Chapter 18
Update, Conclusions, Recommendations for Assessment and Protection of Water Resources in the Czech Republic

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Abstract This chapter presents an update regarding the assessment and protection of water resources in the Czech Republic. The conclusions and recommendations of the chapters presented in this book are generalized and summarized. The chapter presents a summary of the most important findings presented by the contributors to the book. Topics which are covered include water resources in the Czech Republic, including groundwater, small water reservoirs, ponds, wetlands, small bodies of water, rivers and the importance of water for different ecosystems (fauna, flora and for human with no exception). Important topics are the protection of the water resources, the role of the water in the landscape in general and with some specifics in the arable lands, hydrological reclamations in the landscape. Also, a set of recommendations for future research work is pointed out to direct future research towards and development of water resources in the Czech Republic.

18.1 Introduction

Water is an essential medium regarding the transport, decomposition and accumulation of pollutants, whether of natural or anthropogenic origin, which in excessive amounts represent considerable risks for all kinds of living organisms, thus also for human beings. The step towards adequate protection of water resources

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is to know their quality. Systematic investigation and evaluation of the occurrence of surface water and groundwater within the country is a fundamental responsibility of the state, as an indispensable requirement for ensuring the preconditions for permanently sustainable development as well as for maintaining standards of public administration and information. The primary requirement in this context is to optimize the water use especially with the consequences with the long-term drought.

The chapter presents a brief of the essential findings of the studies on the assessment and development of water resources in the Czech Republic, then the main conclusions and recommendations of the volume chapters in addition to few recommendations for researchers and decision-makers.

18.2 Update

In the following, the national studies regarding the water resources, assessment and development in the Czech Republic are presented. The brief results of the studies are introduced.

Paseka et al. [1] studied the new approach to decision-making methods for the design of new reservoir due in times decreasing water resources. The methods have been selected primarily to analyse different design parameters of a new dam, mainly dam heights leading to different reservoir volumes. A simulation model has been coupled with a cost model and a Non-dominated Sorting Genetic Algorithm II multi-objective optimization algorithm to quantify resilience and robustness under a range of uncertain future climate supply scenarios and one possible demand scenario.

Sekáč et al. [2] mentioned the conversion of farmland to non-farm uses that significantly influences the spatial variability of farmland prices. They tested 12 factors of land prices that experience real estate brokers indicated to be the most important determinants for the conversion of farmland to non-agricultural use. Five factors can be described as landscape, four as geographic and three as climatic explanatory variables influencing farmland prices. Their results indicate that the two most important factors in explaining the sales price per square metre were proximity to a river and proximity to a lake. In both cases, the price of land diminished significantly with the increasing distance from the edge of water bodies. The fact that the two most powerful factors indicate the distance to a river, brook, lake or pond shows how important are these freshwater features as determinants of farmland prices in a landlocked country such as the Czech Republic, where this study was performed. The consequences of this finding for water resources planning and management are discussed.

The water demand management was analysed in the study by Slavíková et al. [3]. Water demand management stresses the crucial roles of water user motivations in balancing actual water availability and competing human needs. The study shows how the absence of such motivations influences artificial water scarcity, even in resource-abundant countries, and how slight modifications to economic instruments (surface water charges in particular) might solve the problem. By constructing a simple and relatively static model based on Czech historical data, they were able to illustrate the impacts of surface water payment modifications, particularly the introduction of the capacity (reserved volume) payment into the existing system. The ultimate goal of the modification was to solve the detected problem of artificial water scarcity that has social/political rather than environmental/ecological causes. They found that the modification results in the following outcomes:

– it does not cause a major increase in the average surface water price (when considering the proportional decrease of the initial actual use payment and maintaining the appropriate ratios of both types of payments);
– it slightly increases annual revenues of state water administrators while respecting the user pays principle better;
– it effectively reduces redundant surface water claims (solely based on the individual decisions of water users rather than through non-flexible administrative decision-making).

Moravcová et al. [4] conducted a study of land consolidation project and their impact on land use changes. The case study covers 19 cadastral areas in the western part of the Czech Republic that were affected by the land consolidation process during 2000–2006. The main task of this study was to document how land consolidation processes could affect the change in land use and landscape structure and whether the land consolidation planners take into account the protection of natural resources. The increased acreage of grasslands was the most important change which has occurred in the land use in the 19 analysed cadastral areas, before and after land consolidations. In the studied area, the changes in land use involved 6.8% of the total land consolidation area. This area of grassland significantly increased the protection of agricultural land from water erosion. Regarding changes in the landscape structure, the construction of new field road networks is the most important result. The results confirm the importance of land consolidation processes not only for the organization and recovery of ownership and cadastral records but also for the improvement of agricultural use of landscape and protection of natural resources such as soil, water and plant and animal communities. The main results of this study are that grasslands also significantly increased the protection of agricultural lands from erosion, and significantly increased water resources protection.

Xuan [5] with her colleagues from the Czech Republic focused their study on the intensive forest management and modelling of the long-term water yield effects. Intensive forest management is one of the main land cover changes over the last century in Central Europe, resulting in forest monoculture. It has been proposed that these monoculture stand impact hydrological processes, water yield, water quality and ecosystem services. At the Lysina Critical Zone Observatory, a forest catchment in the western Czech Republic, a distributed physics-based hydrologic model, Penn State Integrated Hydrologic Model (PIHM), was used to simulate long-term hydrological change under different forest management practices, and to evaluate the comparative scenarios of the hydrological consequences of changing the land cover. Stand-age-adjusted leaf area index (LAI) curves were generated from an empirical relationship to represent changes in seasonal tree growth. By consideration of age-adjusted LAI, the spatially distributed model was able to successfully simulate the integrated hydrological response from snowmelt, recharge, evapotranspiration, groundwater levels, soil moisture and streamflow, as well as spatial patterns of each state and flux. Simulation scenarios of forest management (historical management, unmanaged and clear cutting to cropland) were compared. One of the critical findings of the study indicates that selective (patch) forest cutting results in a modest increase in runoff (water yield) as compared to the simulated unmanaged (no cutting) scenario over a 29-year period at Lysina, suggesting the model is sensitive to selective cutting practices. A simulation scenario of cropland or complete forest cutting leads to extreme increases in annual water yield and peak flow. The model sensitivity to forest management practices examined here suggests the utility of models and scenario development to future management strategies for assessing sustainable water resources and ecosystem services.

