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Modelling climate change impacts on thermophilic crops production in central and southern Europe

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Abstract

The agriculture in all its segments is directly affected by extreme weather events and their effects, especially negative, cannot be ignored. However, the increase in the length of the growing season, together with a warmer climate, may increase the potential for growing thermophilic vegetables in open fields in lowland and increase the potential number of harvests in larger areas in Europe.

To develop strategies on climate change adaptation for different varieties of thermophile crops for future climate change in different regions in order to increase productivity, while reducing the water footprint of agriculture per unit product is one the main tasks in climate smart agriculture.

This research presents an assessment of the potential climate change impacts on various types of thermophilic crops in central and southern Europe. In this context, the main objectives of the research will focus on assessing crop water use efficiency and pests and diseases incidence under current and future climate scenarios for various cropping systems, especially thermophilic species (maize, sunflower, vegetables), for various agricultural sites that are vulnerable to extreme climatic events.

First, a comprehensive analysis to determine perspective areas for growing thermophilic crops in study regions is presented, based on projected climatic data provided by regional climate models (RCMs).

Second, applying crop models to evaluate adaptation options to reduce climate change impacts and take advantage from new sequences technologies based on climate change projections.

Third, the effect of climate change on the main pest and diseases in thermophilic crops is based on the sustainable approaches for vegetables protection.

Key words: crop modelling**,** thermophilic crops, regional climate model, plant protection

Introduction

Information needs for agricultural decision making at all levels are increasing rapidly due to increased demands for agricultural products and increased pressures on land, water, and other natural resources. The crop growth models may provide information on plant production based on expected climate conditions.

Although crop models have great potential for practical use in agriculture in general and in horticultural in particular, their use is still limited.

The principle of crop growth models is to incorporate in the basic algorithms the results of measurable biotic processes and their linkages with the abiotic conditions.

The water use efficiency (WUE) also, is a measure of cropping system performance in the use of available water for reproductive growth (the ratio of the net gain in dry matter over a given period, divided by the water loss).

With increasing concern about the availability of water resources in both irrigated and rain-fed agriculture, there is renewed interest in trying to develop an understand of how WUE can be improved and how farming systems can be modified to more efficient 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.

Material and methods

For the Czech Republic, the research methods were divided into two key steps:

I. **experimental research at farm level** including (1) testing the new thermophilic assortment of vegetables in Elbe lowland conditions (Fig. 1-5); (2) monitoring the meteorological data, phenological phases, soil characteristics, leaf area, the amount of aboveground biomass and water balance on a farmer's fields with high growth areas of market vegetables (Fig. 6a); (3) digital elevation model of the crop fields made by means of the GPS and GIS (Fig. 6b).

II. **theoretical part of the research at regional level -** deals with a new assessment of the potential climate change impacts on the assortment of vegetable crops grown in the Elbe River lowland, one of the largest farmed regions for market vegetables in central Europe.

For Romania the main goals refers to: 1) crop water use efficiency under current and future climate analyzed for different cropping systems, especially thermophilic species (such as: maize, sun-flower, vegetables, etc) and different agricultural sites that are vulnerable to climate events extremes; 2) climatic scenarios and the effect upon crops; 3) analysis of adaptation options to climate change.

Input data in crop model: monitoring and analysis of historical climatic data; CMIP3 scenarios projections based on ensembles of numerical experiments with global climate models; CERES model in order to improve crop water use efficiency in dry agricultural areas.

In order to assess the impact of the climate change on maize crop the CERES-maize model was used. The CERES type model has been developed and embedded in a software package called Decision Support System for Agrotechnology Transfer (DSSAT version 4.5). DSSAT itself (Hoogenboom et al. 2010) is a shell that allows the user to organize and manipulate crop, soils and weather data and to run crop models in various ways and analyze their outputs.

The output from the CERES simulation model is used for the impact assessment. The model calibration and validation are important steps in model verification. This step involves a comparison between observed and simulated grain yield of maize crop.

