first in the quantity and quality of litter and later in the superficial 0–10 (30) cm of soils (Zhiyanski et al. 2012).

Analyses on Carbon Sequestration in Forest Ecosystems from the High-Mountain Zone Under Pessimistic Climate Change Scenario

The simulations of changes in carbon sequestration in Bulgarian forests under pessimistic scenario confirmed the expectations of realistic scenario. The development of climatic changes in case of pessimistic scenario is related with stronger negative effects on the processes of carbon sequestration. The simulations show rapid decrease of carbon accumulated in forests located in the lower plain-hilly and hilly-foothill zone, which arrives at 1.76–2.29 kg C/m^2. Subzone of floodplain and riparian forests will be influenced at a higher degree due to the worsen water regime and related stress for the plant species. Clearly expressed negative impact is expected for forest ecosystems formed by durmast, beech and fir in the middle mountain zone of beech and conifer forests, where the decrease arrives at 4.2 kg C/m^2.

In the upper alpine subzone of spruce forests the tendency of increase of carbon accumulation, established under the realistic scenario, is still expected. But the prognosis values are much lower, which indicates for a worsen status of these forests under longer simulation scenario.

In the high-mountain zone the expected changes are related with higher carbon accumulation. It is explained with both appearance of coniferous and shrub species and their improved productivity as a result of more favourable thermic regime.

Vulnerability Zones for Forest Ecosystems

The vulnerability zones for forest ecosystems in Bulgaria at a relevant altitude diapason are defined for the years 2020, 2050 and 2080 according the realistic scenario and for 2080 according the pessimistic scenario (Table 4).

In the results are included the forest areas and zones of Bulgaria and the vulnerability zones in which they fall in the respective years and the different scenarios, outlining mountain forests. The carbon storage values in kg C/m^2 for the respective zones are as follows:

Zone A—forest ecosystems, highly vulnerable to climate change. Estimated reduction in carbon accumulation is above 1.00 kg C/m^2;

Table 4 Vulnerability zones for forests in Bulgaria regarding their potential to store carbon

Forest vegetation zones	Vulnerability zones			
	Realistic scenario (_S)			Pessimistic scenario (_C)
	2020	2050	2080	2080
I. Lower plain-hilly and hilly-foothill zone of oak forests				
1.1. Subzone of floodplain and riparian forests	Zone A	Zone B	Zone A	Zone A
1.2. Plain-hilly subzone of oak and xerothermic forests	Zone B	Zone B	Zone A	Zone A
1.3. Hill-foothill subzone of mixed deciduous forests	Zone B	Zone B	Zone A	Zone A
II. Middle mountain zone of beech and conifer forests				
2.1. Low-mountain subzone of forests of durmast, beech and fir	Zone B	Zone A	Zone A	Zone A
2.2. Middle mountainous subzone of beech, fir and spruce forests	Zone A	Zone B	Zone C	Zone A
2.3. Upper alpine subzone of spruce forests	Zone D	Zone D	Zone D	Zone D
III. High-mountain zone				
3.1. High mountain subzone of forests of spruce and Macedonian pine/Heldreich's pine	Zone D	Zone D	Zone D	Zone D
3.2. High mountain subzone of single trees, dwarf pine and shrub formations	Zone D	Zone D	Zone D	Zone D
3.3. Subzone of alpine pastures[a]	Zone C	Zone C	Zone C	Zone C

[a]For the subzone of alpine pastures no changes are expected if there is no change of land-use

Zone B—forest ecosystems, moderately vulnerable to climate change. Predicted reduction in carbon storage is within the range of 0.50–0.99 kg C/m^2;
Zone C—forest ecosystems, less vulnerable to climate change. Predicted reduction in carbon accumulation is in the range 0.00–0.49 kg C/m^2;
Zone D—forest ecosystems that are not vulnerable to climate change. Predicted increase in carbon accumulation is over 0.01 kg C/m^2 (Figs. 1 and 2).

General Recommendations for Sustainable Management of Forests in Regard to Their Potential to Sequester Carbon

Zone A is expected to be characterized by a decrease of precipitation and increase of temperature under future scenarios of climate change, which will reduce the tree growth in certain habitats. Longer and dry summer is expected to appear more often, with the negative impact of climate change more serious on forest formed on shallow and drained soils, with a high percentage of sand fraction and higher stoniness. The main task of forestry is oriented toward protection of forests ecosystems in this zone under worse climatic conditions—water deficit and higher temperatures.

The recommended measures for adaptation of forests to expected changes in climatic conditions in this zone are listed below:

- Land-use change is not recommended. Forest lands to remain forest lands in order to minimize the carbon losses from different compartments of ecosystems;
- Afforestation of riparian area with fast-growing tree species, which could supply both material and regulation services as erosion control, carbon sequestration and increase biodiversity;
- Establishment of intensive poplar plantations at appropriate habitats to improve carbon storage in aboveground biomass. It is related with the development of guidelines for the management of intensive plantation for biomass production and protection the carbon storage in soils;
- Maintaining, restoring and expanding the system of protective forest belts by supporting afforestation of abandoned agricultural lands;
- Effective utilization of the area of the nurseries that, on the one hand, provide trees for afforestation and, on the other hand, increase carbon sequestration. More effective ways of realization of the production and related opportunities for inclusion in the circular economy;
- Wider implementation of agro-forestry systems, including energy crops for biomass, stimulating the realization of projects under various financial mechanisms;
- Due to the higher part of matured and over-matured coppice forests, specific forestry management activities should be implemented for faster conversion in high-stem forests;
- Implementation of appropriate fertilization in anti-erosion forest plantations on poor sites;

Site 11: Young oak forest (<20 yrs) in East Balkan Mnt

PFT	2010 C biomass kgC/m²	2010 NPP kgC/m²/yr	2020 C biomass kgC/m²	2020 NPP kgC/m²/yr	2050 C biomass kgC/m²	2050 NPP kgC/m²/yr	2080 C biomass kgC/m²	2080 NPP kgC/m²/yr
TeBS	3.221	0.244	3.376	0.193	2.582	0.173	2.810	0.184
IBS	1.169	0.111	0.791	0.076	0.855	0.095	0.649	0.068
TeBE	1.834	0.125	1.619	0.117	1.514	0.137	1.973	0.170
MNE					0.034	0.014	0.027	0.009
C3G	0.018	0.005	0.036	0.021	0.042	0.026	0.048	0.034
Total	6.242	0.485	5.822	0.407	5.026	0.445	5.507	0.465