18.3 Conclusions

The following part of the conclusions have been mainly extracted from the generally known states and the materials prepared by the Ministry of Agriculture of the Czech Republic [6, 7]

The Czech Republic, sometimes called ‘the roof of Europe’, is a landlocked country in the heart of Central Europe, which predetermines its relation to the European river network. Czech rivers drain away all meteoric and spring water from our mountainous springy drainage area to the surrounding lowlands. The main European watershed (drainage divide) runs through the territory of the Czech Republic and meets with the drainage divide between the Baltic Sea and the North Sea. The triple divide point is located at the Czech-Polish border on Mt. Klepý in the Králický Sněžník Mts.

The territory of the Czech Republic is drained into three seas—the drainage area of the North Sea covers 66.2% of the country´s territory, the Black Sea drainage area covers 24%, and the Baltic Sea drainage area covers 9.8% of the territory. The long-term average annual precipitation on the Czech Republic territory is approx. 670 mm, i.e. 53 milliard m^3 of water, of which approx. 29% (15 milliard m^3) are drained by rivers.

The main hydrographic network comprises nearly 108 thousand km of watercourses with both natural and artificially channelled beds. The Water Act classifies the watercourses of the Czech Republic as significant and minor, and their administration is performed in accordance with the provisions of the Water Act. The main administrators of watercourses within the scope of the Ministry of Agriculture are the River Basin Administrations, state enterprises, and the Forests of the Czech Republic, state enterprise; as of 2016, they provide administration of 94.4% of the total length of watercourses within the Czech Republic. Other subjects that may administer the remaining 5.6% of minor watercourses include the Ministry of Defence, the National Park Administrations and other natural persons or legal entities.

In total, there are 819 significant watercourses on the territory of the Czech Republic with the total length of 16,350 km, managed by the individual River Basin Administrations (RBA), state enterprises: the Elbe RBA, the Morava RBA, the Oder RBA, the Ohře RBA and the Vltava RBA. The backbone watercourses are the Elbe River (370 km) with 'the Vltava River (431 km) and the Ohře River (254 km) in Bohemia, the Morava River (269 km) and the Dyje River (194 km) in the south of Moravia and the Oder River (135 km) with the Opava River (131 km) in the north of Moravia and in Silesia' (http://eagri.cz/public/web/file/10537/Professional_management_of_watercourses_20).

All the other watercourses are in the category of minor watercourses, and their administration is carried out on the basis of the respective appointment by the Ministry of Agriculture of the Czech Republic. 'The administration of minor watercourses may be carried out by the municipalities through the territory of which they flow' (http://eagri.cz/public/web/file/10537/Professional_management_of_watercourses_20), by natural persons, legal entities or by the organizational units of the state using them or performing activities with which these minor watercourses are connected. The total length of minor watercourses (as of 2016) according to the Central Register of Watercourses is 83,200 km.

As of 2013, there are 165 significant water reservoirs and 523 minor water reservoirs in the Czech Republic. The total length of the Czech Republic´s waterways is 522.2 km.

The country is extremely poor in lakes; the small number of lakes is due to the long-term development of the territory and to the fact that it was not affected by significant climatic changes during the Quaternary. Our lakes are located in the areas affected by the Quaternary glaciation. Numerous lakes were found in the Ostrava region and in the North-Bohemian hooks some 200,000 years ago; however, during the last glacial periods, they eroded through and thus were naturally drained. The main region of our lakes is the Šumava Mts. with a total of eight cirque lakes, five of which are on the Czech side and three on the Bavarian side. The lakes are open (exorheic), supplied by precipitation and streams. The Bavarian lakes and the Čertovo jezero lake drain to the Danube River Basin, and the remaining Bohemian lakes to the Elbe River Basin. Their cessation is slow as the rock erosion is held back by forests; the lakes are oligotrophic with bottoms formed of sand and sludge. In 1831, our largest lake (5, 21 km^2 including the swamps at its periphery) by Komořany u Mostu was artificially drained to give way to agricultural land. It had probably been a residuum of a large Tertiary lake in the Most basin. Some of the lakes in the Czech Republic developed as oxbow lakes along larger watercourses. Oxbow lakes are river meanders that had been cut off from the main stem and can be found in the central Polabí region (between the towns of Pardubice and Lovosice) and along the lower stretches of the Morava and the Dyje rivers. Karst lakes developed in cavities formed by cave corrosion and at the bottoms of abysses. In the Czech Republic, such type of lake is represented by the upper and the lower lake of the Macocha Abyss or by the lake at the bottom of the Hranice Abyss. The bodies of water accumulated in the peat bogs may also be viewed as lakes; the largest of them is the lake in the Chalupská slať peat bog (1 ha) by the upper stretch of the Vltava river. Similar lakes are found in the Hrubý Jeseník Mts. (the lake near the Rejvíz municipality) or in the Krušné hory Mts. (the Velké Jeřábí Jezero and the Malé Jeřábí Jezero lakes).

Peat bogs cover an area of 23.000 ha in the Czech Republic with half of this area belonging to mountain bogs and a half to fens or transitional types between bogs and fens. A mountain bog filling a depression (basin), receiving water exclusively from precipitation and with an elevation in the centre of the basin resulting from the massive accumulation of peat moss layers is called a raised bog. Raised bogs are found mainly in the Šumava Mts. where they cover an area of 5.000 ha with the centre of their occurrence in the Šumava Plains, i.e. an area between the upper stretches of the Vltava, the Otava and the Řezná Rivers. Bogs can be found in the mountains with the occurrence of old flattened surfaces, for example, at the horst of the Krušné Hory Mts., in the Jizerské Hory Mts. or at the north of the Hrubý Jeseník Mts. Larger areas of bogs are also present in the Slavkovský Les upland by the town of Mariánské lázně. The wetlands of the lower altitudes are called fens and are eutrophic (as compared to the oligotrophic bogs). The fens are found in lower or basin elevations, such as in the Třeboň basin between the towns of Soběslav and Suchdol nad Lužnicí or in the Litovelské Pomoraví area. Temporary swamps occur in the northern part of the Ralská pahorkatina Hills or in the region of the Žďárské vrchy Hills in the form of bogs in lower altitudes on subsoils poor in minerals.

