Project No. 037005

CECILIA

Central and Eastern Europe Climate Change Impact and Vulnerability Assessment

Specific targeted research project

1.1.6.3.I.3.2: Climate change impacts in central-eastern Europe

D6.3: Recommendations to improve effective use of water in the different production systems

Due date of deliverable: 31st May 2008
Actual submission date: 28th May 2008

Start date of project: 1st June 2006 Duration: 36 months

Lead contractor for this deliverable: University of Natural Resources and Applied Life Sciences, Vienna, Austria (BOKU)

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1. AUSTRIA (BOKU)

1.1. Introduction

The investigation area Marchfeld is located in the north-eastern (NE) part of the country and is one of the major field crop production areas in Austria; though it is also one of the driest regions. Higher temperature in next decades implies higher evaporation and therefore higher water demand for the crops in this region. The phenological development rates of the crops will increase due to the higher temperature and an increase of heat stress as well as drought stress can be expected. These issues influence mainly the water balance and the yield of the crops in the investigation area.

The main aim of this deliverable was to find possible adaptations for current agricultural cropping systems in the Marchfeld region to climate change. As adequate strategies to adapt cereal and maize cultivations, an adjustment of tillage and a shift of average sowing dates were analysed. It should provide recommendations to improve effective use of water in the different production systems.

1.2. Recommendations to improve effective use of water in the different production systems

The DSSAT model was applied to winter wheat, spring barley and maize to assess potential yield under climate scenarios for NE Austria. For this deliverable the climate scenarios for NE Austria were performed with the global circulation models (GCMs) CSIRO, HadCM and ECHAM (see D6.2). A CO_2 concentration in the atmosphere of 360 ppm was assumed according the emission scenario A2 for present conditions and 535 ppm for the year 2050 (IPCC, 2001). 5 soil classes were analysed in the investigation area (see D6.1 and 6.2). The simulated values of the climate scenarios contain the CO_2 fertilizing effect, adapted sowing date and contemporary crops without consideration of potential profit cuts caused by pest or diseases.

A shift of average sowing dates is one strategy to adapt different cultivations in the Marchfeld region towards climate change. A climate change in 2050 forces a delay of the sowing date of winter wheat in comparison with present conditions (maximal 14 days in October HadCM 2050, high climate sensitivity). In case of spring barley and maize climate change allows an earlier sowing date in spring (8 days for HadCM/CSIRO 2050 high climate sensitivity) (automatic planting) (figure 1).

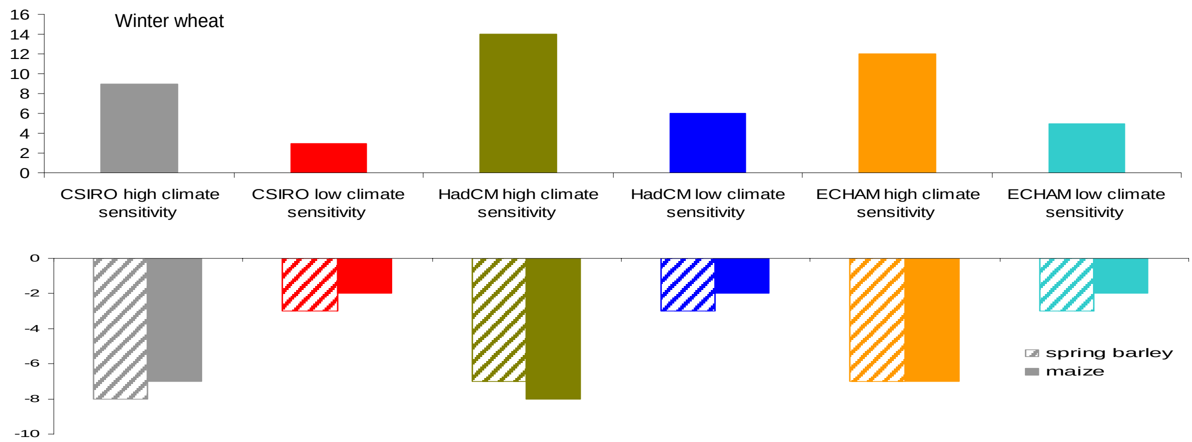


Figure 1.1. Day changes of the average sowing date of winter wheat, spring barley as well as maize in comparison with present conditions

As second adaptation strategy a replacement of ploughing by minimum tillage and direct drilling was analysed. Based on a tillage field trial at Raasdorf, Marchfeld, plant growth of the three crops was simulated. Such replacement leads to an increase of plant available field capacity, a better water supply for the crops as well as a decrease of unproductive water losses (Rischbeck, 2007). Due to a replacement yield potential of winter wheat in Marchfeld increases by 2% (in comparison with ploughed soil, area-weighted average) in 2050. In particular on sandy and shallow soils (soil class 1 and 2) minimum tillage enhance yield potential (figure 2).

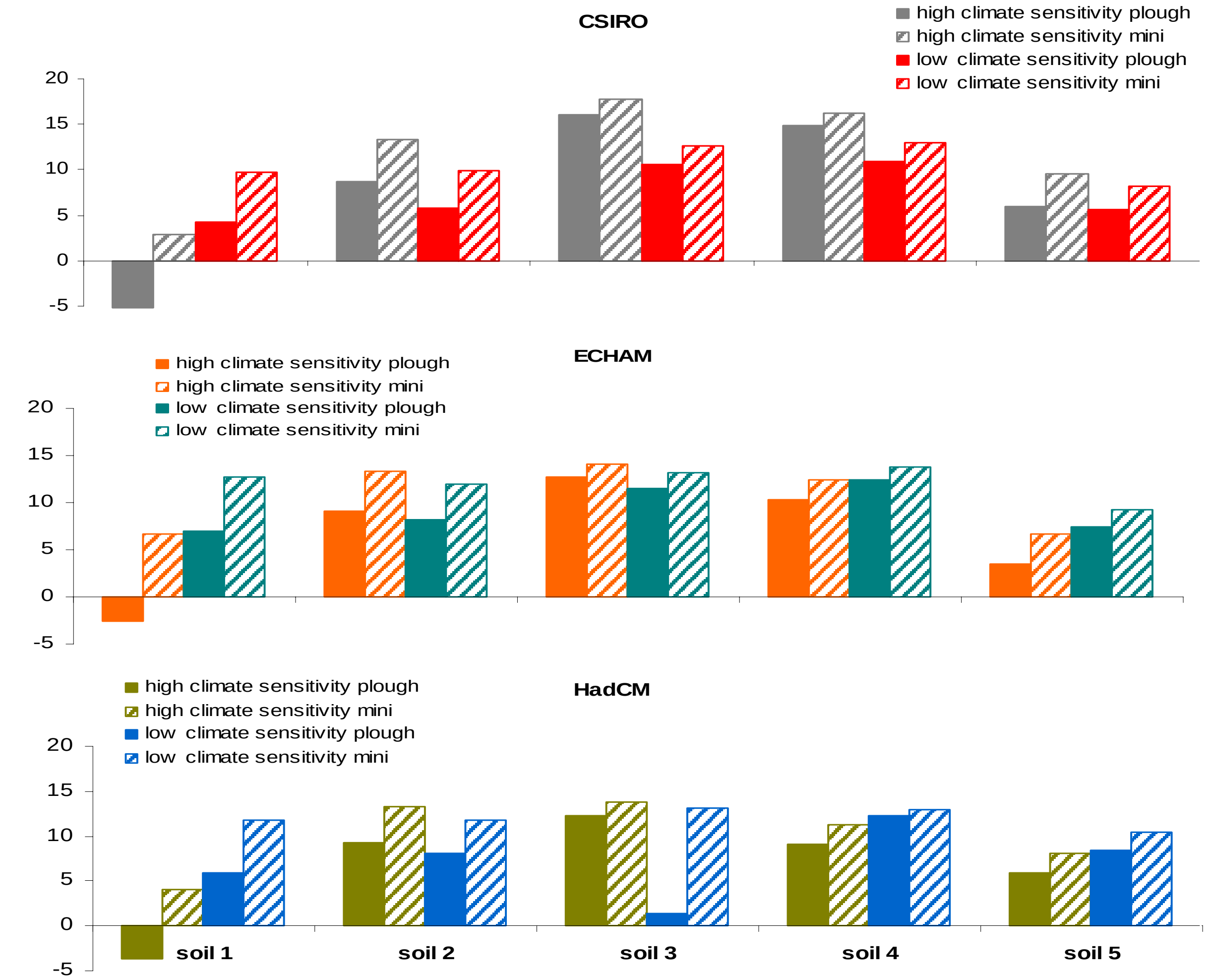
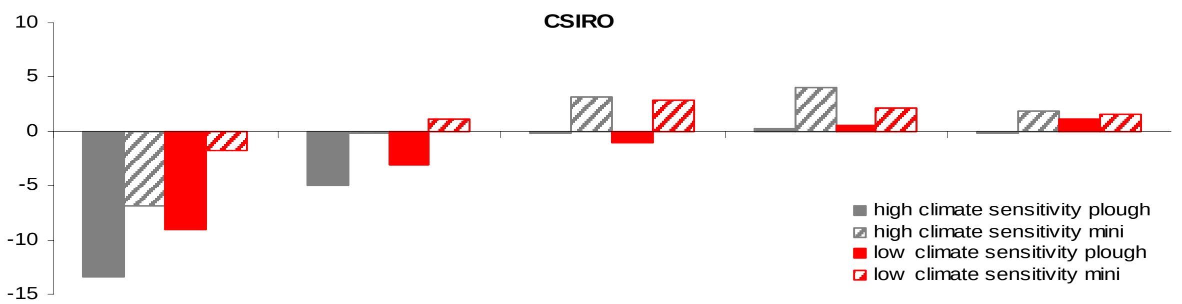


