Sima et al. Earth Perspectives (2015) 2:5
DOI 10.1186/s40322-015-0031-6

Earth Perspectives
a SpringerOpen Journal

RESEARCH ARTICLE Open Access

A farmer-based analysis of climate change adaptation options of agriculture in the Bărăgan Plain, Romania

Mihaela Sima*, Elena-Ana Popovici, Dan Bălteanu, Dana Magdalena Micu, Gheorghe Kucsicsa, Carmen Dragotă and Ines Grigorescu

Abstract

The paper has in view the assessment of the impact of climate change on agriculture in the main agricultural region of Romania (Bărăgan Plain), by understanding the contextual socio-economic factors of agriculture in the area as a key step towards climate adaptation, but also through identifying the user needs, awareness and requirements in terms of climate information. A special attention was given to the analysis of the changes in the socio-economic and political context of Romania since 1989, the post-communist period, marked by fundamental transformations in agriculture, with collective and state property being replaced by private property. The poor development of the productive services in agriculture resulted in the degradation of land's productive potential and the intensification the adverse effects of extreme climatic phenomena, proving a strong dependency of crop yields and productivity on climate. The mid-term (2021–2050) and long-term (2071–2100) climate variability and change of some key variables affecting crop development (air temperature, precipitation, evapotranspiration), under different scenarios have been investigated in relation to the potential impacts on main crops. A set of relevant climate extreme and agro-meteorological indices was further used to estimate the potential climate change impacts on agriculture. The study was focused on the interaction with farmers, the main actors of the climate adaptation process in the area, aiming to evaluate their perception and response to climate change. The research approach was mainly done through face-to-face interviews, as farmers did not respond positively to organised meetings. An important difference was noticed in terms of adaptive capacity between the large farms with a high adaptive capacity and low subsistence farms (family-run farms), the most vulnerable category to both socio-economic and climate change. The main climate adaptation measure considered crucial by the farmers is the rehabilitation/construction of irrigation systems. The study provides useful scientific insights which could improve the understanding of farmers and decision-makers on the potential impacts of the future climate change on crops, but also to mainstream climate adaptation actions in the agriculture policy.

Keywords: Climate change adaptation; Agriculture; Farmers; Bărăgan Plain; Romania

Introduction

Agriculture is an economic sector directly influenced by climatic conditions, thus any change in the climate patterns will have immediate effects on it. Generally, Europe is delineated in two main regions in terms of potential climate change impacts on agriculture: the Northern Europe which is expected to benefit from climate change by the introduction of new crop varieties, higher yields, expansion of suitable areas from crop cultivation; by contrast, the Southern Europe is more likely to be affected by negative effects, through the reduction in water availability and increased demand for irrigation; extreme heat events and higher yield variability (Iglesias et al. 2007; Falloon and Betts 2010). The EU report on adaptation to climate change in the agricultural sector (Iglesias et al. 2009) includes Romania in the *continental south* agro-climatic zone, mentioning some potential benefits for agriculture driven by temperature increase: increase in yields for some crops, increase in grass yields

* Correspondence: simamik@yahoo.com
Romanian Academy, Institute of Geography, 12 Dimitrie Racovita St., sector 2, Bucharest 023993, Romania

and decrease of livestock costs due to longer growing season. However, the adverse impacts are likely to be more significant than the positive ones, by means of: higher drought risk, lower yields, increased frequency of extreme weather events, new pests and diseases, lower soil fertility and land availability. Adaptation measures should be therefore focused on improving water resources availability during summer and oriented towards more drought-resistant crops or crops that could adapt to the new climatic conditions (Olesen and Bindi 2002; Iglesias et al. 2009; Olesen et al. 2011).

Farmers have always performed adaptation in their agricultural activity, but there is a category of small farmers and low-income subsidence farms, highly dependent of rain-fed agriculture. This farmer category is very common in Romania and is likely to be the most affected by climate change, needing a particular attention and support in terms of adaptation. Adaptation of agriculture to climate change could cover a wide range of measures, from changes in the farming management practices (e.g. choice of crop varieties, use of pesticides, change in crop calendar, rainwater harvesting) to large investment schemes in developing and/or improving the agriculture infrastructure (e.g. irrigation equipments).

There is a growing interest in specialist literature on identifying specific climate adaptation options for the agriculture sector worldwide and determining the changes in agricultural practices related to with observed or future climate change, focusing on a farming-based approach and on assessments of farmers' perception of climate change in various regions (e.g. Gbetibouo GA: Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability. The Case of the Limpopo Basin and South Africa. IFPRI Research Brief 15–8 2008; Below et al. 2010; Nyanga et al. 2011; Wiles E: Farmers' perception of climate change and climate solutions. Global Sustainability Institute 2012; Okonya et al. 2013; African Technology Policy Studies Network ATPS: Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile et al. 2013). Most studies indicate a relatively accurate perception of farmers in terms of long-term observed changes of temperature, precipitation and associated extreme events, which determine some of them to perform an autonomous adaptation, by adjusting the land management, independently on any institutional intervention (Parry et al. 2007).

Many studies also refer to poor and vulnerable communities, with a low adaptive capacity to climate change, emphasizing the need to approach the issue from a farmer-based perspective as the current awareness of farmers in terms of climate change and need for adaptation might still be low and incomplete (Olesen et al. 2011; Below et al. 2012). It is often considered that awareness is a prerequisite step towards adaptation (Nhemachena and Hassan R: Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper 00714 2007; Gbetibouo GA 2008: Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability. The Case of the Limpopo Basin and South Africa. IFPRI Research Brief 15–8; Idrisa et al. 2012) and policies should be designed based on how the farmers understand climate-related risks and respond to them (Menapace et al. 2014).

Although some common patterns may be identified for farms located elsewhere, as the effects and responses to climate change are regionally, country or even locally-specific and many other factors influence the farm-level decision making, studies with a regional and local focus are very important in orienting the policies and strategies in the field. In this respect, the local knowledge of farmers has been proved very useful and important in enhancing their adaptive capacity and designing climate adaptation policies (Ogalleh et al. 2012). The impact of climate variability on crop yields largely depends on farm characteristics; therefore farm management is an important feature to be considered when analyzing climate adaptation (Reidsma et al. 2007).

Agriculture is seen as a major vulnerable sector to climate change in Romania, as recognized within the Romanian National Climate Change Strategy (2013–2020), in its Adaptation component, which will be followed by an action plan at sectoral level. There are several studies estimating the potential impact of climate change on the Romanian agriculture (Cuculeanu et al. 1999; Mateescu et al. 2003; Mateescu and Alexandru 2010; Sandu et al. 2010). However, their focus is mostly centered on climatic aspects. There is still a need to strengthen the interdisciplinary cooperation and to involve agro-specialists in developing adaptation strategies, by considering the differentiations between agro-climate zones in correlation to different adaptive capacities and adaptation options for farmers at local level. The topic of agriculture and climate change adaptation in Romania was included recently in several European projects, which address the main climate change challenges and related risks for agriculture in different parts of Romania (e.g. the SEE Orientgate project, 2012-2014, focused on Covasna County and Oltenia Plain and Interreg IVC WaterCore project, 2010-2013) (National Meteorological Administration 2014). Although it is considered that farmers in Europe are largely adapted to the local climate (Reidsma et al. 2007), when considering the cumulated effects of climate change, most regions of Europe are expected to suffer from their negative effects. This appears to be also the case for Romania, included in the Pannonian zone, strongly affected in this respect (Olesen et al. 2011).

The current study was conducted in the framework of the EU FP7 ECLISE Project (Enabling climate information services for Europe) and analyses the main challenges in the Romanian agriculture sector towards climate change adaptation at local level (the Bărăgan Plain region, southeastern Romania). A close interaction with agriculture stakeholders (end users) was established during the project implementation, in order to identify their response to the observed climate variability and their needs in terms of future climate information. The main steps in the analysis have been directed towards:

– **Understanding the contextual factors of agriculture in the area as a key step towards adaptation** through an analysis of socio-economic and political context of agriculture in Romania in the last 25 years, covering the transition period from communist period to the integration and post-EU integration, and new key challenges of EU Common Agricultural Policy;
– **Understanding the future impacts of climate change:** analysis of the projected changes of some key climate variables influencing crop growing (air temperature, precipitation, evapotranspiration), as well as of some indices relevant for studying the climate-crop requirements relationship, in order to estimate the future potential agro-meteorological stress to support climate adaptation for local farming practices;
– **Analysing the context for adaptation measures of agriculture** by the interactions with key actors involved in the process (farmers), assessing their knowledge, understanding and actions in terms of climate change and identifying common adaptation options.

Study-area in Romania and context for climate adaptation of agriculture

The paper focuses on the Bărăgan Plain region, located in the Southern Romanian Plain (Danube Plain), the main agricultural region in Romania, well known for high productivity of soils and good crop yields (Fig. 1). The main crops in the region are: winter wheat, maize, sunflower and rapeseed.

According to the agro-climatic zonation in Romania (Neacşa and Berbecel, 1979; Mateescu et al., 2003; Sandu et al., 2010), the Bărăgan Plain is a warm (10.5 °C) and moderately dry region (480 mm/year), with rich thermal and radiative resources, but limited hydric resources, translated in a significant water deficit during the active crop vegetation period (April-October). The most severe droughts in the region were recorded in 2000, 2003, 2007 and 2012, while 2005 was the wettest year.

Climate of Romania is on a significant warming and predominant drying, with an increasing frequency of warm and dry extremes, particularly in the southern and southeastern regions (Busuioc et al., 2010; Croitoru and Piticar, 2013; Birsan and Dumitrescu 2014; Busuioc et al., 2014; Bojariu et al. 2015), also recognized as the most important agricultural regions of the country. These changes became visible from observational data since mid-to-late 1980s (Busuioc et al., 2014).

Sandu et al. (2010) followed by MADR (2014) provide a comprehensive overview on the observed climate change in the agricultural regions of Romania over 1961–2008 and on their effects on the main crops (winter wheat, maize). The key messages of these studies, related to the observed change in temperature and precipitation, particularly obvious in 1981–2013 against the 1961–1990 period, are relevant for the agriculture of the Bărăgan Plain region: an ongoing and significant

Fig. 1 The location of the Bărăgan Plain in Romania

increase of the annual mean temperature with about 0.4 °C; an intensification of heat stress associated to a higher frequency of days with maximum temperature exceeding the critical biological threshold for crops (32 °C), particularly during the maximum water demand interval for crops (June-August); a decrease in winter severity along with a downward frequency of days with minimum temperatures below the critical biological crop resistance thresholds (−15° and −20 °C); a decrease of annual precipitation (about 4 %).

There are no statistical significant changes detected in respect to drought intensification in the region, considering the trends of some relevant drought indices studied over 1961–2013 e.g. Palmer Index, Standardized Precipitation Evapotranspiration Index (Bojariu et al., 2015). However, a significant and spatially extended increase (p-value < 0.05) was found only for autumn by Cheval et al. (2014), when analyzing the seasonal variability of Standardized Precipitation Index over 1961–2010.

The observed climate warming and drying proved to have negative effects on the water availability for crops in the southern, southeastern and eastern agricultural regions of Romania, affecting their productivity and quality. Such effects were particularly obvious during the droughty agriculture years 2006–2007 and 2011–2012 as showed in MADR (2014). According to the Ministry of Agriculture and Rural Development estimations, the excessively droughty agricultural years 2011–2012 impacted about 5.9 million hectares of crops all over Romania (corn, wheat, barley, sunflower, and rape).