In order to reduce the threat of soil erosion and the consequences of drought as well as to increase protection against the negative effects of surface runoff, it is necessary to propose and to implement appropriate measures, preferably in a complex system. A combination of organizational, agro-technical and technical measures is most recommended. The most effective tool for the implementation of such measures in a landscape is the process of land consolidation. To the present (as of 2016), simple and complex land consolidation has been performed at more than 31% of the agricultural land area and at nearly 7.1% of the area it is currently in progress. Within the realization of common facilities, anti-erosion and water management measures had been performed at 705.1 and 461.25 ha, respectively, by the end of 2016. The costs of the anti-erosion measures realized within the land consolidation process in 2016 exceeded 13 million CZK and the costs of the realized water management measures exceeded 67 million CZK.

In 2016, 9.972 million inhabitants (i.e. 94.4% of the total population) of the Czech Republic were supplied with tap water. The waterworks altogether produced the total of 593.3 million m^3 of drinking water. The volume of drinking water supplied against payment (invoiced) was 478.9 million m^3, of which 322.3 million m^3 were supplied to households. The length of the water supply network was 77,681 km in 2016. New construction and completion of the existing water supply network segments increased the number of the inhabitants supplied with tap water by 42,806. The length of the water supply system per capita (of the inhabitants supplied with tap water) is, therefore, 7.79 m.

In 2016, 8.944 million inhabitants of the Czech Republic lived in houses connected to the sewage system, which represents 84.7% of the total population. The total of 446.9 million m^3 of wastewater was drained away by the sewage system, of which 97.3% went through wastewater purification. In 2016, the total length of the sewage system reached 47,141 km, and the total number of wastewater treatment plants was 2554.

There are currently approx. 24 thousand fish ponds and water reservoirs on our territory with the total area of about 52,000 ha, of which more than 41,000 ha are used for fish farming. They are managed by 70 major fisheries, each with annual production over 5 tons, and a several hundred minor fish farmers. Over 2.000 fishing grounds have been designated in the Czech Republic with a total area of 42.000 ha, and there are approx. 350,000 registered recreational fishermen.

International cooperation of the Czech Republic in the field of water protection is based on the principles set by the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes, signed by the Czech Republic in 1992.

Second part of the book with the title '**Surface and Ground Water Bodies**' consists of 6 Chapters and here are the main conclusions of them.

The chapter '**Rivers in the Czech Republic**' provides basic information about rivers in the Czech Republic which is a small landlocked country located in Central Europe between Poland, Germany, Austria and Slovakia. Being an inland country in Central Europe with rugged relief and located on the Main European Divide of three seas, the Czech Republic has no other source of water than precipitation. Of the 76,000 km of natural watercourses, 28.4% are altered. Although there has been a significant improvement in water quality since 1990, particularly a decrease in saprobic pollution, other significant pressures have emerged such as eutrophication, morphological alterations of the channels, disruption of sediment transport or fish migration that degrade aquatic ecosystem functions and restrict the structure of their biological communities. Moreover, many streams and rivers in the Czech Republic have experienced extreme climate fluctuations leading to unexpected floods and long periods of drought in recent years. Regardless of what degree these extreme fluctuations are a consequence of ongoing climate change or the result of improper landscape management, flooding and drought are expected to adversely affect instream life as well as people. Therefore, future management of streams and rivers should consider the needs of water supply, wastewater dilution, hydropower generation or navigation on the one hand; and on the other hand, the good ecological status of watercourses supports sustainable water balance of the landscape. Thus, while diffuse pollution from arable lands may be reduced by improved agricultural practices, hydro-morphological alterations could also be considerably improved through stream restoration efforts (e.g. [8, 9]), reopening and creation of side channels and by the construction of effective fish ladders at weirs [10–12].

The next chapter '**The Role of Water in the Landscape**' pays attention to the important aspect that in recent years, the Czech Republic has experienced extreme weather fluctuations leading to unexpected floods and long periods of drought. The current situation is a result of the long-term use of our landscape which is no longer able to retain and accumulate water, mainly due to technical alterations of watercourses, changes in land use and deforestation. The principles outlined in this chapter call for alternative approaches to land use and land management. Widespread agricultural practices in Czech Republic that reduce the soil's capacity to retain water (e.g.

through soil compaction, reduced organic matter, etc.) should be replaced with strategies that work within the confines of the hydrological cycle. In particular, the European Commission's Climate-ADAPT programme suggests checking and rebuilding old drainage systems; establishing variable water flow regimes; rehabilitating and reconstructing/adapting morphological structures in rivers; adopting crop rotation, minimal or no-tillage systems and improved soil cover management practices; in addition to other recommendations [13]. Unchecked growth of urban areas, often coinciding with increased area of impervious surface, should be put in check and/or developed in a manner allowing maximum water retention in the landscape. Riverine elements within or adjacent to the stream (floodplains, wetlands and alluvial ecosystems) have a disproportionately large impact on water storage capacity relative to their small surface area as compared to uplands, and should, therefore, be granted special protection where they existed and prioritized as areas for restoration where they have been degraded.

The chapter '**Small Water Reservoirs, Ponds and Wetlands**' **Restoration at the Abandoned Pond Areas**' addresses the small water reservoirs that are one of the basic elements of the agricultural landscape in the Central European space. They are one of the most valuable nature-loving elements of the cultural landscape. In the Czech Republic, they have a long historical tradition. The abandoned pond areas often have soils which are not very suitable for intensive agricultural production (e.g. the area near Dolní Bojanovice). The options include a transformation to permanent grasslands (the area near Popovice) or plantations of energy species (fast-growing woody species). However, it is necessary to consider the suitability of plantation of non-indigenous species in watercourse plains where most of these areas are located. Grasslands may also be included in the anti-erosion measures; they can also serve as bumper zones preventing soil entry into watercourse beds. On the contrary, plantations of woody species may cause problems during floods: spillage regulation, creation of barriers, etc. In some cases, the reservoirs can fulfil flood protection and retention functions. However, this function may be restricted by field modifications and adaptations, as in the case of the area near Kopřivnice. Recreation represents another function. This function, however, is dependent on the water environment quality, level of contamination, which is, unfortunately, high in the Czech river network in terms of eutrophication. Eutrophication represents a considerable risk for the recreational function.

