ORIENTGATE WP 4 REPORT

Thematic Centre

"Forest & Agriculture"

A structured network for integration of climate knowledge into policy and territorial planning

DELIVERABLE INFORMATION	
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Activity:	4.1 Thematic centre set up
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TABLE OF CONTENTS

1. Introduction

The Thematic Centre of WP 4 focuses on the assessment of agro- and silvicultural adaptation issues of management and policy in the context of climate change and its impact.

By means of **two Pilot Studies**, one focusing on climate change adaptation in forest of the Austrian Alps (LTER Zöbelboden), the other on agricultural adaptation in Romania (Covasna and Caracal agricultural area), recommendations for a more sustainable land use which takes into account climate change are derived. Interactions with other work packages, especially WP 3 and 7, for data and knowledge exchange are obvious.

For each Pilot area, adaptation strategies and guidelines are elaborated in close cooperation with important regional stakeholder so that a practical implementation can be guaranteed. These are the Forest Service of Upper Austria in Pilot 1 and the Environmental Protection Agency of Covasna in Pilot 2. Built on this expertise, jointly prepared training courses in the Pilot areas offered forest landowners respectively managers and farmers an opportunity to become acquainted with goal oriented silvicultural and agricultural measures necessary for the adaptation to climate change. For the international workshop in each Project area a broader audience – also beyond the national border - was invited to effectively improve capacity building and awareness raising.

The Pilot Study regions represent characteristic areas of the respective countries: on the one hand the forest types of LTER Zöbelboden are typical for the Northern Limestone Alps in Austria. On the other hand, the agricultural areas of Covasna County, situated in the central part and Caracal County in the South, cover the typical range of agroclimatic conditions of Romania. The adaptation to climate change through better harmonized management on forest ecosystem functions as well as crop system is indispensable. First of all the existing knowledge on climate change effects, adaptation strategies and relevant policies were reviewed in both areas. By means of modelling and scenario development - taking into consideration data from WP 3 - different forest ecosystems respectively agricultural sites were assessed as to their vulnerability to climate change like water scarcity, drought or other extreme weather events. From these results optimal management solutions for forest and agriculture were derived and existing policies as well as economic constraints were evaluated.

2. State of the Art

2.1 Forestry

Almost 50 % of Austria's drinking water resources are originating from the karst areas of the Northern and Southern Limestone Alps. There, the montane and subalpine life belt is dominated by forests. The assessment of potential impacts of climate change as well as forest management on the quality and quantity of drinking water resources is therefore of pivotal importance.

Numerous studies showed that stable and resilient forest stands are indispensable for a high drinking water quality and quantity under current climate conditions as well as under climate change. However, the establishment of homogenous Norway spruce plantations on various different forest sites of the Limestone Alps in Austria causes instable forest stands, which are highly vulnerable to wind throw, bark beetle infestations or snow damages. This existing sensitivity will most probable increase under climate change since Norway spruce is not well adapted to a warmer and drier climate.

Although the protection and monitoring of water bodies is satisfactorily defined in the Austrian Water Act there are still some gaps in the practical application of protective measures. As the province authorities issue the decrees for Drinking Water Protection Areas the “quality” differs. Additionally, the limitations of clear cuts – potentially causing contamination of water in the Austrian Federal Forest Act are not strong enough for ensuring source water protection.

2.2 Agriculture

In Romania, from a total agricultural land of 14.7 million ha, 63.9% are arable lands – approximately 9.4 million ha - and the rest are represented by pastures, vineyards and orchards. Frequent and prolonged drought affects approximately 7.1 million ha, which represent 48% from the total agricultural land (2011). The South, South-East and East regions are the most droughty areas (<600 m3/hectare water – extreme and severe pedological drought). During the extremely droughty years average yields of various crops represent only 35-60 percent of the potential yields.

The 2001-2012 interval was particularly droughty, the mean yield by ha decreased by more than 50-60%. According to the Ministry of Agriculture and Rural Development data, the excessively droughty agricultural years 2011-2012 strongly impacted about 5.9 million hectares, the level of losses varying over different areas and crops such as: corn, wheat, barley, sunflower, and rape.

Drought periods and heat waves are of particular interest, the main agricultural crops in Romania, winter wheat and maize, being the most affected crops by the occurrence of these two phenomena. In this context, the adaptation of crop species to limitative conditions can be mainly based on scientific approach. Every solution aimed to support the actions for climate risk adaptation policies in agriculture should include the complete range of known measures (agro-technical, cultural, irrigation etc.) as well as dedicated technical practices to locate and confine every extreme weather phenomenon in order to avoid aggravated consequences (Mateescu et al, 2010, 2012).

In July 2013, the Romanian Government adopted the Governmental Decision no. 529/2013 on the National Climate Change Strategy (2013-2020). The National Climate Change Strategy (2013-2020) establishes the post Kyoto objectives, targets and actions for two main components, respectively the reduction in the concentration of greenhouse gases (Mitigation) and the adaptation to climate change (Adaptation). One of the main sectors vulnerable to CC refers to the agriculture. According the integration of the adaptation plans in the sectoral strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change (including drought and other extreme events). In other words, this gives support to develop the scientific results based on dedicated pilot studies.

3. Pilot studies

3.1 Pilot Study 1

3.1.1 Objectives

Nearly 22 % (about 18.000 km^2) of Austria’s total area consist of carbonate rocks. About 15 % of the whole territory is karstified (Trimmel, 1998). In classic definition karst areas consist of soluble rocks (e.g. limestone, dolomite, gypsum, anhydrite, halite etc.) und they are characterized by largely absence of surface drainage. Karst catchments provide half of the water supply for the Austrian population. Due to the often short residence time, the filtering and transformation capacity of vegetation and soil are very important for the quality of karst spring water. Large karst areas are located in the Limestone Alps, where in the montane and subalpine life belt forests are the dominating land cover. Forest management and climate change directly or indirectly exert impacts on water supply, both in terms of quality and quantity. In order to safeguard water resources, forest management should focus on maintaining a continuous forest vegetation cover, on minimizing disturbance, and on the prevention of soil degradation.

The Environment Agency Austria runs a long-term ecosystem research site in the “Kalkalpen” national park (LTER Zöbelboden, N 47°50'30", E 90 14°26'30"). The forest types of LTER Zöbelboden are representing major forest types of the Northern Limestone Alps in Austria, in particular mixed spruce-fir-beech forests. The core of Pilot study 1 was the development of model based scenarios of climate change effects on water runoff amount and quality. The scenario results were discussed with local authorities, forest managers, and policy makers and optimal adaptation strategies for forest management were defined.

3.1.2 Methodology

A forest ecosystem model (Landscape DNDC, Haas et al. 2013) was used together with a hydrological catchment model (VarKarst, Hartmann et al. 2012) to study effects of climate change and management on runoff dynamics and the water quality. The models were calibrated and validated with long-term measurements of forest growth, soil, soil water and runoff water. In addition, high resolution rain event sampling provided information on event-driven pollutant transport.

Future climate projections were derived for A1B-, A2- and B1-scenarios for three time slices: 2025-2035, 2045-2055 and 2085-2095. We used downscaling scenarios for Austria reclip:century (http://reclip.ait.ac.at/reclip_century/) together with the weather generator

ClimGen (Stöckle et al. 1999). The latter was calibrated with meteorological data measured at the site. Three forest management interventions were defined: low (continuous forest cover spruce-beech management), medium (spruce shelterwood management, natural regeneration) and high intervention (spruce clear-cut management, planting).

A number of impact, sensitivity and adaptive capacity indicators were used for the vulnerability assessment. The potential impact is described with a suite of climate indicators such as total precipitation in wet days (PRCPTOT), precipitation days with ≥ 50 mm (R50mm), annual accumulated snow water equivalent (SWE), and consecutive dry days (CDD).

In order to describe the sensitivity of functions forests exert on drinking water protection in an operative way, the water protection functionality index (WPFI) was applied. The WPFI was calculated for the current situation and for L-DNDC model simulations.

For characterizing the adaptive capacity of a certain forest stand the arising financial compensation, as it is developed in the framework of the EU Rural Development Regulation 2014+ (new program "Forest for Water" of BMLFUW) can be used. This measure accounts for additional expenses as a result of adaptive forest management for water protection.

3.1.3 Stakeholder involvement

The Forest Service of Upper Austria is responsible for forest management planning in the entire province and the local foresters implement management plans at the very local scale. Both parties were involved in model building, the definition of concrete forest management scenarios and checked the plausibility of the model results. Jointly prepared training courses in the Pilot areas offered forest landowners respectively managers and farmers an opportunity to discuss climate change adaptation options. Since we focused on forest-water relations, experts and local authorities in the water sector also participated in the discussions. Further outreach took place through an international workshop.

3.1.4 Results

Forests play an important role as they stabilize the fragile soil and humus horizons which dominate the Northern Limestone Alps and, when managed appropriately, keep water pollution at a low level. A paradigm among forest managers is that forests should be close to the tree species diversity of the potential natural forest community and a continuous cover forest management system should be applied in order to guarantee a long-lasting and sustainable protection of the drinking water resources in karst areas. The high diversity of tree species according to the natural forest communities provides a robust basis for the stability and resilience of forest stands, both under current climate and also under expected climate change

(Koeck and Hochbichler 2011a, Zimmermann et al. 2013). In the past and even under current forest management, the establishment of homogeneous Norway spruce (*Picea abies* Karst.) plantations created forest stands, which are vulnerable to wind throw, bark beetle infestations or snow damages and therefore accelerated erosion rates and collateral turbidity impacting drinking water supply. These forests are managed with clear-cuts or shelterwood cuts in order to maximize economic return. When adapting the management in water protected areas of the Northern Limestone Alps, forest management should follow Best Practices for drinking water protected areas (Koeck and Hochbichler 2011b). The main focus is on the prevention of clear-cut management and the subsequent establishment of a continuous cover forest management system. Also the transformation of Norway spruce plantations into forests according to the potential natural vegetation which mostly are mixed forests with a dominance of European beech (*Fagus sylvatica* L.) is of crucial importance. Additionally, management should minimize felling of a larger proportion of trees by the application of a maximal timber yield percentage since contamination of water with nitrate and other elements (e.g. increased turbidity and microbiological contamination) may occur and soil organic matter may erode.

Nitrogen deposition acts in addition to climate change

At present, nitrogen pollution seems to be the most widespread threat for groundwater in the Northern hemisphere (Sutton et al. 2011). Though contamination of drinking water with nitrate is usually attributed to fertilization of crops and grassland, an excess input of atmospheric nitrogen from industry, traffic and agriculture into forests has caused reasonable nitrate losses (Kiese et al. 2011). Although monitoring results show that nitrate concentrations in karstic springs in Austria are rather low (BMLFUW & Umweltbundesamt, 2014), the Northern Limestone Alps are areas of particularly high nitrogen deposition so that high loads of nitrate reach the groundwater (Jost et al. 2011). However, combined effects with climate change can be expected because the nitrogen cycle is tightly linked to climate and to any disturbances that disrupt the tree canopy such as clear-cuts, wind-throw and bark beetle infestations. Expected longer periods of dryness in summer time will intensify these problems.

Warmer summers and wetter winters

Climate change in the Northern Limestone Alps will exert warmer temperatures and a precipitation change, which is rather uncertain however, may increase in winter in form of more rain and decrease in summer (Figure 1).

	Min/**Mean**/Max **Summer**	Min/**Mean**/Max **Winter**
T baseline	+15.8	-0.1
T 2030	+0.1 / **+0.7** / +1.7	-0.7 / **+0.6** / +1.8
T 2060	+1.3 / **+2.0** / +2.8	+1.0 / **+2.0** / +3.2
T 2090	+2.1 / **+3.4** / +4.7	+2.1 / **+3.3** / +4.0
P baseline	495	321
P 2030	+8 / **-1** / -7	-9 / **+4** / +21
P 2060	0 / **-12** / -18	+3 / **+7** / +9
P 2090	-3 / **-11** / -22	-4 / **+5** / +23

Figure 1: *Expected seasonal climate change as compared to the current climate (baseline 1990-2010). Mean current climate is given in the first row. Minimum, mean and maximum temperature change (T in °C) and precipitation change (P in %) at LTER Zöbelboden in B1, A1B and A2 Scenarios, which were derived from two downscaled Global Circulation Models (ECHAM5 and HADCM3; http://reclip.ait.ac.at/reclip_century/).*

Less karst water in summer and more in winter and spring

Runoff may decrease in the summer season by 10 to 50 % and, depending on the scenario, will increase in winter by a maximum of 40 % (Figure 2). The latter is not only an effect of increasing precipitation but also snowmelt which occurs already during winter or earlier in spring.