Figure 1.2. GCMs CSIRO, HadCM, ECHAM 2050: ploughing and minimum tillage (mini), winter wheat (relative change of the yield to the present conditions)

The effect of minimum tillage for spring barley is more significant. An adjustment of tillage would mean a yield increase up to 4% in comparison with ploughing in 2050 (area-weighted average). Minimum tillage would have positive effects on all soil types (figure 3).



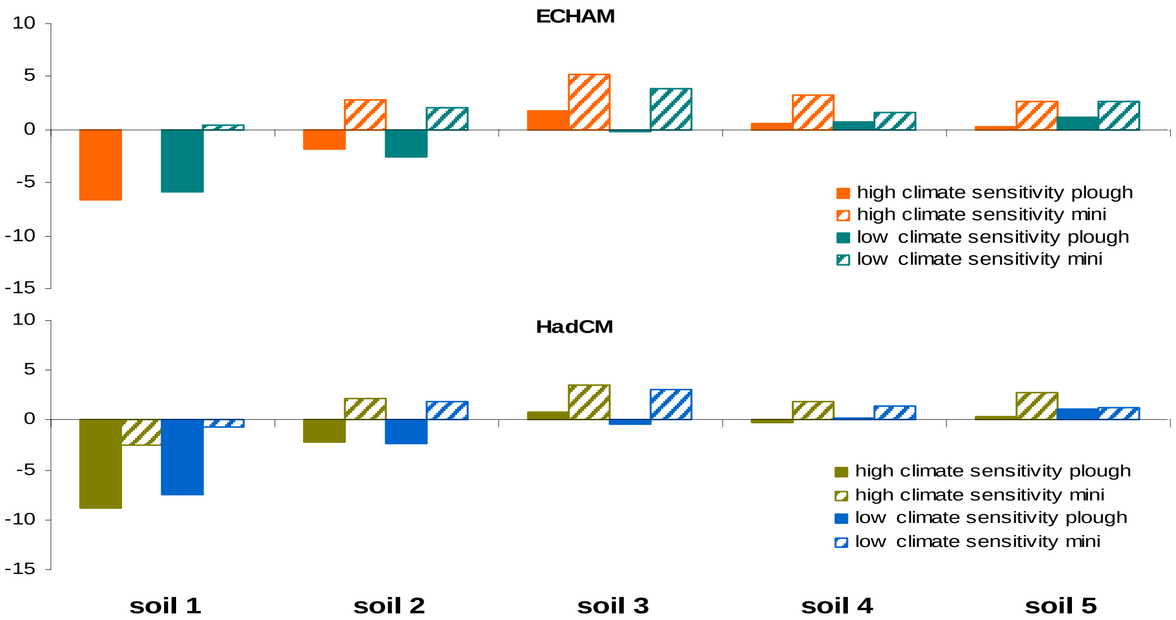


Figure 1.3. GCMs CSIRO, HadCM, ECHAM 2050: ploughing and minimum tillage (mini), spring barley (relative change of the yield to the present conditions)

Such improvements by changing tillage could not be achieved for maize (figure 4). Mere on soil class 1 a higher yield was analyzed in all GCMs.

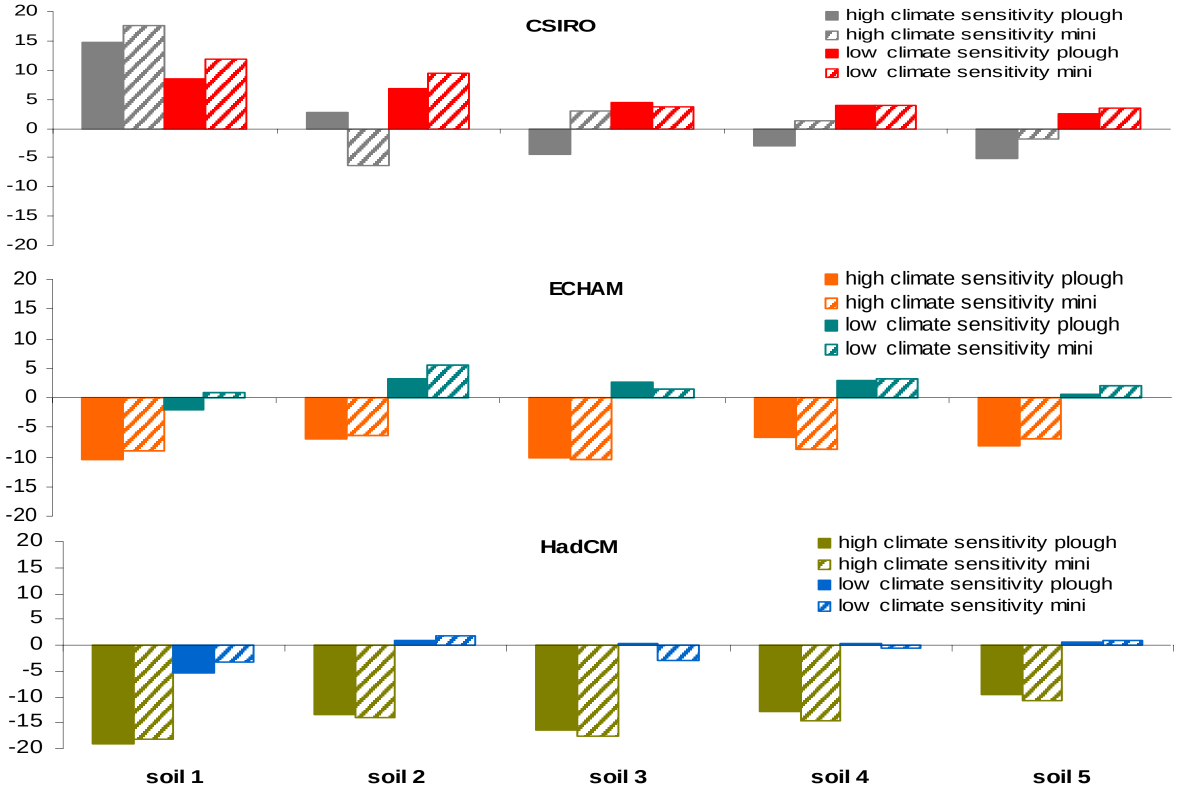


Figure 1.4. GCMs CSIRO, HadCM, ECHAM 2050: ploughing and minimum tillage (mini), maize (relative change of the yield to the present conditions)