On the contrary, for the utilization as fish ponds, it is relatively marginal. Because intensive fish farming may imply higher contamination by nutrients [14], it is not possible to apply this utilization for all the renewed reservoirs. Besides the functions mentioned above, the main function will probably be the creation of water supply in the landscape and support of the creation of water-related biotopes. Virtually, all the three examined areas may fulfil both functions in case of change of their utilization, including the retention of contamination transport, and may also be complemented with the function of sports, fishing or breeding of regulated and targeted fish quantities.

The chapter '**Small Bodies of Water which have Disappeared from the Czech Landscape and the Possibility of Restoring them**' deals with pond management that is a historical and landscape-forming phenomenon in the Czech lands. The ponds, whose traditional role is linked mainly with the economically lucrative fish farming, did, however, play a wider role within the historical landscape, where they fulfilled the requirements of society for water, they formed a potential supply of energy to power production facilities or they were part of the fortification of noble estates. The chapter describes the development and decline of pond management in the Czech Republic. There has been an intensive discussion in recent years on close-to-nature measures in both catchment areas and watercourses themselves, as such measures contribute to a reduction in flood risk and loss of soil, and they also support infiltration and accumulation of water in the landscape, thus slowing down surface runoff. A sophisticated approach to the issue of water retention, i.e. combining all suitable and mutually compatible measures, will be an optimum solution for the landscape as a whole. Such measures should be set in successive order with regard to the current state of a particular area. 'Soft' measures must be preferred on farm and forest land, such as establishing wetland areas. The construction and renewal of reservoirs, as a technical measure, should only be a subsequent step in a complex system of solutions. Among these measures in individual catchment areas within the Czech Republic, ponds have a fundamental role, their main benefit being their ability to retain and accumulate water for use in periods of drought. As is apparent from the preceding text, many of these water bodies have disappeared from the Czech landscape, and it is vital to consider their renewal in many areas.

The chapter '**Protection of Water Resources**' is oriented to water protection in the Czech Republic, in accordance with EU requirements, helping to improve the state of water resources, aquatic ecosystems, promote sustainable water use and mitigate the adverse effects of floods and droughts. In many catchment areas, the agriculture is the most important polluter for surface and underground water, because of that we have to find a way with the proper target to provide people with enough quality drinking water.

The chapter '**Groundwater Flow Problems and Their Modelling**' presents groundwater flow and methods how it can be solved. It also presents groundwater flow modelling. Groundwater is an inseparable component of the hydrological cycle and water resource systems. For practical calculations, it is crucial to choose and provide appropriate existing groundwater modelling software. There are numerous computer codes on the market [15–19] solving groundwater flow and contaminant transport using numerical methods like finite difference, finite volumes or finite element methods. Solving practical problems needs, except for theoretical background [20], skill and familiarity with the software used. Before using commercial codes, it is advisable to search for relevant professional reviews [21].

The third part of the book titled "**Water in the Landscape**" consists of 4 Chapters. Conclusions are as followed.

The chapter '**Hydrological Mine Reclamations in the Anthropogenically Affected Landscape of North Bohemia**' deals with the surface mining of brown coal that has long burdened the landscape of the northern part of the Czech Republic. The chapter presents the case study results obtained by numerical experiment. The area is disturbed by surface quarries, external spoil tips and related anthropogenic interventions in the territory and its vegetation. Most of these interventions resulted in the removal of vegetation and were connected with the distortion of the natural dynamics of surface water and groundwater. Transforming residual mining pit into an artificial lake within the process of hydrological reclamations is the most logical and effective way how to integrate it into the surrounding landscape. Several aspects need to be taken into consideration to ensure the stable development of the lake. Essential is to provide a quality source of the filling water and to secure geotechnical stability of the lake's slopes. It is recommended to choose revitalization of the slopes by planting stabilizing tree species, and not to turn to natural succession. Natural succession is a much slower process, and the slopes are often endangered by erosion. As to the planning process, professional and non-professional public should be included in the decision-making process since the beginning. Participation of citizens and civic initiatives is important for the creation of recreationally attractive area. All decisions on reclamations and revitalizations should always be guided by the principle of sustainable development.

The chapter "**Modelling of the Water Retention Capacity of the Landscape**" provides basic information about the procedure for calculation of spatial specification surface runoff is based on a combination of specific functions of geographic information system which is enabled by runoff curve number method. The formulated LOREP model represents an application of a solution using a methodical approach for the identification and localization of areas with low flood storage capability. The modelling of the water retention function is currently subjected to new challenges.

The chapter '**Floodplain Forests—Key Forest Ecosystems for Maintaining and Sustainable Management of Water Resources in Alluvial Landscape**' represents the floodplain forests as key forest ecosystems in lowland regions of the European temperate zone. Ecosystem services of floodplain forests are essential for maintaining and sustainable management of water resources. The biodiversity of floodplain forests is significantly influenced by the hierarchical level of β-diversity (beta-diversity), i.e. by the changes in biodiversity depending on the changes in environmental gradients (in this case, these are changes in micro-relief and meso-relief of the floodplain in dependence on the distance from the river channel, changes in the frequency of floods, etc.).

The chapter '**Agrotechnology as Key Factor in Effective Use of Water on Arable Land**' describes the necessity of water for food production. Demand for good-quality food puts pressure on agricultural production. Agriculture influences the amount of water available, and the quality of water is tightly connected with the intensity of farming and the use of crop protection agents and fertilizers. The Central European agriculture, including agriculture in the Czech Republic, faces a number of challenges associated with water management in the landscape. In connection with the ongoing climate changes, irregular rotation of intensive rains and long periods of drought, and the growing demand for agricultural raw materials, we need to apply procedures stimulating effective retention and economic use of water. The key factors include various agro-technical measures leading to effective water management.

The fourth part of the book is titled "**Hydro-management of Water Resources**" and consists of 5 Chapters.

The chapter titled '**Management of Drinking Water Resources in The Region Of South Moravia, Czech Republic**' presents and discusses the supplies of good-quality water for supply in the region of South Moravia that to residents is sufficient. However, it is necessary, these sources maintain, where appropriate, restore, monitor their quality and quantity and ensure their adequate protection from spoilage. In the past, the Czech Republic, in the face of extreme floods, was preparing to protect itself from increased flows and the occurrence of drought was greatly underestimated. Scientists have warned that floods and drought are two sides of the same coin. There is finally a public debate on the need for water management in the countryside and water resources. It is necessary to prevent the rapid flow of water from the landscape, by appropriate measures, such as the revitalization of watercourses, the construction of reservoirs, pools and wetlands.