Alongside the changing agro-climatic conditions, the socio-economic and political context, as well as the technological developments can be considered important drivers of the trends in the agricultural sector in Romania over the last 25 years. The end of 1989 marked the beginning of a period of transition to the market economy, a new stage in the evolution of agriculture and implicitly in land use.

The post-communist period can be divided into two distinct intervals: 1) *of transition (1990–2003)*, marked by fundamental transformations in agriculture, with collective and state property being replaced by private property. In general, the transition period could be characterized by some key words: decollectivization, privatization, fragmentation of agricultural land, and 2) *post-transition (2003-to-date)*, corresponding to Romania's pre- and post-accession to the European Union, a period that registered several land-use changes connected with the adoption and implementation of the EU Common Agricultural Policies (CAP) (Popovici et al., 2013).

The most important changes of that period appeared in the space dynamics of the main land use/cover categories and their quality, a new type of land property and exploitation (Popovici 2008, 2010). The ***permanent expansion of private property*** during the transition period was the direct outcome of the decollectivization and privatisation of agriculture, a process that had begun in 1990 (Law 18/1991, completed and modified by Law 169/1997 and Law 1/2000) (Popescu 2001; Bălteanu et al. 2004, 2005). This set of laws stipulated the retrocession of agricultural and forest land to their former owners or their heirs; initially, it was to be 10 ha equivalent arable land/family, Law 247/2005 eventually providing for *restitution in integrum*. In 2013, 93.6 % of the agricultural terrains and 39.6 % of the forest lands were privately owned, while under communism (1945–1989) all land-use categories, except for hayfields, were *collective property, the state possessing* the largest high-grade land uses – vineyards and orchards. *Private owners* held mainly pastures and natural hayfields in hilly and mountainous regions.

In parallel with the change of property, *the exploitation of agricultural land was changing*, too. Before 1989, in Romania there were two main forms of agricultural exploitations: *collective farms* (3,776 units in 1989) which held 60.8 % of the overall agricultural area, average surface 2,374 ha, and *state farms* (411 units in 1989) which owned 29.7 % of the overall agricultural area, average surface 5,000 hectares (Table 1). *Peasant households* possessed around 9.5 % of the total agricultural area, consisting mostly of pastures and hayfields in hilly and mountainous regions.

After 1989, the large farms from the communist period (collective and state farms) gave way to small, peasant-type family farms. In 2010, in Romania there were two types of agricultural exploitations: individual farms (without legal status) and units with legal status (Table 1). The individual farms represent 99.2 % of total agricultural farms, holding over 56 % of the overall agricultural area used. Average agricultural area/individual farm was of 1.95 ha. *Units with legal status* held only 0.8 %, average surface 190.84 ha (2010).

Some of the negative effects of the post-communist land reform were the excessive fragmentation of farm land and the marked degradation of productive agricultural services and land quality. In this way, all of these changes have led to a new land-use system, by far more vulnerable to extreme environmental perturbations and less resilient.

Also, inadequate agricultural practices, deforestation, poor management (little mechanisation, difficulties in implementing new technologies, poor and arbitrary fertilisation of crops, abandoned or destroyed irrigation and other land improvement systems, etc.) led to the quality degradation of agricultural land and eventually to its abandonment in low-productive regions.

Table 1 Comparative number and size of farms in Romania

	Communist period (1989)		Post-communist period (2010)	
	Collective farms	State farms	Individual farms	Units with legal status
Number	3,776	411	3,825,576	30,669
Average area (ha)	2,374	5,001	1.95	190.84

Data source: Statistical Yearbook, 1990; General Agricultural Census, 2010

In the general context of the socio-political changes in the post-communist period, associated to the climate variability, the agricultural land use in Bărăgan Plain was influenced by a complex of proximate socio-economic and climatic drivers that have been permanently interacting (Fig. 2).

Data and methodology

Landuse and agricultural data

In order to understand the changes driven by the socio-economic and political context and impacts on agriculture in the region, a detailed analysis of land use and land cover structure as well as the main change flows have been undertaken. In this respect, data on land use and land cover changes (classification level 3) elaborated under the CORINE Programme *(European Environment Agency; www.eea.europa.eu)* were processed in GIS for two representative years (1990, immediately after the fall of the communist regime) and 2006 (overlapping the pre-accession to the European Union). Additionally, statistical data supplied by the National Institute of Statistics (Romanian Statistical Yearbooks 1990–2010; General Agricultural Census 2002, 2010; Agricultural Farm Survey 2005; TEMPO-Online database, etc.) were used to analyze the farms category, crop production, irrigation facilities and use of fertilizers.

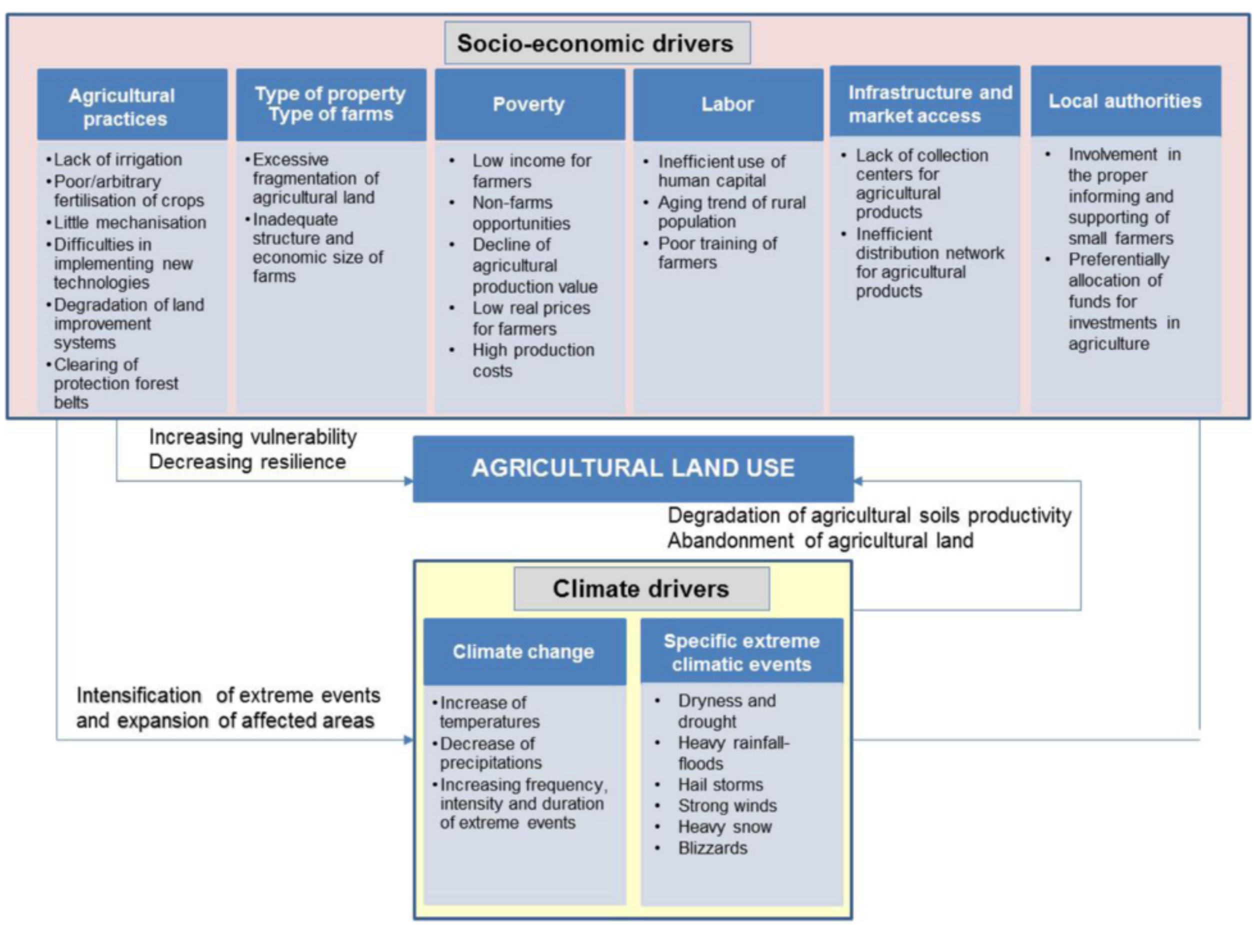

Fig. 2 Proximate causes of change in the Bărăgan Plain agriculture

Climate data

The study analyzes the projected changes of three key climatic variables influencing plant growth (air temperature, precipitation and potential evapotranspiration) over two future time-frames (2021–2050 and 2071–2100), under different scenarios. Herein, potential evapotranspiration was calculated using the Thornthwaite relation (adjusted for 45° latitude N). The evaluation of future climate change is based on simulations with three global climate models (GCMs) from the Coupled Model Inter-comparison Project Phase 5 (CMIP5), available from Euro-CORDEX project, and four regional climate models of the ENSEMBLES project, at 25 km horizontal resolution. Table 2 is summarizing the description of the selected models and the corresponding variables, future time-frames and scenarios used in this paper.

Climate change signals are expressed as a multi-model mean change relative to the 1971–2000 reference period. The statistical significance of trends derived from simulations was estimated with the non-parametric Mann-Kendall test, relative to the 0.05 level.

Additionally, six climate extreme indices with agro-meteorological relevance are used to investigate the potential effects of climate extremes on agriculture. The indices are derived from the daily temperature data and have been selected from the core set of descriptive indices of extremes, developed by the Expert Team on Climate Change Detection and Indices (ETCCDI), as well as from the national agro-meteorological literature (Sandu et al., 2010; MADR 2014). The description of the selected indices and their relevance for agriculture are presented in Table 3.

Observational data and performance of models

Despite the RCMs advantage over GCMs in reproducing regional climate features, their results are still subject to substantial model errors, affecting the reliability of the assessment of the potential future climate change impacts (Heinrich and Gobiet 2012). The simulated temperature model data used in this study is bias corrected by the SMHI, based on the E-OBS gridded dataset. Historical simulations of air temperature (1971–2000) have been tested against observation from three representative local weather stations (Grivița, Dâlga and Făurei), provided by the National Meteorological Administration (NMA). Overall, the models perform adequately in capturing the seasonality of mean and extreme temperature during the present climate period. The models also reproduce correctly the decadal oscillations, giving the general cooling variation over the 1970s and the warming after mid 1980s across the region. For modeling uncertainty reasons and end user interest purposes, the study exploits only the results of temperature projections obtained within the EU FP7 ECLISE.

