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SPATIAL CHANGES OF SPRING BARLEY YIELDS IN CONDITION OF CHANGING CLIMATE ON DANUBIAN LOWLAND FROM THE POINT OF VIEW OF YIELD SECURITY

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Abstract. Evaluation of the climate change impacts of spring barley yields was based on simulations by agro-ecological model DAISY. Atmospheric data were controlled and homogenized in daily scale and then recalculated to the ALADIN-Climate/CZ grid of 10 km horizontal resolution. (SRES A1B).

Except for mean yields the yield security of spring barley was evaluated on 90% probability (percentile) level of grain yields in time slices 1971-2000, 2071-2100. Average spring barley yields exceed 4,0 t.ha^{-1} on the most of the evaluated territory while the 90% probability level of grain yields is significantly lower - 3,5 t.ha^{-1} in climate change conditions. Most of the Danubian lowland was recognized as the vulnerable region according to variability of yields.

Comparing average and 90% probability level of grain yields security we can conclude that variation of yields on level 0,5-1,0 t.ha^{-1} in period of years 1971-2000 will increase on 1,0-1,5 t.ha^{-1} in period of years 2071-2100 on the most of Danubian lowland. The variation of yields can reach 2,0-2,5 t.ha^{-1} on the most vulnerable regions (appr. 15 % of acreage).

Introduction

Global warming is probably one of the most important environmental problems of mankind in its history. Disproportion between stability of the Earth climate system as a natural source on the one hand and energetic and water needs of mankind on this source on the other hand contributes to the increase of potential risk in the agricultural sector too. Possible climate change impact could have crucial influence on agricultural production and consequent socioeconomic impacts.

Several climate change impact studies were elaborated for agricultural sector in Danubian lowland region during last decade of years. Except for works focused on drought effects of climate change (Škvarenina et al. 2004, Šiška, Takáč 2009) most of studies were focused on crop yield modeling and testing of adaptive measures to reduce negative climate change impact. Results are strongly affected by level of growth simulation models as well as general circulation models outputs (Eitzinger et al. 2004, Žalud et al., 2002) and therefore still new results and relations are found.

New generation of GCM and climate change scenarios are available for agro-climatic modeling in conditions of Slovak republic since 2008 (Skalák et al., 2008). High resolution climate change scenarios allow evaluate also possible sensitivity of agricultural regions to climate change impacts.

The aim of this paper is to evaluate possible climate change impact on spring barley and winter wheat yields according to new generation of GCM and emission scenario – SRES A1B for different soils of Danubian lowland - the most productive agricultural area of Slovakia.

Materials and methods

Evaluation of the climate change impacts on spring barley yields was based on simulations by agroecological model DAISY. DAISY is a one-dimensional model simulating water, energy, nitrogen and soil organic matter content balance. Crop development and yield is possible to simulate in dependence on crop rotation and various management strategy. DAISY simulates plant growth and development, including the accumulation of dry matter and nitrogen content in different plant parts. The main plant-growth processes considered in DAISY are photosynthesis, respiration, partitioning of assimilates, stress factors and leaf and root development. DAISY allows for building complex management scenarios (Hansen et al. 1990, Hansen 2000, Abrahamsen and Hansen 2000).

Meteorological data were processed in daily step: mean, maximum and minimum air temperature, precipitation, relative humidity, wind speed and sunshine duration. Global radiation was recalculated according to Ångström formula.

The model data were corrected according to validation results carried out for the period 1961-1990. For this task a gridded dataset of station observation was created. All input station observations were quality controlled and homogenized in daily scale (Štěpánek et al., 2009) and then recalculated to the ALADIN-Climate/CZ grid of 10 km horizontal resolution. Daily station measurements in a vicinity of each grid point were first reduced on the grid point's (model's) altitude by a local linear regression and then weighted averaged to a grid point location according to their distance form the grid point. The inverse distance (1/d) factor was used as a weight for air temperature, while 1/d3 factor was taken for precipitation. Gridded dataset of station observations was then compared with the past climate (1961-1990) GCM driven ALADIN-Climate/CZ simulations in each grid point. According to relationship between these two datasets (Skalak et al., 2008), outputs of A1B scenario integrations of the future climate were corrected applying an approach of Déqué (2007) that is based on a variable correction using individual percentiles. After the correction, the model outputs are fully compatible with the station (measured) data. The gridding and all data processing including the presented analysis were done by ProClimDB database software (http://www.climahom.eu/) for processing of climatological datasets (Štěpánek, 2008).