Last but not least, the change in farming, both on agricultural land and forests. Particularly in the catchments of drinking water supply systems, it is necessary to strictly observe the measures for improving the water absorption into the subsurface layers, by keeping the water in the landscape. A possible tool for improving the situation is artificial water infiltration [22]. Scientists have been inspired by Israeli experts in this context. In the Middle East, water is captured in this way for a long time. South Moravia is the most affected area in the Czech Republic, so the implementation of this measure is about to be done in the South Moravia region and Břeclav. In places where the construction of a new building is underway, rainwater management is already required according to the legislation. Rainwater is not discharged through a pipeline into water courses or wastewater treatment plants. Capture tanks and trenches are built to catch it or use it for further use. These measures, and in particular the building of nature-friendly measures, should be administratively and mainly financially supported by state subsidies.

In the chapter titled '**Ecosystem Services and Disservices of Watercourses and Water Areas**', the authors discuss ecosystem services and disservices of the watercourse network in the Czech Republic. Ecosystem services and disservices are not systemized in detail yet. A complex system already developing on the international scene allowing for practical applicability of the approach is missing in The Czech Republic. A complex (and detailed) evaluation of ecosystem services and burdens provided by watercourses has not yet been performed in the Czech Republic. Moreover, yet there is a number of sources for the evaluation provided by research institutions—for example, the TGM Water Management Research Institute, the catchment area management establishment, universities (Mendel University in Brno, South Bohemian University in České Budějovice, University of J. E. Purkyně in Ústí nad Labem) as well as interest groups (the Czech Fishermen´s union, the Czech Ornithological Union, etc.). At the same time, there are ready-to-use general methodologies for evaluation of ecosystem services [23, 24], so far dealing with complex but only general evaluation of ecosystem services of all types of ecosystems existing in the Czech Republic.

The chapter '**Water Resources Management Planning in the Czech Republic**' deals with the planning in the water sector that performed within the hydrological basins and is a systematic conceptual activity undertaken by the government. Its purpose is to determine and mutually harmonize public interests of water protection as a component of the environment, to reduce adverse effects of floods and drought and to ensure sustainable use of water resources. Management, administration and planning in the water sector have been designed and implemented logically and effectively in the Czech Republic. The current situation is complemented by planning and implementation of flood protection. Despite this fact, the Czech Republic sometimes has problems with floods, but recently, drought is a problem. This is caused on the one side by the intensity of both phenomena and on the other side by the state of the long-term intensively utilized landscape. All measures proposed and implemented in the field of water management, administration and planning are unable to save everything. It is necessary to continue in a close link with other forms of the planning of landscape utilization and management, which include, in particular, land use planning, forest management planning, regional development, agricultural activities and, to a lesser extent, reclamation plans, for example.

The chapter '**Technical and Economic Evaluation of River Navigation**' is devoted to a possible solution to water freight transport in the Czech Republic. One part discusses possibilities of evaluation of the economic efficiency of waterway projects by CBA method as well. Methodological documents of the Czech Republic define a certain list of basic benefits and damage and further enable to include other specific items in the evaluation. Based on results of the research, authors recommend supplementing a methodology with determining of the impact of investment projects on landscape character in the form of evaluation of permanent ecological damage, if the investment action leads to the occupation of habitats. Another influence that should be included in the methodological procedures according to the authors is possible to impact of waterway projects on historical monuments by determining their historical value.

The chapter '**Water Balance and Phase of Hydrocycle Dynamics**' is about the climate dynamics in the Czech Republic that has been increasing during the past 20 years and even before it was already characterized by high variability. The number of weather extremes increases, there is a statistically significant increase in air temperature, but not of precipitation. It should, however, be emphasized that the onset of drought, as well as places affected, are variable depending on precipitation. In general, drought is most common in the warmer regions with the lowest average annual precipitation. Results also prove that the extent of drought in a certain year is affected by the conditions during the previous year, especially by the conditions at the end of vegetation period, fall and winter. If it is dry even during fall and the water deficit is not compensated during winter, the drought will be apparent in soils in spring of the next year. Also, as recent studies show, the air temperature increases even in winter and the amount of snow decreases—this leads to a decrease in soil water content in spring. Soil properties (both agricultural and forest) are very important from the perspective of retaining precipitation water in the landscape, where most of the absorption takes place. It is therefore important to take measures that will lead to better infiltration abilities and increased soil retention capacity to its original level. This includes measures aiming to decrease soil erosion because the topsoil horizon has a significantly higher capacity than eroded soils. Increasing the variability of the landscape will contribute to lower water outflow, also because of decreased airflow and subsequent lower evapotranspiration.

18.4 Recommendations

The part of the book with the title '**Surface and Ground Water Bodies**' consists of the recommendations as followed.

There is still a gap between the findings of scientists and water management [25]. Coordination of activities among individual sectors is unsatisfactory, and standards are not clearly defined (e.g. among the watercourse administrators, fishing organizations and private owners). It is also clear that employing purely technical solutions in water management, such as construction of new dams, will not provide sufficient water for our streams and rivers [26]. Natural river beds with a rich structure of benthic sediments and frequent overbank flows can be used as an effective and relatively inexpensive means of solving numerous problems in water and landscape management [25, 26]. To avoid disturbances caused by extreme water fluctuations, we need to systematically change the way our landscapes are managed to support water retention.

Future research should strive to elucidate a better understanding of how water functions at both global and local scales. Many controversies about the most basic functions of rivers still exist; for example, whether restoration of wetlands adjacent to small streams and subsequently increased water retention translates directly into increased late-summer streamflow and reduced water temperature, both vital to aquatic life (see [27] and [28] for differing viewpoints). Increased understanding of aquatic–terrestrial linkages would help provide the knowledge basis for difficult decisions about managing uplands, floodplains, wetlands and river ecosystems in general. Studying the connections among wetlands, floodplains and small water bodies to climate change—for example, their complex role in acting as carbon and methane sources and/or sinks—would further aid managers and policy makers in balancing the needs of (and benefits from) ecosystems with a growing human population.