The simulated results under the baseline climate (1961-1990) are compared to the simulated values under the climate change scenarios (2020-2050 and 2070-2100).

The effect of climate change scenarios on crop yield formation and water balance elements are estimated considering the 30-year means of the following simulated parameters: grain yield (kg/ha), season length (d), amount of the evapotranspiration and precipitation (mm) in the crop growth period.

Results and discussion

Due to climate change, the breeding of new and improved vegetable crop varieties can lead to the extension of suitable areas for the profitable cultivation of vegetables. Some thermophilic vegetables that currently grow mostly in the southern Europe (e.g., melons, eggplants, tomatoes and peppers) may become more suitable for cultivation in lowland areas in the central Europe.

A general increase in the length of the frost-free period in the lowlands, primarily a result of an earlier start of the growing season (GS) has been detected. The impacts that these changes may have on agriculture include a reduced risk of spring and fall frost damage to crops and a lengthened GS for vegetables (Fig. 4). In the Elbe river lowland, the sowing/planting period is affected (advanced) by the majority of temperature-based climate variables (Potop et al. 2012, 2013a-b, 2014a-b).

The maps of regionally observed growing season reveal three basic regions of GSL:

- The first region, with the longest GS duration, is located on the north-eastern Prague plateau and it is connected with the warmest areas of the middle Elbe River valley.
- Furthermore, this area shifts towards the middle Poohří located in the western part of the Bohemian plateau. The second region, with a moderate GS duration, is a contiguous area in the central part of the Elbe River basin.
- The third region, with the shortest GSL≥5, 10 and 15°C, is a transition area (Fig. 3) between the frost hollows of the Kokořín and Ralská hills (north-western part), where the lowland relief along the Elbe River significantly increases to the northern part of the Bohemian plateau. This area, in conjunction with the Svitavská hills (eastern part) has the shortest growing season.

As a practical recommendation, the authors suggest that the first two regions may be suitable for the cultivation of thermophilic vegetables in conjunction with an irrigation system that would ensure profitable yields (Potop et al. 2014a). To maximise the yield potential of vegetables in hilly areas, it is necessary to use special agro-technical measures, which increases the cost of cultivation. However, the short duration of the GSL in the transition area allows for the planting of leaf and some brassica vegetables more than once per season with repeated harvesting.

Under projected future climate conditions and temperature thresholds, the dominant dates of BGS and EGS for the entire study region are projected to be significantly advanced and delayed, respectively, compared with the current climate. A climate warming scenario suggests lengthening of the GSL in the coldest areas of the study region to the level of the warmest areas of the current climate (e.g. Fig. 5).

In Romania, on the background of predictable climate change, it has been estimated a broadening of the crop areas affected by annual precipitation deficits of higher intensity – according to the drought classes: excessive drought (less than 350 mm). The frequency and the severity of drought in close relation to climate change are projected to increase significantly. In the southern and the eastern Romania, a reduction of 20% in water resource has been estimated (Fig. 7-9).

Regions that are currently dry are expected to become drier and could be affected by desertification in the future (Fig. 7). According to climatic predictions, in the southern agricultural areas a shortening by more than 15-21 days of the vegetation period in thermophilic crops (maize, sun-flower) is possible by 2020-2050 and, a 22-26 days one by end of century due to increasing air temperatures and, consequently, 12…22% lower yields by 2020-2050 and 21-42% lower yields by 2071-2100 respectively, as a result of higher in-soil water deficits mainly during the grain fill period (July-August).

In the rainfed conditions, without taking into account the CO_2 effect, WUE decreases significantly by 22% in 2020 up to 74% in 2050. By application the 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.