The level of uncertainty in simulated precipitation from the selected RCM-GCM CORDEX projections is rather high for the Bărăgan Plain region. Despite the general warming tendency, precipitation is showing a dominant opposite trends at both annual and seasonal scales over both future periods, in all the selected CMIP5 models. Kjelltröm E, 2014: Future changes in the European climate as deduced from an ensemble of CORDEX simulations. Deliverable 2.3 report. FP7 ECLISE project (http://www.eclise-project.eu/content/mm_files/do_825/ECLISE%20D2.3.pdf) (2014) related this behavior to the larger precipitation response in the regional model RCA4 compared with the underlying GCMs. The bias correction increased the overall models' capability to capture the timing of seasonal precipitation cycle, but less its magnitude all over the year. Since precipitation is an essential climate variable in estimating the expected climate change

Table 2 List of simulation runs and forcing scenarios used in the present study

GCMs	RCMs	Modelling centers	Forcing scenarios	Time horizons	Variables
ENSEMBLES					
ECHAM5	RCA3	Swedish Meteorological and Hydrological Institute (SMHI)	A1B	1971-2000 (reference)	Daily minimum and maximum temperatures
BCM	RCA3	Swedish Meteorological and Hydrological Institute (SMHI)		2021-2050 (mid-future)	
HadCM3Q3	HadRM3Q3	Met Office Hadley Centre			
ARPEGE	CNRM-RM5.1	Centre National de Recherche Météorologique – Météo France (CNRM)			
CORDEX					
CNRM-CM5	RCA4	Centre National de Recherches Météorologiques/ Centre Européen de Recherche et Formation Avancée en Calcul Scientifique	RCP4.5, RCP8.5	1971-2000 (reference)	Daily mean temperature
				2021-2050 (mid-future)	
EC-EARTH	RCA4	EC-EARTH consortium	RCP2.6, RCP4.5, RCP8.5	2071-2100 (far-future)	
HadGEM2-ES	RCA4	Met Office Hadley Centre	RCP4.5, RCP8.5		

Table 3 Climate extreme indices calculated for the Bărăgan Plain

Index	Short name	Definition	Unit	Time scale	Relevance	Reference
Length of growing season	GSL	Number of days with Tmean ≥ 5 °C for 5 consecutive days	days	Annual, seasonal	Length of vegetation season	ETCCDI
Early spring coefficient	ES	Sum of mean temperatures ≥0 °C in February-March interval	Units	Monthly interval	Start of the vegetation season	Sandu et al. (2010); MADR (2014)
Frost days	Tmin0	Number of days with Tmin ≤ 0 in November-March interval	Units	November-March	Cold stress (relevant especially for winter wheat)	Sandu et al. (2010); MADR (2014)
Frost units	FU	Sum of mean temperatures < 0 °C over November-March interval	Units	November-March	Cold stress	Sandu et al. (2010); MADR (2014)
Extremely hot units	Tmax32	Maximum number of 3 or 5 consecutive days with Tmax ≥32	Units	Annual, seasonal	Heat stress	Sandu et al. (2010); MADR (2014)
Tropical days	Tmax30	Number of days with Tmax ≥30	Days	Annual, seasonal	Critical (lethal) thresholds for crops	ETCCDI

impacts on agriculture, future precipitation changes have been extracted from the key findings of some agro-meteorological studies, focusing on climate change projections in Romania over the 21st century, with references to the southern and southeastern plain regions.

User interaction

A stakeholder-oriented approach was considered in this study, aiming at gathering information on the interest of different local groups (farmers, local authorities, agricultural administrations, regional development agencies) in terms of climate information and particular needs for climate data to be considered in the farming management activities. Thus, a first step in the analysis was to identify which are the relevant actors at local level who are likely to have interest in the topic, either by being affected or affecting the issue.

In the majority of the cases, the main communication tool was through direct meetings and interaction (face-to-face), rather than workshops and other tools, as farmers did not respond positively in attending scientific professional meetings organized with other stakeholders in the area. Although time and resource consuming, these individual interviews offered a good understanding of the socio-economic aspects of the area and the challenges the farmers face, but also offered the farmers an easier access to climate information and facilitated the better understanding of the information provided by researchers. The direct communication and trust involved in the discussions should not be neglected in such interaction, the majority of further contacts being established based on personal contacts, as a consequence of these dialogues. A total of 110 randomly sampled farmers in two counties (Calarasi and Ialomita) were interviewed. The focus was on the medium-sized (5–100 ha) and large agricultural farms (over 100 ha and even thousands of hectares), the most representative categories for the region as using over 70 % of the total agricultural surface. Additionally a sample of around 20 small holder farmers have also been interviewed.

A four-part structured questionnaire with closed and open ended questions has been used. Part One contains 12 questions on the current situation of agricultural farms in the Bărăgan Plain (spatial dimension, land use and land property, structure of the cultivated area, average production/hectare for the main crops, the marketing of main crops, types of investment, input, technical endowment of the farm, etc.). Part Two tests the farmers' perception of climate change. Part Three refers to climate change, more precisely, to the way in which climate change is seen as influencing crops. Part Four supplies information on the farmers' response and adaptation to climate change and the major problems they must cope with. The aim of the questionnaire was also to find out whether farmers were interested in getting information on future climate and which is their particular interest in this respect. During the meetings, tailored climate change data and information have been presented and discussed with farmers in terms of climate extremes, drought and water availability, from the available literature regarding the region as well as the project's own results of climate simulations.

4. Results and discussions

4.1. Land use and main features of agriculture

Agricultural terrains in the Bărăgan Plain include *arable land* (84 % of total plain area), *pastures and hayfields* (4 %), *vineyards and orchards* (1 %) (Fig. 3). Other land-use categories are represented by built-up areas which cover about 6 % of the terrains and mostly include rural settlements, different buildings for agricultural and industrial activities, road and rail networks, etc. *Natural and semi-natural vegetation* (forest and transitional woodland-shrubs) cover small surfaces (3 %), and water-covered areas with 2 %.

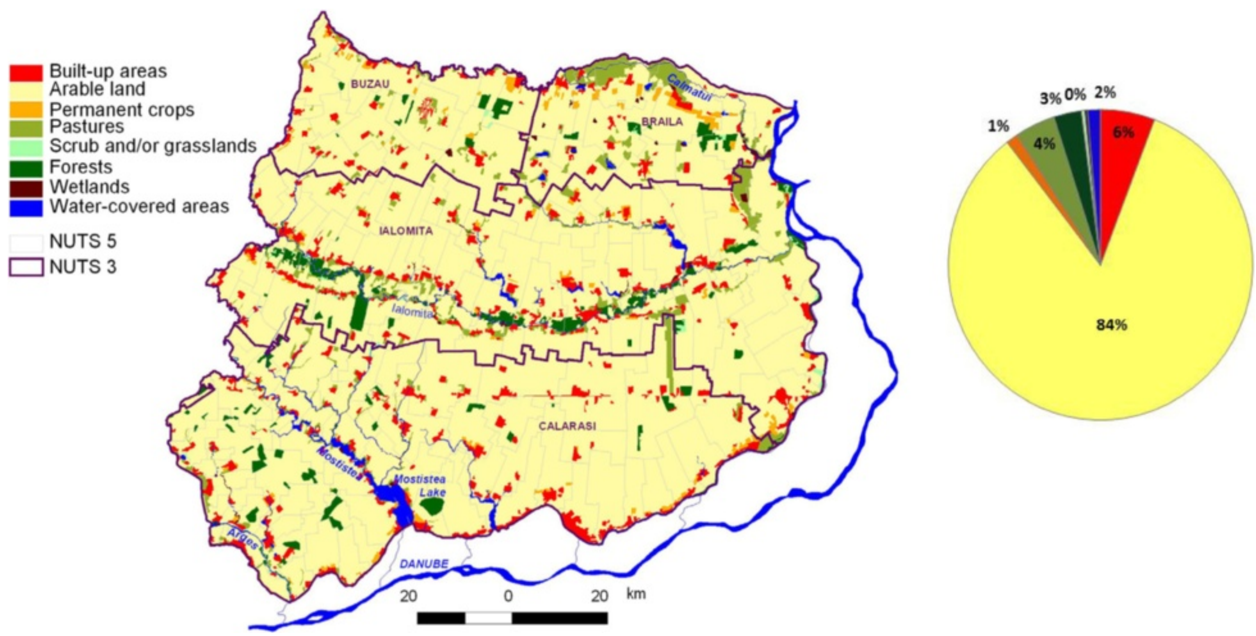

Fig. 3 Land use in Bărăgan Plain, 2006

Changes in land-use/cover structure in the post-communist period

The political and socio-economic changes that began in early 1990s had a strong impact on farm lands both in point of quantity and quality. Over the 1990–2006 period, a total of 42.8 thou ha (4.83 % of the total plain area) underwent changes. Farming experienced significant spatial changes either inside the land-use agricultural categories (internal conversions), or between these categories and other land-use classes, such as built-up terrains, forest lands, etc. During this period, arable land, vineyards and orchards shrank, while pastures and natural hayfields extended (Fig. 4). Arable land lost over 30 thou ha (most of them in favour of pastures, permanent crops, and built-up areas), and gained only 10 thou hectares (Fig. 5).

The most frequent land use/cover flows over the 1990–2006 interval were extensification of agriculture

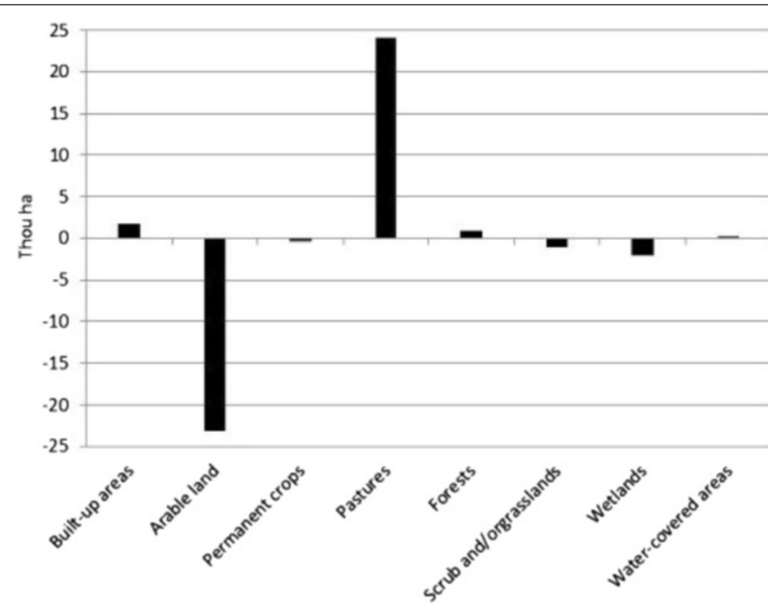

Fig. 4 Net changes in land use between 1990–2006

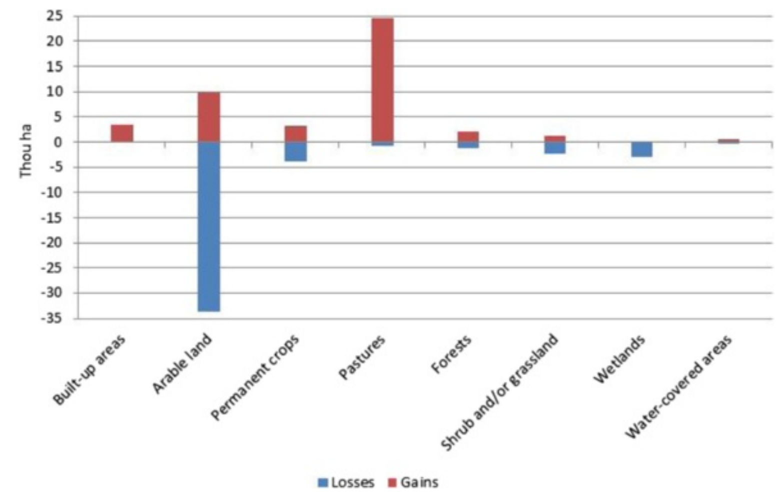

Fig. 5 Gains and losses by land use categories, 1990–2006

(60 % of total changed area) and intensification of agriculture (23.7 %). *Extensification of agriculture* was characteristic in the transition period (1989–2003) and involved conversion from arable land and permanent crops to pastures and heterogeneous agricultural surfaces, as well as degradation of productive services for agriculture In the post-communist period, the conversion of arable lands into pastures is the result of the abandonment of the former, particularly in low-productive regions. Several causes for abandoning arable lands is their high fragmentation, money shortage with the small farmers, the absence of markets to sell the products, few if any irrigation systems, etc. The highest rates of extensification process were registered in the eastern and north-eastern parts of the plain. After the Romania's accession to the European Union in 2007, the arable area that remained fallow each year has significantly decreased, as a result of rent or lease by large farms that practice a modern and competitive agriculture.