1.3. Summary

The Marchfeld region is one of the most important field crop production areas of Austria and simultaneously one of the driest regions. Higher temperatures and lower summer precipitation in the next decades imply higher water demand for the main crops in the area. Despite higher drought stress, winter wheat yields may increase due to compensation by higher CO_2 concentrations (except very light and shallow soils). However, if the CO_2 response of the crops is less than assumed in the model, the yields would decrease significantly. For spring barley and maize, being more sensitive to climate change (although for different reasons), yield stagnations and decreases were simulated (Thaler et al., 2008). A shift of the average sowing dates is one strategy to adapt crops in the Marchfeld region towards climate change. As second adaptation strategy - replacement of ploughing by minimum tillage and direct drilling - was analysed. Minimum tillage leads to further increases of mean yield for winter wheat (up to 2% in comparison with ploughed soil, area-weighted average) and spring barley (up to 4% in comparison with ploughed soils, area-weighted average) in 2050. This effect is mainly a result of better water supply for the crops and a decrease of unproductive water losses. Such yield increase could not be simulated for maize.

A re-running of all results of this and previous deliverables using new RCM simulations will be done within next months.

1.4. References

IPCC - Intergovernmental Panel on Climate Change, 2001. Third Assessment Report: Climate Change 2001. Cambridge, Cambridge University Press.

Rischbeck, P.M., 2007. Der Einfluss von Klimaänderung, Bodenbearbeitung und Saattermin auf den Wasserhaus halt und das Ertragspotential von Getreide im Marchfeld. PhD Thesis, University of Natural Resources and Applied Life Sciences, Vienna, Austria.

Thaler S., Eitzinger J., Dubrovsky M., and Trnka M., 2008: Climate change impacts on selected crops in Marchfeld, Eastern Austria. 28th Conference on Agricultural and Forest Meteorology, 28 April - 2 May 2008, Orlando, Paper 10.7, available (08.05.08): http://ams.confex.com/ams/pdfpapers/138941.pdf

2. Czech Republic (IAP)

2.1. Introduction

Crop water use efficiency is a crop specific parameter but its practical impact is affected by the local climate and soil conditions. Differences in crop productivity between individual regions of the Czech Republic and generally in Central Europe are to a large extent determined by variations of climate and soil conditions.

The first aim of this study was to develop a methodology and a tool that would enable a sophisticated and flexible analysis of various agroclimatic indicators and their dynamics under climate change conditions for the selected central European region of Czech Republic and Austria. The results of this effort were summarized into the AgriClim software package that provides users with a wide range of parameters essential for evaluation of climate related stress factors (e.g. drought, snow presence or frost damage) in agricultural crop production. Although the methodology is primary aimed at conditions of rainfed field crop production for a specific region it could be adapted for all types of agricultural systems. To demonstrate the possibilities offered by AgriClim we investigated possible changes in agroclimatic zones and stress factors across Czech Republic and parts of Austria. Our work complements the studies that have been performed so far at the area as they were primarily focused either on particular crops (e.g. winter wheat, spring barley or maize) or only single indicators e.g. reference evapotranspiration.

2.2. Climate change scenarios

We compared the present agroclimatic conditions of the region with those expected in near future (around 2020) and around middle of the century assuming realization of two SRES scenarios (i.e. A2 and B1) and various GCM and RCM. In this part of CECILIA project the climate change scenarios were developed by means of a "pattern scaling" technique (Santer *et al.,* 1990) and then used to modify parameters of the Weather generator Met&Roll (Dubrovský, 1997), where differences between current and future GCM simulations are added to an observed climate baseline or series. In the pattern scaling method, the climate change scenario is defined by a product of the standardized scenario and the change of the global mean temperature. This allowed us to reach more general conclusions than those made in impact studies based on crop models and also thanks to the selected range of indicators to cover most of key climate factors limiting water use and crop production.

2.3. AgriClim software package

In order to understand better to the impacts of changing climate during 21st century whole range of agroclimatic indices was applied either at the selected sites or for all 129 sites used in the study. These indicators computed by AgriClim included **i)** duration of growing season, **ii)** number days suitable for sowing during spring/autumn sowing windows ; **iii)** number of days suitable for crop harvesting; **iv)** water deficit during key parts of growing season; **v)** duration of period with late/early frosts occurrence; **vi)** duration of snow cover, **vii)** probability of serious frost damage to winter field crops.

Table 2.1. Overview of mean values of selected key agroclimatic parameters at 4 representative sites (1- Laa an der Thaya warm dry region, 2 – Olomouc warm wet region, 3 - Tabor cool wet region, 4 – Cervena - cold wet region) for present (1961-2000) climate and expected changes under limatic conditions according to 2 SRES scenarios and 3 GCM models by 2020 and 2050.

Characteristic	Station	Present Climate	HadCM				ECHAM				NCAR-PCM			
			SRES-B1		SRES-A2		SRES-B1		SRES-A2		SRES-B1		SRES-A2	
		1961-1990	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050	2020	2050
Length of growing season (days)	1	***220±19***	+9	+13	+12	+30	+9	+13	+12	+30	+9	+12	+10	+26
	2	***210±20***	+12	+14	+20	+35	+12	+13	+18	+35	+13	+12	+18	+30
	3	***199±16***	+8	+13	+21	+32	+7	+12	+19	+29	+7	+11	+18	+27
	4	***182±22***	+8	+12	+19	+30	+8	+8	+16	+27	+8	+8	+16	+25
Water deficit from April till June (mm)	1	***-111±50***	-25	-27	-28	-51	-22	-21	-19	-32	-20	-18	-15	-25
	2	***-53±54***	-9	-13	-18	-40	-6	-8	-10	-25	-5	-5	-7	-19
	3	***-28±50***	-17	-17	-22	-43	-14	-12	-15	-28	-12	-10	-11	-22
	4	***-6±40***	-7	-11	-20	-50	-3	-6	-16	-32	0	-2	-5	-22
Number of snow days (days/agriculture year)	1	***54±23***	-6	-13	-20	-30	-8	-14	-21	-33	-5	-11	-18	-26
	2	***64±21***	-9	-15	-20	-35	-10	-16	-21	-38	-8	-14	-18	-32
	3	***76±22***	-6	-17	-21	-32	-7	-18	-22	-36	-5	-14	-18	-28
	4	***122±22***	-10	-13	-20	-40	-11	-13	-20	-43	-9	-10	-16	-33

As it is apparent from Table 1, the length of growing season will increase by 10-21 days by 2020 and up to 35 days by 2050 assuming A2 SRES emission scenario. The magnitude of growing season extension is obviously much larger than in the case of B1 SRES scenario with stations 3 and 4 showing the biggest gains (Table 1). The prolongation of the length of growing season, which has been already detected in the observed series, is almost symmetrically spread between spring and fall. These changes are accompanied by even longer periods with mean temperatures above 10°C and 15°C and significant rise of the sum of effective temperatures above these biologically relevant thresholds.