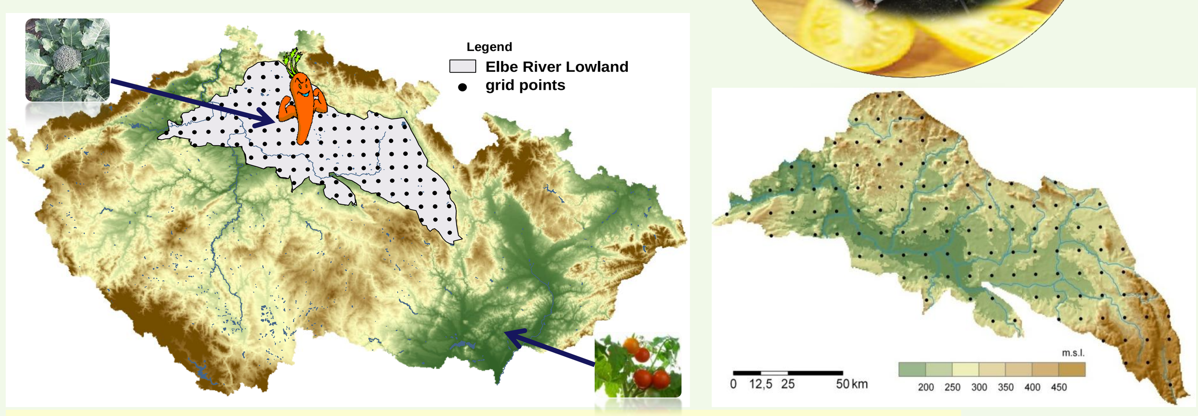
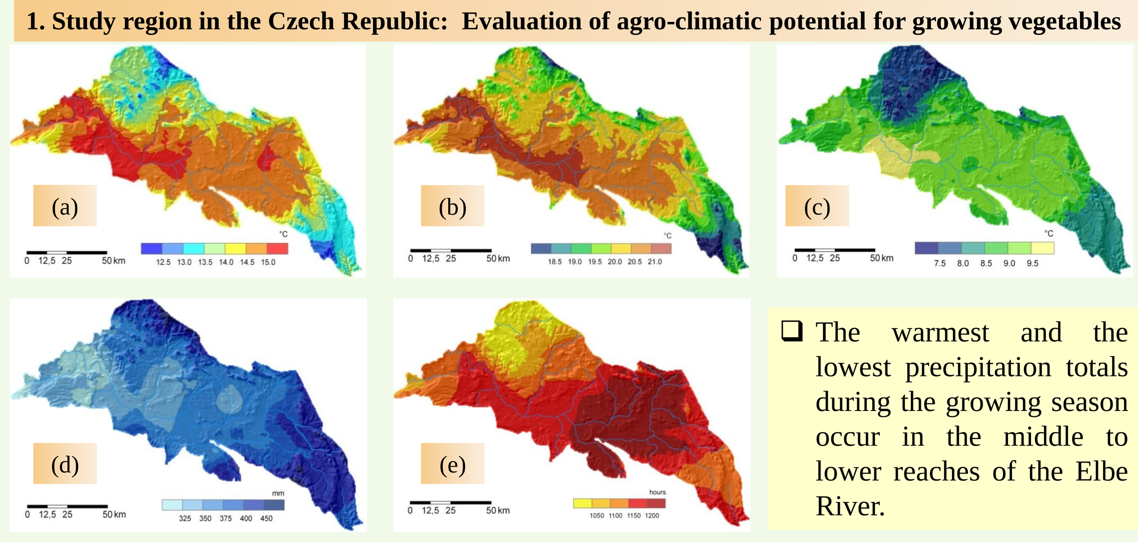


Fig. 1. Study region in the Czech Republic and boundaries of Elbe River Lowland

The Elbe River lowland has traditionally been a region of cultivation of brassica vegetables, while south Moravia is a profitable region for thermophilic vegetables (e.g., tomatoes and peppers).

1. Study region in the Czech Republic: Evaluation of agro-climatic potential for growing vegetables



- The warmest and the lowest precipitation totals during the growing season occur in the middle to lower reaches of the Elbe River.