Crop parameters were set up according to the experimental data from field trials of the Slovak University of Agriculture in Nitra, Slovakia, located in Malanta near Nitra during years 2001 – 2005.

Cliamte change impacts on yield variability were evaluated on the base of

Time slices:1971-2000 – Reference period of years 2071 - 2100

SRES A1B (IPCC, 2007)

Evaluation of the climate change impacts on soil water regime under field crops was based on simulations by agro-ecological model DAISY. DAISY is a one-dimensional model simulating water, energy, nitrogen and soil organic matter balance. Crop development and yield is possible to simulate in dependence on crop rotation and various management strategy. DAISY simulates plant growth and development, including the accumulation of dry matter and nitrogen content in different plant parts. The main plant-growth processes considered in DAISY are photosynthesis, respiration, partitioning of assimilates, stress factors and leaf and root development. DAISY allows for building complex management scenarios (Hansen et al. 1990; Hansen 2000).

Spring barley yields were evaluated comparing average and 90% probability (percentile) of grain yields in period of years 1971-2000 and 2071-2100.

Results

Variability of spring barley yields are influenced first of all by availability of soil water. The highest yields are simulated in regions of Rye islands (except for shallow soils on gravels) and nearby rivers Nitra, Váh and Hron. Range of yields in regions with available water in soil profile are relatively small (green areas on both right and left figures). We can find in these regions also the most fertile soils of Slovakia.

On the other hand the high variability of yield we can find on sandy loams, luvisols and fluvisol of whole western Slovakia. Shortage of precipitations in some years makes sandy soils very vulnerable especially in northern part of the region. Seasonal distribution of rainfall significantly influence variability of field crops yields on shallows and sandy soils.

Winter wheat rooting system is better prepared for occurrence of drought during growing season and so grain yields vary less then yields of spring barley. Especially during ripening transport of assimilates can be stopped due to very high temperatures and shortage of water during ripening.

Average spring barley yields exceed 4,0 $t.ha^{-1}$ on the most of the evaluated territory while the 90% probability level of grain yields is significantly lower - 3,5 $t.ha^{-1}$ in climate change conditions. Most of the Danubian lowland was recognized as the vulnerable region according to variability of yields. Increase of CO_2 concentration and consequent increase of photosynthesis rate can positively affect the biomass and grain yields, but the variability of yield will very probably increase.

Comparing average and 90% probability level of grain yields security we can conclude that variation of yields on level 0,5-1,0 $t.ha^{-1}$ in period of years 1971-2000 will increase on 1,0-1,5 $t.ha^{-1}$ in period of years 2071-2100 on the most of Danubian lowland. The variation of yields can reach 2,0-2,5 $t.ha^{-1}$ on the most vulnerable regions (approximately 15 % of acreage).

Increase of CO_2 concentration and consequent increase of photosynthesis rate positively affect the yields of spring barley. On the other hand high temperatures generated by GCM during growing seasons (especially in ripening time) frequently led to the fall of simulated yields.

Upland biomass yield will be formed mainly by straw yield in future climate. Grain yields will be very probably reduced by higher temperatures during ripening. Transport of assimilates from other parts of the plant into grains is not so effective because of accelerating effect of high temperatures on ripening of cereals. Based on the simulation results, fertilization effect of CO_2 on spring barley grain and biomass yield is evident. Increasing temperature and CO_2 concentration will cause the increase of yields up to the year 2075, when the yields will gradually begin to decline.