Carbon fluxes kgC/m²/yr

Vegetation trend 3D

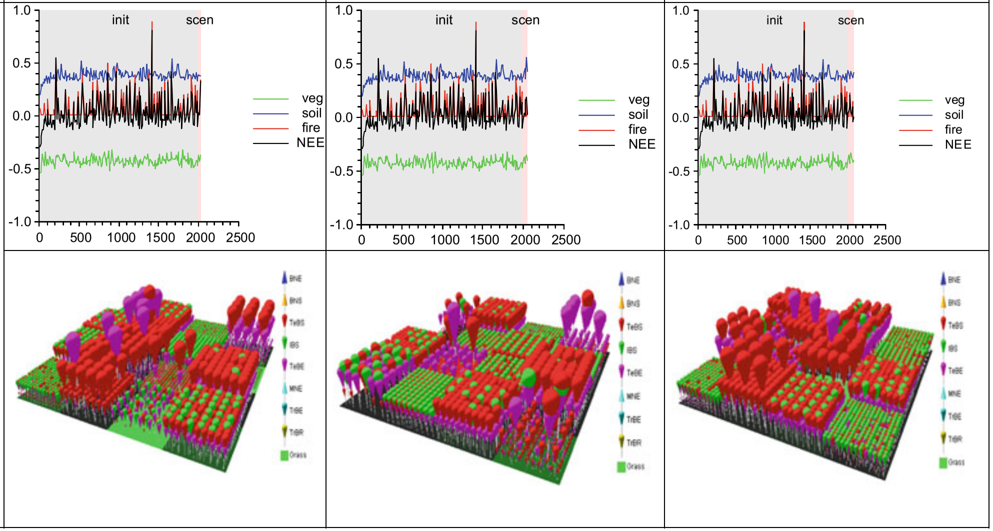


Fig. 1 Examples of simulated changes in carbon sequestration under the realistic scenarios of climate change in selected sites (2020, 2050 and 2080)

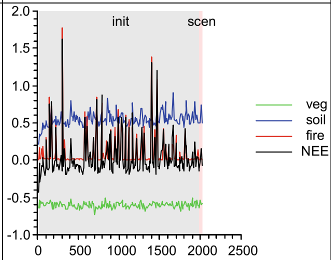
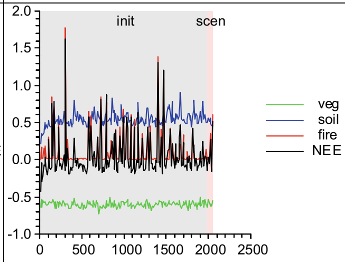
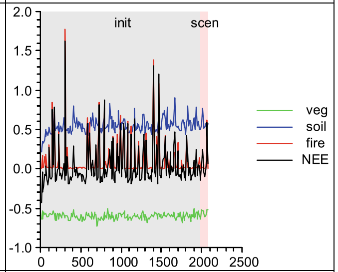
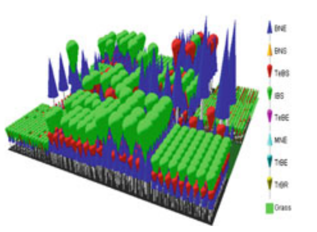
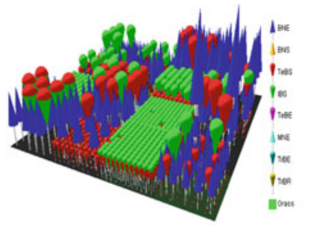
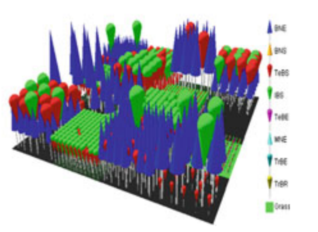
Site 21	2010	2020	2050	2080
Mixed oak forest (40-60 yrs) Western Balkan Mnt	PFT / **C** biomass kgC/m² / NPP C/m²/yr BNE 7.744 0.350 TeBS 1.998 0.119 IBS 3.707 0.259 C3G 0.016 0.011 Total 13.465 0.740	PFT / **C** biomass kgC/m² / NPP kgC/m²/yr BNE 7.861 0.298 TeBS 1.854 0.124 IBS 3.710 0.231 C3G 0.008 0.004 Total 13.433 0.657	PFT / **C** biomass kgC/m² / NPP kgC/m²/yr BNE 10.846 0.367 TeBS 2.214 0.131 IBS 1.835 0.128 TeBE 0.021 0.009 C3G 0.027 0.020 Total 14.942 0.655	PFT / **C** biomass kgC/m² / NPP kgC/m²/yr BNE 7.947 0.217 TeBS 3.005 0.193 IBS 2.533 0.189 TeBE 0.081 0.022 C3G 0.027 0.016 Total 13.593 0.637
Carbon flux kgC/m²/yr				
Vegetation trend 3D				

Fig. 1 (continued)

Site 30	2010	2020	2050	2080
Spruce forests (40-60 yrs) in Pirin highland	PFT / C biomass kgC/m² / NPP kgC/m²/yr BNE 15.461 0.602 TeBS 0.226 0.060 IBS 0.651 0.187 C3G 0.044 0.031 Total 16.382 0.880	PFT / C biomass kgC/m² / NPP kgC/m²/yr BNE 16.953 0.846 BNS 0.032 0.001 TeBS 0.086 0.015 IBS 0.343 0.057 C3G 0.017 0.013 Total 17.431 0.931	PFT / C biomass kgC/m² / NPP kgC/m²/yr BNE 20.786 0.899 TeBS 0.047 0.009 IBS 0.230 0.036 C3G 0.001 0.000 Total 21.066 0.944	PFT / C biomass kgC/m² / NPP kgC/m²/yr BNE 21.334 0.809 BNS 0.082 0.020 IBS 0.148 0.037 C3G 0.021 0.016 Total 21.586 0.882
Carbon flux kgC/m²/yr		(chart)	(chart)	(chart)
Vegetation trend 3D		(3D view)	(3D view)	(3D view)

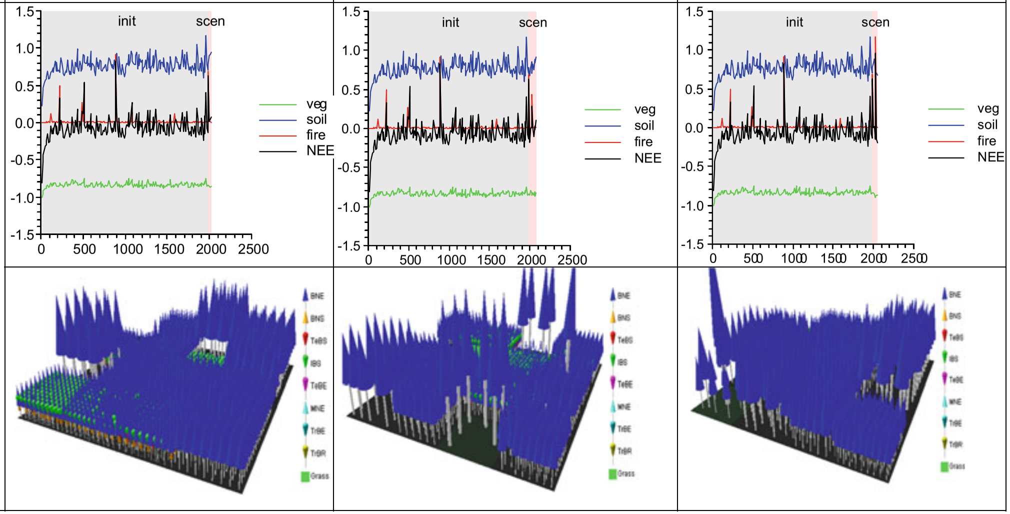


Fig. 1 (continued)

Site 11.