Fig. 2. Spatially distribution of averages of mean temperature (a), maximum temperature (b), minimum temperature (c), precipitation amount (d) and sunshine duration (e) generated with geostatistical techniques during growing season (1961-2011).

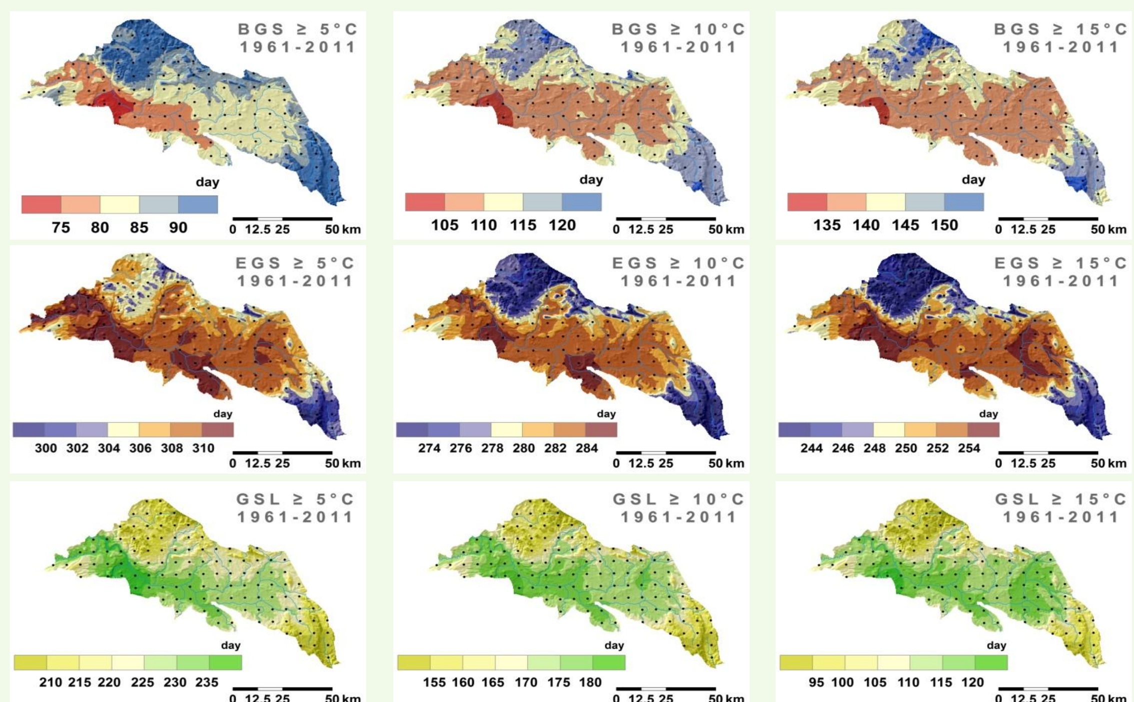


Fig. 3 Spatial variability of the mean values of the start (BGS), end (EGS) and length of the growing season (GSL) for the temperature thresholds of 5, 10 and 15°C from 1961 to 2011 in the Elbe River lowland.

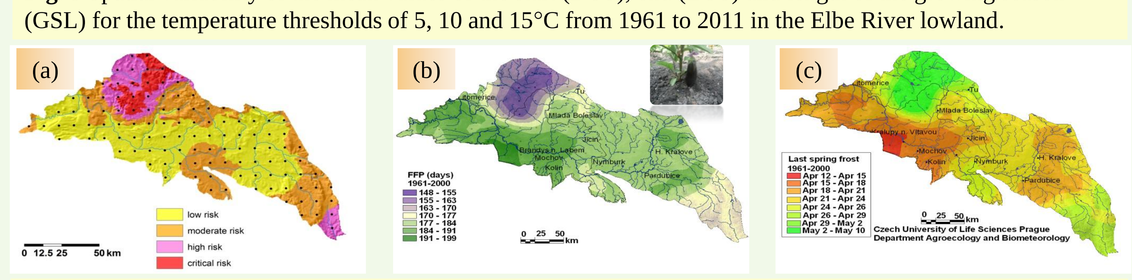


Fig. 4 Frost risk maps for the last spring frosts during sowing/planting of thermophilic vegetables (a), the length of the frost-free period (b), and date of the last spring frost (c) over the Elbe River Lowland (1961-2011).