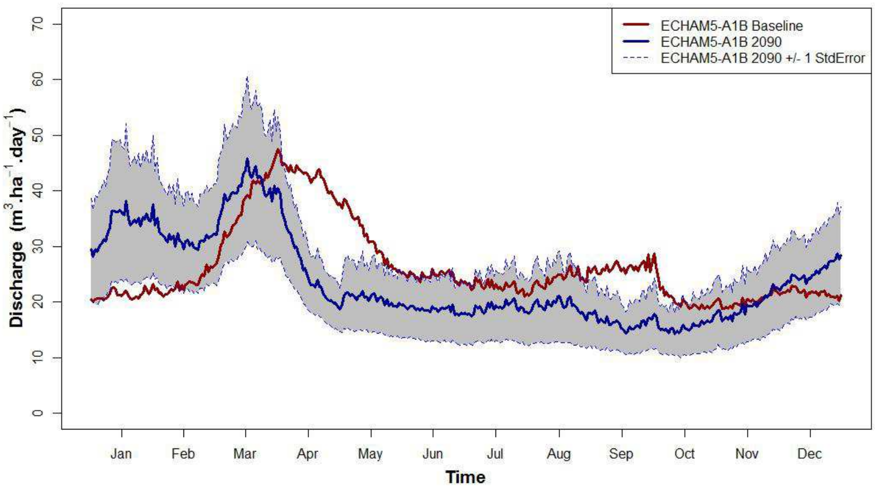


Figure 2: *Expected seasonal runoff distribution in the year 2090 (A1B Scenario, ECHAM5) as compared to the baseline (1990 to 2010).*

Inferring climate change effects without considering ecosystem changes is difficult

Since nitrate leaching from forest soils is strongly driven by the amount of water infiltrating the soils (Jost et al. 2011), higher nitrate losses may occur in winter and in early spring whereas during summer nitrate may decrease under expected climate change. However, these predictions only hold if no larger forest disturbances – natural or by management – occur and if we exclude effects of climate change to tree growth and soil processes such as nitrogen turnover. These effects will be discussed in the next chapter.

Forest management determines the contamination of drinking water with nitrate

Trees take up nitrogen and lose nitrogen via above and belowground litter fall. Furthermore, trees control the microclimate of soils, which, in turn, determines nitrogen turnover. Tree harvest hence exerts a strong control to nitrogen cycling but also to the loss or accumulation of soil organic matter. Forest management interventions may cause severe nutrient and humus losses from the soils, which may lead to a partial loss of soil functions (Katzensteiner 2003). Clear-cut disrupts the nutrient cycle so that nitrate is mobilized and washed out from the soils. Typically these effects are strongest during only a few years after the event (Katzensteiner 2003; Weis et al. 2006). However, reasonable nitrate leaching occurs during this phase and may contaminate the groundwater. The L-DNDC model showed that seepage water nitrate concentrations reached > 80 mg/l after a total clear-cut whereas without disturbances nitrate concentration is mainly < 20 mg/l.

Tree species choice also influences nitrate leaching. Coniferous trees such as Norway spruce intercept more nitrogen from the atmosphere and these forests show higher nitrate concentration in the seepage as compared to mixed or deciduous forests (Jost et al. 2011). Forest management concepts like single tree or group selection cuts, or continuous cover forestry and mixed forest stands are an option to prevent clear-cut phases and its negative consequences.

Climate change has both positive and negative effects to water quality

Climate changes have both positive and negative effects to nitrate loss from managed forests. Peak nitrate concentrations in the seepage during clear-cut and thinning increased under all scenarios. Also during understorey reinitiation in clear-cut and shelterwood systems nitrate leaching was higher as compared to the current climate. This is due to a retarded understorey tree development as a consequence of increasing water stress in summer and nutrient deficiency (see e.g. Christophel et al. 2013; Pröll et al. submitted). Nitrogen is therefore taken up by trees less efficiently, transpiration is lower and higher infiltration enhances the transport of nitrate below the rooting zone and subsequently into the groundwater. At the altitude of the study area of 950 m a.s.l. a warmer climate will be beneficiary for the growth of Norway spruce (Hartl-Meier et al. 2014). In L-DNDC simulations, the enhanced growth of spruce trees under the climate scenarios outweighed the stem wood biomass accumulation under the current climate and, consequently, nitrate loads to the groundwater were lower (Figure 3).

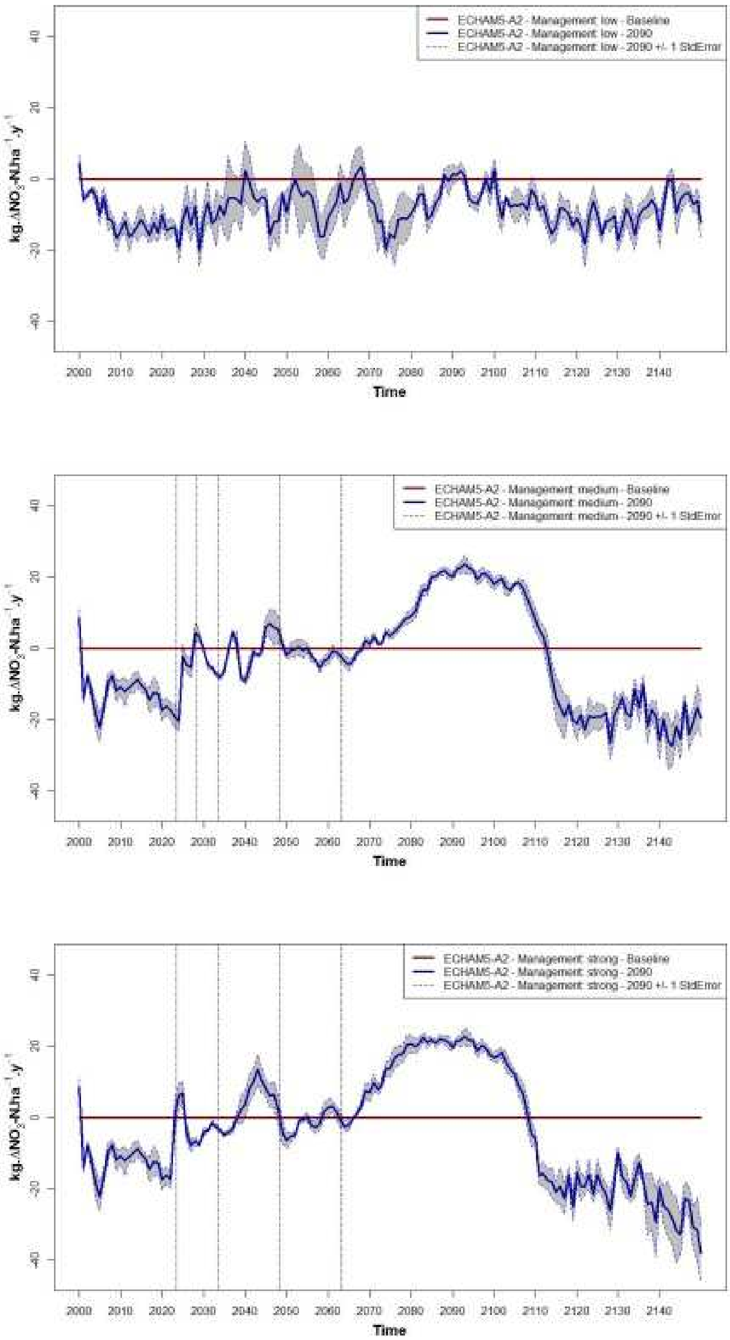


Figure 3: *Climate effects to nitrate leaching from a managed Norway spruce forest at LTER Zöbelboden during a rotation period of 120 years. Difference of nitrate leaching in seepage water (derived from the L-DNDC model) between the current climate (red horizontal line) and an ECHAM5-A2 scenario by the year 2090 (blue line with interannual variation in grey shade). Left to right: continuous forest cover management, shelterwood-cut management (vertical lines: 50% felling, total felling, three thinnings of new tree generation), clear-cut management (vertical lines: 100 % clear-cut, three thinnings of new tree generation).*

Climate driven forest disturbances may have a strong effect on water quality

Indirect effects of climate change on forest ecosystems, such as wildfire, wind-throw and insect outbreaks, may be more severe than direct effects because soil organic matter and related pollutant losses are severe after disturbance. Seidl et al. (2011) show that climate change was as important as forest management for the increase in forest area burnt, wind and bark beetle damage in Europe during the last decades. Climate change and forest disturbances owing to insect infestations are closely correlated. Wind-throw and biotic disturbances increase runoff peaks, soil erosion and nitrate leaching. Moreover, long-lasting soil organic matter degradation may occur after forest disturbances, particular in the Northern Limestone Alps with their shallow soils.

The effects of changes in climate extremes

Though predictions as to whether or not extreme climate events will change are still uncertain, the related effects should be addressed in assessment studies but are still extremely challenging. Pollutant transport in karst areas is often driven by strong runoff events when potential pollutants spoil the drinking water.

The use of climate indicators

The used climate indicators refer to the infiltration of precipitation in the soil and subsequent drainage through the karst mountain. Since these are the main processes driving pollution in karst areas, total annual precipitation (PRCTOT) is a useful indicator. In particular snow accumulation (SWE) is tightly linked to elevated pollutants loss to the drinking water in spring and is also highly sensitive to climate changes. On the other hand, indicators reflecting changes in extreme events (R50mm, CDD) are less useful since current models are highly uncertain with regard to such changes. Forest sensitivity indicators, such as the water protection functionality index (WPFI) play an important role due to the high impact of forest management practices to forest functions (e.g. drinking water effects).

3.2 Pilot Study 2

3.2.1 Objectives

The Pilot Study 2 has as main objective the identification of measures to adapt crops to climate change in two different areas in Romania (Caracal in South of the country and Covasna in the centre). Secondly, the Pilot is creating direct linkages between the researchers and the practitioners (farmers). It is seen as an opportunity by the scientific community to share findings and learn from the practical measures and knowledge in two different sites selected based on historical climatic data how show that these areas where frequently affected especially by drought and periodically by other extreme events (heat waves, heavy rainfall, wind storms, etc). Also, the need to identify critical issues related to climate adaptation was crucial. Another important argument was the structure of crops and the need to find different adaptation options for farmers in the context of current and future climate changes. In these two selected areas the agriculture is traditionally developed by farmers in order to get sustainable production in every year and to provide better crop management systems. For this reason the linkage between scientific community and practitioners must be correlated with the need to put in practice the scientific climate knowledge according with the necessity to improve the technology and resource management in terms of relation of the crops-water-soil.

3.2.2 Methodology

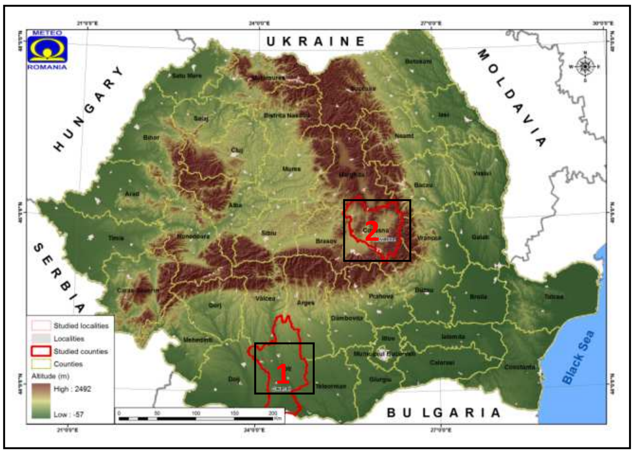
Two Romanian partners were leading the work: National Meteorological Administration (NMA) as responsible for implementing of Pilot Study 2 and Environmental Protection Agency of Covasna (EPA Covasna) as contributor to the implementation process. In order to analyze the historical data (1961-2010) meteo- and agrometeorological information from two weather stations has been used considered as representative of these two test areas: Caracal weather station and Tg. Secuiesc station from Covasna area. To perform the study different cropping systems (winter wheat and maize) were selected and the CERES models in combination with the climatic predictions [RegCMs/SRES A1B climatic predictions at a very fine resolution (10 km) over 2021-2050 vs. 1961-1990 obtained in FP7 project ENSEMBLES and ensemble mean from CMIP5 experiments - RCP 2.6 and RCP 8.5 scenarios for 2021-2050 period vs. 1961-2000 interpolated at station point]. Also, the DSSAT model was applied to evaluate the potential impact of weather patterns on the productivity of selected crops. Different technological sequences were analyzed by alternative simulations of crop management practices: changes in sowing date, altered genetic coefficients (P1V and P1D) for genotype selection and crop irrigation needs during the vegetation season. Crop model were developed using observed field data (2001-2014) from both sites and were then used to assess climate change impacts. Climate conditions are also monitored through the testing stages of Pilot Study. The EPA Covasna acquired weather station and computer software to gather and analyze daily meteorological data of Tg. Secuiesc area. Consequently local data, for example on soil moisture, water demand and rainfalls, air temperature, and phenological data were recorded in regional geographic information system (GIS) maps. Additionally, the NMA used satellite-derived indicators for the evaluation of crops vegetation state in the interest zones of the Pilot Study 2 such as: NDVI, NDWI, NDDI, ET and LAI. In order to highlight the land cover / use categories of the test area an unsupervised image classification for the Pleiadés images at different dates (10 May 2013, 03 July 2013 and 26 August 2013) was applied. By regrouping the classes, a map with 6 main land cover / use classes (water, winter crops, summer crops, pastures, barren soil, urban), was finally obtained. A set of dedicated indicators (1961-2010) was used for the risk assessment like: Standardized Precipitation Index 3 months (SPI3), Soil Moisture reserve – Rf (SM), Heat stress (HT), Aridity Index (AI), total precipitation in wet days (PRCPTOT), and consecutive dry days (CDD). Also, satellite derived indices such as: Normalized Difference Vegetation Index (NDVI), Normalized Difference Drought Index (NDDI), Normalized Difference Water Index (NDWI) was applied.