PFT	**C** biomass kgC/m²	NPP kgC/m²/yr
TeBS	2.198	0.121
IBS	0.318	0.033
TeBE	2.221	0.186
MNE	0.081	0.011
C3G	0.030	0.011
Total	4.848	0.363

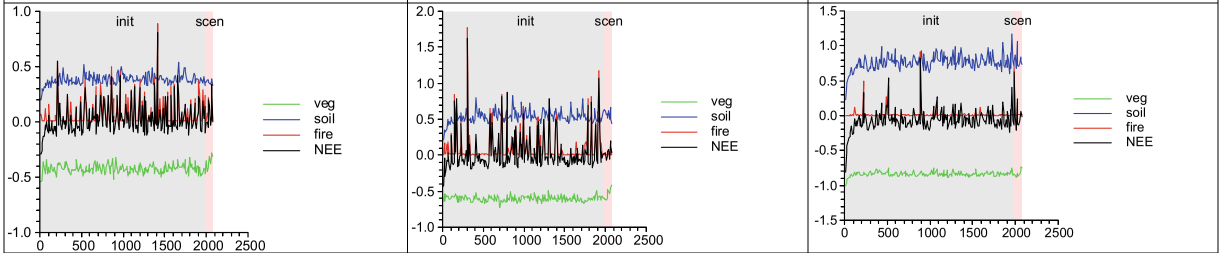
Site 21.

PFT	**C** biomass kgC/m²	NPP kgC/m²/yr
BNE	5.294	0.131
TeBS	2.519	0.194
IBS	1.587	0.127
TeBE	0.452	0.064
C3G	0.028	0.018
Total	9.880	0.534

Site 30.

PFT	**C** biomass kgC/m²	NPP kgC/m²/yr
BNE	19.994	0.582
TeBS	0.562	0.048
IBS	2.241	0.236
TeBE	0.000	0.000
C3G	0.010	0.003
Total	22.807	0.869

Carbon flux kgC/m²/yr



Vegetation trend 3D

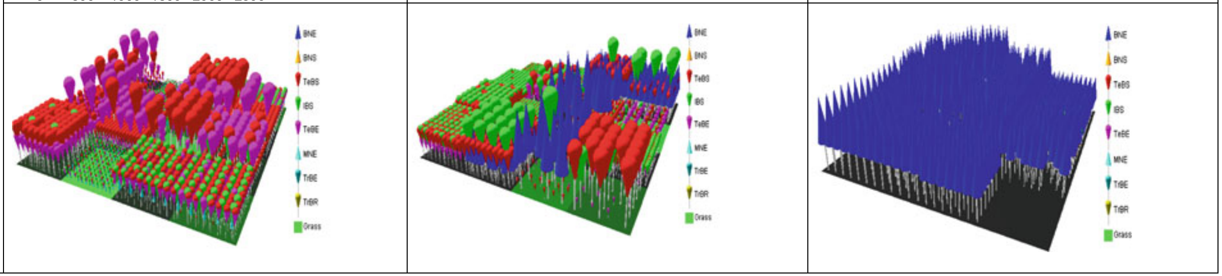


Fig. 2 Examples of simulated changes in carbon sequestration under the pessimistic scenarios of climate change in selected sites (2080)

- To be ensured that in the mixed forests the tree species are compatible regarding the growing intensity and requirements for light in order to reduce carbon losses in case of higher mortality rates;
- Strict implementation of the silvicultural activities in forests more vulnerable to windthrows to prevent carbon losses from aboveground biomass;
- Increasing the rotation periods in some intensive plantations that will benefit from a higher carbon storage compared to the short-term rotation systems;
- Diversify the age structure, species composition and genetic diversity of forests with species that are appropriate to the zone under current and future climatic conditions. Species for afforestation is recommended to be introduced from the southern areas of the country, considering altitude specifics and the origin of species, to ensure sustainable carbon accumulation;
- Identifying soils under risk of carbon loss and selection of species from specific locations, considering exposition of slope, topography and soil characteristics for maintaining carbon sequestration in soil and forest floor;
- Preparation of a strategy to reduce the risk of pests and pathogens, outlining the abilities tree species and forest ecosystems to minimize the risk of future biomass loss;
- The periods of afforestation to be defined precisely considering the changed conditions. The increased amount of precipitation in the autumn and winter and temperature inversions, together with short growing periods, could lead to new approaches in maintaining saplings introduction and replenishment;
- Supporting natural regeneration when the diversity of species and their adaptive potential is likely to be limited due to the climate changes to ensure sustainable carbon accumulation in aboveground biomass;
- Carbon inventory in forests with performing additional studies and collecting database for different parameters of forest stands and soil is recommended for more accurate calculation of carbon stocks at different levels.

The strategic task of forestry in Zone B is to define targets and actions to ensure appropriate conditions for survival of a wider range of tree and shrub species.