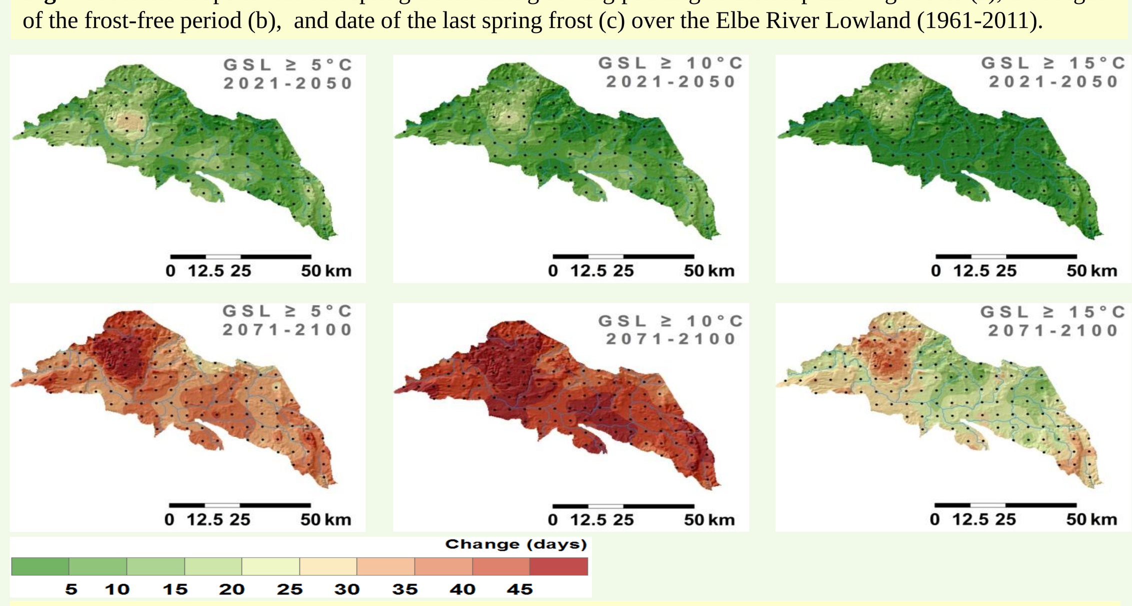


Fig. 5 Spatial distribution of the projected changes in GSL for the three threshold temperatures based on ALADIN-Climate/CZ simulation data under the A1B SRES scenario for two future periods, 2021–2050 and 2071–2100, respectively, over the Elbe River lowland.

2. Experimental research at farm level

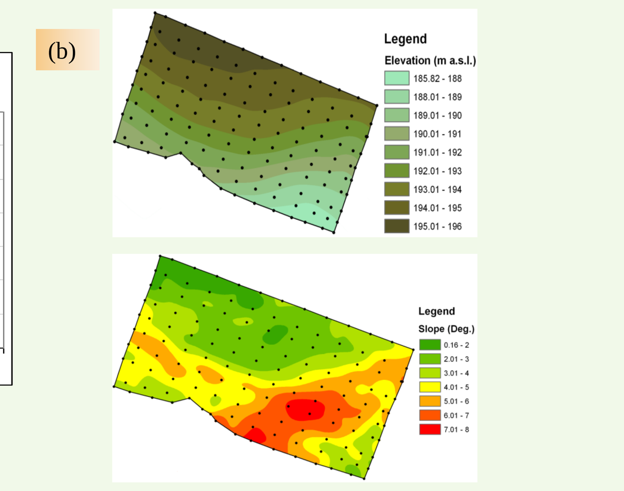


Fig. 6b) Digital elevation model derived from RTK-GPS data: 138 grid points collected by GPS (3.2 ha). Model of the slopes based on the interpolated elevation data.