Higher winter temperatures will result in the shortening of the period between the first and the last day with the snow cover as well as number of days with snow. The change is more pronounced toward the end of winter and occurs more at lowland sites (i.e. the present dominating grain maize and sugar-beet production regions represented by stations 1 and 2). The mean length of the snow period in these sites will decrease from present two months to one month from the mid December to mid January. The number of days with snow cover will be reduced by 16-22 days at 2020 and up to 43 days at 2050 assuming A2 SRES emission scenario (Table 1). Under B1 emission scenario the changes will be more subtle.

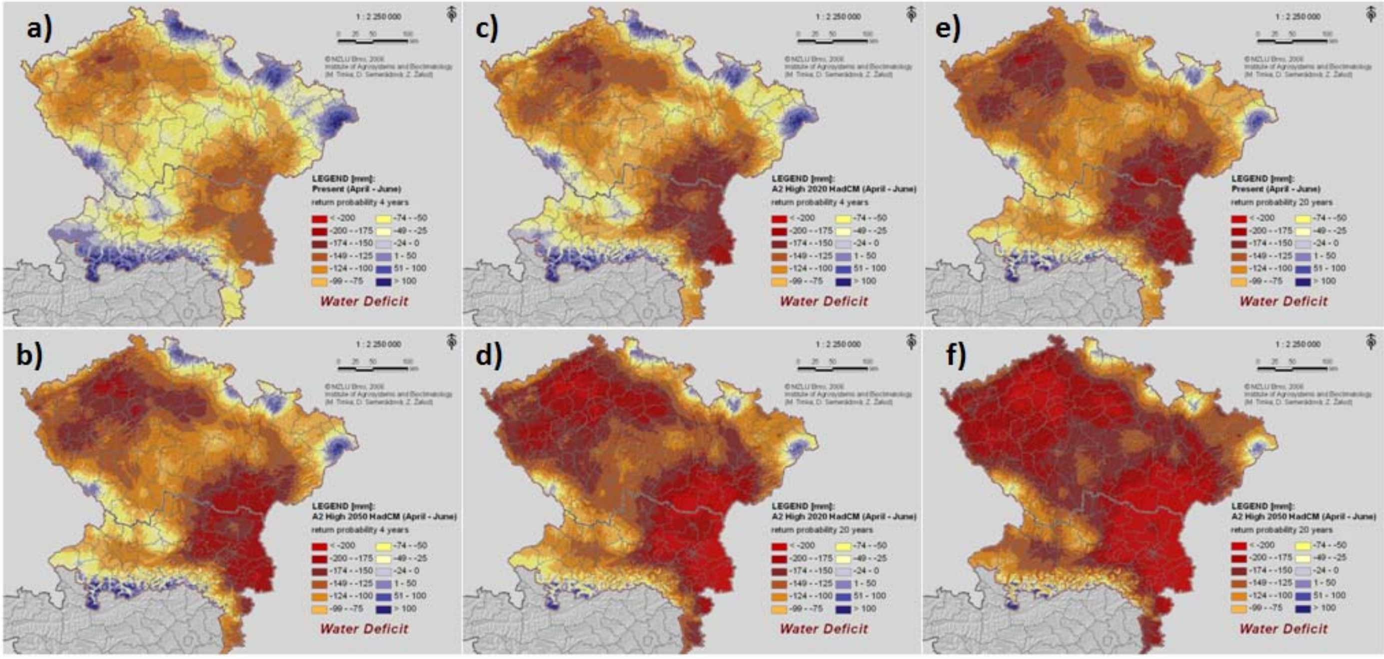


Figure 2.1. Values of water deficit with return probability of 4 (a,c,e) and 20 (b,d,f) years during key crop production period (April – June) for the present climate conditions (a,b) and those expected around 2020 (c,d) and 2050 (e,f) based on the A2 SRES scenario and HadCM model.

The expected changes in the water balance during key parts of growing season are of particular interest as almost entire agriculture production in Czech Republic and to a large extend in Austria is rainfed. The main attention has been focused on precipitation changes in the period from April to June that has been shown as critical for water stress sensitivity of field crops in the region. The increase of incident global radiation and higher ambient air temperature (leading to increased saturation deficit) are assumed according to all GCM at least in some parts of the studied period. As a result a higher rate of reference evapotranspiration is expected under future climate that is not matched by adequate increase of precipitation (with HadCM even predicting net precipitation decrease) which leads to more severe water deficit (Table 1). As Fig. 1 shows, the area that will be hit by severe water deficit with return probability of 4 and 20 years will increase almost three fold and the areas that have presently even during dry springs positive water balance will be faced with substantial water deficit.

2.4. Water stress

Change in agroclimatic conditions reported in the Fig 1 and Table 1 lead to higher water deficit for most important agricultural regions. However when the water stress indicators are considered in a crop specific way the effect of increased CO_2 concentration (leading to higher WUE) in combination with earlier sowing must be taken into account. Event the driest and warmest of all GCMs used (i.e. HadCM) indicates reduced water stress in most regions of the Czech Republic by 2050. Interestingly reduced water deficit is still achieved even when CO_2 effect is not taken into account (indirect influence at Fig 2.). This is partly due to the fact of shorter growing season and its shift towards the earlier period of the year. The combination of higher water use efficiency also positively influences crop production as Figures 3 and 4 document.

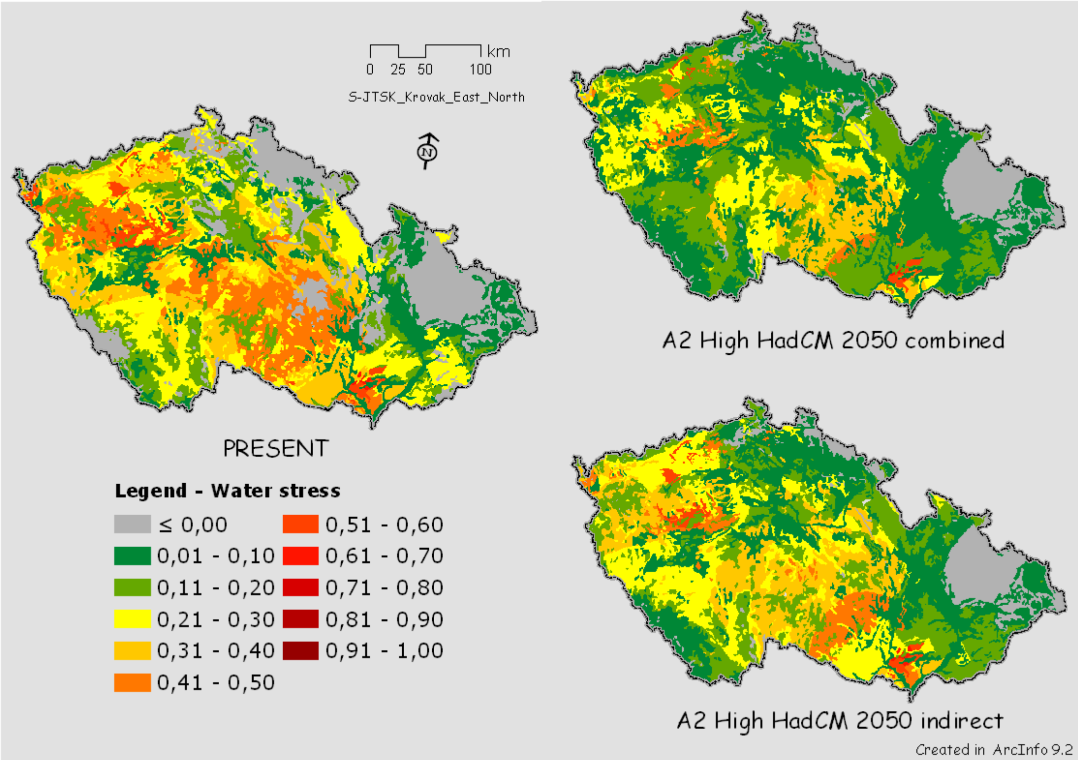


Figure 2.2. Water stress for winter wheat from anthesis to maturity according to HadCM model for 2050, emission scenario SRES-A2, for the Czech Republic. The higher number in legend the higher water stress.