Finally, we recommend engaging stakeholders and professionals from diverse disciplines in discussions about how to manage water on the landscape in a manner that is beneficial to all parties, including humans but also wildlife and ecosystems. Author of this chapter outlines recommendations for coordination among natural scientists, land and water users, water managers, planners and policymakers with the desired outcome of better water management practices too. These various disciplines, having disparate objectives, will need to find common ground if productive dialogue will ensue about scarce water resources in Czech Republic and elsewhere, especially in the face of a rapidly changing climate.

To conclude, it may be said that small water reservoirs, including a specific category of ponds, i.e. fish ponds, are currently one of the basic elements of the agricultural landscape. They are one of the most valuable near-natural elements of the cultural landscape. Many locations currently belong to protected areas, some of them within Natura 2000. One of the possibilities to increase or preserve the ecological stability of the landscape, and, at the same time, to improve its aesthetic, urbanistic, water management and agricultural activities, is to restore roles and functions of small water reservoirs and ponds, together with landscape revitalization (projects of complex field adaptations and elements of territorial systems of ecological stability). The cases of three pilot locations document a process of selection of the best utilization of abandoned pond areas. This process, when applied in planning and state and local administration, as well as by the plot owners, will facilitate the selection of right functions of the planned small water reservoirs and their construction and technical project. It may also help to eliminate the negative phenomena potentially occurring after the reservoir (pond) realization unless previous in-depth surveys and right assessment of input conditions (climatic, hydropedological, hydrogeological, hydrological and qualitative) were performed. Particular attention in the aim of a pond or small water reservoir restoration should be paid to water environment contamination and quality. Since this factor is difficult to connect with general tools and indicators of abandoned pond area assessment, it is necessary to provide local monitoring of pollution sources and water quality of the water network. A detailed observation, with comparable results of the survey of fish ponds [29, 30], has brought important data for projects of renewal or construction of small water reservoirs in the landscape so that they do not become a source of contamination within their drainage basin, as it often happens nowadays.

The greatest proportion of defunct pond land is now used for agricultural purposes, and it seems that the current use is far from optimum in a number of these localities. This is why a more detailed evaluation of soil conditions in former pond areas will be important in the future, as well as considering the possibilities for changes in the use of some of these areas towards the restoration of water bodies, with respect for natural conditions and socio-economic criteria. Soil conditions will be fundamental in the decision-making process, and available data shows that the soil in many of these areas is heavy, not highly productive, with low infiltration ability, etc. making such areas more suitable for the renewal of bodies of water. Regarding the renewal of some ponds within forests, their benefit is mainly in improved water management in upper parts of catchment areas. This can have a positive effect in dry periods and also reduce flood damage. Forest owners and companies managing forests would welcome better access to water supplies in the case of forest fires, and nature conservationists can appreciate the creation of suitable conditions for the development of communities bound to a water environment or wetland.

Protection zones, like preventive protection, are necessary. Due to their importance, we have to support with conducting education. However, there is needed legislation and political wish and support. As far as legislation is concerned, it is primarily necessary to solve the raised problem with the Decree No. 137/1999 Coll. which is ineffective, and some of the provisions of this Decree are inconsistent with valid Water Act. In this way, it is necessary for the Central Water Protection Authority to add activity and novelize or at least abolish that Decree. In relation to climate change and the effects of drought, we recommend specifying in more detail the protection of water resources for season droughts—i.e., to solve in more details the protection of water resource efficiency.

The valid legislation needs to be elaborated, supplemented, updated and in practice adapted to a wide variety of natural and economic conditions (depending on the location, soil conditions, hydrology, hydrogeology and the way water is used).

The goal is not to recreate unified methodology, according to which should be proposed the protection zones of water sources. The suggestion of protection zones in counter should be processed in a form which shows attitudes in the landscape above the source of drinking water. The proposal of regime and scope of the protection zones should always be solved individually according to specific conditions.

However, it would be advisable to devote more attention towards the problem of financial compensation in protection zones, and the development of a methodical approach could be beneficial. This issue needs to be elaborated. The failure to solve the current situation is not a starting point for farmers operating in the protection zones, and for water companies, it is not for improving the quality of drinking water.

The practical journey is clearly based on cooperation and understanding between water-farmers and farmers, as well as the involvement of researchers from universities who are independent experts.

One of the possible tools for the protection and rational use of land in the protection zones are land consolidation, which offers the potential for the creation of a flexible, ecological and sustainable agriculture. Combined with the protection zones optimization, this could be an effective tool for solving conflicts between agriculture and water management in the protection zones of water sources.

It is necessary to emphasize that the groundwater management and seepage modelling is a multidisciplinary issue at which significant role is played by geologists and hydrogeologists, water managers, hydraulic and civil engineers, for the development and adjustment of computer codes the cooperation with mathematicians and programmers is necessary.

Practical experience shows that many times the role of computers and numerical modelling is overestimated and traditional engineering feeling is frequently abandoned. It must be remembered that one of the most important activities at the modelling is the definition of objectives, conceptual formulation of the problem and relevant interpretation and rational explanation of results achieved. Based on the final decisions and technical proposals are carried out. All these items need experienced staff with good knowledge about the necessary data for the solution and a clear vision about the results and their application.

The part titled '**Water in the Landscape**' consists of the recommendations as you can see bellow.

In the context with the ongoing climate change, with irregular alternation of flash abundant rainfall and long periods of drought, it is essential to well describe the current and future state of the landscape. The following recommendations should be followed when modelling a water retention function:

(i) work with a model that best simulates real water behaviour in the landscape, (it means that the model works with an advanced multiflow algorithm to simulate real water movement in the landscape),
(ii) use a model with an advanced iteration algorithm to calculate infiltration, which can estimate at each step whether retention capacity is already achieved or not and
(iii) use the appropriate drain equation according to the evaluation of this state. Static (GIS) data describing the state of the landscape should be integrated with sensor data (e.g. snow supply, soil moisture) to update hydrological/hydropedological conditions.

Digital representations of all landscape components (terrain, land use, soil) should be current and at the same scale and for the same period. The scale should be detailed enough to capture the small line elements in the landscape and their orientation towards the direction of the surface runoff. For the conditions of the Czech Republic, it is appropriate to scale 1:10,000. To identify the problem areas, it is necessary to work with the model in a raster environment in order to divide the studied area into sub-watersheds, not exceeding 25 m^2. This tool is really useful in the situation when almost all plots of concentrated surface runoff should by identified and multidirectional runoff, including runoff along small line elements, should be assessed.