3.2.3 Stakeholder involvement

Local municipalities in Caracal and Covasna were involved during the whole project-period. They provided technical support for the implementation of results in order to develop drought-risk management tool and adaptation measures and contacts with local farmers for testing techniques and implementing results. Also, the Agricultural Research-Development Station of Caracal will use the findings of the pilot results to develop own research on obtaining varieties and hybrids with high adaptability to local climate and soil conditions. To ensure transfer of knowledge 3 thematic seminars and 3 scientific meetings among *OrientGate* partners and Romanian stakeholders were planned: local, regional and national authorities in the sectors of agriculture, farmers, water, environment, emergency response, education and public administration; urban planners; academic institutions; and representatives from civil society. We can say so that project results are useful to a better understanding of the climate change impact and adaptation actions as a good example at regional and local level helping the authorities to implement measures and actions resulted from the Study Pilot 2.

3.2.4 Results

The area of interest of the Pilot Study 2 is represented in Figure 4 indicating the 2 test areas in the South (Olt County / Caracal area) and Center (Covasna County / Tg. Secuiesc area) of Romania.

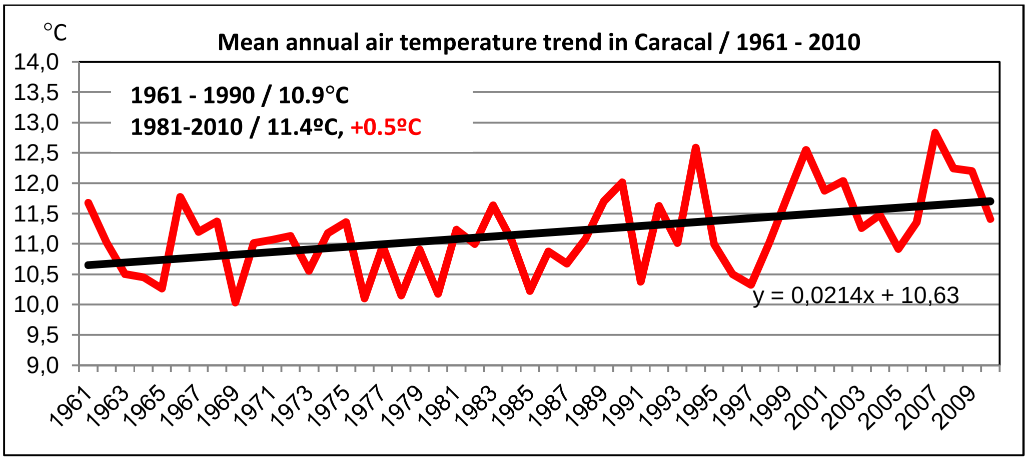


1. Olt County (Caracal area) is located in the south part of the Oltenia region, in a vulnerable area to extreme conditions (drought/water scarcity).
2.Covasna County (Tg. Secuiesc area) is located in the south-eastern part of the Transilvania region, in a vulnerable area to extreme events (drought/floods).

Figure 4: *The target area of Pilot Study 2*

Observed changes and future scenarios on climate conditions

In Caracal area, the mean annual air temperature rose by 0,5°C and in Tg. Secuiesc area by 0.4°C in the 1981-2010 period in comparison with climatic period of reference (1961-1990), Figure 5. As regards precipitation, a trend of decreasing in the annual precipitation amounts in Caracal area (526.1 mm/1981-2010 vs. 565.9/1961-1990) and a slight increase in the Tg. Secuiesc area (513.1 mm/1981-2010 vs. 500.8 mm/1961-1990) could be observed.



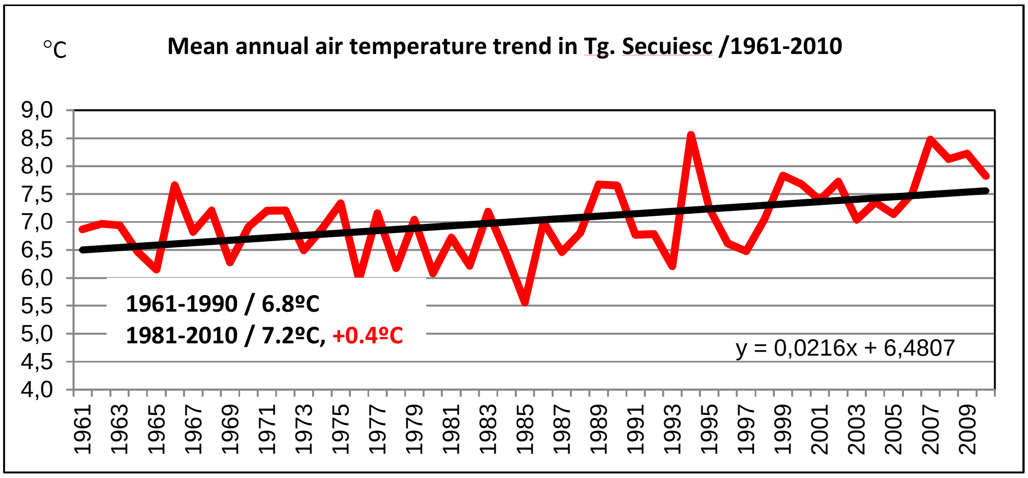


Figure 5: *Air temperature trend in Pilot Study 2 agricultural area*

The frequency of droughty/rainy years recorded in the two test areas is shown in Figure 6. Notice that in both of these areas dominated by the droughty years which recommend specific measures for the adaptation of agricultural technologies to water deficit.

CARACAL / 1961 – 2010	TG. SECUIESC / 1961 – 2010
⇒ 2 years / 4.0% - excessively droughty years (<350.0 mm/year) ⇒ 9 years/18,0%-dry years (351.0–450.0 mm/year) ⇒ 25 years/50,0% - moderate dry years (451.0– 600.0 mm/year) **TOTAl years - 36 years / 72,0% excessively droughty, dry and moderate dry years** ⇒ 6 years/12,0%-optimal years (601.0– 700.0 mm/year) ⇒ 8 years/16,0% - excessive rainy years (701.0 – 800.0 mm/year)	- ⇒ 14 years/28,0%-dry years (351.0 – 450.0 mm/year) ⇒ 28 years/56,0% - moderate dry years (451.0– 600.0 mm/year) **TOTAl years - 42 years / 84,0% dry and moderate dry years** ⇒ 6 years/12,0%-optimal years (601.0–700.0 mm/year) ⇒ 2 years / 4,0% - excessive rainy years (701.0 – 800.0 mm/year)

Figure 6: *The frequency of droughty/rainy years in Pilot Study 2 agricultural area*

Since 1901 until now, in the Pilot Study 2 agricultural area in every decade one to five extremely droughty/rainy years and an increasing number of droughts being more and more apparent after 1981 can be seen (Figure 7 and Figure 8).

DECADE	CARACAL area / OLT County XX-TH CENTURY	
	EXTREMELY DROUGHTY YEARS	EXTREMELY RAINY YEARS
1961-1970	**1961-1962, 1967-1968 / 2 years**	**1968-1969, 1969-1970 / 2 years**
1971-1980	**1973-1974, 1975-1976 / 2 years**	**1972-1973, 1978-1979 / 2 years**
1981-1990	**1982-1983, 1984-1985, 1986-1987, 1989-1990 / 4 years**	-
1991-2000	**1992-1993, 1994-1995,1995-1996, 1999-2000 / 4 years**	**1990-1991 / 1 year**
	XXI-ST CENTURY	
2001-2010	**2000-2001, 2001-2002, 2002-2003, 2006-2007, 2008-2009 / 5 years**	**2004-2005, 2005-2006, 2009-2010 / 3 years**
2011-2020	**2011-2012, ………..**	**……….**

Figure 7: *The frequency of droughty/rainy years in Caracal agricultural area*

DECADE	TG. SECUIESC area / COVASNA County XX-TH CENTURY	
	EXTREMELY DROUGHTY YEARS	EXTREMELY RAINY YEARS
1961-1970	**1961-1962, 1962-1963, 1963-1964 / 3 years**	**1969-1970 / 1 year**
1971-1980	**1973-1974, 1975-1976 / 2 years**	**1972-1973, 1974-1975, 1978-1979 / 3 years**
1981-1990	**1984-1985, 1985-1986, 1986-1987, 1989-1990 / 4 years**	-
1991-2000	**1991-1923, 1993-1994,1997-1998 / 3 years**	**1990-1991 / 1 year**
	XXI-ST CENTURY	
2001-2010	**2000-2001, 2002-2003, 2005-2006, 2006-2007 / 4 years**	**2009-2010 / 1 year**
2011-2020	**2011-2012, ……….**	…………….

Figure 8: *The frequency of droughty/rainy years in Covasna agricultural area*

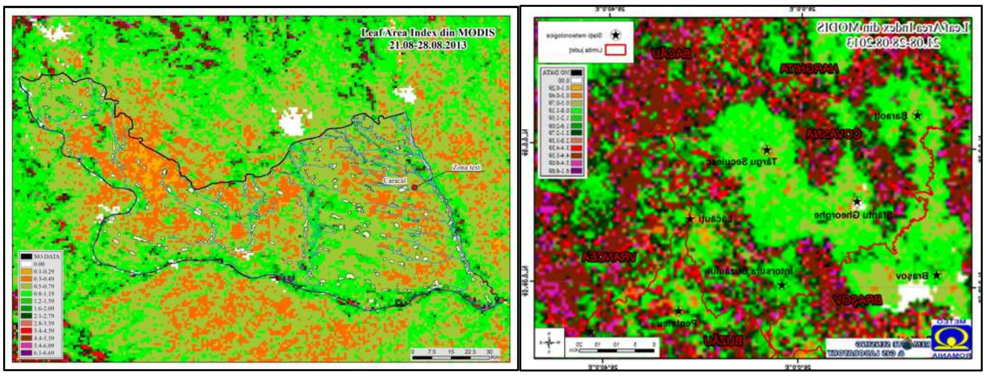
The RCP 2.6 projection from the CMIP5 experiments for 2021-2050 periods vs. 1961-2000 has predicted an increase in mean annual air temperatures by around 1.8°C in Caracal area and 1.5°C in Tg. Secuiesc area respectively. The projections indicate a decrease of annual amount rainfall by 0.7% in Caracal and an increase by 6.1% in Tg. Secuiesc. In the summer season the monthly rainfall will decrease in comparison with the current period, an obvious decrease being possible especially in Caracal area (Figure 9).