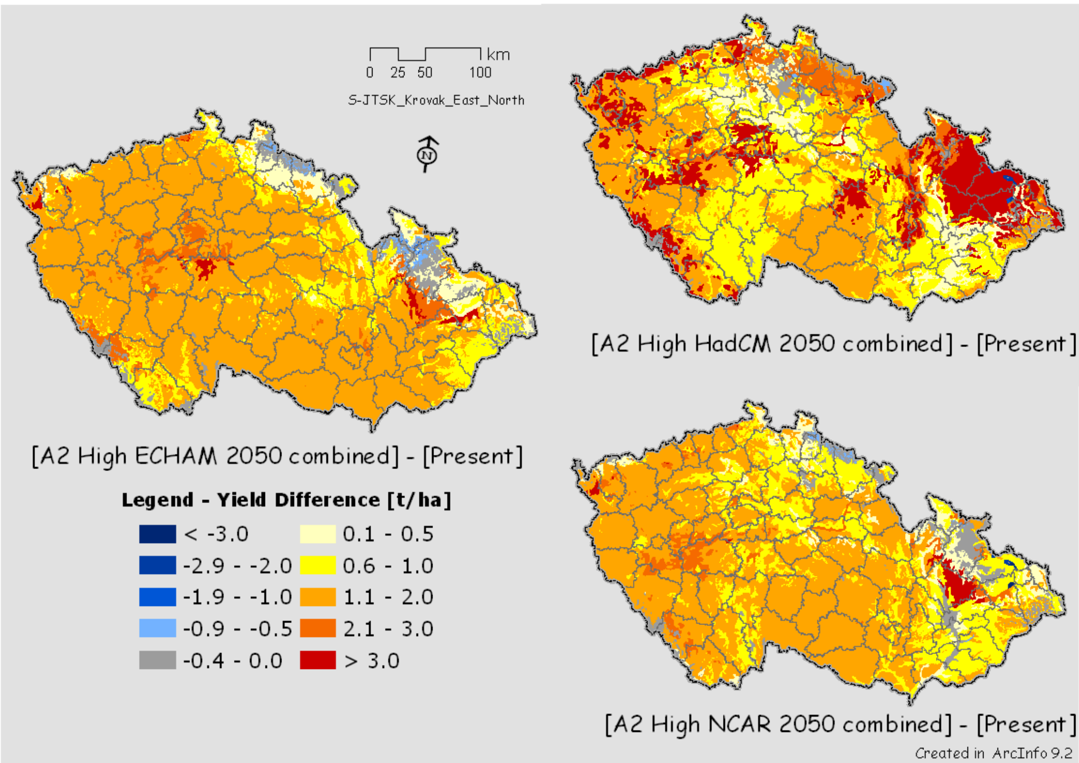


Figure 2.3. Difference between winter wheat yield for present climate conditions (1961-2000) t/ha and expected climate according three climate change scenarios for 2050, emission scenario SRES A2.

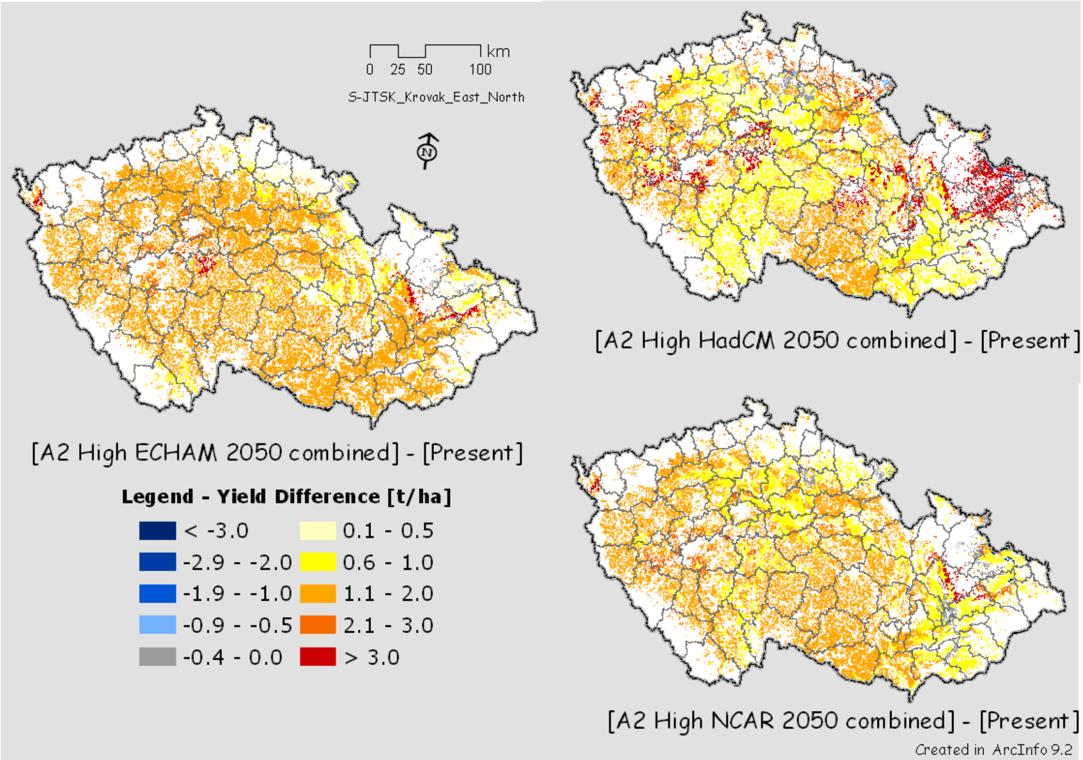


Figure 2.4. The same as Fig 3 but for arable land

2.5. Conclusions and recommendations

i) By 2020 the combination of increased air temperature and changes in the amount and distribution of precipitation will lead to prolongation of growing season and significant shifts in the agroclimatic zones. Current most productive areas will be reduced and replaced by warmer but drier conditions, which are less suitable for rainfed farming. Building and re-building of irrigation systems in economic profitable conditions (e.g. drip irrigation systems) will be necessary for crops grown over the summer months;

ii) While the trends of the changes expected in lowlands are mostly negative according to the production potential of rainfed crops, the higher elevations will most likely experience improvement of their agroclimatic conditions. However this positive effect might be a relatively short-lived situation as by 2050 (at least if SRES A2 is realized) even these areas might experience much drier conditions than nowadays. Change of crops, varieties and crop rotation must be introduced and respected.

iii) Diary oriented agriculture (based on permanent grassland) at higher altitudes could suffer through an increased evapotranspiration demand combined with the decrease of precipitation leading to the intolerable water deficits.

iv) The areas that are already warm and relatively dry (i.e south-east) we will experiencing 20-year drought intensity three times as frequently and water deficits that have not been encountered before.

v) Farmers will most likely be able to take advantage of earlier start of growing season at least in the lowland areas as the proportion of days suitable for sowing will increase. Shift of the sowing date to the beginning of the year to use winter water resources and is able to mitigate the negative effects of summer droughts in case of cereal production;

vi) the proportion of days suitable for harvesting should increase during July-September with decrease of interseasonal variability. However harvesting conditions in June will remain relatively unfavorable that might pose problems for harvesting early maturing crops (e.g.

winter barley or winter rape);

vii) interestingly the negative effects of increased water deficits during vegetation season seem to play smaller role than expected when crop model simulations are used. However results of more detail analysis suggest that even though the yield increase might be expected by 2050, yield reductions are more likely in the next 10-20 years.

viii) Overall the negative impacts on the field crop production will be probably felt more in Czech Republic than in Austria for several reasons such as very limited water resources available for irrigation and larger field sizes in Czech Republic. On the other hand the decreasing suitability for permanent grassland production is likely to become a serious problem in some drier parts of Austria due to complex terrain limiting adaptive capacity. Water saving technologies and the structural changes to the agrosystems will have to be applied.