We can conclude that sustainable biodiversity conservation in dynamic floodplain forest ecosystems require territorial protection in the form of various categories of protected areas and maintaining of ecosystem connectivity at the landscape level (ecological networks). The key target is the maintaining the conditions for the functioning of the ecological floodplain phenomenon. This means that the basic principle of maintaining the floodplain forest biodiversity is the protection and undisturbed functioning of the dynamics of fluvial erosion and accumulation processes in the landscape. Floodplain forest protection is, thus, clearly based on the ecosystem approach, which providing a functioning of the floodplain forest ecosystem services [31].

In the Czech Republic, the currently used management system in the Czech floodplain forests should follow the Croatian model of forest management supporting a multi-layered forest structure [32]. Focus on individual tree growth and stability with high economic value and high reproductive potential is recommended as one of the main principles of sustainable floodplain forest management [33].

When considering the management procedures in the arable land that lead to water retention in the landscape, we can follow several recommendations. One of the basic aspects is a good knowledge of the local soil–climatic characteristics. It is very important to set a rational cultivation plan in connection with a suitable management system. In the Central European conditions, a system that is appropriate in terms of water management is conservation tillage, i.e. various methods of soil treatment without ploughing, or sowing directly in untreated soil. This should be accompanied by agro-technical procedures connected with cover crops systems, intercropping systems, strip intercropping, strip till technology, agricultural terraces, etc. Using these agro-technical procedures over a long-term can improve the soil structure, thus making it possible to increase infiltration of water into the soil, reduce the surface runoff and reduce the risk of erosion, which constitutes one of the most significant problems connected with the cultivation of arable land. Reduction of intensity of soil treatment also usually reduces the consumption of energy required throughout the cultivation cycle and also saves time. It also supports carbon sequestration with a growing proportion of soil organic matter, which originates, e.g. from left post-harvest residues. In general, these practices have significant environmental benefits.

In the part called '**Hydro-management of Water Resources**' can you find recommendations as follows in the text.

Czech legislation and administration developed a number of documents for water management and territorial planning where ecosystem services of the blue–green infrastructure might be applied—Catchment area plans, regional forest development plans, regional development principles, zoning plans, territorial analysis document, etc. Another large potential application area is the EIA process where the value of ecosystem services can be used for initial investigation as well as for the actual documentation preparation.

The above-mentioned suggests the need for further enlightenment and above all cooperation along the following two axes:

(1) Between basic research in the area of monitoring of ecosystem elements and processes (biological, climatologic, hydrologic) and applied research focused on support for the decision-making processes, zoning planning, environmental management and environmental accounting using ecosystem services;
(2) Between applier ecosystem service research (within the scope of point (1) above) and public administration for practical applications of the mechanisms of assessment of ecosystem services in state administration and the decision-making process.

For the implementation and further use of stakeholders, it is necessary to use the full range of tools:

– Awareness raising and popularization—focused on the professional and the general public;
– Processing of clear and understandable, scientifically published and accepted methodologies, applicable in the conditions of the Czech Republic;
– Incorporation into legislation;
– Incorporation into conceptual residential documents, as a river basin plans, regional development plans, spatial development principles, zoning plans and territorial Analysis;
– Financial support for measures to optimize and support ecosystem services based on their knowledge and assessments;
– Continuation of research and case studies. Implement the results of major international projects, as an OpenNESS, Opera, Esmeralda and others. The participation of stakeholders in projects and research activities is also very important.

Further development of water management and planning in the Czech Republic can be supported:

- implementation of new sectoral knowledge and practical results of agricultural, forestry, urban and other research into river basin management plans.
- implementing progressive decision-making principles.
- reflecting the complex of ecosystem services and disservices and their implementation in water planning.
- reflecting the participative approach, where appropriate.
- developing a comprehensive approach to the state of the river basin.
- improvement of expert arguments in the EIA process, especially for clearly damaging structures, such as the planned Danube–Odra–Elbe channel.

Sustainable catchment management requires integration among natural and social scientists, land and water users, land and water managers, planners and policymakers across spatial scales [34]. The principle of managing rivers, their floodplains and entire watersheds for balanced human and ecological goals is being embraced globally by scientists, NGOs, water managers and various policy and government institutions [35]. River managers still lack appropriate science-based tools to realize the integration of human and environmental water needs; however, natural scientists will be required to consider the socio-economic setting and implications of their research [35]. All groups, including scientists, engineers, environmental managers and stakeholders faced with hydro-ecological problems need to converge upon a common vision and a unified approach. We believe that coordination between these groups is possible and will provide numerous benefits. However, it will be necessary to overcome many barriers in thinking established between both professional branches during the nineteenth century through the present [36].

References

1. Paseka S, Kapelan Z, Marton D (2018) Multi-objective optimization of resilient design of the multipurpose reservoir in conditions of uncertain climate change. Water 10:1110. https://doi.org/10.3390/w10091110
2. Sekáč P, Šálek M, Wranová A, Kumble P, Sklenička P (2017) Effect of water features proximity on farmland prices in a landlocked country: the consequences for planning. Soil and Water Res. 12:18–28
3. Slavíková L, Vojáček O, Smejkal T (2016) Artificial shortage of surface water: how can water demand management mitigate the scarcity problem? Water Environ J 12–19, ISSN 1747-6586. https://doi.org/10.1111/wej.12217
4. Moravcová J, Koupilová M, Pavlíček T et al (2017) Landscape Ecol Eng 13:1. https://doi.org/10.1007/s11355-015-0286-y
5. Xuan Y, Lamačová A, Duffy Ch, Krám P, Hruška J, White T, Bhatt G (2015) Modelling long-term water yield effects of forest management in a Norway spruce forest. Hydrol Sci J 60(2):174–191. https://doi.org/10.1080/02626667.2014.897406
6. *Fakta o vodě v Čeké republice* [online]. Praha: MZe ČR, 2013 [cit. 2018-11-27]. Dostupné z: http://eagri.cz/public/web/mze/voda/osveta-a-publikace/publikace-a-dokumenty/publikace/fakta-o-vode-v-ceske-republice.html
7. *Zpráva o stavu vodního hospodářství ČR v roce 2016* [online]. Praha: MZe ČR, 2017 [cit. 2018-11-27]. Dostupné z: http://eagri.cz/public/web/mze/voda/osveta-a-publikace/publikace-a-dokumenty/modre-zpravy/zprava-o-stavu-vodniho-hospodarstvi-cr-v-4.html