	CARACAL RCP 2.6 2021-2050 vs. 1961-1990		TG. SECUIESC RCP 2.6 2021-2050 vs. 1961-1990	
	Air Temperature (°C)	**Rainfall (%)**	**Air Temperature (°C)**	**Rainfall (%)**
January	1.6	**1.5**	1.5	7.4
February	2.1	3.7	2.1	12.2
March	2.4	1.1	2.4	12.3
April	2.3	5.5	2.1	13.5
May	2.4	**0.3**	1.9	4.8
June	2.5	**-8.2**	2.0	-5.1
July	2.3	**-6.2**	1.7	0.6
August	1.8	**-2.7**	1.1	5.2
September	1.2	**5.7**	0.7	11.7
October	1.0	**-2.8**	0.6	8.3
November	0.9	**-0.9**	0.7	6.3
December	1.2	**-1.1**	1.0	4.6
Annual	**+1.8°C**	**-0.7%**	**+1.5°C**	**+6.1%**

Figure 9: *Projected changes of the monthly air temperature and rainfall for decade 2021-2050 in Pilot Study 2 agricultural area (ensemble mean from CMIP5 experiments /RCP 2.6 scenario for 2021-2050 periods vs. 1961-1990 interpolated at station point)*

Satellite-derived indicators for crops vegetation state monitoring and assessment

Figure 10 provides an evolution trend of the LAI values in the Olt and Covasna agricultural areas from 27 July to 28 August 2013. The lower values correspond with moderate and strong pedological drought over large agriculture surface in this period.



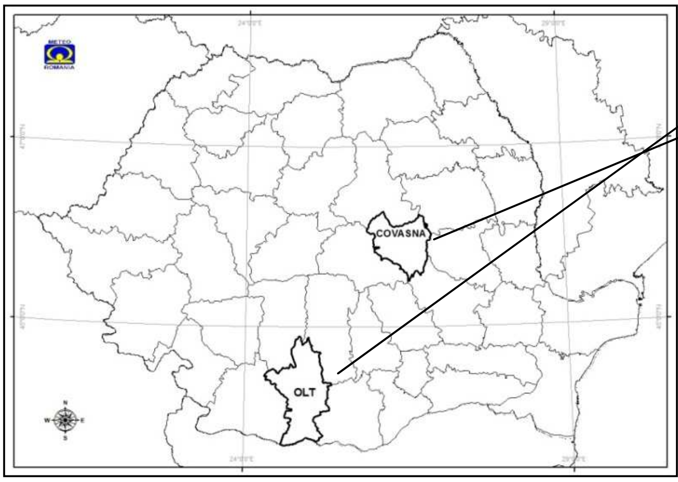
Date	Soil moisture (mc/ha)	% CAu (Soil water supply capacity)	Classes
10.07.2013	**1216**	**76 %CAu**	**Close to the optimal supply**
20.07.2013	**883**	**55 %CAu**	**Satisfactory supply**
31.07.2013	**695**	**43 %CAu**	**Moderate pedological drought**
10.08.2013	**548**	**34 %CAu**	**Strong pedological drought**
20.08.2013	**667**	**42 %CAu**	**Moderate pedological drought**

Figure 10: *MODIS – LAI (1 km) evolution in the Olt and Covasna agricultural areas from 27 July to 28 August 2013*

Recommendations and adaptation options to improve water use efficiency (WUE), the genotype varieties and yields

According to climate predictions, a shortening by 9-13 days of the vegetation period in winter wheat and by 15-18 days in maize crops is possible over 2021-2050 period due to increasing air temperatures and, consequently, 10.8-14.4% lower yields of maize, respectively, as a result of higher in-soil water deficits mainly during the grain fill period (July-August) in both selected sites.

In the Pilot Study 2 water is used more efficiently by the winter wheat crop with the later sowing date (October 20 and November 1 in Caracal area; September 10 and October 5 in Tg. Secuiesc area) in comparison with earlier dates of end of September and beginning of October. For the maize crop water is used more efficiently with an earlier sowing date (April 1 and 11 in Caracal area; March 20 and April 1 in Tg. Secuiesc) in comparison with later date (April 20 or 10), Figure 11.



Pilot Study 2:
Olt County / Caracal area
Covasna County / Tg. Secuiesc area

2021-2050 period:
Winter wheat: later sowing date
Caracal area: October 20 and November 1
Tg. Secuiesc area: September 10 and October 5

Maize: earlier sowing date
Caracal area: April 1 and 11
Tg. Secuies area: March 20 and April 1

Figure 11: ***Adaptation measures: changing the sowing date in the Pilot Study 2***

Under future climate condition for the winter wheat crop the most suitable genotype are varieties with high or moderate vernalization (P1V=6.0…P1V4.0) and with moderate photoperiod requirement (P1D=3.5), respectively version 2 of the total of five simulated (Figure 12).

	Current climate P1V=6.0	Scenario VAR 1 P1V=3.0/ P1D=3.0	2020-2050 VAR 2 P1V=4.0/ P1D=3.5	/ 450 ppm VAR 3 P1V=6.0/ P1D=2.5	VAR 4 P1V=4.0/ P1D=2.0	VAR 5 P1V=6.0/ P1D=1.0
GY (kg/ha)	4452	5014	**5238**	5118	5022	4989
SD (days)	270	258	255	252	243	241

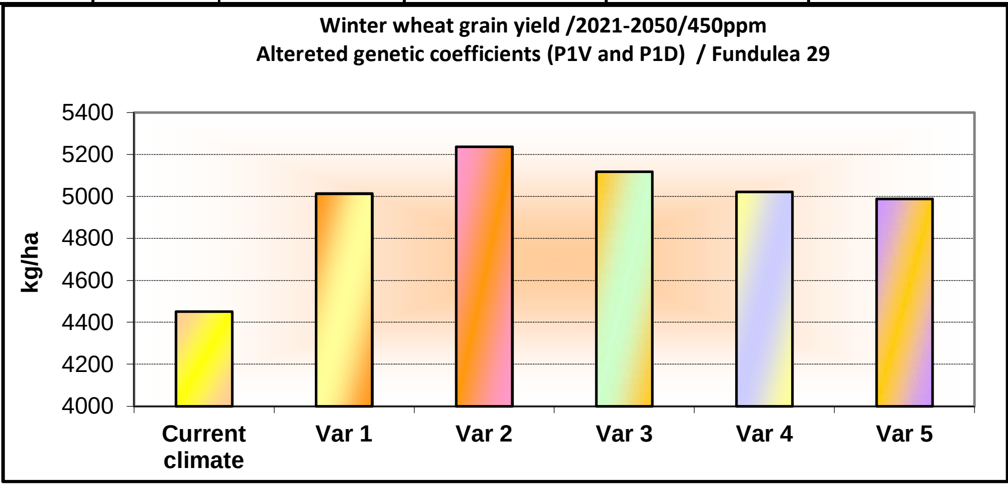


Figure 12: *Winter wheat - altered genetic coefficients (P1V and P1D)/ Fundulea 29*

The results shown in this Pilot study can contribute to developing the management adaptation options to climate change-related negative effects affecting crop systems. These options could include: changing the sowing date, cultivation of winter wheat genotypes that require a high or moderate vernalization and moderate photoperiods as well as certain maize hybrids with a better resistance to hot summer and drought.

By identifying practical adaptation measures the farmers can establish options to improve climate resilience of the crop systems by new agricultural technologies based on water use efficiency in irrigated or non-irrigated regime. In this project adaptation measures are presented at local and regional level. It is important, however, to extend the research to other areas with similar or different conditions in order to establish actions in accordance with regional/national policy planning.

4. Conclusions and lessons learned

4.1 Pilot Study 1

During the 19th century until today temperature has risen by almost 2°C in the European Alps. In the study area, which is representative for the Northern Limestone Alps in Upper Austria, a further increase of 2-5 °C is predicted until 2100, with highest increase in the summer. The expected precipitation changes (up to approx. 20% increase in winter and the same range of decrease in summer), though predictions as to the latter are still rather uncertain, might cause drier summers and wetted winters and early springs. The used climate indicators are well suited to show these changes.

The Northern Limestone Alps are characterized by shallow soils which are vulnerable to nutrient loss and erosion once the forest cover is damaged. Since many settlements in the region depend on high quality drinking water supply stemming from forested headwaters, forest functions such as water retention and filtering of pollutants have to be maintained and even restored where necessary.

The forests of the Northern Limestone Alps will be affected by further climatic changes. Norway spruce is the most abundant tree species in Austria but is also the most vulnerable to additional temperature increase. Many forest sites at lower to middle altitudes will not be suitable for Norway spruce in the future. Also in the present the homogeneous spruce plantations created at natural beech forest sites can be regarded as highly vulnerable and instable.

At higher altitudes however, Norway spruce might even experience growth stimulation. However, a particular risk in all spruce forests is the increase of bark beetle infestations, very probable driven by climate warming, on large spatial scales causing both damage to forest ecosystem functions and less economic return for forest owners.

Forest management affects water quality in various ways. The prevalent Norway spruce management has led to even-aged, homogeneous forests. These forests are less resilient than mixed conifer-deciduous forests and therefore face stronger and more frequent disturbances. Moreover, the usual management of Norway spruce forests is done with clear-cuts or shelterwood-cuts potentially causing a contamination of water pollution. With regard to nitrate, but most probably also regarding turbidity, expected climate change will enhance the negative effects of these management interventions to water quality. An adequate management option for optimizing water protection, which is particularly important in water protected areas, is therefore the creation of mixed forest stands which includes a wider range of naturally occurring tree species and the establishment of a continuous cover forest management system. Those two goals are part of an overall Best Practice catalogue for forest management in drinking water protected areas (Koeck and Hochbichler 2011b). Particularly in the light of expected climate change effects to forests, an adaptation towards such a management system is recommended.

A number of constraints exist as to the adaptation of forest management in water protected areas. Since in many cases even-aged Norway spruce forest plantations predominate, the transformation into mixed forests is a long-term task. Educated personnel have to be built up, the appropriate planning instruments have to be made available and a monitoring and evaluation system has to be established in order to guarantee a continuous adaptation of forest management. Secondly, different user interests exist in headwater areas which might counteract continuous cover forest management. In major parts of the forests in the State of Upper Austria tree regeneration is suppressed significantly due to browsing damages caused by elevated wild ungulate populations. Hunting management is therefore as important as forest management if adaptation to climate change has to succeed. Economic constraints are the third issue. The establishment of mixed forests and a continuous cover forest management system leads to less economic return for the forest owners. This is a constraint against adaptation, particularly if the headwaters are not owned by the community so that different interests compete against each other. Hence in many cases forest management adaptation towards an optimization of water quality needs a compensation payment to the forest owner. Though financial subsidies can improve the adaptive capacity to climatic changes of the forestry in water protected areas, it is still very important to raise the awareness among forest owners, headwater managers and the local water works in the communities.

Uncertainty as to the magnitude of climate change effects is significant. Adaptation will therefore be a dynamic process rather than a single decision. The availability and the usage of the most recent modeled climate pathways would have clear benefits. However, this is novel to most local forest managers and regional forest services. Firstly this data has to be made available in an understandable way and in a meaningful resolution. Secondly, training is necessary as to how climate scenario data can be used efficiently. As an example, the forest service of Upper Austria uses brochures which provide clear management guidelines for forest owners using rather simple climate scenarios for different regions. The provision of more detailed indicators could be a next step. Last but not least, research has to accompany adaptation in order to gain continuous knowledge as to the best adaptation measures.

The importance of the drinking water protection should be more emphasized within the relevant forest related legislation. As an example, the land-use regulation or forest management aspects in the area of drinking water protection and conservation zones should be determined and strictly observed. Also in the Austrian Federal Forest Act binding legislative rules have to be defined specifically for drinking water protected areas. As several studies already documented, that clear-cuts have a severe influence on water quality, the restrictions of clear cuts by the Forest Act (below 0,5 ha or below 2 ha, if the regional forest authority gives its permission) are too weak to ensure source water protection.

4.2 Pilot Study 2

The climate is already changing and the agricultural areas of Romania are vulnerable to these changes. The temperatures become higher, precipitation variable in time and space and extreme weather events more frequent and severe. In this context, agriculture sector, which play a major role in ensuring of food security will be strongly affected by CC because of its dependence on the weather. In this context, ensuring stable agricultural production in a changing climate is one of the main challenges of the coming decades. Facing this challenge requires developing a dedicated pilot study as best practices in order to identify adaptation measures that can be taken to reduce the climate change impacts.

In the agricultural area of Pilot Study 2, the winter wheat yield will slowly increase in comparison with the current conditions as a consequence of increased CO_2 concentrations in the atmosphere (affecting photosynthesis) and of using water supplies to counter-balance the negative effect of shorter vegetation periods. The maize yields will decrease due to higher temperatures that shorten the vegetation season, coupled with a water stress, mainly during the phenological phases of grain formation and filling.