2.6. References

Dubrovsky, M.,1997. Creating daily weather series with use of the weather generator. Environmetrics, 8, 409–424.

Santer BD, Wigley TML, Schlesinger ME, Mitchell JFB (1990) Developing climate scenarios from equilibrium GCM results. Report No.47, Max Planck Institute für Meteorologie, Hamburg

3. Romania (NMA)

3.1. Introduction

Water use efficiency (WUE) represents a given level of grain yield per unit of water used by the crop. With increasing concern about the availability of water resources in both irrigated and rainfed agriculture, there is renewed interest in trying to develop an understanding of how WUE can be improved and how farming systems can be modified to be more efficient in water use. Soil management practices affect the processes of evapotranspiration by modifying the available energy, the available water in the soil profile, or the exchange rate between the soil and the atmosphere.

The consequences of the humidity effect on water use are that crops use and require more water under less humid conditions (to keep the stomata open) to get the same yield as under humid conditions. Alternatively, the same amount of water results in less yield (due to closure of stomata) under less humid conditions. Therefore, crops grown in arid areas have lower WUE than in humid areas. Also, different plant species absorb CO_2 at different rates, so WUE can be different between crops such as wheat and maize.

WUE seems to be the more relevant parameter to the question of impact on agricultural production. Climate change will affect water use in several ways: firstly it is not all bad, there is a benefit because increased CO_2 improves growth by enhancing photosynthesis, but there are further benefits because higher CO_2 also tends to close stomata and slow down the rate of water loss from the leaves. So high CO_2 gives more food for less water consumed. On the down-side, loss of water from crops (evapotranspiration) will be greater due to the warmer climate, but yields could go up or down with the higher temperatures. Most importantly, on average there will be less rainfall during the critical growing period and crops will suffer from soil moisture deficits. Drought stress caused by higher evapotranspiration and reduced summer rainfall will probably override any growth benefits from the higher CO_2 levels.

The main objectives of the present report within the CECILIA project, were to evaluate crop water use efficiency under current and future climate for different cropping systems (winter wheat and maize), for 9 sites located in SE Romania and also to identify agricultural measures that can improve effective use of water by crops. Our contribution is based on the results and conclusions of a case study conducted for the pilot station Calarasi, applying the CERES simulation models in combination with two climate change scenarios predicted by global climate model HadCM3, SRES-A2 emission scenario. Three different technological sequences were analyzed by alternative simulations of crop management practices: application of irrigation, using different soil classes, and changes in sowing date. In addition, the crop models were run for the current climate and two scenarios (2020s and 2050s) with and without simulation of the direct effect of CO_2 on grain yield, evapotranspiration and water use efficiency. A CO_2 concentration in the atmosphere of 330 ppm was assumed for current climate, 400 ppm for 2020 and 500 ppm for 2050.

3.2. Recommendations to improve effective use of water in the different production systems

The effect of climate change scenarios on crop water use efficiency was estimated considering the 30-year means of the two simulated parameters, GY: grain yield ($kg.ha^{-1}$) and ET: amount of the evapotranspiration (mm) in the crop growth period.

The water use efficiency being a measure of cropping system performance in the use of available water for reproductive growth, the different plant species absorb CO_2 at different rates, so WUE can be different between crops such as winter wheat and maize.

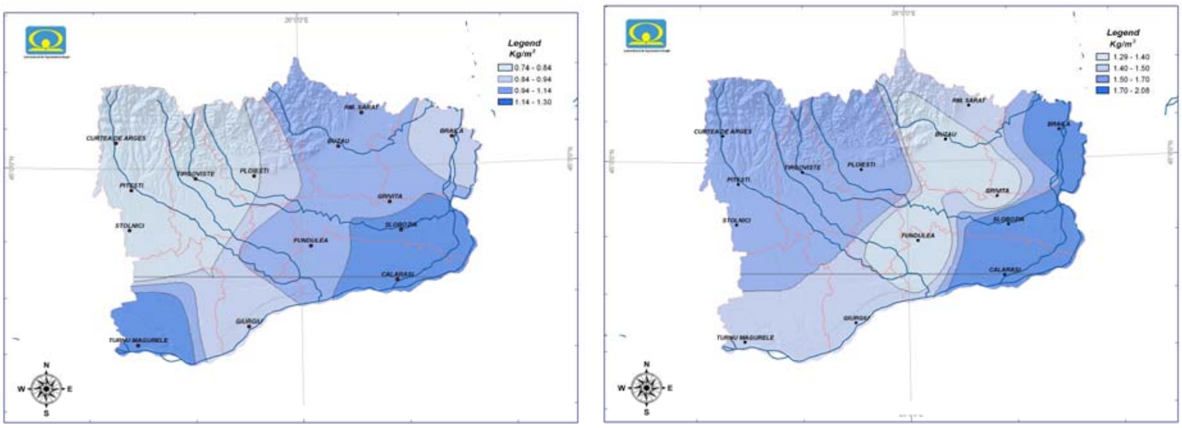
For example, in the current climate, for winter wheat crop, the WUE calculated as GY/ET, is between 0.74 and 1.30 $kg.m^{-3}$, site such as Targoviste, Galati, Ploiesti and Giurgiu have lower

WUE than other sites in the region. So, the winter wheat crop at Calarasi, Buzau, Fundulea and Tr. Magurele used the soil available water more efficiently.

For maize crop, the water use efficiency is greater than for winter wheat crop, ranging between 1.29 kgm^{-3} at Buzau and 2.08 kgm^{-3} at Calarasi (Tab.1 and Fig. 1).

Table 3.1. Winter wheat and maize WUE simulated for the current climate (1961-1990) and all sites in the target area (the SE Romania)

Site	Soil type	WINTER WHEAT WUE (kg m^{-3})	MAIZE WUE (kg m^{-3})
Calarasi	Cambic chern.	1.26	2.08
Buzau	Cambic chern	1.06	1.29
Fundulea	Cambic chern.	1.11	1.36
Targoviste	Brown reddish	0.74	1.67
Ploiesti	Brown reddish	0.84	1.70
Tr.Magurele	Cambic chern	1.30	-
Giurgiu	Cambic chern	0.85	1.46
Galati	Cambic chern	0.76	1.72
Rm.Sarat	Brown reddish	-	1.49



a) b)

Figure 3.1. Zoning of the simulated winter wheat (a) and maize (b) water use efficiency for the current climate (1961-1990) in the SE Romania

3.2.1. Application of irrigation

For both rainfed and irrigated conditions, the average WUE of *winter wheat crop* calculated for the current climate (over a 30-year period) is quite similar, 1.26 kg.m^{-3} and 1.29 kg.m^{-3}, respectively.

Under climate change conditions WUE will be enhanced. Simulated results show that the winter wheat crop uses the available soil water more efficiently in both scenarios. The winter wheat WUE greatly increases, particularly in the case of 2050 scenario. Taking into account the CO_2 effect on both rainfed and irrigated winter wheat, the crop water use efficiency increases significantly by 10-11% in 2020 and by 32-33% in 2050, compared with the current conditions, due mainly to the increased CO_2 assimilation rate (Tab. 2 and Fig. 2a). Greater concentrations of CO_2 generally result in higher photosynthesis rates and may also reduce water losses from plants.

For *maize crop*, by application irrigation, the water use efficiency increases for both scenarios by 1.5-2.5% (without CO_2) up to 8-19% (with CO_2), compared with the current climate (Tab. 3 and Fig. 3).