To improve carbon sequestration and for forest adaptation the recommendations include:

- Afforestation of non-regenerated woodland and open forest areas, with a view to increasing carbon stocks in terrestrial ecosystems;
- Anti-erosion afforestation to prevent carbon loss from soil and to increase its accumulation in aboveground biomass;
- Due to the higher part of matured and over-matured coppice forests, specific forestry management activities should be implemented for their faster conversion to high-stem forests;
- In forest management mixed forests of tree species suitable for the specific habitat to have priority. The tree species preferably to be of local origin. This will ensure better adaptation of forest ecosystems to changing environmental factors and ensure carbon sequestration in different ecosystem compartments;

- Newly established forest plantations can include species typical for hot and dry climates in Southern Bulgaria that improve forest sustainability over the long-term perspective and store carbon. The choice of species should be limited to areas and sites with a modern climate close to that predicted for Bulgaria in the future to ensure optimum carbon accumulation. Also the possibility of an impact on native biodiversity to be considered avoiding those with invasive threat;
- In forest management the natural regeneration to be a priority. This approach supports evolutionary adaptation and maintain a diverse stand structure in forests, as well as contributes to store and increase carbon stocks in above-ground biomass;
- Increase of growing stocks through harvesting intensity, which maintains an optimal stand structure or selective forestry systems, which will ensure a sustained increase of carbon sequestration in the different components of forest ecosystems;
- Forests will become more vulnerable to fire in the dry spring and summer, especially in areas that are frequently visited. Developing a fire risk assessment and providing early warning systems during the high-risk periods will minimize the risk of carbon losses in case of fires;
- Preservation and enhancement of soil organic carbon after felling through utilization of modern forestry practices including technological soil treatment activities, irrigation activities and the distribution of at least 30% of organic waste after felling on the site.
- Conservation and extension of peri-urban forest parks and recreation forests to increase the carbon sequestration potential of peri-urban areas and provisioning of variety of cultural ecosystem services.

The strategic task of forestry in Zone C in relation to carbon sequestration can be defined as: sustainable development and enhanced carbon storage in forest ecosystems.

What are the recommended measures to implement these goals?

- Reducing land-use change related to the conversion of forest into another land-use type to prevent carbon losses due to land-use change;
- Maintaining the network of protected forest areas to preserve both the primary structure of the most valuable natural forests and their environmental functions and ecosystem services (incl. sustainable carbon sequestration);
- Selective management of forests in order to increase carbon stocks in the soil compared to all other silvicultural regimes;
- Introducing environmental-friendly forms and technologies for conducting harvesting activities, cuttings and sanitary felling in forest at watershed or stand levels, reducing damages in forest ecosystems and landscapes, and minimizing carbon losses;
- Wider implementation of forest certification;
- Conservation and improvement the conditions in pasture and meadow ecosystems in mountain areas within the forest territory;
- Anti-erosion afforestation to increase carbon accumulation in forest vegetation and soils;

– Prevention of forest fires and the introduction of early warning systems to minimize carbon losses;
– Managing forest plantations on steep slopes to reduce the impact of strong, intense and long rains causing landslides and erosion to minimize carbon loss. On steep slopes in areas with higher rainfalls, forestry systems oriented at forming of high-stem forests could increase the risk of landslides and damages of infrastructure facilities and should be limited. In such places, as well as in places with difficult access, adaptive forestry systems to be applied—natural forests, traditional coppice plantations;
– Prevention and protection of forests from pests and diseases to enhance the resilience of forest ecosystems, as well as the preservation of the carbon stored;
– Increasing the density of the forest plantations through additional activities to stimulate natural regeneration and increase of carbon accumulation;
– Carbon accumulated in soils, shrub and tree vegetation of natural forest ecosystems is in significant quantities, and ways of conserving these stocks must be sought when developing the forest management plans.

Most of the tree species, which are currently well suited to the soil and climate conditions of today's habitats, are likely to continue to be appropriate until the middle of the century. Types that are poorly suited to places in the current climate, where water deficiency is a limiting factor, are likely to become less relevant in the future. For many sites in Zones A, B and C, the effect of a changing climate will be expressed with reduced productivity as a result of projected summer droughts. However, this does not mean that these species will cease to be functional components of these forest ecosystems.

Beech (*Fagus sylvatica*) is vulnerable to moisture deficiency during the growing season, especially in mature stands formed in shallow, well-drained soils. Oriental hornbeam (*Carpinus betulus*) and common chestnut (*Castanea sativa*) are drought-resistant species and are considered to be alternative to habitats that will be too dry for beech in the future. On deeper, clay and well-structured soils, beech will continue to be a good species in our country, with a view to the good carbon sequestration potential in forest ecosystems.

Douglas fir (*Pseudotsuga menziesii*) requires adequate moisture for good growth on well-drained soils. However, together with Scot's pine (*Pinus sylvestris*), it is considered as relatively resistant to drought and therefore is a suitable species for carbon capture on fertile soils, and in mixed pine plantations on less fertile soils.

European oak (*Quercus robur*) and durmast oak (*Q. petraea*) have a different distribution, which is partly determined by their requirements for soil moisture. The European oak is tolerant to the fluctuations of groundwater during summer and winter. Durmast oak requires good soil moisture in the summer. European oak may remain a suitable species for habitats characterized by groundwater fluctuations, but it is likely that a decrease in growth and hence accumulated carbon will be reported due to the decrease in the presence of water in drier summers.

Ash (*Fraxinus excelsior*) requires good moisture throughout the growing season, and high yields must be provided with many fertile habitats with abundant moisture.

The habitats that are currently growing well can continue to be appropriate, including those in riparian and coastal areas. However, any prolonged dry period will seriously affect this species, especially in places with limited access to moisture and lead to carbon losses in ecosystems. Forest plantations of this species require special attention in order to store carbon.

In climate change associated with drought and elevated temperatures, an alternative approach is for drought-resistant species to occupy shallow and poorly drained habitats, or those for which soil moisture fluctuation during the growing season is typical—such as heavy clay soils and chernozems in Northern Bulgaria. For dry and well-drained soils, there are difficulties in choosing species that in the past have been limited to individual *Pinus* species, while deciduous species are now the priority. In Zone A and Zone B, there is a need for additional research on carbon sequestration and its dynamics in newly established forests, for the development of recommendations, national programs and strategies.

Zone D is the optimal area regarding carbon sequestration and storage for forest vegetation. It is expected that this area will be located in the subzone of spruce forests in the mountain regions of the country over 1500 m above sea level.

The strategic task of forestry in Zone D can be defined as: Maintaining the sustainability and productivity of forest ecosystems and maintaining the optimal balance between supply-demand of ecosystem services provided by forests.

These tasks can be achieved through the following management measures:

– Maintaining the potential of forests to store carbon at watershed or stand level, by applying appropriate forestry measures, selective forestry, certification, protection of biodiversity and old forests;
– Protection of forests, which provide specific regulation ecosystem services;
– Protected forests to be preserved. In the long term perspective, natural protected forests can be a resource for monitoring the effects of climate change, with a wide range of species in them providing evidence to guide adaptation for selection of species with higher potential to store carbon;
– Correction of the harvesting periods according to the maximum productivity of the forests in the conditions of the future climate, combined with fire measures;
– Restricting the urbanization zones in high-mountain areas to ensure maximum carbon sequestration and storage;
– Stimulating grassland form of land-use, increasing carbon accumulation, protecting the specifics of pastoral ecosystems and biodiversity, with the exception of steep highland pastures with weak and torn grass and the risk of soil erosion;
– Conservation and improvement of pastoral and meadow ecosystems in mountainous areas characterized by high carbon content and specific biodiversity.