Analysing the simulated results it can be highlighted that the future climate evolutions may have important effects upon crops and they could be conditioned by an interaction between following factors: future climate changes on a local scale, severity of climate scenario, CO_2 concentrations level and the influence on photosynthesis, and the genetic nature of plant types (C3 and C4). Winter wheat can benefit from the interaction between increased CO_2 concentrations and higher air temperatures, while maize is more vulnerable to future climate scenarios, mainly in the case of a scenario predicting hot summer and droughty conditions.

The management and sustainable development decisions should aim to increase the agricultural production by growing in each region the appropriate crops that have the largest benefit from the natural potential for agriculture, which is evaluated through analysis of local agropedoclimatic conditions.

Within the field crop production, the selection of the cultivated species includes mainly the correlation of the local environment conditions with the degree of genotypes resistance (varieties / hybrids) according to the limitative vegetation conditions (drought, humidity excess, high temperatures, cold / frost period, etc.).

The presented results of climate change impact studies on agricultural crop production in Romania highlighted following key points:

1. Climate change will cause significant shift in the environmental conditions, adaptation of the farmers being crucial;
2. Drought frequency and severity is expected to increase;
3. Yields of winter wheat crops are expected to increase and for maize to decrease mainly in the case of a scenario predicting hot summer and droughty conditions;
4. The agriculture will face more climate-related risks, the adaptation options being requiring continuing research on the effect from irrigation and sustainability of yields under various water saving methods and irrigation technologies;
5. Modeling of the potential impacts of climate change on farming systems with identification of adaptation responses and need to develop the capacity of stakeholders to implement these measures in practice are goals that requires long-term responses.
6. Numerical experiments to determine the optimal dates and water quantity for irrigation crops for various climate scenarios are necessary to be carried out and the calculations are applied by taken in regard to biophysical and economic analysis of the final yield associated with the economic models.
7. Better dissemination of meteorological information to farmers and raise awareness on water saving techniques in order to prevent drought and water scarcity.

Concerning current policies regarding drought monitoring and management in the past few decades it has become evident that in all countries affected by drought and water scarcity is a clear need to improve national and regional policies with the goal of improving preparedness measures and reducing negative impacts. Better coordination of the management policies is also needed due to the transboundary or regional/local character of drought events.

As well as direct benefits during the project implementation EPA Covasna had the opportunity to learn from NMA Bucharest how to get use of climate data in environmental planning:

- due to purchasing of the Automatic Weather Station beneficiaries from Covasna County have access to climate data online, on EPA Covasna's website: http://apmcv.anpm.ro;
- two specialists from EPA Covasna were trained by specialists from NMA Bucharest, between 24 to 28 February 2014, on programs for processing geographic information systems (ArcGIS) and other similar programs. As part of training, NMA experts presented techniques and methods for using various meteorological and climate data for creating GIS products, useful for the activity of the local authorities and farmers from Covasna County.

Taking into account on this activity the NMA can create some climate changes adaptation tools in the field of several economic sectors affected by CC such as: agricultural, water resource, environmental, forests, etc. The adaptation component is based on the integration approach at sectoral level and aims to provide an action framework and guidelines to enable each sector to develop an individual action plan in line with national strategic principles.

The following actions can be developed by NMA: (1) periodically updating climate change projections; (2) supporting climate research and building a national data base on climate change and impacts; (3) monitoring and analysis of adaptation to climate change. These activities are in line with the National Climate Change Strategy (2013-2020) objectives.

Another benefit basically consisted in transferring of the information from research results to local authorities between EPA Covasna and NMA Bucharest.

In the context of climate change the assessment of drought risk is a key challenge. In terms of water resources the common feature is related to the variability and changes especially in terms of temperature and rainfall. If these changes will enhance, they will clearly result in the increase of drought hazards. The sector most vulnerable to drought losses is agriculture (Bojariu et all, 2012, Mateescu et all, 2010, 2012). But, in the severe drought situation, shortages of water supply to population and industry (including the energy sector) may also be affected. Each time when the drought occurs, many of the same issues are raised in Romania.

5. Recommendations

5.1 Pilot Study 1

Austria is quite water rich and the importance of water is well addressed by the tight legal framework (Austrian Water Act). All of the drinking water is abstracted from groundwater where half of it comes from, usually vulnerable, karstic areas. Severe problems with regard to the quality and the quantity of drinking water in general are not expected – also not in the future under climate change conditions. Nevertheless, qualitative as well as quantitative problems might locally occur. It is essential to continue and even strengthen all efforts for the protection of drinking water for future generations. With regard to an enhanced consideration and integration of forestry management in drinking water protection the following aspects could exhibit room for improvement:

- In the **Austrian Federal Forest Act** specific binding legislative rules have to be defined exclusively for drinking water protected areas, for example the limitation of clear-cuts and game management regulations (like prohibition of feeding etc.).
- Some of the existing **water protection zones** from former times are too small to protect the whole relevant water body. Therefore an "Action Plan" should be elaborated. For the most important zones - established trough hydrogeological surveys - adequate measures (e.g. enlargement of the protection zone) have to be implemented.
- Relevant **spatial planning instruments** (e.g. local development concept, land use plans) should take into account the importance of water protection and conservation areas. The value for the beneficial functions in the Forest Development Plan (a high value "3 or 2" could be the result of the existence of an important water source within a forested catchment area) should also be taken into consideration. Additionally the observation and evaluation of the respective land-use regulations or prohibitions within these water protection and conservation zones is mandatory, as there were still identified gaps in the practical application of protective measures (BMLFUW, 2011).
- Several **adaptation and mitigation policies and strategies** (e.g. Austrian Strategy for Adaptation to Climate Change, 2012; Austrian Forest Program, 2005; Climate Change Adaptation Strategy for Upper Austria, 2013) in connection with climate change are already elaborated and have to be implemented continuously. Concerning the reduction of emissions of greenhouse gases due to the Kyoto protocol Austria lags far behind. Therefore great efforts have to be made within this context, especially regarding the traffic policy.
- **Awareness raising** of forest related actors (land-users like forest owners and stakeholders) on the effects of forest management on the quality and quantity of water is essential. By means of training events an introduction to the efficient use and

application of management guidelines can be achieved. Also the adequate use of climate scenario data has to be provided in an understandable way and in a reasonable resolution. The Forest Service of Upper Austria, for example, published brochures for different regions with a guideline for the appropriate choice of tree species under actual climate. For each water protected area and conservation zone a suitable **forest management plan** should be elaborated. In case of forestry the drinking water protection functionality has priority to guarantee the provision of the relevant ecosystem service ‘provision of freshwater supply’. Therefore respective “Best Practices” (guidelines) have to be defined and applied. For the continuous adaptation of forest management educated personnel has to be built up, the appropriate planning instruments have to be made available and a monitoring and evaluation system has to be established. Additionally it is important to allow for knowhow exchange among local and regional forest managers because success of forest management adaptation often depends upon a few local stakeholders.

- As these claimed forest management measures (Best Practices) require additional efforts and estimated pecuniary compensations the Forestry Department of the Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) looked for a solution for motivation to implementation and for compensation payment to the forest owners. A prerequisite to improve and protect the quality is that water suppliers know the recharge areas of the springs and wells they are presently using and potentially will be included in their network. This allows the water suppliers to evaluate the vulnerability (e.g. nitrate leaching, turbidity, microbiological contamination etc.) of the “raw water” to forest management measures and allow to negotiate with the forest owners. In addition, forests have far more benefits than pure water supply such as protection function for settlements and communities to prevent avalanches, floods, general erosion, landslides etc.. Within the framework of the EU Rural Development Regulation 2014+ **a new program “Forest for Water”** will be developed. In addition to the already existing initiative “Protection through Forest” (in VOLE 2007-2013: ISDW) a similar subsidy-tool will be created to improve the forest effects on the water regime and to clean up ditches and riverside forests taking into account scientific findings and recommendations. Due to the long implementation period these measures, which will be supported by the VOLE-programme (2014-2020), have to be seen only as an initial step towards the desired outputs and status. In any case this new program takes into consideration several EU strategies and legislations, like the EU Water Framework Directive (2000), the EU Groundwater Directive (2006), the EU Floods Directive (2007), the EU Forest Strategy (2013), the Blueprint to safeguard Europe´s water resources (2012) etc.

- The knowledge as to the future effects of climate change is still scarce. The provision of more detailed indicators could be a next step. Also the difficult structure of karstic areas and their vulnerability and risk assessment require further scientific investigations. Particularly **research** which is useful for local management and which is accompanying practical adaptation is important for gaining continuously a better understanding and deeper knowledge about the best adaptation measures.

5.2 Pilot Study 2

The climate in Romania is expected to undergo **significant changes** over the coming decades. In the next decades, the most pressing consequences are those related to thermal changes (e.g. hotter summers with more frequent and persistent heat waves) over entire country and to reduction in mean precipitation especially in Southern, South-eastern and Eastern parts of Romania (Mateescu at all, 2009, 2020, 2012).

In order to **study the regional aspects and variability of climate change impacts in agriculture** field four critical areas must be addressed:

1. The effect of climate change on the future climatic conditions at regional and local level;
2. The effect of climate change (including the effect of CO_2 concentration) on crop growth and productivity of cultivated key crops;
3. Developing recommendations for adaptation options based on the dedicated case study results.
4. Much more vulnerability assessments have to be coupled with the information about physical basis of climate change to obtain updated and improved knowledge for adaptation in agriculture field.

A number of agronomic **adaptation options** can be recommended to avoid or reduce negative climate change effects and exploit possible beneficial options. Hereby short-term adjustments and long-term adaptation can be differentiated. The first ones imply changes in planting dates as well as cultivars, changes in external input like irrigation, and techniques to conserve soil water. Long-term adaptations include major structural changes to overcome disadvantages caused by climate change. Land use, breeding and biotechnology applications, crop substitution as well as changes in farming systems are some examples for long-term adaptations (Sandu I. at all, 2010, 2014).

Given the fact that at the end of 2014 a new process of revising of the Environmental Action Plan for Covasna County will start, the EPA Covasna will find solutions to include the results of the Pilot Study 2 into actions at regional level (Figure 13). A similar goal will have also the

Municipality of Caracal. This approach will serve as a bridge between scientific community and stakeholders such as local/regional authorities and farmers.

The need for policy coordination at regional, national and local level as an urgent issue is important to develop and implement specific adaptation measures, especially in the case of areas vulnerable to climate change and drought. The development and implementation of **regional training, education and public awareness programs** focused on adaptation to climate change and drought impact on agricultural crops, having as focus groups the regional and local authorities, relevant stakeholders and scientific communities, quantifying the effects at regional and local levels by encouraging contributions and personal action in addressing climate change will conduct to appropriate technologies, climate-friendly attitudes and behavioral changes.

General Objective	*Specific Objective*	*Target*	*Actions*	*Responsible for implementation*
1.1. Increasing capacity of authorities to handling issues related to the phenomenon of climate change	1.1. Identifying and accessing funding sources projects for human resource development and international exchange	1.1.1.1. Increase the training of personnel involved in managing the climate change issues	105. Identification and implementation of projects on the topic of climate change, including research projects	- County Council - institutions - municipalities
			106. Developing international cooperation and exchange of experience in the field	- County Council - institutions - municipalities
			107. Cooperation of institutions / authorities to integrate climate change issues in the development of policy sector and the promotion of environmental efficiency;	- County Council - institutions - municipalities

Figure 13: *Local Action Plan for the Environment/ Covasna County*

The Romanian National Strategy for Climate Change (2013-2020) adds extra guidance on the approaches and institutional cooperation needed to cope with climate change in an integrative and multi-sectoral approach. As for the sectoral recommendations, a sound base for assessing costs related to climate change for different sectors is the evaluation of the state of the art in the knowledge of adaptation to climate change. Defining specific objectives on different time horizons and the tools to monitor the way to reach these are also important for sectoral approach of adaptation. In this context, the integration of the adaptation measures in the sectoral strategies will help to have a comprehensive approach and select appropriate measures for the direct and indirect effects of climate change. To develop a realistic adaptation strategy the existing sectoral strategies on climate change basis have to be adjusted.

The autonomous **adaptation capacity** has to be assessed and the direct and indirect effects of climate change and the intersectoral links between the most important sectors of the economy have to be evaluated and the **risk assessment approach** taking into account the frequency and magnitude of the future effects of climate change on different economic, social and environmental systems has to be amended.