Table 3.2. CERES-Wheat results by climate change scenarios (without/with direct CO_2effect on rainfed and irrigated winter wheat crop) at the pilot station Calarasi. *Changes from base are shown as a percentage.*

		Rainfed			Irrigated		
Specific.	**Scenario**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**
	Base	**4945**	**391**	**1.26**	**5833**	**452**	**1.29**
Without CO_2	2020s	-1.5%	-3.6%	+2.4%	-1.2%	-4.0%	+3.1%
	2050s	+12%	-5.9%	+19.8%	-	-9.7%	+10.9%
	2020s	+5.6%	-3.8%	+10.3%	+3.9%	-6.2%	+10.9%
With CO_2	2050s	+20.9%	-8.7%	+33.3%	+13.0%	-14.2%	+31.8%

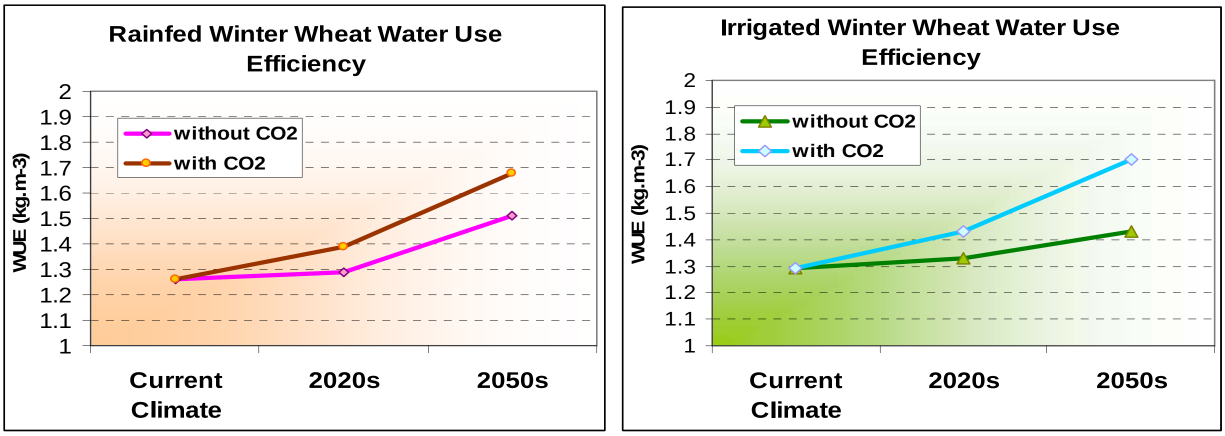


Figure 3.2. Water use efficiency of rainfed and irrigated winter wheat crop simulated with CERES-Wheat model at the Calarasi site, in the current climate and the two climate change scenarios predicted by HadCM3 model

Table 3.3. CERES-Maize results by climate change scenarios (without/with direct CO_2effect on rainfed and irrigated maize crop) at the pilot station Calarasi. *Changes from base are shown as a percentage.*

		Rainfed			Irrigated		
Specific.	**Scenario**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**
	Base	**7196**	**346**	**2.08**	**10198**	**510**	**2.0**
Without CO_2	2020s	-32.9%	-14.4%	-21.6%	-3.9%	-5.5%	+1.5%
	2050s	-81.5%	-30.3%	-73.5%	-9.8%	-12.2%	+2.5%
With CO_2	2020s	-13.7%	-14.4%	+0.1%	-2.9%	-10.2%	+8.0%
	2050s	-20.8%	-26.9%	+8.2%	-8.6%	-23.1%	+19.0%

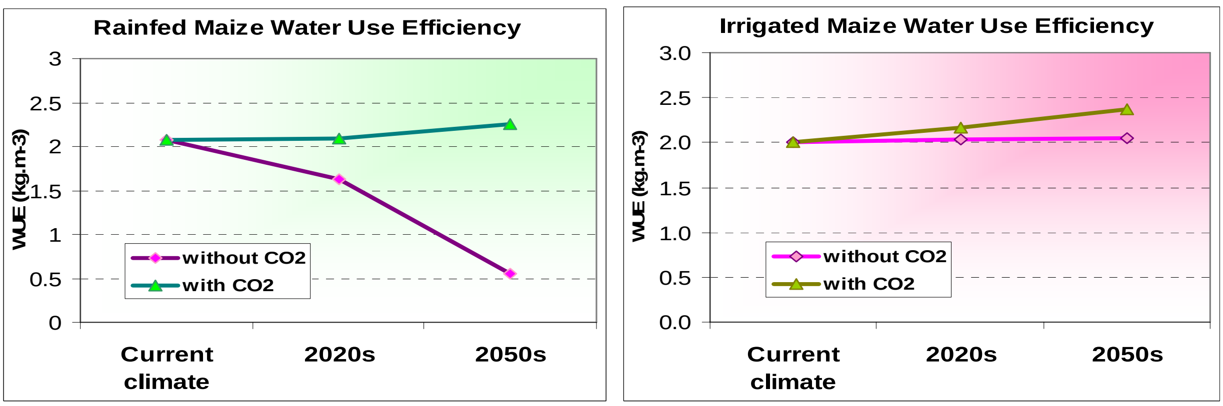


Figure 3.3. Water use efficiency for rainfed and irrigated maize crop (without/with CO2 effect) in the current and future climate, at the pilot station Calarasi

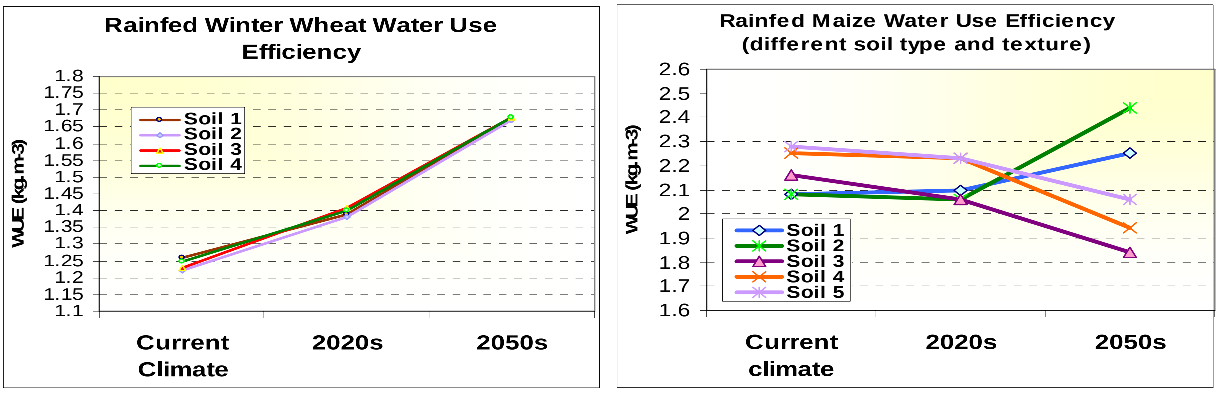
3.2.2. Using different soil classes

Four soil classes were selected for simulation of rainfed *winter wheat crop*. The first 3 soil classes are medium cambic chernozems with different textural classes (clay loam, clay and sandy loam, respectively), and soil 4 is brown reddish with fine loamy sand. The winter wheat crop uses the available soil water more efficiently in both scenarios, the WUE shows an increasing trend for all soil classes, but there are not differences between the four soil classes (Tab. 4 and Fig. 4a).