Fragmentation of agricultural land

In the Bărăgan Plain, besides inadequate agricultural practices and intensification of extreme climatic events, the excessive fragmentation of land has a significant influence on agricultural land productivity.

According to Agricultural Census 2010 in the Bărăgan Plain's counties there were 178,968 agricultural farms, of which 99 % are *individual farm*s that used over 31 % of the overall agricultural area used with an average agricultural area/individual farm of 1.8 ha (Table 4). *Units with legal status* held only 1 % of total farms with an average area of 347.9 ha. The agricultural area used of these farms represents over 69 % of total agricultural surface.

Concerning the spatial dimension of farms, two categories can be clearly distinguished within the farm-size class (2010). *The first category* includes *very small and small farms* of less than 5 hectares (94 % of existing farms). It should be remembered that 75 % of the farms in this category have below one hectare, therefore they are not eligible for receiving direct payment/hectare (Fig. 6a). *The second* category consists of *large and very large farms* of over 100 ha, or 1,000 ha even which represent about 0.9 % of total farms, but they possess over 78 % of the total agricultural area used. In the Bărăgan

Table 4 Agricultural farms in the Bărăgan Plain, 2005 and 2010

County	Agricultural holding without legal personality		Agricultural holding without legal personality		Agricultural holding without legal personality		Agricultural holding without legal personality		Agricultural holding without legal personality		Agricultural holding without legal personality	
	(number)		(number)		(average area ha)		(average area ha)		Agricultural area used %		Agricultural area used %	
	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
Brăila	60962	48331	352	531	3,1	3,0	364,7	469,3	59,3	37,5	40,7	62,5
Călăraşi	74375	75485	532	759	1,3	1,4	548,1	407,8	24,7	24,5	75,3	75,5
Ialomița	70028	63444	336	512	1,7	1,9	719,6	501,4	33,6	31,3	66,4	68,7
Total	205365	187260	1220	1802	2,0	1,8	431,7	347,9	39,2	31,1	60,8	68,9

Data source: General Agricultural Census, 2010

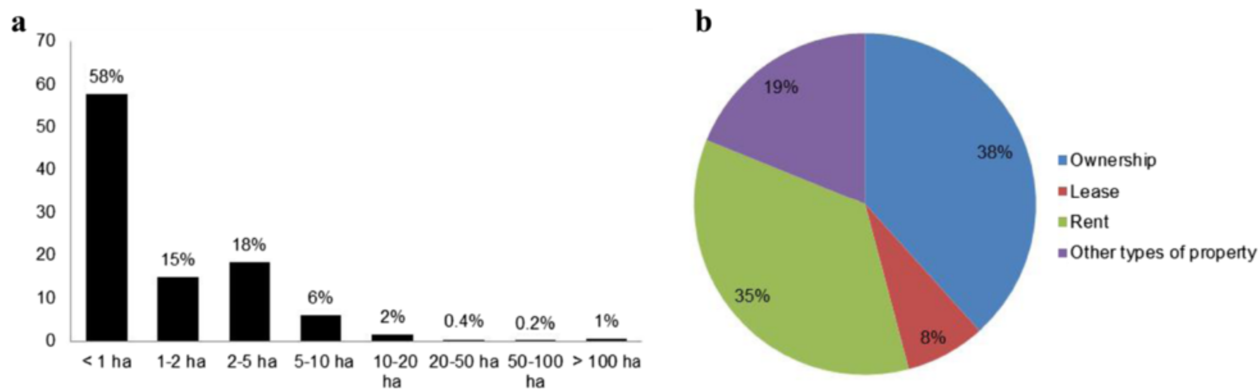

Fig. 6 Farms by size class of agricultural area used in Bărăgan Plain, 2005 (**a**) and agricultural farms by type of property over the agricultural land (**b**) Data source: General Agricultural Census, 2010

Plain there are five of the largest farms in Romania having an area between 6 thou and 35 thou ha. Four of these farms are hold by foreign investors (Portuguese, Lebanese, Danish, etc.). In-between two main categories stand *the medium-sized farms* (5–10 ha, 10–50 ha and 50–100 ha), basically family associations, producing for the market or some of them for self-consumption. Although these farms should be dominant, yet they represent only 5.1 % of the total number of farms.

In terms of type of property, 38 % of total agricultural area used is in ownership of farmers, follow by rent with 35 %, while lease represent only 8 % (Fig. 6b).

In the post-transition period, the fragmentation of agricultural land has been little reduced, terrains being amassed into large commercial farms, Law 247/2005 stipulating the reform of the property and justice systems, and Law 312/2005 that gave foreign citizens and stateless persons the right to landed property. These two legal provisions allowed foreigners to invest in Romanian agriculture and acquire vast stretches of land (to lease, to rent or to buy). Nevertheless, Bărăgan Plain agriculture is still dominated by very small and small farms with little financial resources, owned by undertrained ageing people. This situation makes it almost impossible to use new production technologies, undertake efficient management and marketing steps capable to increase productivity and make this sector competitive. Most individual farms practice subsistence agriculture, for the consumption of farmers themselves.

Dynamics of main crops was strongly influenced by the socio-economic and political conditions of the post-communist period. This influence depended on the farming practices (the absence of functional irrigation systems, fewer natural and chemical fertilisers, poor mechanisation), inadequate farm structure, agricultural policies, etc., and besides, the intensification of climate change-induced extreme phenomena (dryness and drought, heavy rainfall-floods, hail-storms, blizzards, etc.) annually affecting ever larger cultivated terrains (Sandu et al., 2010; MADR 2014). During that period, output variations in the main rain-fed crops (wheat, maize and sun-flower) were thus climate-related.

In terms of structure, most of the cultivated area is occupied with grain cereals (over 55 %) which are suggestive of a cereal-growing agriculture; oleaginous plants (mainly sunflower and rape seed) over 36 % and other plants (vegetables, fodder plants, etc.) 11 %.

During the past 15 years, grain crop areas shrank in favour of oleaginous plants (rapeseed and sun-flower). The spectacular expansion of brassica cultivated areas, from 0.1 thou ha in 1995 to 150 thou ha in 2010 (Fig. 7), plant thought to be best suited to biodiesel production,

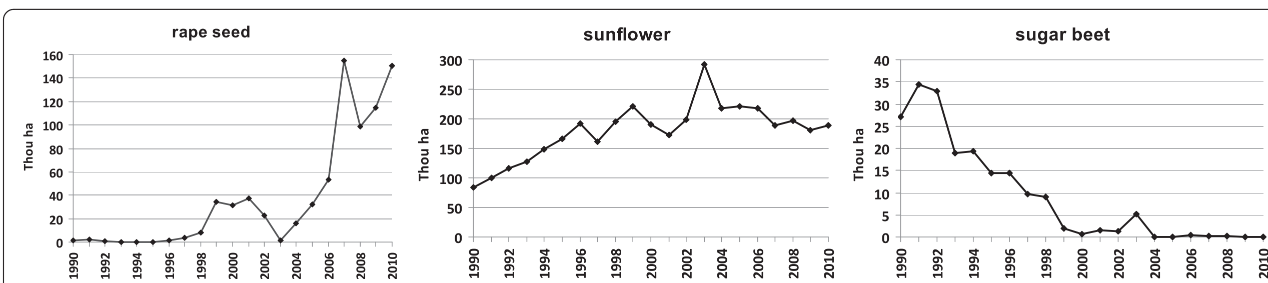

Fig. 7 Dynamics of areas cultivated with rape, sunflower and sugar beet (ha) (Data source: National Institute of Statistics, Tempo online database, accessed in 2013)

given that it has the highest caloric value of all oil plants. Thus, the areas cultivated with these crops have increased is largely the result of farmers receiving financial assistance from the state. Also, in the Bărăgan Plain (Călărași County) there is one of the largest biodiesel plants in Europe with a production capacity of 100,000 tonnes per year.

The area allocated to *textile plants*, *sugar beet* and *fodder plants* has shrunk considerably over 1990–2010 (Fig. 7) because costs are high, products take a low price, and the industrial animal breeding farms were closed.

Crop production

Over 1990–2000, the production of most crops kept decreasing because the allocated surfaces shrank and technological regression largely reduced average outputs. After 2000, overall and average yields, especially of maize, sun-flower, sugar-beet, potatoes and vegetables improved. Another factor involved in the yearly crop yield was the climate. Thus, in rain-deficient years, average production/ha was extremely low, simply because irrigation systems were not operational. For example, in drought years of 2000 and 2007, average outputs/ha for the main crops (wheat, maize and sunflower) were significantly lowered.

In 2007, lowest cereal average yields registered the counties of Ialomița (872 kg/ha) and Călărași (996 kg/ha). The same for sunflower: 364 kg/ha in Călărași and 425 kg/ha in Ialomița, the yields being much lower than EU average (over 5,000 kg/ha for wheat and 1,800 kg/ha for sunflower).

Irrigation

Before 1990, in the Bărăgan Plain over 86.2 % of total arable area was managed with irrigation systems (947.6 thou ha), most of them being destroyed after 1990, or left in an advanced state of degradation. In 2010, only 6.9 % of the total agricultural area equipped with irrigation facilities was managed for irrigation (Fig. 8).

The irrigation system in Romania was built during the communist period (more than 40 years) and most of it has not been used for 25 years. The rehabilitation and modernization of the old irrigation system are hampered by several factors:

- Subsidies for irrigation and the state support are missing. The rehabilitation and modernization of irrigation systems are the responsibility of farms, but most of them do not benefit of sufficient financial resources;
- The old irrigation systems require retehnologization, especially for the pumping aggregates, in order to minimize energy consumption and water losses;

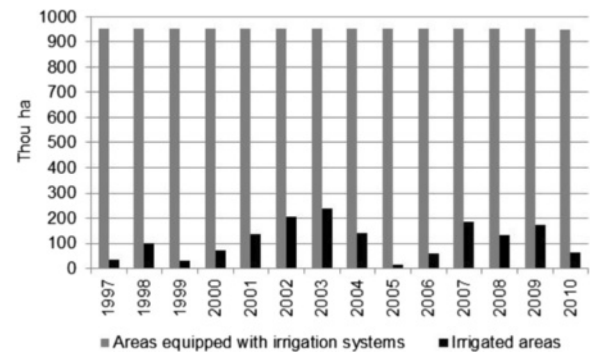

Fig. 8 Area equipped with irrigation systems and irrigated area (Data source: Ialomita and Calarasi Counties Agricultural Directions, 2013)

- The high price of water due to high energy consumption;
- Inadequate farm structure, with small plots owned by different farms;
- Poor association/organization of farmers;
- The property right and maintenance of irrigation infrastructure, in the most cases are unclear, etc.