Finally, mainstreaming climate change adaptation considerations into **key EU policies** must be the most important elements of the work in the area of adaptation. Building on this existing work, the **EU Adaptation Strategy** aims to enhancing the preparedness and capacity to respond to the impacts of climate change in the EU, its Member States and regions, down to the local level. Also, **the Horizon 2020 (12) Programme** referring to the call named "Climate action, environment, resource efficiency and raw materials (2014-2010)" aims to improve understanding of the impacts of climate change on the water cycle in order to better inform decision makers and ensure sustainable water management and agricultural productivity improvements in the EU.

The impact of the climatic extremes varies function of the crop type and the local characteristics of the climatic and agro-meteorological conditions. In other words, **the climate change has a significant impact on agriculture** through that is diminished the crops in both quantity and quality, it shortens the vegetation period and it modifies the water balance elements, especially in the agricultural areas highly prone to drought and having low adaptation potential.

Therefore, **drought hazard mapping** is instrumental towards enhancing Romania's ability to address the major priorities for the programming period 2014-2020 consequently focusing on the implementation of projects for rehabilitation and development of the land reclamation infrastructure and ensuring the access to water for the irrigation in areas with chronic shortage of water resources wherein drought has been increasing sharply for the last years.

Furthermore, additional gains are expected, such as substantially **raising** the living standards of the local population, as a result of increased agricultural production, improving the conditions of conservation of soil and constant supply of food.

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7. Annexes

7.1 Glossary

7.1.1 Pilot Study 1

L-DNDC – Landscape DNDC Ecosystem Model

LTER – Long-term Ecosystem Research

VarKarst – Hydrochemical Catchment Model for LTER Zöbelboden (Pilot 1)

3D-CMCC-FEM: 3D Forest Ecosystem Model of the Centro Euro-Mediterraneo sui Cambiamenti Climatici

GCM: General Circulation Model

IPCC: Intergovernmental Panel on Climate Change

RCM: Regional Climate Model

RCP : Representative Concentration Pathway

SRES: Special Report on Emission Scenario

7.1.2 Pilot Study 2

DSSAT - Decision Support System for Agrotechnology Transfer

CERES – Crop simulation models for Wheat and Maize crops

NMA Bucharest – National Meteorological Administration, Bucharest

EPA Covasna – Environmental Protection Agency, Covsana

GCM: General Circulation Model

IPCC: Intergovernmental Panel on Climate Change

RCP: Representative Concentration Pathway

SEE: South-Eastern Europe

SRES: Special Report on Emission Scenario

7.2 List of Indicators

7.2.1 Pilot Study 1

Short Name	Long Name	Short description
R50mm	Precipitation days with RR ≥ 50 mm	Precipitation days with a daily amount (RR) ≥ 50 mm. Count the number of days in chosen period (during growing season; other season)
PRCPTOT	Total precipitation in wet days	Precipitation amount on days with RR ≥ 1 mm in a chosen period (e.g. year)
SWE	Snow water equivalent	measurement of the amount of water contained in snow pack
SPI12	Standardized Precipitation Index	see WP 3 description
CDD	consecutive dry days	see WP 3 description
WPFI	Water protection-Forest-Index	Forest stand and soil indicator which describes the functionality of forest ecosystems for water protection
FWF	Forest-Water-Funding	financial compensation of additional expenses due to adaptive forest management measures according to water protection
GPP	Gross Primary Production	It denotes the total amount of carbon fixed in the process of photosynthesis by plants in an ecosystem, such as a stand of trees. GPP is measured on photosynthetic tissues, principally leaves.
NPP	Net Primary Production	It denotes the net production of organic matter by plants in an ecosystem-that is, GPP reduced by losses resulting from the respiration of the plants (autotrophic respiration).
AR	Autotrophic Respiration	Autotrophic Respiration (or plant respiration) represents the photosynthetically fixed carbon that is lost by internal plant metabolism.

CE	Canopy Evapotranspiration	It is the sum of evaporation and transpiration from forest canopy.
MAmaxT	Mean Annual maximum Temperature	The average of the maximum temperature for the year.
MAminT	Mean Annual minimum Temperature	The average of the minimum temperature for the year.

7.2.2 Pilot Study 2

Short Name	**Long Name**	**Short description**
CDD	Consecutive dry days	It represents a maximum length of dry spell. It counts the largest number of consecutive days in a chosen period where RR < 1 mm.
PRCPTOT	Total precipitation in wet days	Precipitation amount on days with RR ≥ 1 mm in a chosen period (e.g. year)
SPI03	Standardized Precipitation Index 3 months	Computation of the SPI involves fitting a Gamma probability density function to a given frequency distribution of precipitation totals for a station. It is calculated from the long-term record of precipitation in each location (at least 30 years) It represents a meteorological drought indicator, convenient for both monitoring and prediction of drought events. Its nature allows an analyst to determine the rarity of a drought event at a particular time scale (seasonal in this case) for any location in the world that has a precipitation record.
AI	Aridity Index	it is a numerical indicator of the degree of dryness of the climate at a given location Let P be accumulated precipitation and

		PET Thornthwaites' potential evapotranspiration in the chosen period, the aridity index for the period is given by P/PET.
SM	Soil Moisture	It is calculated based on soil water balance model. - it allows analysing the in-soil water reserve over various profiles / depths and at crop-specific calendar dates; - it identifies areas potentially affected by pedological drought phenomenon dynamics (intensity, duration and spatial distribution).
HS	Heat stress	It occurs when the maximum temperature reaches 32°C during the summer season (June-July)
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation Index	It is the solar radiation reaching the canopy in the 0.4–0.7 µm wavelength region. fAPAR parameter is considered a good indicator for detecting and assessing the impact of drought on plant coatings (crops, natural vegetation). fAPAR is one of the 50 Essential Climate Variables recognized by the UN Global Climate Observing System (GCOS) as necessary to characterize the climate of the Earth. Is a satellite derived product being obtained from SPOT Vegetation data (1 km spatial resolution).
NDVI	Normalized Difference Vegetation Index	It is a satellite-derived index from the visible (VIS and Near-Infrared (NIR) and Short Wave Infrared channels. The index can be used to provide information for agriculture and vegetation health situation. This information is useful in determining water stress levels in vegetation and estimation of crop yield and is useful in drought assessment.
NDWI	Normalized Difference Water Index	NDWI is a satellite-derived index from the Near-Infrared (NIR) and Short

		Wave Infrared (SWIR) channels. Is a good indicator of water content of leaves and is used for detecting and monitoring the humidity of the vegetation cover. It is known that vegetation during dry periods is affected by water stress, which influence plant development and can cause damage to crops in agricultural areas. NWDI holds considerable potential for drought monitoring because the two spectral bands used for its calculation are responsive to changes in the water content (SWIR band).
NDDI	Normalized Difference Drought Index	It is a new index for drought monitoring which is calculated from normalized difference vegetation index (NDVI) and normalized difference water index (NDWI). It combines information from visible, NIR, and SWIR channel. NDDI can offer an appropriate measure of the dryness of a particular area, because it combines information on both vegetation and water. NDDI had a stronger response to summer drought conditions than a simple difference between NDVI and NDWI, and is therefore a more sensitive indicator of drought.
IrrReq	Irrigation Requirements	Fraction of crop water requirement to be supplied via irrigation
GDD	Growing Degree Days	It represents the number of temperature degrees above a threshold base temperature (8°C in this case) in a chosen period.
CropYld	Crop Yield	It represents the measure of the yield of a crop per unit area of land cultivation.

7.3 Complementary Analyses

7.3.1 Pilot Study 1 - Forest growth modelling at LTER-Zöbelboden

Authors: A. Collalti, M. Santini

Objectives

Forests are recognized and expected more and more suffering from climate change and variability because of their high dependence on weather regime (especially temperature and precipitation) to sustain growth and maintenance, as well as to allow recovery after disturbances or meteorological extreme events. An additional model-based analysis was performed at Intensive Plot 1 (IP1) of LTER Zölbelboden site, in order to assess and project the impacts of new climate regime on carbon and water fluxes regulating forest growth and resilience. The outcomes of this study are a further example of useful analyses when aiming to consider climate change in designing and implementing adaptation strategies within forest management and protection plans.

Data and methods

The additional analyses performed at IP1 consisted first of all in calculating climate indicators based on simulated variables (maximum and minimum temperature and precipitation) from bias-corrected RCM COSMO-CLM (http://www.clm-community.eu/) runs performed along 1971 to 2005 under 20C3M GHG forcing (http://www.ipcc-data.org/ar4/scenario-20C3M.html), and along 2006 to 2070 under RCP4.5 and RCP8.5 forcings (IPCC-AR5; http://sedac.ipcc-data.org/ddc/ar5_scenario_process/RCPs.html); in all cases the boundary conditions were set by CMCC-CM GCM. Bias-correction of these model simulations was performed applying the method of Sperna-Weiland et al. (2010), reducing the threshold for the multiplicative factor from 10 to 4 according to previous analyses on the same data for the simulation domain. Selected climate indicators are: APA, MAmaxT and MAminT, PRCPTOT, R50mm and CDD (see 7.2.1).

Successively, daily data for precipitation, maximum and minimum temperature, relative humidity and solar radiation from above bias-corrected simulations, extracting the model grid point closest to the IP1 site, were used to drive runs of the 3D-CMCC Forest Ecosystem Model (Collalti et al. 2014). 3D-CMCC-FEM has the advantage to be a dynamic process-based model to simulate growth, carbon allocation, and forest dynamics in heterogeneous populations. Daily eco-physiological processes that govern GPP, NPP, and dynamics of carbon stocks, structure of the population, of the biomass pools, soil and climatic conditions are considered in the model. The same initialization than L-DNDC (see main text) for the Spruce dominated forest of IP1 was adopted. In particular model has been set to reproduce, in addition to the other processes above described, competitive processes (i.e. for light and water) between the two cohorts and the two layers (i.e. dominant and dominated) that reflect the IP1 stand: the dominant layer is composed by a 115 years old of Picea abies, the dominated layer is composed by Fagus sylvatica.

To rely on climatologically significant (25-30 years) length of simulated periods to be analysed and compared, model runs were designed as follows:

- Control RCP 4.5 simulation (CTL4.5): it consisted of an initial 25-year "actual-synthetic" period 1996-2020, representative of the current conditions, generated by repeating from 2011 to 2020 daily observed meteorological series for 1996-2010, and then continuing with 2021-2070 data from RCP4.5 driven climate projections simulations.
- Control RCP 8.5 simulation (CTL8.5): as above, but continuing with 2021-2070 data from RCP8.5 driven climate projections simulations.
- Model-based RCP 4.5 simulation (MOD4.5): it consisted of an initial 25-year "actual-synthetic" period 1996-2020, representative of the current conditions, generated by repeating from 2006 to 2020 daily modelled meteorological series for 1996-2005, and then continuing with 2021-2070 data from RCP4.5 driven climate projections simulations.
- Model-based RCP 8.5 simulation (MOD8.5): as above, but continuing with 2021-2070 data from RCP8.5 driven climate projections simulations.

Model outputs of interest are represented by four indicators of forest status: GPP, NPP, AR and CE (see 7.2.1). To allow consistent evaluation climate sensu, all indicators have been averaged along medium term (2021-2050) and long term (2041-2070) periods to be compared to the average of "actual-synthetic" period (1996-2020, representing current conditions).

Given that the model grid point, although being the closest to IP1, can have different characteristics (e.g. topographic attributes) than IP1, the anomaly/bias between MOD and CTL during 1996-2020 served to adjust the successive MOD simulation period (2021-2070) for the bias detected in the actual-synthetic period. This was made easier by the fact that the 1996-2020 results between the two CTL simulations are equivalent, as well as those between the two MOD simulations, as not affected by RCP emission scenarios. Then, for the 2021-2070 time frame, the average of the two RCP (4.5 and 8.5) simulations was considered both for the medium and the long term periods, since assumed representative of the uncertainty spread related to the emission scenarios.

Results

Climate indicators of maximum and minimum temperature (Figure 14a) confirm what found in terms of expected temperature trends from SRES ensemble simulations reported in the main text. In particular, on an annual average, the maximum and minimum temperatures (MAmaxT and MAminT, respectively) are expected to increase by 0.7 and 0.9°C respectively for the medium term period, and by 1.9 and 2.0°C respectively for the long term period. Moreover, the recognized uncertainty in precipitation is confirmed by the fact that the average of RCP-driven simulations, while confirming a drying trend in summer (but only in the long term), project the same also for winter (in both future periods and opposite than in SRES-based results); spring and autumn are expected to become wetter (Figure 14b). On an annual average, both APA and PRCPTOT indicators suggest an increase for precipitation in the medium term and a decrease in the long term. Finally, indicators like R50mm and CDD suggest an increase of extreme events, with more frequent intense precipitation days and longer periods of dry days.