For many areas in Zone D, the effect of changing climate will be related with increased productivity as a result of predicted elevated temperatures.

Norway spruce (*Picea abies*), European larch (*Larix decidua*) and hybrid larch (*Larix eurolepsis*) and others are planted in the cooler areas on wetter habitats. These species can continue to be suitable for loamy and humid locations and in areas with poor drainage. Because of the warmer climate, productivity will likely increase in appropriate locations in Zone D, which will increase carbon stocks in both the aboveground biomass and the forest floor and soil of the ecosystems formed by these tree species. Studies on the quality of wood of these species are necessary in the context of changes in the environment.

Pinus peuce and *Pinus heldreichii* are spread in high-mountain areas and climate change is supposed to increase their productivity. Studies on the quality of wood of these species are needed in the conditions of changed climate and increased biomass accumulation.

More recommendation and measures could be defined for specific location and levels, which could contribute for a better management of forests in respect to carbon sequestration and related ecosystem services.

Conclusions

Forest ecosystems, which are included in the area of Zone A, are very vulnerable to expected climatic changes in respect to the potential of carbon sequestration. According to the simulations and analyses on the changes in carbon sequestration under realistic scenario in the next years, in 2020, negative effects could be expressed in most of the riparian and floodplain forests in Mizia (Northern Bulgaria), especially in Dobrudzha region. The negative changes are stronger in 2080, covering the plain-hilly subzone of oak and xerothermic forests and hill-foothill subzone of mixed deciduous forests in South border region. In 2050 Zone A includes also Low-mountain subzone of forests of durmast, beech and fir in Stara Planina Mountain, Eastern Rhodopes and Pirin sub-regions. Under the pessimistic scenario in 2080 the expected “picture” is quite negative: sustainable tendence of decrease of carbon sequestration in the whole lower plain-hilly and hilly-foothill zone of oak forests as well as in the middle mountain zone of mixed forests. Zone A could be qualified as the most dangerous vulnerability zone under future climate changes with sustainable decrease of carbon sequestration in forest ecosystems.

Zone B is expected to cover territories within the altitude diapason between 200 and 600 (700) m a.s.l. It includes the northern part of Danube plain, South Dobrudzha, part of Trakia lowland and Black Sea coastal region, without Strandzha. In 2050 Zone B extents its cover up to 600–800 m a.s.l. including Danube plain, Dobrudzha, foothills of Stara Planina Mountain, Trakia lowland, big part of Sredna Gora and Strandzha Mountains, and Sofia field. In 2080 Zone B sharply proceeds to Zone A. Under pessimistic scenario Zone B is not expected.

Zone C is expected to cover small territories in South border region in the Middle mountainous subzone of beech, fir and spruce forests. The area of alpine pastures, where no significant changes in carbon sequestration are expected if land-use stays unchanged, are also referred to this Zone C. In these ecosystems the tendency in sustainable accumulation of carbon the turf and superficial soil is stable.

Zone D is optimal for forest tree vegetation regarding their potential to sequester carbon. This zone is expected to be expanded in the subzone of spruce forests in mountain regions located over 1500 m a.s.l.

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Erosion Control Service of Forest Ecosystems: A Case Study from Northeastern Turkey

Can Vatandaşlar, Mehmet Yavuz and Michael Leuchner

Abstract Erosion is one of the most significant environmental problems in Turkey and many other regions of the world. Thus, appropriate erosion control services can help reduce soil loss and maintain ecosystem services (ES). Forests play a crucial role in this process as they are very useful in erosion control when properly managed. This chapter depicts a case of erosion control service in a forest ecosystem in northeastern Turkey by assessing statistical relationships of soil properties with forest inventory data through field observations, direct measurements and calculated data of growing stock, basal area, and soil erodibility (K-factor) from 108 forest plots. We found several significant correlations between those factors and in particular tree density, basal area, stand age, layered forest structure, stand height, undergrowth, and species composition along with some ecological parameters proofed to be useful indicators for a quick assessment of erosion control ES of forests. Erosion rates could be reduced by increasing the number of trees per unit area with smart forest management. It seems that optimum species composition can easily be achieved through the presence of the broadleaved trees ES indicator. Because mixed forests generally had lower silt content in their soil, they seem to be less prone to erosion processes. This case study helped to identify the site-specific key indicators for assessing erosion control ES as well as potential mitigation strategies for forest ecosystems in northeastern Turkey. It also showed that a single proxy indicator might not sufficiently represent such complex processes. Thus, the use of a bundle of indicators may result in more accurate estimates. For a more general assessment, sound ES indicators still need to be developed on regional or national level for decision-makers and practitioners to make wise decisions and proper land allocations.

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Introduction

Ecosystem services (ES) are briefly defined as "*contributions of ecosystem structure and function to human well-being*" (Burkhard et al. 2014, p. 5). These services can be divided into three main categories: (i) provisioning (forest products, fodder production, among others), (ii) cultural (e.g., recreational, hunting, bird watching, fishing as well as aesthetic value of fruit trees and shrubs), and (iii) regulating services (climate regulation, erosion control, etc.) (Burkhard and Maes 2017). Erosion occurs as a combined effect of such factors as (i) climate characteristics, (ii) soil type, (iii) topography (slope and slope length), (iv) vegetation cover, and (v) conservation measures (e.g., contour farming, terrace, etc.) (Ekinci 2005; GDF 2017). Since humans can easily modify the latter two, erosion studies generally focus on controlling these factors. Thus, both vegetation cover and its management play crucial roles in soil protection. Since forests are those ecosystems with the densest vegetation cover on Earth, they protect soils against erosion in the best possible way (FAO 1992).

The mountainous topography, climate characteristics, and soil structure of Turkey make its lands very susceptible to soil erosion by water. The mean elevation of Turkey is 1132 m a.s.l., reaching around four times the mean elevation of Europe (GDA 2007). When steep topography is coupled with an irregular rain pattern, various erosion types (i.e., gully, sheet) at different severities occur in approximately 80% of the country's area (Çepel 2007). Ultimately, between 168 million (CDE 2015; GDEA 2012) and 500 million tons (Çepel 2007; TEMA 2015) of productive topsoil are estimated to be lost every year as a result of various erosion processes. Therefore, soil erosion is still the most important environmental problem of Turkey (Kantarcı 1993; Çepel 2007; Günay 2008; Yavuz and Tufekcioglu 2019).