For *maize crop*, five soil classes were selected for simulation. The first 3 soil classes are medium cambic chernozems with different textural classes (clay loam, sandy clay and sandy loam, respectively). Soil 4 and 5 are brown reddish with two textures (clay and fine loam). The maize plants growing on cambic chernozem soils (Soil 2: sandy clay and Soil 1:clay loam), that have the highest available water capacity, show the highest WUE increases in 2050 up to 2.25 -2.44 kg.m^{-3}, with 8.2-17.3% higher as compared to the current conditions (Tab. 5 and Fig. 4b). For the rest of classes (Soil 3, 4 and 5), WUE decreases especially in the decade 2050.

Table 3.4. Water use efficiency of winter wheat crop simulated for different soil types and textural classes in the current climate and the two climate change scenarios, at Calarasi site

Soil classes	WUE (kg.m^{-3}) **Base**	WUE (kg.m^{-3}) **2020s**	WUE (kg.m^{-3}) **2050s**
Soil 1: Cambic chern.-clay loam	1.26	1.39	1.68
Soil 2: Cambic chern.-clay	1.22	1.38	1.67
Soil 3: Cambic chern.-sandy loam	1.23	1.41	1.68
Soil 4: Brown reddish-fine loamy sand	1.25	1.40	1.68



a) **b)**

Figure 3.4. Water use efficiency of rainfed winter wheat (a) and maize (b) growing on different soil types and textural classes at the Calarasi site, in the current climate and the two climate change scenarios

Table 3.5. Water use efficiency of maize crop simulated for different soil types and textural classes in the current climate and the two climate change scenarios, at Calarasi site

Soil classes	WUE (kg.m^{-3}) **Base**	WUE (kg.m^{-3}) **2020s**	WUE (kg.m^{-3}) **2050s**
Soil 1: Cambic chern.-clay loam	2.08	2.10	2.25
Soil 2: Cambic chern.-sandy clay	2.08	2.06	2.44
Soil 3: Cambic chern.-sandy loam	2.16	2.06	1.84
Soil 4: Brown reddish – clay	2.25	2.23	1.94
Soil 5: Brown reddish – fine loam	2.28	2.23	2.06

3.2.3. Change in sowing date

The predicted WUE of the both variants (rainfed and irrigated maize) increased by 6.1-18.2% in both scenarios, with an earlier sowing date (April 1) in comparison with current dates

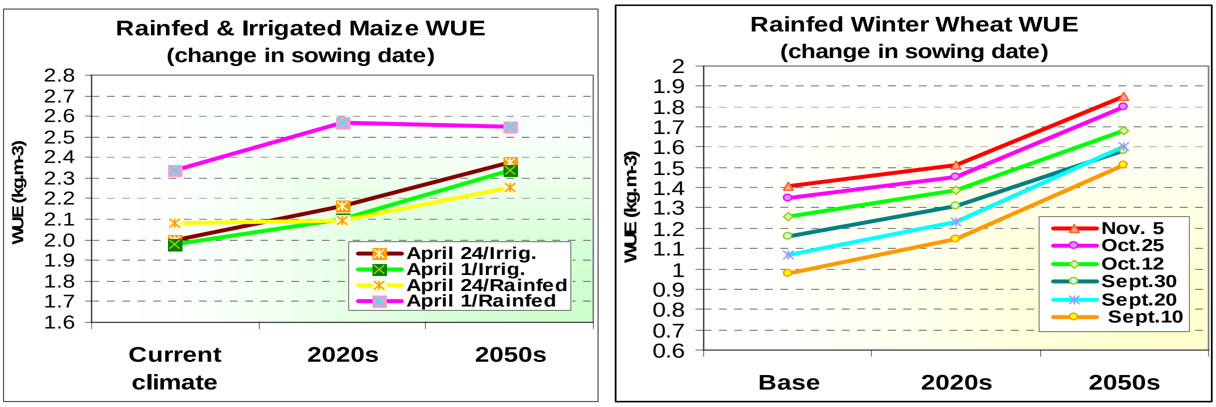
(April 24)-Tab. 6 and Fig.5a. In the case of winter wheat, water is used more efficiently with the later sowing date, October 25 and November 5, respectively (Tab. 7 and Fig. 5b).

Table 3.6. Water use efficiency of rainfed and irrigated maize by change in sowing date in the current and future climate, at Calarasi site

		Rainfed			Irrigated		
Sowing date	**Scenario**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**	**GY (kg.ha-1)**	**ET (mm)**	**WUE ($kg.m^{-3}$)**
	Base	**7196**	**346**	**2.08**	**10198**	**510**	**2.0**
April 24	2020s	-32.9%	-14.4%	+1.0%	-3.9%	-5.5%	+8.0%
	2050s	-81.5%	-30.3%	+8.2%	-9.8%	-12.2%	+19.0%
	Base	**8158**	**348**	**2.34**	**10251**	**518**	**1.98**
April 1	2020s	-0.5%	-9.2%	+9.8%	-7.3%	+12.7%	+6.1%
	2050s	+18.1%	+24.7%	+9.0%	+10.5%	+24.3%	+18.2%

Table 3.7. Water use efficiency of rainfed winter wheat by change in sowing date in the current and future climate, at Calarasi site

Sowing date	WUE (kg.m-3) Base	WUE (kg.m-3) 2020s	WUE (kg.m-3) 2050s
November 5	1.41	1.51	1.85
October 25	1.35	1.45	1.8
October 12	1.26	1.39	1.68
September 30	1.16	1.31	1.58
September 20	1.07	1.23	1.6
September 10	0.98	1.15	1.51



a) b)

Figure 3.5. Water use efficiency of maize (a) and winter wheat (b) by changing sowing date at the Calarasi site, in the current climate and the two climate change scenarios

3.3. Summary

A case study in Calarasi site for different cropping systems (winter wheat and maize) was performed, applying the CERES simulation models and two climate change scenarios predicted by global climate model HadCM3, SRES-A2 emission scenario. The present report summarizes some ways to improve crop water use efficiency in dry agricultural areas as follow.

By application of irrigation for minimizing water stress during sensitive development phases, the WUE can be significantly increased by 10.9% in 2020 and 31.8% in 2050. The irrigation application that increases grain yield and minimizes evapotranspiration is likely to increase more significantly the efficiency of water utilization by the both crops.

The highest increase of maize WUE, up to 8.2 -17.3% in 2050, can be expected for the medium Cambic Chernozems soils (sandy clay and clay loam).

The predicted WUE of maize crop increases by 6.1-18.2% in both scenarios (2020s and 2050s), with an earlier sowing date (April 1) in comparison with current dates (April 24). In the case of winter wheat, water is used more efficiently with the later sowing date, October 25 and November 5, respectively.

3.4. References

Cuculeanu V., Adriana Marica, Simota, C., 1999. Climate change impacts on agricultural crops in Romania and adaptation options, Climate Research (CR SPECIAL 6, Book Version), vol. 12, Inter-Research ISSN 0936-577X, Germany, pp. 153-160

Marica Adriana, Aristita Busuioc, 2004: The potential impacts of climate change on the main components of water balance relating to maize crop, Romanian Journal of Meteorology, Vol.6, No.1-2, ISSN 1223-1118, pp. 40-49, Bucharest, Romania

Marica Adriana, V. Cuculeanu, 2000. Use of a decision support system for drought impact assessment and agricultural mitigation options in Romania, Proceedings of the Central and Eastern European Workshop on Drought Mitigation, Ed. RePRINTStudio Ltd., Budapest-Felsogod, Hungary, ISBN 963 00 3890 0, pg.259-266

Mateescu Elena, Marica Adriana, D. Alexandru, 2008, The phenology of agricultural crops-present conditions and perspectives in the context of climate change, 8th COST 725 MC and WG meetings and scientific fieldtrip, National Meteorological Administrattion, 6-7 May 2008, Bucharest, Romania

Mateescu Elena, Agriculture and Climate Change in Europe-Regional facts and challeges, 2007: ACCRETE project, pp.1-82, University of Rostock, Germany