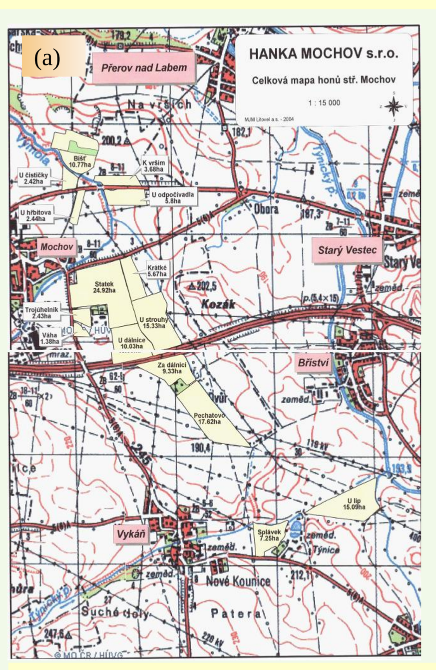


Fig. 6a) Topographic map of location fields at the farm Hanka Mochov s.r.o.

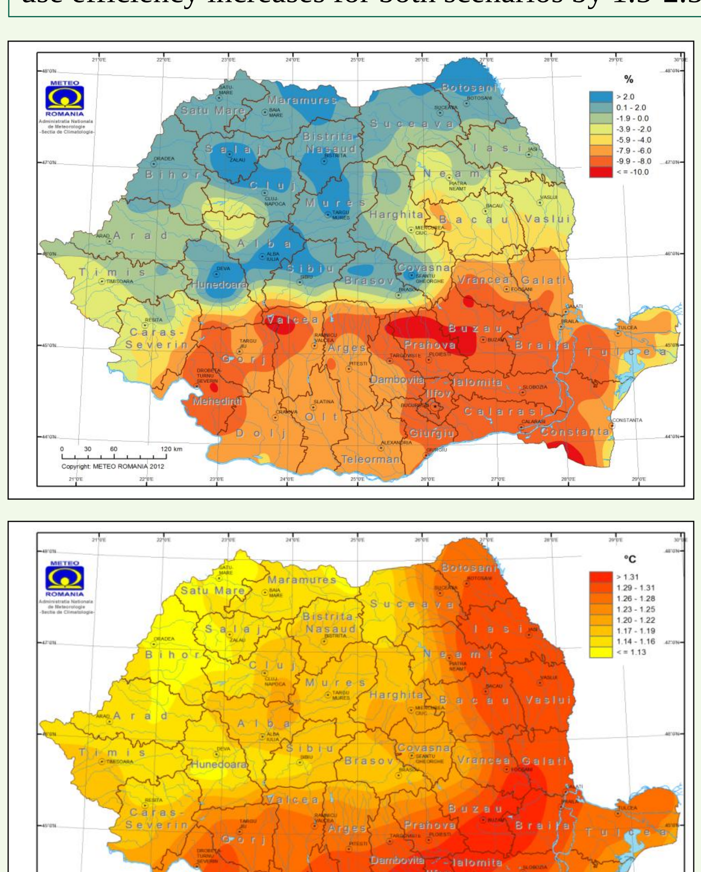


Fig. 7 Multiannual mean changes (2011-2040 vs.1961-1990) in air temperature (°C) and precipitation (%) computed from 9 runs with 9 regional climate models. Climate model results are taken from the FP6 Ensembles project.