In the absence of irrigation and adequate land management during long periods of severe drought (e.g. in 2000, 2007 and 2012), crop productions were dramatically diminished, e.g. by 80 percentage points for maize, 20-75 % for sunflower and 8-65 % for wheat compared to the year before (Fig. 9).

Fertilisation of crops

A particularly important problem of Romanian agriculture is the agro-chemical degradation of soils following *inadequate crop fertilisation*. In the Bărăgan Plain the quantity of the chemical fertilisers used was almost three times lower that of 1990; similarly, twenty times fewer pesticides. As a result, vast cultivated areas were yearly deprived of fertilisation. In most cases, chemicals are arbitrarily applied, without specialist advice for the optimal dosing and time required by the respective plants and the soil demand for nutrient supply. Thus, the random use of nitrogen fertilizers did but enhances acidification, soil and water pollution and the enlargement of degraded areas.

Future climate conditions and potential influence on crops

Temperature is an important determinant of plant progresses, influencing the key phenological phases towards reaching their maturity and harvest stages. Projection results provide evidence of a significant ongoing and widespread warming in the Bărăgan Plain, at all the time-scales considered (Fig 10). These results indicate that the annual mean temperature warm at a rate from

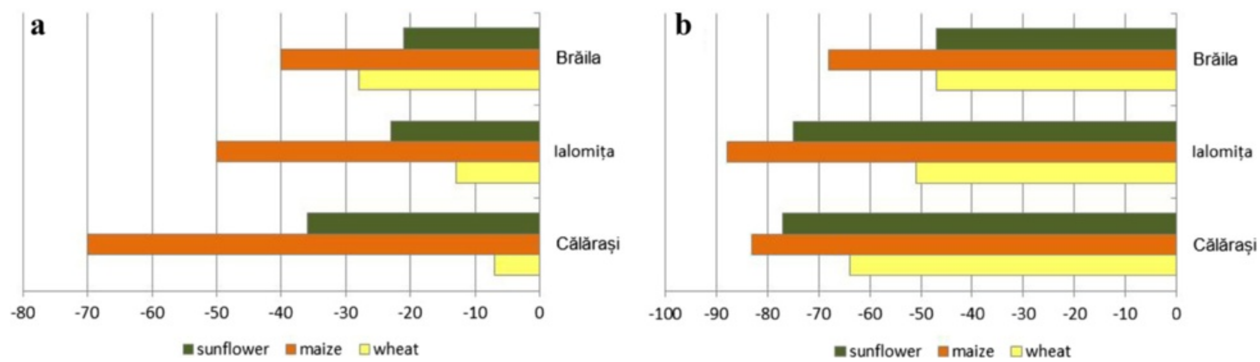

Fig. 9 Impact of the drought on average yield for main crops (% reduction) for 2000 relative to 1999 (**a**) and 2007 relative to 2006 (**b**) in Bărăgan Plain (Data source: National Institute of Statistics, Tempo online database, accessed in 2013)

about 2.0 °C by 2050 to over 4.0 °C by 2100. Generally, the largest positive change is projected under the high-emission scenario (RCP8.5).

The projected temperature increase are the highest during winter under all RCPs, especially during the far-future interval, with rates in the range of 2.6-4.1 °C. In spring, warming signal is larger than in summer and autumn (1.8 °C under RCP4.5 and RCP8.5), and is largely connected to the positive feedbacks induced by the early snowmelting trends observed during the present climate in most regions of Romania, including some areas of the southern plain region (Birsan and Dumitrescu 2014). These feedbacks are expected to be potentially augmented by the projected warming across the study region. In summer, temperature rise will continue and intensify during the far-future interval, especially under RCP8.5, from about 2 °C by 2050 to 4.6 °C by 2100. Monthly, the highest temperature increase is projected for February and March, supporting the decrease of cold stress, the earlier spring onset and an advanced active crop growth, as well as for the May-June interval, which marks the maximum sensitivity period of winter cereals (wheat) and weeding crops (maize). In general, the warming signals of spring and summer are considered most relevant in estimating the future crop vulnerability to heat stress, suggesting a potential augmentation of agro-climatic risk on cultivated plants, especially during the their heading, flowering and grain filling development stages.

These results are in agreement with those reported by Bojariu et al. (2015), which provides the most recent overview on climate change signals in Romania for the 21st century, based on the outputs of six RCM-GCM CMIP5 simulations of the EUROCORDEX project, under RCP4.5 and RCP8.5 (2021–2050 and 2070–2099, relative to 1961–1990 and 1971–2000 baseline intervals). Accordingly, the Bărăgan Plain region is expected to exhibit an intense warming in summer (above 4.3 °C over 2070–2099) and winter (of about 2.0 °C over 2021–2050).

The analysis of future trends of annual and seasonal daytime and nighttime temperatures by 2050 is relevant for highlighting the months with deviations from the optimum limits of the significant physiological processes (e.g. photosynthesis, respiration), influencing the plant growth and efficient development (e.g. dry matter accumulation). Annually, minimum temperatures are projected to rise slightly more (1.5 °C) than the maximum temperatures (1.3 °C). Seasonally, the largest warming signal is expected in summer (about 2.0 °C), especially in

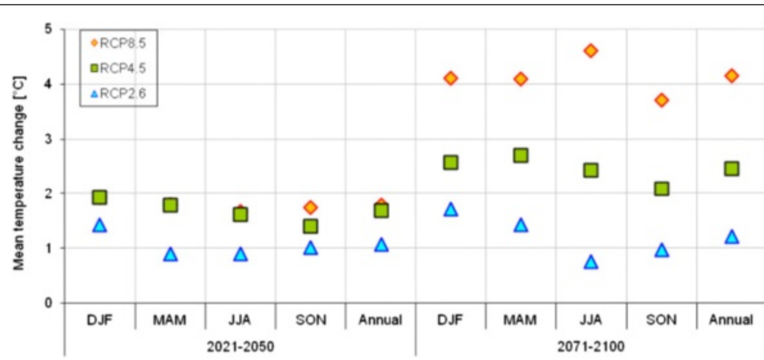

Fig. 10 Projected changes in annual and seasonal mean temperature in the Bărăgan Plain under different RCPs

July and August (Table 5), overlapping a period of soil moisture deficits. This signal is likely to determine a shortening of vegetation season and lower of maize crops yields, more sensitive to hot and dry summer conditions. In winter and spring warming is less intense (generally below 1.0-1.5 °C), especially during the day. The changes in the upper tails of the future daily temperature distributions suggest an upward in the frequency and duration of day and nighttime extremes (e.g. tropical days/nights, heat waves) in all seasons, but mostly in summer. These results are consistent with the findings of Busuioc et al. (2010), obtained with 18 downscalled ENSEMBLES simulations, for the period 2021–2050 (A1B scenario).

The projected behavior of future temperature extremes is likely to affect the future crop growth, development and yields in the region, particularly for the crops most sensitive to strong water deficit during the months of peak water demand (e.g. maize during July-August interval). MADR (2014) provides evidence of critical influence of the present climate warming on some key crop development stages e.g. flowering-fructification stage for winter wheat (May-June), for maize and sun flower (July-August), mostly in relation to the higher frequency of daytime extremes (e.g. days with maximum temperature greater than 32 °C).

There are signals of marked future changes in **precipitation** regime of the Bărăgan Plain region, as indicated by some representative studies on the projections of climate change in Romania over the 21st century, using the ENSEMBLES and CORDEX simulations and different climate scenarios. Analyzing the projection of precipitation changes using 18 downscalled ENSEMBLES simulations under A1B scenario, Busuioc et al. (2010) showed that for far future period (2071–2100), summer precipitation will decrease all over the entire country, especially in the southeastern regions (10-20 %). A decrease of spring precipitation (20 %) is also likely in the southern plain regions of the country. The downward trends are less pronounced by 2050 all over Romania. Using higher resolution ENSEMBLES simulations (10 km), an increasing frequency of heavy precipitation days in winter and decreasing in summer is also expected by 2050 in southern and southeastern Romania. MADR (2014) suggest an increasing frequency of severe droughts along with a significant downward trend of summer precipitation (7-8 %) by 2100 in the southern and southeastern plain regions of Romania, according to the ensemble mean of 21 CMIP5 simulations (RCP2.6 and RCP8.5). Considering the precipitation projections, this report provides evidence of decreasing of the soil moisture reserve for maize crops, especially during the months of maximum water demand (July-August). Bojariu et al. (2015) indicates less spatially coherent changing precipitation signals across Romania. The results indicate non-statistically significant trends of precipitation in winter and spring, under RCP4.5 and RCP8.5. Yet for summer, the projections suggest a clear downward trend particularly over 2070–2099 and an intensification of drought, under both RCPs, most visible in the southern, southeastern and eastern regions of Romania. Accordingly, the expected decrease in summer precipitation in the Bărăgan Plain is about 5 % by 2100.

Table 5 Expected monthly changes (°C) in maximum and minimum temperature by 2050, in the Bărăgan Plain, under A1B scenario

Months	Tmaxcrtl	Tmax2050	Tminctrl	Tmin2050
Jan	5.5	+1.5	−1.8	+1.4
Feb	8.0	+1.0	−0.9	+1.1
Mar	12.7	+0.9	2.2	+1.1
Apr	17.4	+0.7	6.2	+1.1
May	22.4	+1.0	11.0	+1.3
Jun	28.1	+1.3	15.5	+1.8
Jul	31.5	+1.9	18.3	+1.8
Aug	30.9	+2.2	17.2	+2.0
Sep	25.4	+1.3	12.6	+1.6
Oct	18.4	+1.5	7.3	+2.1
Nov	11.6	+0.8	3.0	+1.1
Dec	6.1	+1.5	−0.7	+1.4

The heat stress risk is expected to be detrimental to crop production when associated to higher evapotranspiration and severe moisture deficits, especially in summer and spring. In response to the projected climate warming, an increasing trend in **evapotranspiration** is expected during the active crop vegetation season (April-October) by 2100, under all RCPs. A intensification of summer drying is more likely in June and July, all over the region. These months corresponds to those of maximum water demand for maize (July) and winter wheat crops (June). The changes in evapotranspiration associated to the timing and lower amounts of precipitation during early and mid-summer, suggest also a prominence of soil moisture deficit, which is likely to lead to an increasing need for surface irrigation supplements in the region, particularly by 2100 under RCP8.5 (Fig. 11).

Table 6 synthesizes the projected changes in the indicators of climate-crop relationship and highlights their relevance for crop development. These changes indicate an intensification of heat stress (and an implicit amelioration of cold stress), a overall lengthening of the general vegetative season, but a shortening of intervals in which cultivated plants could absorb the photosynthetic products. These trends could explain much of the shifts expected in the crop calendar of the region, as illustrated in Fig. 12.