8. Just T (2016) Ecologically oriented management of watercourses in relation to their morphological state (in Czech). Metodika AOPK ČR, Praha, p 83
9. Just T (2017) Maintenance of small watercourses against drought and floods? [in Czech]. Vodní hospodářství 6:25–26
10. Birklen P, Dobrovský P, Slavíková A, Horecký J, Musil J, Marek P (2009) Seeking for water system permeability for fish in the Czech Republic [in Czech with an English abstract]. Ochrana přírody 5:1–3
11. Birklen P (2014) The experience of the preparation and implementation of fish passages in the Czech Republic [in Czech with an English abstract]. Vodní hospodářství 9:1–5
12. Jurajda P, Peňáz M, Reichard M, Bernardová I (2008) Water quality improvements following political changes, enhanced fish communities, and fisheries in the Czech Republic. Am Fish Soc Symp 49:845–850
13. Improved water retention in agricultural areas (2015) European Climate Adaptation Platform. Retrieved from https://climate-adapt.eea.europa.eu/metadata/adaptation-options/improved-water-retention-in-agricultural-areas. Accessed on August 20, 2018
14. Všetičková L, Adámek Z, Rozkošný M, Sedláček P (2012) Environmental im pacts of carp pond farming on discharged water quality. World Aquaculture 44(4):46–49
15. Chiang WH, Kinzelbach W (2001) 3D-groundwater modeling with PMWIN: a simulation system for modeling groundwater flow and pollution. Springer-Verlag, New York, p 346
16. Harbaugh AW (2005) MODFLOW-2005, the U.S. Geological survey modular ground water flow model—the groundwater flow process. USGS Techniques and Methods 6-A16. U.S. Geological Survey, Reston, Virginia
17. ANSYS (2018) Finite element engineering analysis system. https://www.ansys.com Last viewed January 2018
18. MODFLOW 6 (2018) USGS Modular Hydrologic Model. https://water.usgs.gov/ogw/ modflow Last viewed January 2018
19. GMS—Groundwater Modeling System https://www.aquaveo.com/software/gms-groundwater-modeling-system-introduction (Last viewed January 2018)
20. Bear J, Verruijt A (1992) Modeling groundwater flow and pollution, D. Reidel Publishing Company, 414 p
21. IGWC integrated groundwater modelling center http://igwmc.mines.edu/software/review_software.html. Last viewed January 2018
22. Kyncl M (2017) Study of supply of drinking water in dry seasons in the Czech Republic. IOP Conf Ser: Earth Environ Sci 92(1) (2017) ISSN: 1755-1307 Online ISSN: 1755-1315
23. Seják J, Dejmal I et al (2003) *Hodnocení a oceňování biotopů České republiky*. Praha. Available via: http://fzp.ujep.cz/projekty/vav-610-5-01/hodnocenibiotopucr.pdf
24. Vačkář D, Frélichová J, Lorencová E, Pártl A, Harmáčková Z, Loučková B (2014) Metodologický rámec integrovaného hodnocení ekosystémových služeb v České republice [online]. Available via: http://www.ecosystemservices.cz/userfiles/page/246/72fc39cc8d8e7f501934794636059d8c.pdf
25. Petřík P, Květ J, Pithart D, Pokorný J, Matěna J, Elster J, Maršálek B, Ráb P, Poštulka Z, Ansorge L (2008) Research priorities in the freshwater ecosystems in the Czech Republic. Institute of Botany, Czech Academy of Sciences, Průhonice, Czech Republic, BioStrat review
26. Pithart D (2014) Involvement of aquatic and wetland ecosystems in addressing current challenges of water management [in Czech with English summary]. pp 26–35. In: Fanta J, Petřík P (eds) Floods and droughts: landscape as the basis for a solution. Proceedings from seminars of the Comission for environment of the Czech Academy of Sciences held in October 8th 2013 and June 5t 2014, Institute of Botany the Czech Academy of the Science
27. Tague C, Valentine S, Kotchen M (2008) Effect of geomorphic channel restoration on streamflow and groundwater in a snowmelt-dominated watershed. Water Resour Res 44(10):W10415. https://doi.org/10.1029/2007wr006418
28. Nash CS, Selker JS, Grant GE, Lewis SL, Noël P (2018) A physical framework for evaluating net effects of wet meadow restoration on late-summer streamflow. Ecohydrology 11(5):e1953. https://doi.org/10.1002/eco.1953

29. Frajer J, Geletič J (2011) Research of historical landscape by using old maps with focus to its positional accuracy. Dela 36(2011):49–67
30. Pechar L (2007) Impacts of long-term changes in fishery management on the trophic level water quality in Czech fish ponds. Fish Manag Ecol 7:23–31
31. Pehlivanov L, Fikova R, Ivanova N, Kalchev R, Kazakov S, Pavlova M, Doncheva S (2014) Analysis of ecosystem services of wetlands along the Bulgarian section of the Danube River. Acta Zoologica Bulgarica, suppl 7:103–107
32. Dobrovolny L, Martinik A, Drvodelić D, Orsanić M (2017) Structure, Yield and Acorn Production of Oak (Quercus robur L.) dominated Floodplain Forests in the Czech Republic and Croatia. SEEFOR—South-east Eur For 8:127–136. https://doi.org/10.15177/seefor.17-18
33. Machar I, Cermak P, Pechanec V (2018) Ungulate browsing limits bird diversity of the central european hardwood floodplain forests. Forests 9:373. https://doi.org/10.3390/f9070373
34. Macleod CJA, Scholefield D, Haygarth PM (2007) Intergation for sustainable catchment management. Sci Total Environ 373:591–602
35. Poff NL, Mathews JH (2013) Environmental flows in the Anthropocence: past progress and future prospects. Curr Opin Environ Sustain 5:667–675
36. Pithart D, Dostál T, Langhammer J, Janský B et al (2012) Significance of water retention in river floodplains [In Czech: Význam retence vody v říčních nivách]. Daphne ČR—Institut aplikované ekologie, 141 pp