PRODUKCE JARNÍHO JEČMENE V ČESKÉ REPUBLICE VE ZMĚNĚNÝCH KLIMATICKÝCH PODMÍNKÁCH

CZECH SPRING BARLEY PRODUCTION UNDER THE CLIMATE CHANGE.

MIROSLAV TRNKA(1), MARTIN DUBROVSKÝ(2), PETR HLAVINKA(1), DANIELA SEMERÁDOVÁ(1), PAVEL KAPLER(1), ZDENĚK ŽALUD(1),
MARTIN MOŽNÝ(3A), LADISLAV METELKA(3B)
1) Ústav agrosystémů a bioklimatologie, Mendelova zemědělská a lesnická univerzita v Brně, Česká republika, mirek_trnka@yahoo.com
(2) Institute of Atmospheric Physics, Czech Academy of Sciences, Prague, Czech Republic
(3) Czech Hydrometeorology Institute, (A) Agrometeorological observatory Doksany and (B) Branch office Hradec Králové, Czech Republic

Abstract:

It is obvious that production stability and quality would be influenced under changed climatic conditions and that these changes will be locally depended. In order to assess trends, magnitude and effect of adaptation strategies we applied crop growth model CERES-Barley. This model was evaluated using data from 17 experimental sites with 230 experimental years in total. The experimental database was also used to verify whether the model correctly simulates differences in crop growth processes caused by varying farming techniques, climatic and soil conditions. In order to carry out spatial analysis, the model was run for all combinations of 125 weather stations using 394 characteristic soil profiles using special software package: Marwin. The results were then interpolated into a 1x1 km grid matrix using ArcInfo GIS and only grids on arable land were analyzed further. The "indirect" effect related to changing climatic conditions was found to be mostly negative especially due to higher water deficit during vegetation season. The magnitude of the "direct" effect of increased CO_2 on the stressed yields is quite significant but its manifestation remains to be seen in practice. The model outputs show that some areas will likely suffer from much higher yield variability with frequent chance of crop failure whilst others regions (especially those in higher altitudes) are likely to benefit.

Introduction

Central Europe is located between East and South European climate change hot-spots (Fig. 1) where the climate change impacts are thought to become visible sooner or will be more pronounced or both (Giorgi, 2006). Despite the fact that agriculture is by no means a dominant activity in the region it remains an essential part of economy, and of the landscape. In many cases it specializes on production of selected crops (e.g. spring barley) that are then utilized for valued commodities. Therefore it is necessary to evaluate potential risks to spring barley production and propose set of feasible measures for eventual mitigation of the impacts. Crop growth models, which have been developed since the 1960´s, have been regarded as important tools of interdisciplinary research (e.g. Witt *et al.,* 1985) and have since been used in number of areas as e.g. assessment of agriculture potential of a given region (e.g. Aggarwal, 2000), in the field of crop yield forecasting (e.g. van Diepen, 1992 or Perdigão and Supit, 1999) or as climate change impact assessment tool (e.g. Wolf *et al.,* 1996; Alexandrov and

Hoogenboom, 2000; Izaurralde *et al.*, 2003). Even though there have been several studies evaluating risk of expected climate change on the Czech cereal production in the past (e.g. Kalvová et al., 2002; Žalud and Dubrovský, 2002; Trnka et al., 2004b or Trnka et al. 2004b) none included spatial aspect in the assessment. The presented study is the first of this kind (at least to the author´ s knowledge) that have been conducted with such high resolution over the entire territory of the Czech Republic.

Material and methods

The crop model CERES-Barley (v. 3.5) was calibrated at 4 sites across the study area (Fig. 1) that were characterized by significant altitudinal range (176 and 540 m a.s.l.) and rather representative climatic conditions for the spring barley production in the Czech Republic (mean annual temperature from 6.8 to 9.6 °C and mean annual sum of precipitation between: 461 and 575 mm). Following the calibration the model performance was verified by independent data set at 13 other experimental sites (Fig. 1). Their altitude ranged from 190 to 650 m a.s.l. with mean annual temperatures between 6.2 and 9.3°C. The mean annual precipitation range was from 439 mm at the driest site to 738 mm at the highland areas.