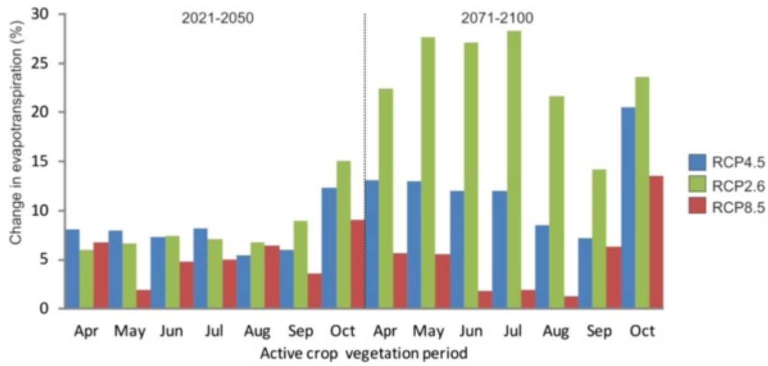

Fig 11 Projected change in evapotranspiration during the active crop vegetation period under different RCPs in the Bărăgan Plain region

Interaction with farmers in the Bărăgan Plain

In order to identify which are the relevant actors in the area interested in the impact of climate change on agriculture, contacts have been established with local institutions and authorities, a good feedback being given by the South-Muntenia Regional Development Agency (RDA). The agency showed a real interest in the study in terms of including relevant climate impact information in the development plans which are periodically revised but also of being a contact point with local farmers in the region.

Table 6 Key messages towards adaptation to future temperature changes in the Bărăgan Plain agricultural region

Climate indicators	Agro-meteorological relevance	Projected change	Potential implications for crop development
GSL	Reflects the length of the vegetative season for both indigenous and cultivated plants, when they experience the most growth, and calendars under average climatic conditions	GSL is on a notable increase under RCP4.5 and RCP8.5, from up to one week to one month and a half by the end of the 21 century. Under RCP8.5, the lengthening rates are the largest, ranging from 8 days (2021–2050) to 49 days (2071–2100).	Higher temperatures are likely to accelerate the development of cultivated plants in the study region (e.g. winter wheat) and to shorten the growth stages during which the photosynthetic products are absorbed, affecting the overall crop productivity.
ES	Provides evidence of the growing season onset for crops and is also a reliable estimator of the changes in the greening phenological phases of plants in certain years.	There is evidence of increasing frequency of earlier spring onsets, most significant changes being projected for the far-future (30 to 86 %), in all scenarios.	This is an indication of decreasing cold stress and advancing active crop vegetation season.
FU Tmin0	Proxy indicator of winter severity, is a relevant indicator for assessing the cold stress influence on crops sowed during autumn, which extend their vegetation period also during the winter (e.g. winter wheat) (Sandu et al., 2010).	Under present climate, the study region is highly exposed to cold stress, generally from November to March. By 2050 (A1B), FU is on significant decrease (34 %), suggesting the transition towards milder winters. This signal is consistent with the negative changes in the annual frequency of *frost days* (Tmin ≤ 0 °C) under the same scenario (about 13 %), confirming the general reduction of cold stress in the region, especially in February and March, as well as the increasing rates of photosynthesis.	The milder character of winters is expected to have both positive and negative effects on crops, dependent on the their development stages. For winter wheat, warmer winters are likely to be beneficial (less cold stress on seeds), but rather detrimental during the vernalization phase (the period of cooler growing conditions necessary that winter wheat to develop the reproductive growth).
Tmax30	Important parameters of heat stress on plants during the active crop growth season (April-October). The 30 °C and 32 °C maximum temperature thresholds are considered critical (and even lethal) biological limits for plant development, especially for maize and sunflower crops, when producing over several consecutive days and overlapping the flowering, grain filling and ripening stages (Sandu et al., 2010).	The Bărăgan Plain is frequently affected by severe and persistent heat stress in summer, under the influence of tropical dry airflows of North-African origins. The projections indicate that the region is likely to experience a higher tropical heat stress by 2050, through an increasing frequency of tropical days in summer but also during the early-to-mid autumn interval (in September-October) mid-to-late spring (in April-May).	Tropical days and extremely hot days negatively influence the plant metabolism, producing the so-called "shrivelling" phenomena, highly detrimental to crop development when associated to summer soil moisture deficit.
Tmax32		Heat stress by means of extremely hot units index is likely to be significantly augmented by 2050 all over the region.	

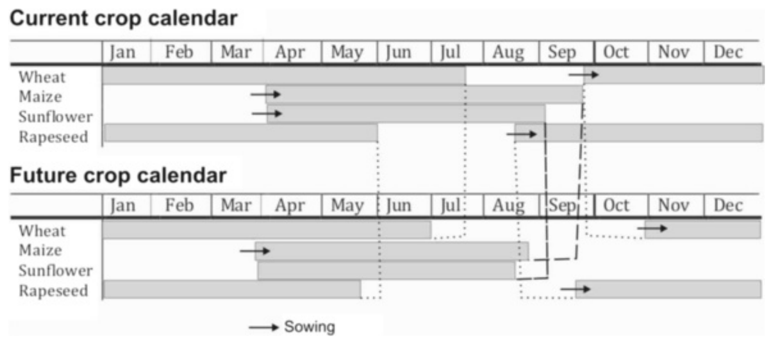

Fig 12 Change in future crop calendar in the Bărăgan Plain

Through the RDA and the county agricultural directions, further contacts have been initiated with farmers in the area, holding different categories of farms: large, medium or small subsistence farms. The farmers were considered the main beneficiaries of the climate information supplied through the project, although their interest in climate services was somehow very narrow, the information needed by them being very general, focused on a short-term interval in the future (5 years or less, their main interest being the weather forecast for the next vegetation season) and less likely to be used for an immediate decision. Farmers did not specifically express their needs in terms of climate services, because they didn't have knowledge on how exactly to use the provided climate information in the future management of their business. The climate information and data presented to farmers tried to provide some consistent messages in terms of climate change in the region based on existing literature as well as results of climate simulations of the project. Based on these sources, the main climate-related messages for the region presented to farmers referred to: increasing the mean, maximum and minimum temperatures, longer hot and dry spells and change in evapotranspiration mainly in summer with consequences on soil moisture, the intensification of drought phenomena, seasonal change in the precipitation patterns and less water available for crops in summer and early autumn, higher variability of crops associated to higher variability of rain. During the individual interviews, the discussions on the presented climate information were rather low, farmers being more interested on the effects of the presented data on their agricultural activity, rather than on the probabilistic information and model skills. When presenting the data to a larger group of farmers, the discussions were more intense in terms of trying to understand the climate data and their reliability. It was interested to note that farmers participating in the group discussions have already identified some ad-hoc solutions to the presented information and tried to translate the data into local adaptation actions: how to make use of the experience of farmers from other countries who experienced the same phenomena (e.g. drought) for long periods, how to associate and rehabilitate the irrigation system for several farm associations, what crops would be more suitable for the future climate patterns etc.

Generally, the farmers' perception in terms of climate change, their adaptive capacity and potential adaptation measures they might consider have been tackled in the interviews performed with them.

Farmers' perception on climate change

All interviewees said that they were aware of climate change from own observations and from the mass-media, feeling its effects either through thermal discomfort in summer (higher temperatures and heatwaves), stronger blizzards and frost in winter, or significant harvest losses in very droughty years (rainfall scarcity).

Everyone affirmed that the main climatic phenomenon affecting the region was drought, next coming freeze and hail (Fig. 13). Most people perceived also a shift in the seasons that only two, instead of four, seasons did exist, namely summer and winter.

People perceive that the climate is changing in that drought and dryness in summer have become increasingly more severe (95 % of the respondents); very high temperatures that stay on for a long time (100 %); absence of rain, especially in summer-time (for 2–3 months) (81 %). Rain has fallen mostly in spring (May) and in early summer (June) over the past few years with no, or very little rainfall in the next 2-3-4 months (July, August, September and sometimes October). It can be noticed the accurate perception of farmers in terms of the observed changes in climate, this being supported by simulation results and research findings of some studies: more rain in winter and spring and less rain in summer and early autumn.

Blizzards in winter, associated with frost, have become ever so frequent (almost every year), snow drifts preventing the deposition of a thick snow layer to cover the

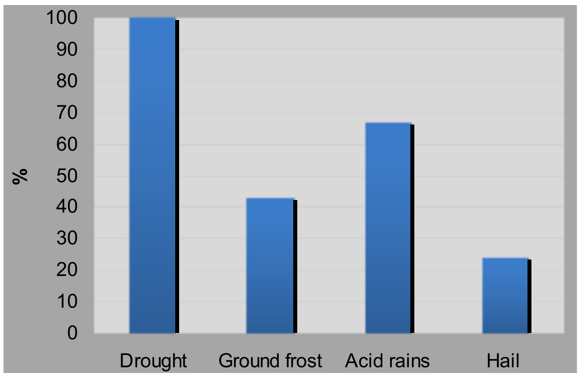

Fig. 13 The climatic phenomenon with greatest impact on agriculture in farmers' opinion

autumn crops and shelter them from low temperatures. So, there were years when their crops have been completely destroyed and the terrain had to be recultivated. Moreover, the absence of protective forest belts favoured significant accumulations of drifted snow (of at least 2–3 m height), affecting outskirts dwellings and disturbing the power supply, transport and food chain. Almost 90 % of the interviewed farmers have noticed more acid rainfall or hail than in the 1990s (Table 7).

Farmers' adaptation measures to climate change

Climate change and especially more drought and dryness have led to larger crop yield losses during the droughty years.

In the farmers' opinion, an essential measure to adapt to climate change and its negative phenomena, thereby reducing unexpected effects on agriculture activity, would be the rehabilitation/construction of irrigation systems and the plantation of forest belts (Table 8). When asked whether they were interested in investing in this enterprise, the answer was affirmative, but the lack of financial resources prevented them from doing it alone without state involvement and support.

Big farmers would use their own money to irrigate the cultivated terrain, digging deep underground wells, but the area irrigated in this way is quite small, no longer than some scores of hectares. Therefore, most such farmers have lodged projects to obtain European funding for this enterprise.

Table 7 Farmers' perception on climatic phenomena

What is your perception of climate change?	No	%
Higher and lasting temperatures	110	*100*
More drought and dryness in summer associated with		
Intensifications of a warm and dry wind	105	*95*
The absence of rain (for days, weeks, or months in a row)	89	*81*
A sharp fall in air moisture	26	*24*
Intensifications of a cold wind and of blizzards in winter	74	*67*
More frequent acid rains and hail	99	*90*

Insofar as forest belts are concerned, it emerged that all protection belts had been cleared in the post-communist period, the farmers striving to replant them. Some did it by themselves, but the majority said that they could not do it because land owners, unwilling to give up cultivating certain areas for this purpose, opposed the initiative, although most leaseholders promised to continue paying the lease for the respective terrain.

Another climate adaptation measure taken by the large farms is the use of advance of technology for agricultural works capable of maintaining water in the soil.

In the case of small farmers, the use of drought-resistant seeds appeared to be the best accessible adaptation option. According to their observations, Romanian varieties got more easily adapted and yielded higher productions in conditions of drought than foreign varieties did. On the other hand, in years of normal precipitation, foreign varieties seemed to be more productive. Therefore, every year farmers would use both Romanian and foreign seeds, in varying proportions.