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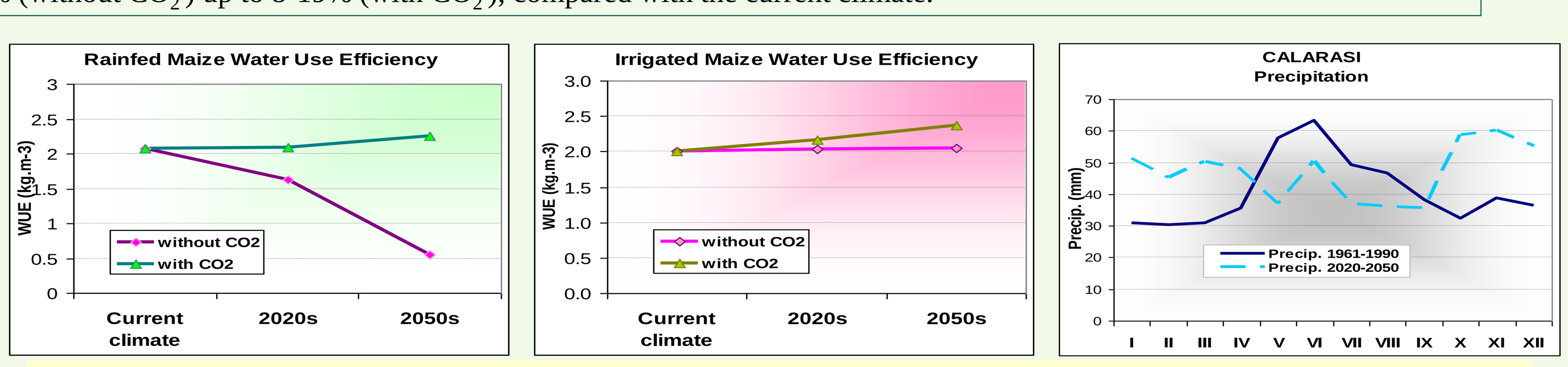

Fig. 8 Maize water use efficiency (Calarasi meteo station, situated in the most droughty area from South of Romania). Multiannual precipitation amounts under current climate conditions (1961-1990) and RegCM3/2020-2050/SRES A1B predictions.

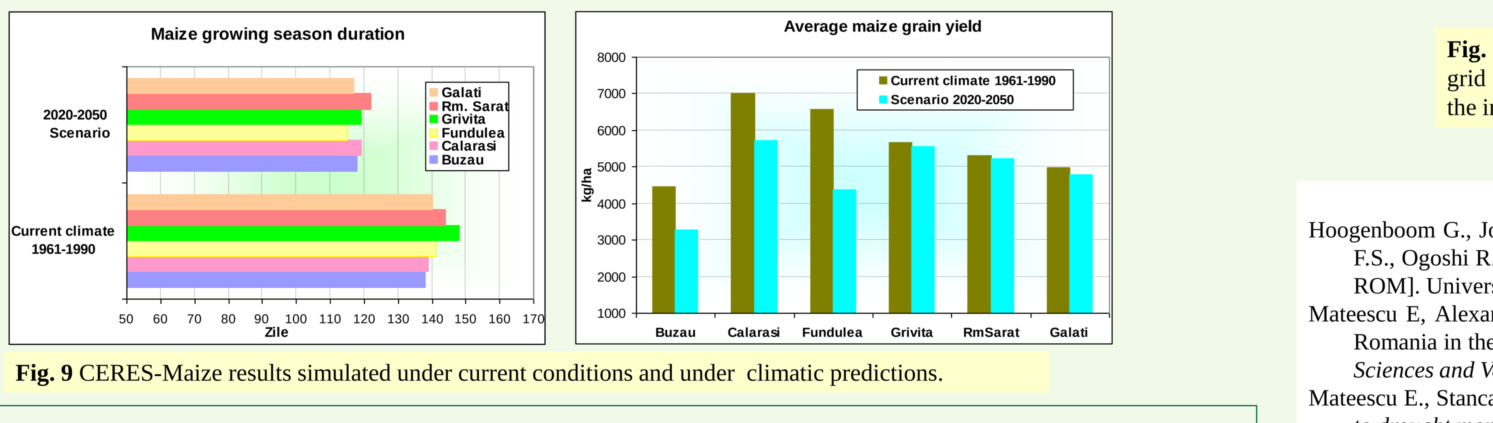

Fig. 9 CERES-Maize results simulated under current conditions and under climatic predictions.