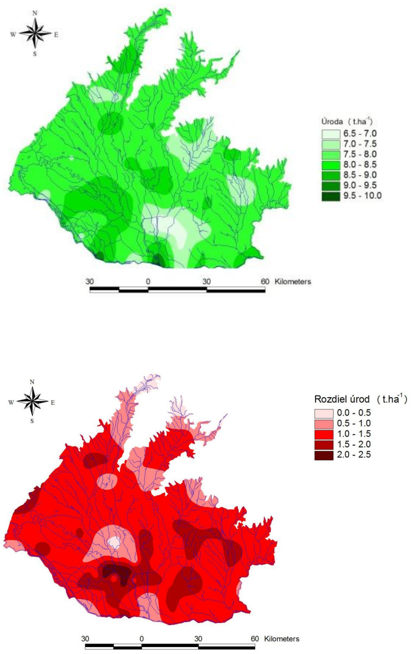

Fig. 1A *Upland biomass yields of spring barley on Danubian lowland (1971 – 2000) up: mean down: differences=mean-90%probability*

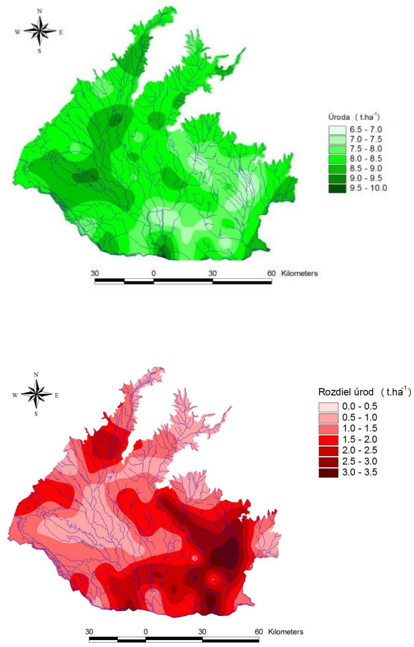

Fig. 1B *Upland biomass yields of spring barley on Danubian lowland (2071 – 2100) up: mean, down: differences=mean-90%probability*

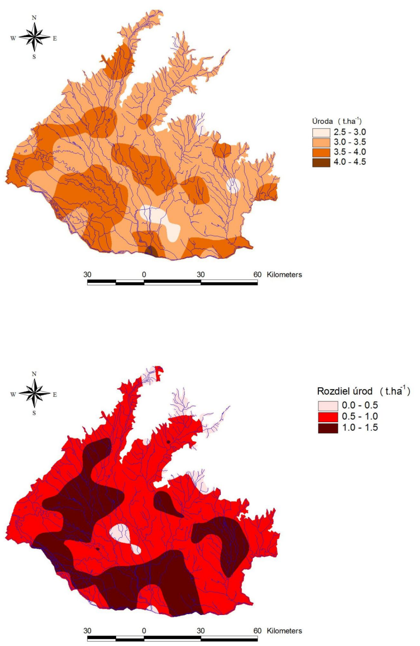

Fig. 2A *Grain yields of spring barley on Danubian lowland (1971-2000) up: mean, down: differences=mean-90% probability*

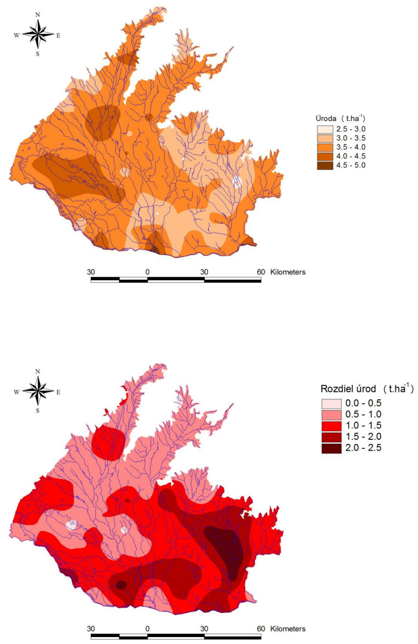

Fig. 2B *Grain yields of spring barley on Danubian lowland (2971 – 2000) up: mean, down: differences=mean-90% probability*

Conclusions:

- Except for some regions of Žitný ostrov (Rye island) and some stands near rivers most of the Danubian lowland was recognized as the vulnerable region according to variability of yields, especially in eastern part of the region.
- If water is available the increase of CO_2 concentration and consequent increase of photosynthesis rate can positively affect the biomass and grain yields of spring barley on Danubian lowland. The highest effect was simulated for Haplic Chernozems on Danubian lowlands
- Spring barley yields will decline after 2070 on all evaluated soils.

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