Also another option for the farmers' adaptation to climate conditions and to the socio-economic situation of the past 25 years was the structuring of cultivated surfaces. Grain-based agriculture was gaining ground, farmers' choice going to better climate-resistant plants that also have more cost-effective growth needs. Therefore, grain cereals (wheat, rye and maize) became the dominant crop, as well as oleaginous plants (sunflower and rape).

The discussions with farmers and specialists and relevant literature, have allowed us to summarize the main categories of adaptation measures already taken by large and medium-small farms as a response to the observed climate variability (Fig. 14).

Farmers have identified as an important limitation towards adaptation the poor support from local and national authorities, through the lack of dedicated policies aimed to sustain them in speed-up the adaptation process, the political incoherence in terms of establishing the investment priorities for the Romanian agriculture (e.g. rehabilitation of the irrigation system), lack of financial resources and adequate information on future changes in the climate, but also the lack of specialists in the field of agronomy that could hold important information and knowledge about climate change.

In this study, a qualitative estimation of the potential increase of the adopted measures in the future has been included, despite that an in-depth cost-benefit analysis of each potential adaptation measure is still necessary. Figure 15 presents the current level of adoption for each measure for large and medium-small agricultural holdings

Table 8 Measures of farmers' autonomous adaptation to climate change

Farmers response to climate change	No (n = 110)	%
Use of drought-resistant seeds	110	100
Give up cultivating high production cost crops	110	100
Prevailing crops: grains (wheat and maize) and plants (sunflower)	110	100
Insure crops against extreme climatic events	110	100
Obtain European funds for modernization	52	47.27
Gather new information about the climate and the farming practices	52	52.72
Use modern soil retention technologies	47	42.73
Exchange experience with other foreign farmers in drier areas	20	18.18
Irrigate the crops	16	14.54
Plant protection forest belts	3	2.72
Rely on soil studies of crop fertilisation	2	1.81

versus the likely degree of change in their implementation in the near-future (increase versus no change by 2020) in the Bărăgan Plain following the model of the Defra report (Defra 2013). Actions that are considered effective and currently adopted at a low level are presented in upper left side of the figure and those being effective and already adopted in the upper right. The already adopted adaptation measures are mostly assigned to the category of "no regret" measures, which deal with choice of crop varieties or some management practices. Comparatively, the measures includes in the upper left side require more strategic and long-term vision in terms of policy and planning (e.g.

Climate adaptation measures	
Large agricultural holdings ***(hundreds or even thousands of hectares)***	**Medium agricultural holdings** ***(5-10-100 ha)***
Climate adaptation measures already undertaken by farmers	
-drought resistant seeds -modern technology to maintain the soil moisture -accessing European funds -insurance of agricultural crops to extreme events-related losses -transfer of knowledge -fertilisation based on soil research studies -irrigation -forest belts	-drought resistant seeds -giving up crops involving high production costs -changes in the structure of cultivated area with predominance of cereals (wheat and maize) and oleaginous plants (sunflower) -insurance of agricultural crops to extreme events-related losses
Needed adaptation measures	
-effective national strategy for adaptation and mitigation the effects of climate change -rehabilitation / construction of irrigation systems -appropriate agricultural practices for mitigating the drought effects on crop yields -insurance of agricultural crops for reducing crop losses due to extreme climate events -involvement of local, regional and national authorities in supporting small farmers adaptation to climate change -knowledge transfer -development of education and research in the field of agronomical sciences	
Major constraints	
- lack of a longer-term planned strategy for adaptation to climate change and variability -poor support of local and national authorities to climate problems -lack of skilled specialists in the field of agronomy -refuse of landowners to plant forest belts on the lands rented to large farms -political incoherence	-lack of financial resources and information -low awareness level -poor support of local and national authorities to cope with climate-related issues -inability to access available European funds -lack of skilled specialists in the field of agronomy -political incoherence

Fig. 14 A synthesis of adaptation measures adopted in the Bărăgan Plain

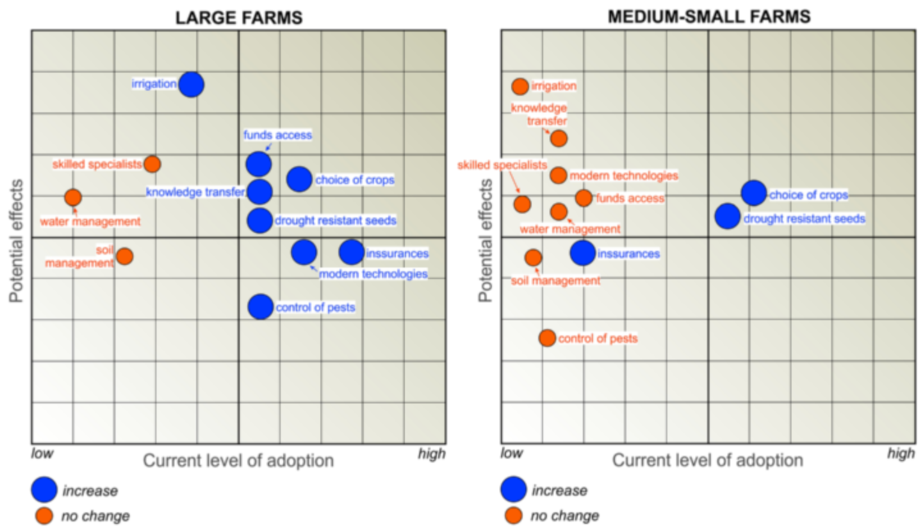

Fig. 15 Adaptation actions of different farms categories

irrigation infrastructure, skilled specialists etc.). The actions added in the bottom right are considered not necessarily effective or climate-driven, while those in the bottom left corner are neither particularly effective nor widespread (e.g. control of pests).

There is an important difference between the large farms that have a higher adaptive capacity and low subsistence farms (family-run farms), the most vulnerable category to both socio-economic and climate change. The low family-run farms have low access to funds, they take short-term decisions based on weather or experience of the previous agricultural year, have a low access to knowledge and collaboration with other farms, being typically owned by older farmers somehow resistant to change. This was seen also in the interaction with them, their interest in climate information being quite limited: "I don't believe in climate change", "I'm afraid to know how the climate will change", "I don't know what to do with what you're offering". Extreme events (e.g. intensive droughts that strongly affect the yield, as in summer 2012) change somehow the farmers' perception that something has changed with the climate. However, this might not be sufficient to the majority of farmers to take actions and decide for a long-term perspective, especially when a dry years is immediately followed by a good year (as 2013), when impressive yields have been obtained due to a favorable rain distribution in the area. However, higher crop yields did not necessarily trigger higher incomes, in the drier years the price the farmers obtain for the crops being higher. This aspect has been previously outlined in some studies conducted in Europe (Reidsma et al. 2007, 2010).

The majority of farmers are skeptical about long-term projections of climate change and they are interested in preventing the short-term impacts (e.g. drought, heat waves) and maximizing the profit and performance in their farming management, rather than mitigating long-term climate change-related risks. Yet, the survey shows that farmers are interested in a certain degree in receiving and accessing short-term climate change information to combat climate variability and natural resource degradation. This is still a difficult task when considering the uncertainty associated to RCM-GCM modeling, especially at short-time and local spatial scales. Thus, the long-terms financial investments should be supported or driven by the government, which should also take the lead to encourage actions and communicate them a clear message, based on research findings.

While most adaptation to climate change will ultimately be characterised by responses at the farm level, it is recognized that encouragement of response by policy affects the speed and extent of adoption, considering the relatively long time (10 to 20 years) of major adaptation measures to be implemented (Iglesias et al. 2010).

A great opportunity for the adaptation process might be the new CAP and the EAFDR (European Agricultural Fund for Rural Development) funding instruments for 2014–2020 that include payments for agri-environment and climate commitments, advisory-services for farmers, and actions that might guide the adaptation process.

Conclusions

The paper overviews the main local-to-regional challenges towards climate change adaptation in the Bărăgan Plain, the most important agricultural region of Romania in terms of cereals production, using a focused picture of farmers' perception on climate change and climate solutions to support farming activities. The region has distinct climatic and socio-economic features and is exposed to intense warming and prolonged droughts, mainly in summer, with negative impact on crop yields. The climate change projections for the 21st century provide evidence of a continuation of the observed warming and drying trend across the region, along with an increasing frequency of warm extremes and severe droughts. This underlines the necessity to consider and integrate climate-related aspects in the short, but also on medium and long-term development plans and to promote dedicated adaptation strategies and policies for traditional agricultural areas like the Bărăgan Region.

The paper addresses mainly to agriculture stakeholders (decision-makers), through providing a valuable basis for prioritisation of investments, developing plans and strategies at regional and local level, with the general aim to enhance the resilience and adaptive capacity of farmers to future climate and weather extreme events. Considering the socio-economic context and the technical development of the region, future climate change could bring an additional concern to the already existing socio-economic difficulties facing the region:

- The socio-economic and political factors in the post-communist period played an important role in the agriculture of the Bărăgan Plain: besides inadequate agricultural practices and intensification of extreme climatic events, the excessive fragmentation of land has a significant negative influence on agricultural land productivity;
- Bărăgan Plain's agriculture is still dominated by very small and small farms with little financial resources, owned by undertrained ageing people. Most individual farms practice subsistence agriculture, for the consumption of farmers themselves. This situation makes almost impossible the use of new production technologies, undertaking efficient management and marketing steps, which could contribute to crop yield increase and competitiveness of this sector. The opposite are agro-industrial farms holding over 50 % of total agricultural area, with important financial resources and who obtain high average yields per hectare for main crops, comparable with the UE countries;
- There is a low concern in the Romanian agricultural community regarding climate change, more concern being provided to the current political and economical factors.

The paper findings on projected climate changes and extreme weather events, as derived from the EU FP7 ECLISE project and extracted from the specialist literature, provide relevant key messages to agriculture stakeholders in terms of adaptation to climate change. The Bărăgan Plain region is projected to become visibly warmer and dryer over the 21st century, under all scenarios. All projections show marked seasonal temperature changes all over the region, with a pronounced warming in summer and winter and moderate in spring and autumn, both daytime and nighttime. Temperature changes support the decreasing trends of cold stress, the earlier spring onset and the advancing active crop growth. The changes in the upper tails of the future daily temperature distributions suggest an increasing frequency of daytime and nighttime extremes (e.g. tropical days/nights, heat waves), in all seasons, but mostly in summer. This climate behavior is likely to be detrimental to future crop growth, development and yields across the region, particularly for the maize crops, more sensitive to soil moisture deficits during the months of peak water demand (e.g. July-August interval). The warming signals of spring and summer are the most relevant in estimating the future crop vulnerability to heat stress, suggesting a potential augmentation of agro-climatic risk on cultivated plants. In response to the projected climate warming an increasing evapotranspiration trend is expected during the active crop vegetation season (April-October) by 2100, under all RCPs. The summer drying concern is likely to be significant all over the region, in June and July. Associating the projected warming to the changes in evapotranspiration and the timing of precipitation during early and mid-summer, the Bărăgan Plain region is expected to experience a notable increase of soil moisture deficit and need for surface irrigation supplements in summer, particularly under the high-emission scenario (RCP8.5).