Apart from Turkey, soil erosion poses enormous environmental risks in many other countries, as well (CEC 2006; Braun et al. 2018). Consequently, 24 billion tons of productive soil in the world is washed away every year (IASS 2015). Soil transport of such an amount additionally causes sedimentation in freshwater springs and makes them unusable (Carpenter et al. 1998; Tüfekçioğlu et al. 2012; Tüfekçioğlu and Yavuz 2016). As a result of such hydrological processes, soil erosion influences a more significant number of population with impacts on the access to drinking and domestic water, a decrease in agricultural production, land degradation, floods, landslides, and desertification (Cerdan et al. 2010; Buttafuoco et al. 2012). Such problems currently adversely influence 1.2 billion people around the world and force approximately 135 million people to abandon their homelands (MEF 2006).

All these examples illustrate the vast importance of erosion control service of ecosystems. Thereby, it is vital to integrate erosion control service of forest ecosystems into management plans as active control over soil resources can be possible only through proper management practices in forested lands. To this end, erosion control ES first need to be quantified in a spatially explicit manner. In this way, forest planners can accurately determine the (i) forestlands that will be designated for soil protection, (ii) optimum species composition, (iii) silvicultural interventions required for the stands which will be managed for erosion control purposes, and (iv) proper harvest scheduling.

Erosion Control Service of Forests

Forest ecosystems provide benefits that can be related to the groups of provisioning, cultural, and regulating ES. Regulating services of forest include pollination, pest control, preserving soil fertility, flood control, global climate regulation, nutrient regulation, water regulation, air quality, noise remediation, and erosion control (Burkhard and Maes 2017). Amongst them, erosion control service is one of the most critical regulating ES, particularly in mountainous countries as they significantly suffer from soil erosion. Therefore, soil research as well as the combatting against erosion has been concentrated worldwide as forest vegetation has been understood to have an active role in soil protection since the twentieth century (FAO 1992). For Utah and Montana, Trimble and Mendel (1995) showed that a decrease of canopy cover to values below 1% increased erosion rates almost 200 times. More recently, Vatandaşlar and Yavuz (2017) stated that the soil protection performance of a fully covered Scots pine (*Pinus sylvestris*) forest was 70 times higher than that of sparsely vegetated and degraded woodland in the Tortum-North watershed, Turkey. They also reported that the amount of soil loss in forestlands was 32 times lower than that of agricultural land use at the same gradient in the same watershed. This protective effect of the forest cover against soil erosion can be outlined as follows: First, due to the canopy layer, forest ecosystems dissipate the energy of raindrops before it can reach the soil surface (Nanko et al. 2004, 2011). Second, they reduce the erosive effects of rainfall through interception (Levia et al. 2017). Third, forests enhance the infiltration capacity of the soil by improving soil structure with its roots (Morgan 2005). Lastly, they reduce soil moisture by transpiration (EPA 2013) (Fig. 1). Thanks to these features, forests are considered as the best ecosystem type on Earth in terms of erosion control ES (FAO 1992). Thus, accurate setting of forest structure (i.e., its composition and configuration) in forest management planning helps foresters to minimize erosion processes on forestlands.

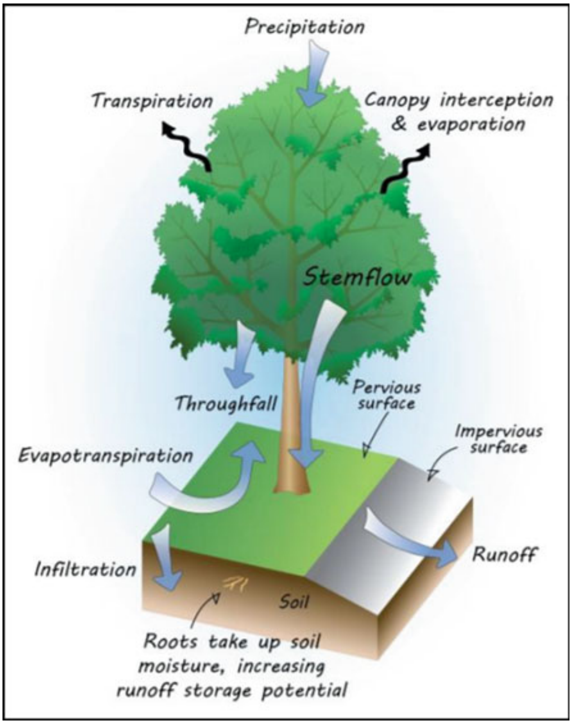

Fig. 1 Functioning of vegetation cover regarding erosion regulation (EPA 2013)

Spatial Quantification of Erosion Control Service

In contrast to provisioning and other regulating services of forest ecosystems, not many studies quantified erosion control ES in a spatially explicit manner. In the limited number of studies reviewed, biophysical quantification is generally made via three different techniques. These are (i) direct measurements (i.e., field experiments), (ii) indirect measurements (i.e., remote sensing or proxy indicators) and (iii) modeling (e.g., RUSLE) (Burkhard and Maes 2017). For all three techniques listed above, it is necessary to use existing ES indicators or to develop new ones. ES indicators are used to monitor the state and dynamics of ES supply, flow, and demand within a specific time interval (Vihervaara et al. 2017). In this context, a substantial indicator base has been developed worldwide in recent years to assess or measure ES.

The quantification of erosion control services was discussed by Guerra et al. (2014), who estimated the potential (without ES provisioning) and actual soil loss for South Portugal using RUSLE and calculated the ES provision capacity of the ecosystem by the difference of these two terms. At this point, land cover management (C) and conservation practices (P) factors played a key role. Then, they mapped the mitigation impact of this ES on soil erosion and provided suggestions like overgrazing being decreased for the risky areas. In another study, Pamukcu (2015) used various landscape metrics as well as Revised Universal Soil Loss Equation (RUSLE) and examined the relationship between these metrics and annual soil loss. A negative correlation was found between soil loss and percentage of landscape, largest patch index, and aggregation index especially in broadleaved forests ($r = -0.60$). Based on these relationships, the author concluded that an increase in aggregation in forestlands leads to a decrease in soil loss.

Researchers from many countries use different indicators in their ES quantification studies (Table 1). These may be primary indicators such as annual soil loss in unit area, or amount of erosion prevented as well as secondary indicators such as land cover, slope, or soil erodibility (Egoh et al. 2012). For instance, when specific forestlands are delineated primarily for erosion control service in Turkey's forest management maps at the planning stage, it is only taken into consideration that the slope rate in the area was over 60%. On the other hand, Koschke et al. (2012) used the run-off coefficient as an indicator in their extensive study in Eastern Germany. They scored the indicator values for each land use type according to expert opinions and assigned these values to related land use types in the map. As the examples demonstrate, there are many different indicators and threshold values in the literature for the same ES. Therefore, the indicators used in different countries are illustrated together in Table 1.