Conclusions

- This study can be considered a first step towards assessing the potential impacts of climate change on the types of vegetable crops grown in the central and south-eastern Europe, specifically in Elbe River lowland and Romania.
- In our future work, we plan to calibrate a field vegetable crop growth model (cucumber, tomatoes and peppers).
- The date of sowing/planting and the harvest period depend on the vegetable variety, agroclimatic conditions, commercial targets, market constraints and horticultural practices. This is probable one of the reason for the absence of data on the sowing/planting and harvest dates of vegetables in the Czech Republic and in other countries. Systematically recorded information on phenology is utterly lacking for most types of vegetables at both the local and the global scale.
- CERES simulation model provided good results for southern Romania, but we need to extend the research to other areas with different climatic conditions, in order to obtain a general view of the potential agroclimatic resources as well as the specialization of agricultural production based on the availability of it and different cropping systems.

REFERENCES

Hoogenboom G., Jones J.W., Wilkens P.W., Porter C.H., Boote K.J., Hunt L.A., Singh U., Lizaso J.L., White J.W., Uryasev O., Royce F.S., Ogoshi R., Gijsman A.J., Tsuji G.Y. (2010). Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.5 [CD-ROM]. University of Hawaii, Honolulu, Hawaii.

Mateescu E, Alexandru D. (2010). Management recommendations and options to improve the crop systems and yields on South-East Romania in the context of regional climate change scenarios over 2020-2050. In: *Series A LIII - Agronomy, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Agriculture*. 328-334.

Mateescu E., Stancalie G. at all (2012). Drought Monitoring in Romania. In: *JRC/DMCSEE/Biotechnical faculty/ "Different approaches to drought monitoring – towards EuroGEOSS interoperability model*", Ljubljana, *23rd – 25th November 2011*, "Towards EuroGEOSS interoperability model in drought monitoring in SEE region", 16-27.

Mitrica B, Mateescu E, Dragota C. S. , Busuioc A., Grigorescu I.E., Popovici A. (2013). Climate change impacts on agricultural crops in the Oltenia Plain (Romania). In: *13th SGEM GeoConference on Energy And Clean Technologies*, *SGEM2013 Conference Proceedings*, June 16-22, 2013, 573 – 584. DOI:10.5593/SGEM2013/BD4/S19.009;

Potop V, Hamouz P, Zahradníček P, Türkott L (2012). A GIS tool to evaluate the spatial evolution of hydro-thermic features during growing season of vegetable crops in Elbe River lowland (Polabí). Geographia Napocensis, 6, 28–39.

Potop V, Zahradníček P, Türkott L, Štěpánek P., Soukup J (2013a). Risk occurrences of damaging frosts during the growing season of vegetables in the Elbe River lowland, the Czech Republic. Nat Hazards. DOI 10.1007/s11069-013-0894-5

Potop V, Türkott L, Zahradníček P, Štěpánek P (2013b). Temporal variability of late spring and early autumn frosts during growing season of vegetable crops in Elbe River lowland (Polabí). Meteorological Bulletin, 66, 135–142.

Potop V, Zahraniček P, Türkott L, Štěpánek P, Soukup J. (2014a). Potential impacts of climate change on damaging frost during growing season of vegetables. *Scientia Agriculturae Bohemica* (in printing).

Potop V, Boroneat C, Možný M, Štěpánek P, Skalak P. (2014b). Observed spatio-temporal characteristics of drought on various time scales over the Czech Republic. *Theor Appl Climatol.* 115 (3). 563-581.

Sandu I**,** Mateescu E, Vatamanu V.V. (2010) Climate change impact on agriculture in Romania. Editura SITECH Craiova, 392.