There are some general remarks on the needs to compensate the future climate variability and change in order to enhance the adaptation:

- the necessity for further investments in the irrigation system: the relevance of irrigation for wheat and maize crops was demonstrated by increasing the current irrigated area up to the level of viable irrigated surfaces as a consequence of investments in the rehabilitation and modernization of the state owned irrigation system;
- use of a combination of sustainable land management measures (e.g. farming practices that increase rain-fed agriculture productivity, use of improved, drought adapted seeds, soil conservation measures etc.) along with intensified agriculture where it is most environmentally efficient could normally respond to productivity demands of the market, while minimizing environmental impacts;
- there is a need for more interdisciplinary studies also involving agronomists to develop stress resilient crops, adapted to temperature rising and higher variability of precipitation, but also to assess the

specific thresholds for each crops to different climate parameters at regional and even local level;
– there is a need for substantial economic analyses regarding effectiveness of on-farm and off-farm adaptation measures to climate change;
– while most adaption ultimately require a response at the local level (farms), there is a need to encourage and support farmers in the process, based on an adapted policy at national level. A strong focus of these should be given to specific local impacts and knowledge to built resilience for adaptation in each agro-climatic region;
– adaptation require strong communication, cooperation and interaction between different stakeholders groups, that should take responsible actions together (individual producers, government organizations, the agri-food industry and research institutions).

The current study aimed to provide a local example on understanding the current level of awareness and concern in terms of climate change of the main involved actors in this business, the farmers, which could be a support for policy to orient climate adaptation actions. However, more research is needed for a more detailed picture of different farms categories in Romania and support needs to be given to farming communities in terms of access to information, but also financial support and guidance to access funds, as well as the need to use more quantitative methods) to prioritize options for adaptation and assess farmers' perception.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
MS coordinated the study, participated in its design and drafted the paper, interpreted the climate data in relation to crops and wrote the adaptation part of the manuscript; EAP participated in framing the context for agriculture and landuse part and contributed to the farmers' perception study; DB elaborated the landuse part, participated in the design of the study and helped to draft the manuscript; DM and CD processed and analysed the climate data, as well as organised and wrote the climate chapter of the manuscript; GK and IG contributed to processing the climate data and GIS analysis. All authors read and approved the final manuscript.

Authors' information
MS is a researcher, with main interest in environmental geography, the human impact on the environment and study of man-environment relationships; EAP is a researcher interested in land use changes and dynamics; DB is a senior researcher having as scientific background the landform processes and land use changes; DM and CD are climatologists; GK is interested in natural protected areas, landuse and GIS and IG is interested in environmental geography and climate change impacts in metropolitan areas.

Acknowledgements
This study was elaborated in the framework of FP7 ECLISE project "Enabling CLimate Information Services for Europe", no. 265240 (2011–2014), coordinated by the KNMI (Royal Netherlands Meteorological Institute). Data on climate modelling have been provided by one of the partner in the projects, Swedish Meteorological and Hydrological Institute (SMHI).
Responsible editor: Asrar Ghassem

Received: 11 November 2014 Accepted: 19 June 2015
Published online: 02 July 2015

References

African Technology Policy Studies Network (ATPS) (2013) Farmers' Perception and Adaptive Capacity to Climate Change and Variability in the Upper Catchment of Blue Nile, Ethiopia. [Bewket Amdu, Azemeraw Ayehu, Andent Deressa], ATPS Working Paper 77; Nairobi, Kenya.

Balteanu D, Popescu M, EA U (P) (2004) Land Tenure and Land Relations in Romania. In: International Encyclopedia of Land Tenure and Land Relations in the World, IVth edn. Edwin Mellen Press, UK, pp 357–453

Balteanu D, Popescu M, EA U (P) (2005) Land use in Romania under the Transition to the Market Economy. Analele Universitatii Bucuresti LIV:99–112

Below T, Artner A, Sieber R, Sieber S (2010) Micro-level practices to adapt to climate change for African small-scale farmers. A review of selected literature. IFPRI Discussion Paper 00953; International Food Policy Research Institute, Washington, D.C.

Below T, Mutabazi K, Kirschke D, Franke C, Sieber S, Sieber R, Tscherning K (2012) Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Glob Environ Change; 22(1), http://dx.doi.org/10.1016/j.gloenvcha.2011.11.012.

Birsan MV, Dumitrescu A (2014) Snow variability in Romania in connection to large-scale atmospheric circulation. Int J Climatol 34:134–144

Bojariu R, Birsan MV, Cica R, Velea L, Burcea S, Dumitrescu A, Dascalu SI, Gothard M, Dobrinescu A, Carburaru F, Marin L (2015) Schimbarile climatice - de la bazele fizice la riscuri si adaptare. Printech, Bucuresti, p 200

Busuioc A, Caian M, Cheval S, Bojariu R, Boroneant C, Baciu M, Dumitrescu A (2010) Variabilitatea si schimbarea climei în României. Pro Universitaria, Bucuresti, p 226

Busuioc A, Dobrinescu A, Birsan M-V, Dumitrescu A, Orzana A (2014) Spatial and temporal variability of climate extremes in Romania and associated large-scale mechanisms. Int J Climat 35:1278–1300

Croitoru AE, Piticar A (2013) Changes in daily extreme temperatures in the extra-Carpathians regions of Romania. Int J Climat 33:1987–2001

Cheval S, Busuioc A, Dumitrescu A, Birsan MV (2014) Spatiotemporal variability of meteorological drought in Romania using the standardized precipitation index (SPI). Clim Res 60:235–248

Cuculeanu V, Marica A, Simota C (1999) Climate change impact on agricultural crops and adaptation options in Romania. Clim Res 12:153–160

Defra (2013) Economics of Climate Resilience Agriculture and Forestry Theme: Agriculture. In: Frontier Economics Ltd. Irbaris LLP, London

Falloon P, Betts R (2010) Climate impacts on European agriculture and water management in the context of adaptation and mitigation – the importance of and integrated approach. Sci Total Environ 408:5667–5687

Gbetibouo GA (2008) Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability. The Case of the Limpopo Basin, South Africa. IFPRI Research Brief 15–8. [www.ifpri.org]

Heinrich G, Gobiet A (2012) The future of dry and wet spells in Europe: a comprehensive study based on the ENSEMBLES regional climate models. Int J Climatol 32:1951–1970

Idrisa YL, Ogunbameru BO, Ibrahim AA, Bawa DB (2012) Analysis of awareness and adapttaion to climate change among farmers in the Sahel savannah agro-ecological zone of Borno State, Nigeria. Br J Enviro Clim Change 2(2):216–226

Iglesias A, Avis K, Benzie M, Fisher P, Harley M, Hodgson N, Horrocks L, Moneo M, Webb J (2007) Adaptation to climate change in the agricultural sector. European Commission DG AGRI, AGRI/2006-G4-05, ED05334 - Issue 1; AEA Energy & Environment [http://ec.europa.eu/agriculture/external-studies/2007/adaptation-climate-change/full-text_en.pdf]

Iglesias A, Garrote L, Quiroga S, Moneo M (2009) Impacts of climate change in agriculture in Europe. PESETA-Agriculture study. European Commission, Joint Research Centre, Institute for Prospective Technological Studies, EUR 24107 EN; Office for Official Publications of the European Communities, Luxembourg.

Iglesias A, Garrote L, Quiroga S (2010) Deliverable 2B3: Agriculture – The Impacts and Economic Costs of Climate Change in Agriculture and the Costs and

Benefits of Adaptation. FP7Climate Cost Project-Full Costs of Climate Change [http://climatecost.cc/images/Deliverable_2B.2.pdf]
Kjellström E (2014) Future changes in the European climate as deduced from an ensemble of CORDEX simulations. Deliverable 2.3 report. FP7 ECLISE project (http://www.eclise-project.eu/content/mm_files/do_825/ECLISE%20D2.3.pdf).
MADR (2014) Codes of good agricultural practices in the context of current and expected climate change. Ministry of Agriculture and Rural Development, National Meteorological Admnistration, p 171
Mateescu E, Alexandru D (2010) Management recommendations and options to improve crop systems and yields on south-east Romania in the context of regional climate change scenarios over 2020–2050, A. Scientific Papers, UASVM Bucharest, p LIII
Mateescu E, Marica A, Oprisescu R (2003) Frecventa si arealul seceti agricole în zona de sud si sud-est a României. Simpozionul Seceta - Masuri pentru diminuarea efectelor asupra culturilor de câmp. Bucuresti, AGRIS
Menapace L, Colson G, Raffaeli R (2014) Farmers' Climate Change Risk Perceptions: An Application of the Exchangeability Method. EAAE 2014 Congress 'Agri-Food and Rural Innovations for Healthier Societies'August 26 to 29, 2014, Ljubljana, Slovenia
National Meteorological Administration (2014) Adaptation measures in Romanian agriculture. SEE Project-OrientGate: A structured network for integration of climate knowledge into policy and territorial planning. NMA, Bucharest
Neacşa O, Berbecel O (1979). Climatologie si Agrometeorologie. Editura Didactica si Pedagogica, Bucuresti.
Nhemachena C, Hassan R (2007) Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI Discussion Paper 00714; International Food Policy Research Institute, Washington, D.C.
Nyanga P, Johnsen F, Aune J, Kalinda T (2011) Smallholder farmers' perception of climate change and conservation agriculture: Evidence from Zambia. J Sust Develop 4(4):73–85
Ogalleh SA, Vogl CR, Eitzinger J, Hauser M (2012) Local Perceptions and Responses to Climate Change and Variability: The Case of Laikipia District, Kenya. Sustainab 4:3302–3325
Okonya J, Syndikus K, Kroschel J (2013) Farmers' perception of and coping strategies to climate change: Evidence from six agro-ecological zones of Uganda. J Agr Sci 5(8):252–263
Olesen JE, Bindi M (2002) Consequences of climate change for European agricultural productivity, land use and policy. Eur J Agron 16:239–262
Olesen JE, Trnka M, Kersebaum KC, Skjelvag AO, Seguin B, Peltonen-Sainio P, Rossi F, Kozyra J, Micale F (2011) Impacts and adaptation of European crop production systems to climate change. Europ J Agron 34:96–112
Parry M, Canziani O, Palutikof J, van der Linden P, Hanson C (eds) (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Cambridge University Press, New York
Popescu M (2001) The lessons of transition. Agriculture 1990–2000. Expert, Bucuresti
Popovici EA (2008) Factorii principali ai schimbarii utilizarii terenurilor în România în perioada post-socialista. Revista geografica XIV-XV:123–128
Popovici EA (2010) Historical land use change in the Cotmeana Piedmont. Brno, Czech Republic, Time-space changes of the regional and landscape structures, pp 108–115
Popovici EA, Balteanu D, Kucsicsa G (2013) Assessment of changes in land-use and land-cover pattern in Romania using Corine Land Cover Database. Carpathian Journal of Earth and Environmental Sciences, XIII, Baia Mare 4:195–208
Reidsma P, Ewert F, Lansink AO (2007) Analysis of farm performance in Europe under different climatic and management conditions to improve understanding of adaptive capacity. Clim Change 84:403–422
Reidsma P, Ewert F, Lansink AO, Leemans R (2010) Adaptation to climate change and climate variability in European agriculture: the importance of farm level responses. Eur J Agron 32:91–102
Sandu I, Mateescu E, Vatamanu V (2010) Schimbari climatice în România si efectele asupra agriculturii. Craiova, SITECH
Wiles E: Farmers' perception of climate change and climate solutions. Global Sustainability Institute 2012, Briefing Note 1.