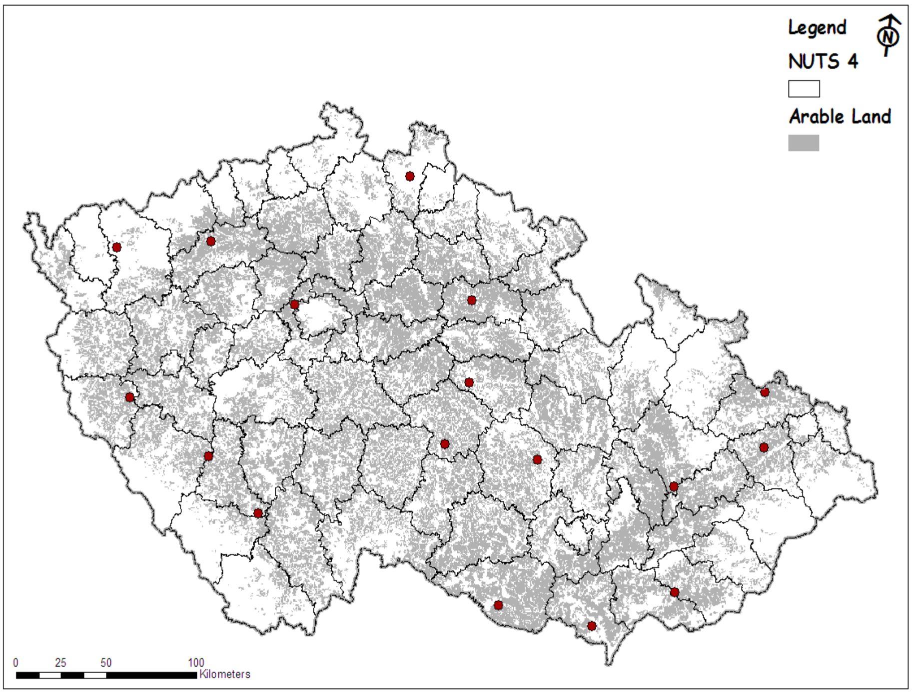

Fig. 1. Geographical location of the experimental sites

The spatial assessment of spring barley production under the present conditions was carried out at 1 sq. km resolution and using combination of more than 1500 continuous soil polygons (described by 394 soil profiles) combined with daily data from 125 weather stations (Fig. 2). The interpolation was from methodological reasons carried at first for the whole territory but then reanalyzed only for the grids on the arable land. The final results were compared with long-term productivity obtained on the farm level at individual districts during 1981-2000 period using statistical data. The sowing date was set automatically by the model, based on the soil moisture and temperature threshold that allow cultivation of the soil.

The impacts of climate change (both increased CO2 and changed climate characteristics) were evaluated using combination of three emission scenarios (i.e SRES-A2, SRES-B1 and SRES-A1T), seven Global circulation models and three assumptions about the climate system sensitivities to increased greenhouse gases. Several time periods (2025, 2050 and 2075) were evaluated as well. Most of the outputs were interpolated using to the 1x1 km matrix. Finally the potential benefits of possible adaptation measures (esp. new cultivar introduction and earlier sowing dates) were estimated at selected locations.