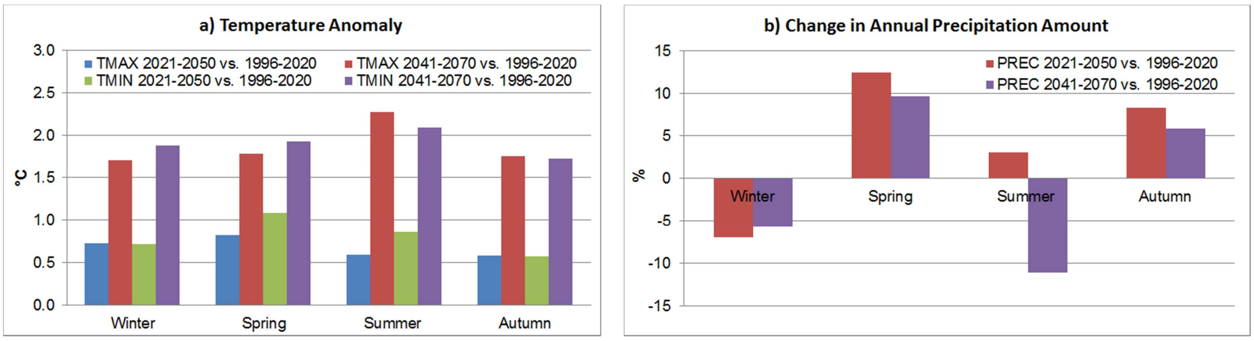

Figure 14

a) Anomalies (°C) of seasonal maximum and minimum temperatures (TMAX and TMIN) for the medium term (2021-2050) and long term (2041-2070) periods vs. the current 1996-2020;

b) Anomalies (%) of seasonal precipitation (PREC) for the medium term (2021-2050) and long term (2041-2070) periods vs. the current 1996-2020.

3D-CMCC-FEM outputs driven by daily series of above climate projections predict significant changes in forest processes in terms of productivity and water fluxes, with drop of all the considered indicators on the order of 20-25% on the medium term, and around 35-40% on the long term (Figure 15).

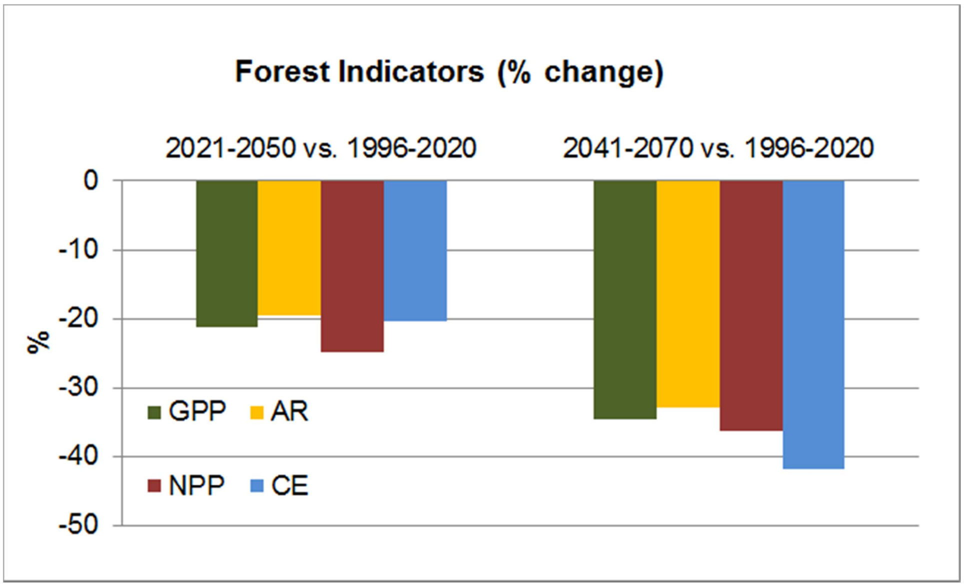

Figure 15: *Anomalies (%) of annual GPP, AR, NPP and CE for the medium term (2021-2050) and long term (2041-2070) periods vs. the current 1996-2020.*

All simulations show remarkable changes in seasonal growth. For both Spruce and Beech there is an increment in the days of “full” growth due to an anticipated beginning of photosynthetic activity (bud burst phase) and a postponed end (litterfall phase). This is counterbalanced in the late spring, summer and early autumn. This trend is mainly related to the new climate regime (with higher temperature and fluctuating trends of precipitation) during the years of simulations. In addition there is a strong mortality reduction, due to crowding competition, for the beech layer during the first years of simulation, this behaviour seems however mainly related to forest structure in IP1 (a very dense dominant layer of Spruce trees), up to determine a complete absence of beeches at the end of simulation (none regenerations processes has been considered in this study).

Conclusive remarks

The expected climate regime for the LTER-Zöbelboden site is projected to exacerbate over time the fragile forest ecosystems, in terms of water quality and quantity (see main text), as well as for productivity and biodiversity maintenance. The less prosperous vegetation could be also more vulnerable and less resistant to additional climate-related disturbances like fires and pest infestations.

Very high resolution and most updated climate projections have been used in this complementary study; they are based on two RCP emission scenarios, comprising the less optimistic RCP8.5 and the intermediate RCP4.5. Even if this could benefit a precautionary assessment, in any case the usage of single (COSMO-CLM) model ensemble and of only two members (RCPs) of the ensemble limit the analysis to a very narrow bound estimate of impacts.

However, the complementation of the principal analysis based on L-DNDC with additional evaluations using an alternative approach like 3D-CMCC-FEM is a preliminary step toward a better representation of ecosystem complexity, by enlarging the set of impact indicators.

Moreover, both climate simulation data, modelling tools and synthesis indicators need to be tailored in order to: become easily available and useable by technicians of e.g. forest offices, environmental agencies and other stakeholders; allow translating scientific results into understandable highlights on vulnerability and risk; and guiding the inclusion of feasible and comprehensive adaptation options into forest management planning.

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7.3.2 Pilot Study 2 - Relationship between changes of climate, irrigation requirement and yield for Romania: indications for wheat and maize

Authors: V. Mereu, A. Trabucco, A. Gallo, D. Spano

High resolution climate simulations performed at 14 km of horizontal resolution over the SEE domain with COSMO CLM have been used to characterize indicators indicating impact of climate on agriculture in Romania. In particular were used simulations characterizing 1) present climate (1980-2011) forced by the ERA-INTERIM meteorological reanalysis and CMCC-CM GCM, and 2) future climate projections forced by the CMCC-CM GCM under RCP4.5 IPCC scenario covering 30 years periods (2006-2036, 2037-2066). From these climate datasets, the following climate variables were extracted and used to characterize climate impact: daily precipitation, net solar radiation, daily minimum temperature and maximum temperature.

The Decision Support System for Agrotechnology Transfer (DSSAT) is a crop modelling software that simulate growth, development and yield for several crop types as a function of dynamics between plant, soil and climate. DSSAT supports and exploits data base management for several types of soil, weather, and crop management and experimental data. The DSSAT program has been utilized within a R-based spatial platform routine to implement spatially distributed projection of crop modeling in combination with large scales GIS databases (e.g. netcdf) of climate, soil and management practices. The COSMO CLM projections made available four daily climate variables at 14 km (precipitation, solar radiation, min and max temperature), which were used in combination with the ISRIC-WISE (http://www.isric.org/data/isric-wise-international-soil-profile-dataset) derived soil properties on a 5 by 5 arc-minutes and country-based estimates of agronomic practices (e.g. planting dates, irrigation, fertilization, etc.) to derive crop predictions (e.g. yield and irrigation requirements) for maize and wheat for the whole Euro-Mediterranean area covering 30 years periods (present 1980-2011; future 2006-2036 and 2037-2066).

Besides other environmental factors (e.g. soil), crop yield is largely fostered by positive climate conditions, like availability of water needed for leaf gas exchanges and photosynthetic processes and temperature influencing crop development rate from emergence to maturity. Climate change would definitively lead to increases in temperatures, which will in turn increase vegetation water consumption (EvapoTranspiration) and intensify growth stages. Growing Degree Days (GDD) measures the number of temperature degrees above a threshold base temperature, and is used to assess suitability for specific crops, estimate growth-stages and heat stress for crops. According to climate projections described above, GDD will increase in Romania with higher rates towards the mid of the century (2050) and in the southern part of Romania (Figure 16). Based on the climate scenario, precipitations are projected to increase in the center-North part of the country (Figure 17), although it is widely recognized that precipitation projections are tied to strong uncertainties. Maize suitability requires 800 to 1400 GDD to reach crop maturity. Thus areas with already high GDD may have shorter growing season in the future for Maize and associated lower irrigation requirements (IrrReq), while areas with lower GDD may see in the future expansion of areas suitable for Maize in North Romania (Figure 18). Rainfed agriculture (e.g. wheat) will increase productivity (CropYld) mostly in the central and northern part of Romania, mostly due to projected increases in precipitation (Figure 19).

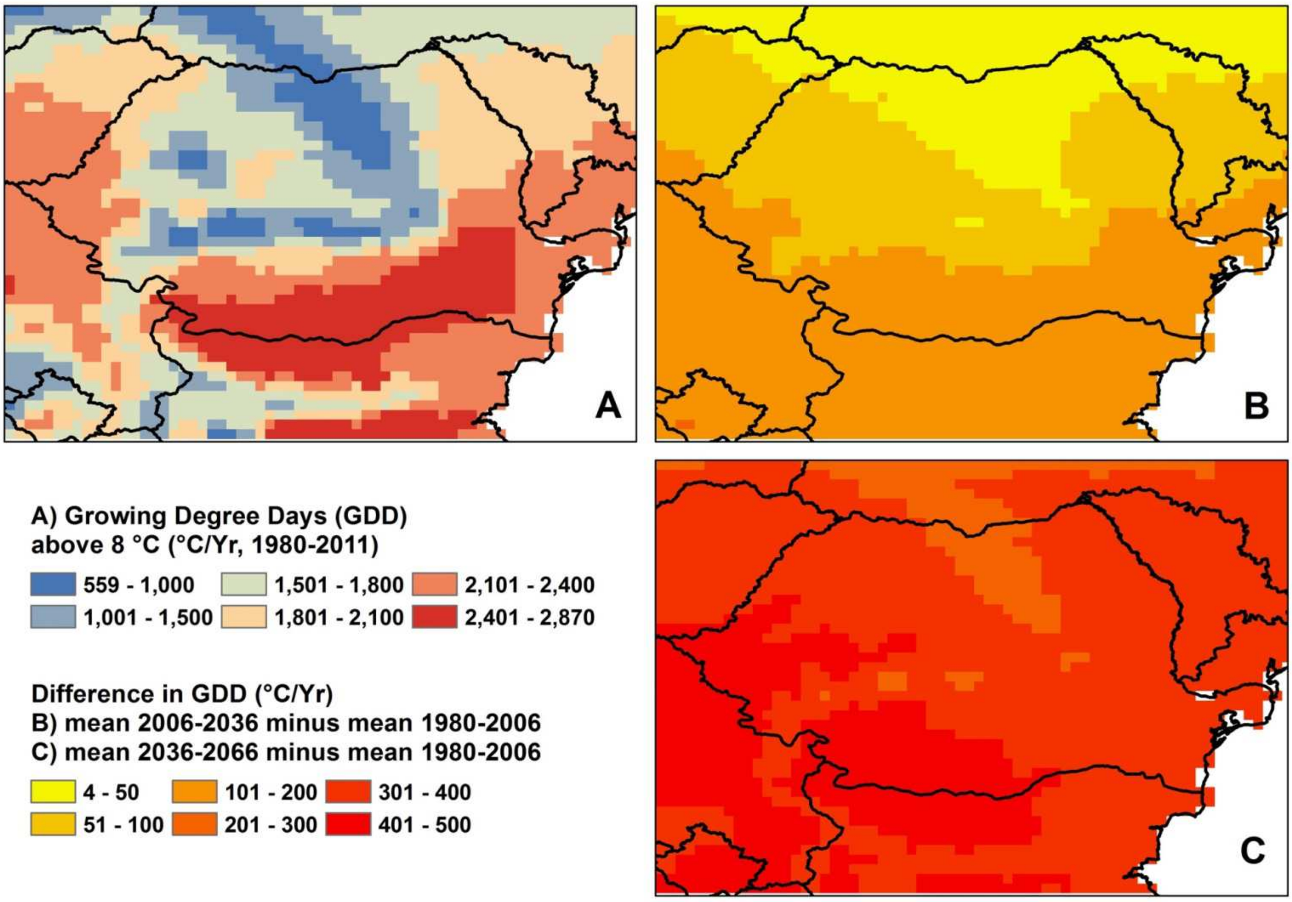

Figure 16

A) Average Growing Degree Days (GDD; base 8 °C) simulated with COSMO-CLM RCM (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in GDD between projected conditions (COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.