Table 1 Indicators used for assessing erosion control service (Yavuz and Vatandaslar 2017)

ES indicators	UK	EU	USA	CA	AU (VIC)	AU (NSW)	TR
Soil loss amount			✔			✔	
Soil type (texture)[a]	✔		✔	✔	✔	✔	
Soil stoniness					✔		
Soil color					✔		
Soil organic matter	✔			✔	✔		
Run-off coefficient					✔		
Rainfall amount						✔	
Elevation a.s.l.		✔					
Slope	✔	✔	✔	✔	✔		✔
Forest area[b]	✔	✔				✔	

[a]i.e., sandy loam, clay loam, silt, etc.
[b]The ratio of forest area which is managed for soil protection to the total forest area

Case Study from Turkey: Useful Indicators for Assessing Erosion Control Service of Veliköy's Forests

Study Area

Veliköy Forest Enterprise is the study area located in Artvin province, northeastern Turkey (Fig. 2). The elevation ranges between 630 m and 3150 m with an average elevation 1808 m. Its mountainous lands have a steep topography with an average slope of 35%. It has a semi-continental climate with 620 mm mean annual precipitation. The temperature ranges from –1.8 to 20.8 °C with an average 10.2 °C based on the Şavşat weather station at 1100 m altitude (TSMS 2018). It is located in the Caucasus Biodiversity Hotspot (CEPF 2003) and consists of highly diverse, uneven-aged mixed temperate forests. The area is dominated by conifers such as Caucasus fir (*Abies nordmanniana subsp. nordmanniana*), oriental spruce (*Picea orientalis*), and Scots pine (*Pinus sylvestris*). Deciduous tree species such as chestnut (*Castanea sativa*), beech (*Fagus orientalis*), birch (*Betula sp.*), hornbeam (*Carpinus orientalis*), poplar (*Populus sp.*), and oak (*Quercus petraea subsp. iberica*) also exist (Yavuz and Vatandaşlar 2018). Regarding soil type, moderately deep sandy loam soils are dominant in the study area (Duman 2017).

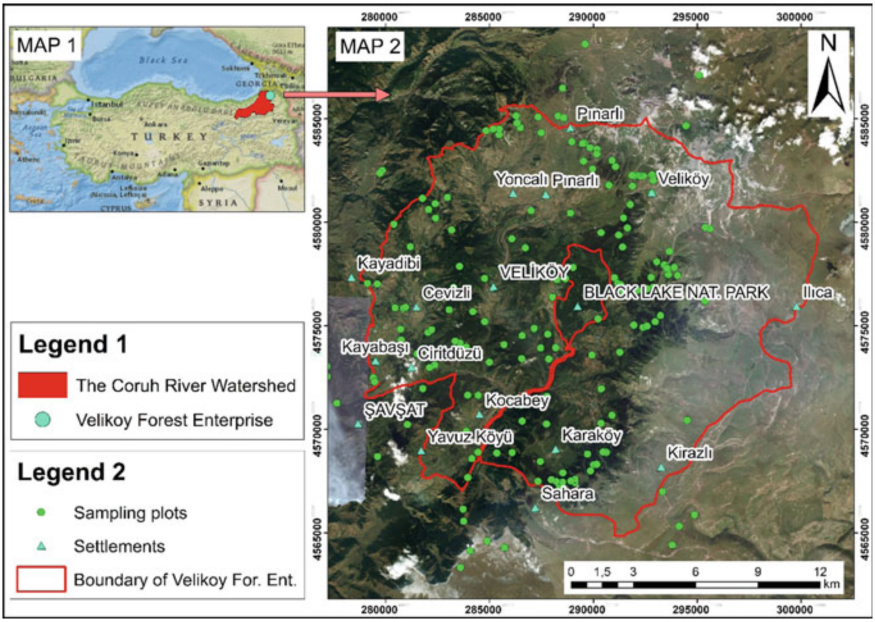

Fig. 2 Location of the study area and the sampling plots

Fieldwork and Methods

In the summer of 2018, 108 forested sampling plots were visited in the study area. A number of field observations and direct measurements were performed at two stages. The first step consisted of typical timber inventory for forest management planning purpose. Measured variables were tree height (m), diameter at breast height (cm), age (years), increment (mm/year^{-1}), canopy closure (%), and the number of dead trees. Moreover, species composition, stem quality, origin (high forest or coppice), and silvicultural interventions (if any) were also observed and noted into the inventory sheets. During the second stage, additional measurements and observations were performed on thickness of litter layer (cm), height (m) and closure of undergrowth vegetation (%), forest structure (even-aged or uneven-aged), regeneration status, number of snags, number of lying trees, number of tree layers, surface stoniness (%), surface roughness, soil color, soil moisture (i.e., very dry, dry, cool, moist, and wet), percent slope and slope length (m), and observed erosion type (i.e., rill, interrill, gully, mass movement). Furthermore, disturbed topsoil samples were collected at 0–15 cm depth in each plot for developing ES indicators. Collected samples were taken to the soil laboratory for mechanical and chemical analyses. Bouyoucos (1962)'s hydrometer method was used for the texture (sand, clay, silt content) analysis while the Walkley–Black wet oxidation method was applied for determining the organic matter content in soil based on Schumacher (2002).

Additional parameters such as growing stock (m^3/ha), basal area (m^2/ha) and K-factor (t ha h ha^{-1} MJ^{-1} mm^{-1}) were also calculated to be included as useful indicators. The K-factor was calculated according to the formulas in (1) and (2) (Torri et al. 1997, 2002). Each indicator was tested for normality through visual inspection of their frequency histograms, as well as the kurtosis and skewness values. After controlling whether they were normally distributed, we assessed the relationships among the indicators using Pearson's correlation analysis, independent samples t-test, and one-way ANOVA. Finally, a large geodatabase was set up in ArcGIS 10.3 for a full understanding of the spatial distribution.

$$K = 0.0293\left(0.65 - D_G + 0.24D_G^2\right)exp\left[-0.0021\left(\frac{OM}{f_{clay}}\right) - 0.00037\left(\frac{OM}{f_{clay}}\right)^2 - 4.02f_{clay} + 1.72f_{clay}^2\right] \quad (1)$$

$$D_G = \sum f_i \log_{10}(\sqrt{d_i d_{i-1}}) \quad (2)$$

where K is the soil erodibility (t ha h ha^{-1} MJ^{-1} mm^{-1}), D_G is the decimal logarithm of the geometric mean of particle size distribution, OM is the organic matter content in soil (%), f_{clay} is the clay content in soil (%), f_i is the mass fraction in the corresponding size class, d_i is the maximum diameter of the *i*th class (mm), and d_{i-1} is the minimum diameter of the *i*th class (mm).