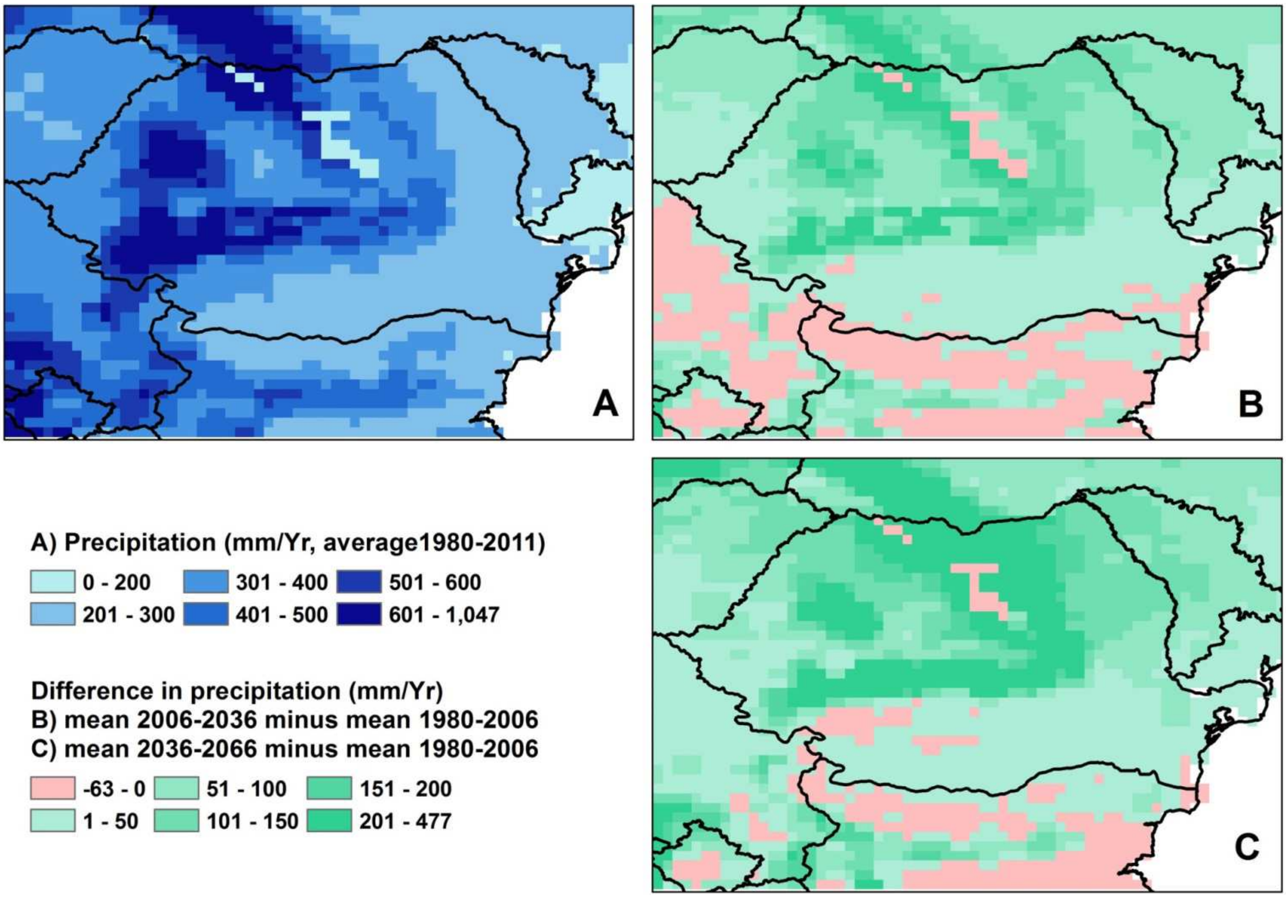

Figure 17

A) Average precipitation simulated with COSMO-CLM RCM (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in precipitation between projected conditions (COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.

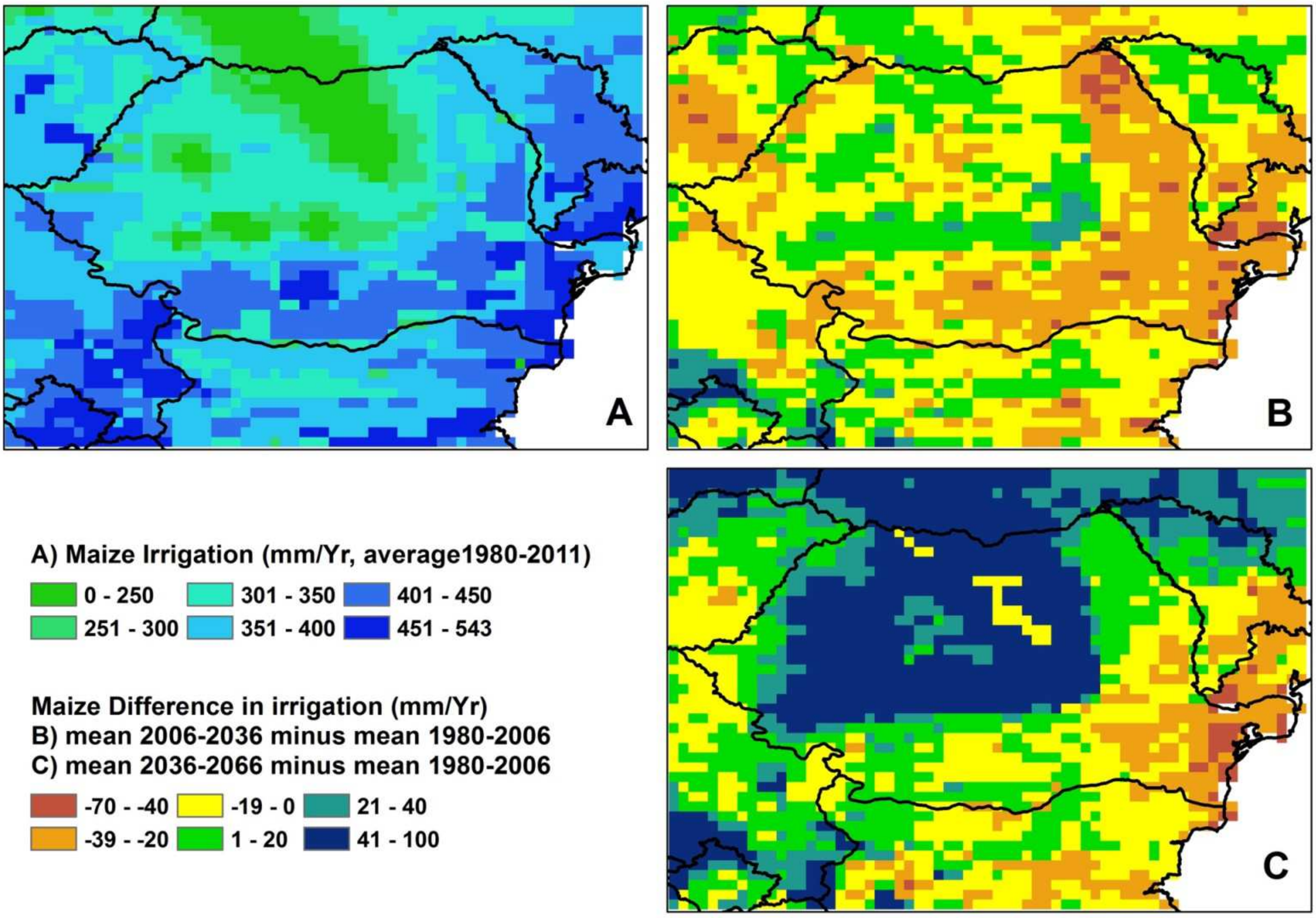

Figure 18

A) Average Maize irrigation requirements (mm/year) simulated with DSSAT crop model based on COSMO-CLM RCM climate data (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in Maize irrigation requirements between projected conditions (DSSAT based on climate COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.

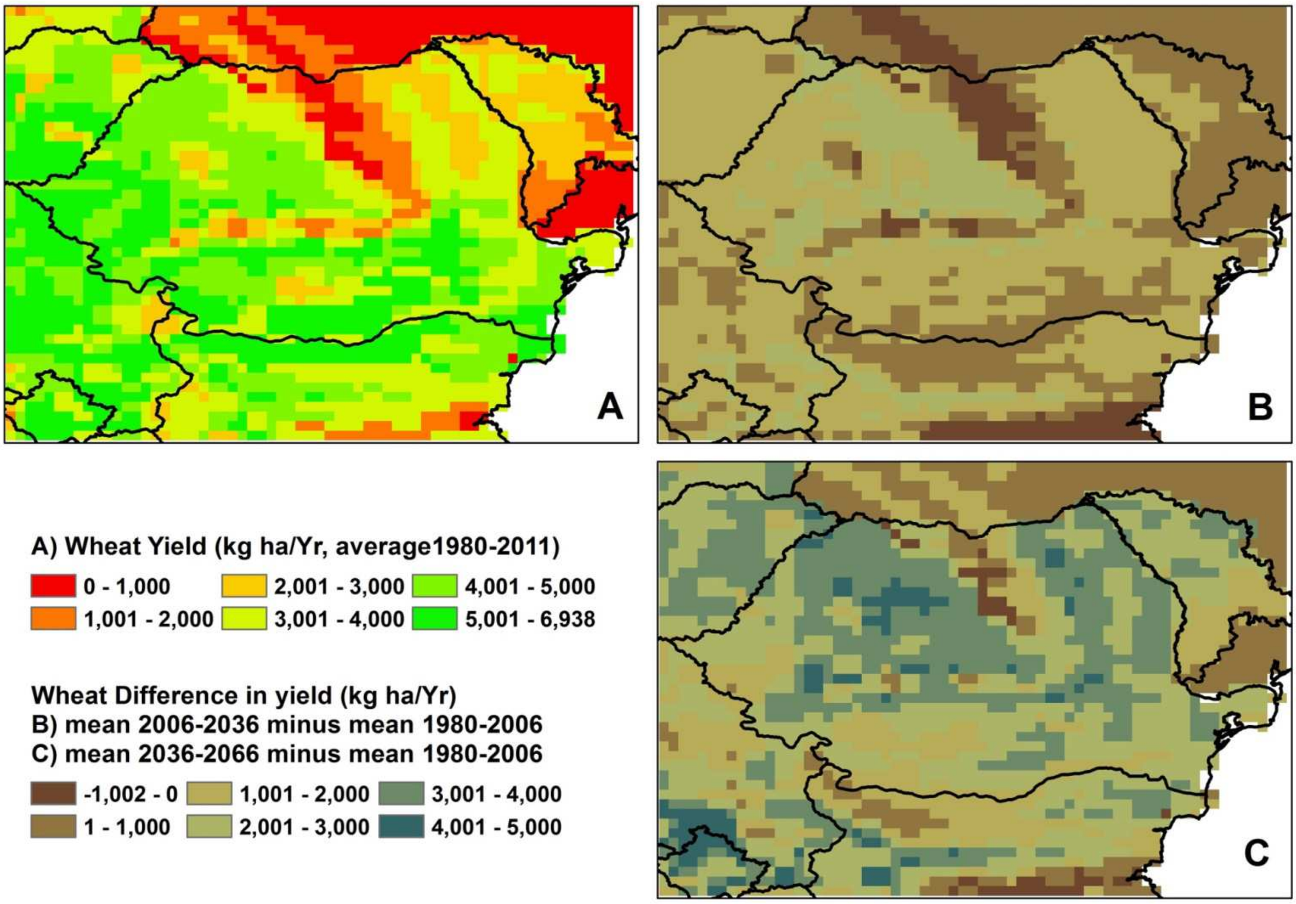

Figure 19

A) Average wheat yield (kg ha/year) simulated with DSSAT crop model based on COSMO-CLM RCM climate data (forced with ERA-INTERIM reanalysis) over the 1980-2011 period. Difference in wheat yield between projected conditions (DSSAT based on climate COSMO-CLM RCM forced with CMCC-CM GCM, RCP45) for 2006-2036 (B) or 2036-2066 (C) and actual conditions.