Results

Statistically significant relationships were found between soil- and forest-related parameters. According to Pearson's correlation analysis, both K-factor and clay content in the soil correlated with tree density in forest stands. Other significant correlations can be seen in Table 2.

Aside from continuous data, there were statistically significant differences amongst soil- and forest-related categorical data. Independent samples t-test and ANOVA results showed that many soil properties differed depending on classified data such as aspect groups, the presence of broadleaved trees or dead trees in the stands (Table 3). We saw that if there were any broadleaved tree species in a coniferous forest, then the sand content in soil was significantly higher while the silt content was lower. Conversely, if there were conifers in a broadleaved-dominant forest stand, the clay content was very high. On the other hand, the presence of common rhododendron shrub (*Rhododendron ponticum*) in a stand, a common undergrowth species in the Eastern Black Sea's forests, generally came along with high K–factor values and low clay content. Moreover, litter layer thickness, soil stoniness, and surface roughness rates statistically differed based on aspect. Namely, stoniness and roughness were higher on the sunny slopes while litter thickness was thinner. Finally, we analyzed soil types for differences and observed that stand age, tree density, number of stumps on the forest floor and slope were significant factors affecting soil properties. Accordingly, tree density was low on loamy sand soils while the stand age was high. However, forest stands were very young on sandy clay loam and clay loam soil types. Clay loam soils, additionally, located on more flat sites in our study area. Regarding the number of stumps, they were highest on the loam soils and lowest on the loamy sand.

Table 2 Correlation analysis results of biophysical parameters

Soil-related data (continuous)	Forest-related data (continuous)	Significant level (two-tailed)	Pearson's r value
K-factor ($t\ ha\ h\ ha\ MJ^{-1}\ mm^{-1}$) (soil erodibility)	Tree density (no/ha^{-1})	<0.01	−0.35
	Mean stand height (m)	<0.01	0.34
	Ht. of undergrowth vegetation	<0.01	0.32
Clay content in soil (%)	Tree density (no/ha^{-1})	<0.01	0.38
	Stand age (years)	<0.05	−0.34
Silt content in soil (%)	Slope (%)	<0.01	−0.34
	Basal area (m^2/ha^{-1})	<0.05	0.30
Sand content in soil (%)	Tree density (no/ha^{-1})	<0.01	−0.34
	Stand age (years)	<0.05	0.31

Table 3 The results of independent samples t-tests and one-way ANOVA

Forest-related data (categorical)	Soil-related data (continuous)	Significant level (two-tailed)	Test (comparison of means)
Forest structure (single canopy vs. layered forest)	K-factor	<0.05	Independent samples t-test
Presence of broadleaved trees in a coniferous forest	Silt content in soil	<0.05	
	Sand content in soil	<0.05	
Presence of conifers in a broadleaved forest	Clay content in soil	<0.05	
Presence of standing dead trees	Silt content in soil	<0.05	
Presence of *Rhododendron ponticum*	K-factor	<0.01	
	Clay content in soil	<0.001	
Aspect groups (sunny vs. shadowed)	Stoniness in soil	<0.05	
	Surface roughness	<0.01	
	Litter layer thickness	<0.05	
Aspect subgroups (e.g., N, NE, E, S, …)	Top height of the stands	<0.05	One-way ANOVA
	Slope	<0.01	
Soil type (e.g., sandy loam, clay loam, silt, …)	Stand age	<0.05	
	Tree density	<0.05	
	Slope	<0.01	
	Number of stumps	<0.01	

Conclusion

It can be concluded that tree density, basal area, stand age, forest structure (i.e., single canopy vs. layered forest), stand height, undergrowth vegetation, and species composition along with some ecological parameters such as aspect groups could be utilized as useful indicators for a quick assessment of erosion control ES of the Veliköy Forest Enterprise. These indicators can help natural resource managers to take measures for appropriate land management. Accordingly, the eastern parts of the study area appear to be more vulnerable to erodibility mainly due to the lower organic matter content in soil. In contrast, the western parts provide higher capacities for erosion control ES as they have a dense and mixed forest cover.

Based on the inverse correlation between tree density and K-factor (soil erodibility), it can be said that erosion rates may be reduced by increasing the number of trees per unit area with smart forest management skills. Similarly, optimum species composition can easily be set through the presence of the broadleaved trees ES indicator. Because mixed forests generally had lower silt content in their soil they seem to be less prone to erosion processes. However, one should always bear in mind that these ES indicators are site-specific. Thus, they may not function in the same way across different regions.

Key Challenges and Smart Solutions

Many researchers from different countries suggest useful indicators for assessing erosion control performance of forest ecosystems (see section "Spatial Quantification of Erosion Control Service"). However, these are usually site-specific; thus, they may change from region to region. Therefore, one should always bear in mind that a robust indicator for a particular region may not represent the overall situation for the national level. That is why new and scientifically sound indicators should be developed primarily for unstudied erosion hotspots. On the other hand, most regulating services are related to ecological functions involving many processes. A single proxy indicator (e.g., land use or slope) may not sufficiently describe or represent such processes (Egoh et al. 2012). Thus, the use of a bundle of indicators (e.g., land use, canopy cover, and litter layer thickness) may result in more accurate estimates.

Another difficulty is related to the fieldworks. Due to historical anthropogenic pressure to nature, forestlands generally have shrunk to remote and mountainous areas across the world as well as the case study site in Turkey. Thus, fieldwork (forest inventory) is generally the most expensive, time-consuming, and labor-intensive stage of a forestry project. Indeed, it is very exhausting and sometimes impossible to reach all sample plots due to lack of road and trails. Moreover, dense understory vegetation makes walking difficult especially in moist forest sites. Aside from the access problem, measurement of some indicators requires expertise. Surface roughness, for example, may not be accurately measured by timber inventory teams. As such, they should be supported by soil and biodiversity experts on-the-ground. By doing so, assessment and mapping of all ecosystem services can be possible in a systematical manner. Therefore, timber inventory teams are periodically surveying all forested lands of the country while updating the management plans generally every ten years.

Conclusive Remarks

Various forestry regulations are made about soil erosion and erosion control service of forests in many countries. General awareness is formed in society. The role of Sustainable Forest Management and ES concepts in the formation of this awareness is undeniable worldwide. To date, we know well that different forest types and structures serve different soil protection performances. Our duty, as natural resource managers, is to model these services in a spatially explicit manner and integrate them into management plans with the help of numerous useful indicators developed for different regions as shown for the case study site from Turkey in the present chapter (see section "Case Study from Turkey: Useful Indicators for Assessing Erosion Control Service of Veliköy's Forests"). Thus, both decision-makers and practitioners will be able to make wiser management decisions and better priority settings than before. Ultimately, it is considered that the amount of billions of tons of soil loss worldwide will gradually be reduced.

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