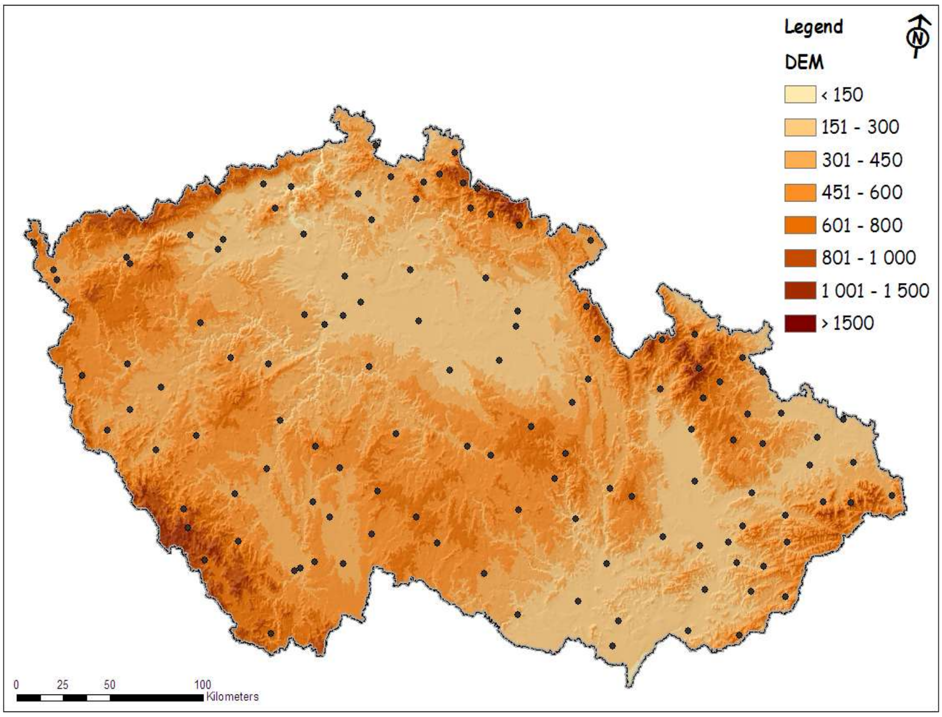

Fig. 2. Location of the 125 weather stations and altitude according Digital Elevation Model used in the study.

Results and Conclusions

The results of CERES-Barley calibration were better at sites with more pronounced water stress than in wetter and colder ones. This phenomena results from factors not considered by the model (e.g. higher pressure of diseases or lower levels of other nutrients than N etc.), which are more pronounced at the higher altitudes. However the model simulated with reasonable precision both developmental and production parameters of the crop at all calibration locations (Fig. 3). Verification using the independent data set of 161 independent experimental years demonstrated that the CERES-Barley is in general able to represent crop growth variability caused by differences between seasons and sites (Fig. 4). The CERES-Barley estimated well the onset of key stages and grain yield (Fig. 4). The number of total outliers was rather low considering that model was not adjusted for these sites. The model performs better in lowland and drier locations compared to highlands and wetter regions, which could be explained by the characteristics inherent to the model design. However the great majority of crop yields were simulated with an acceptable bias (i.e. less than 20% of the observed yields). The study also shows that the crop model can explain much larger degree of yield variability compared to the simple regression techniques (even when relatively sophisticated methods are used – see e.g. Hlavinka et al. (2006) in this issue).

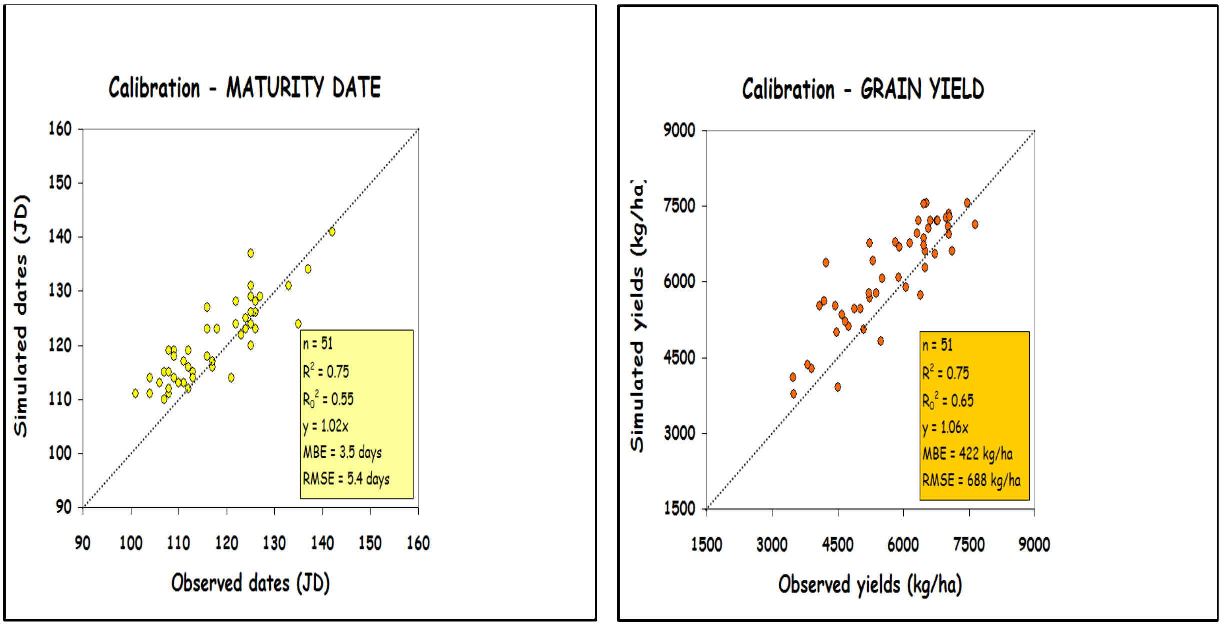

Fig. 3. Comparison of key crop growth parameters of spring barley observed at 4 experimental sites and values estimated by CERES-Barley model

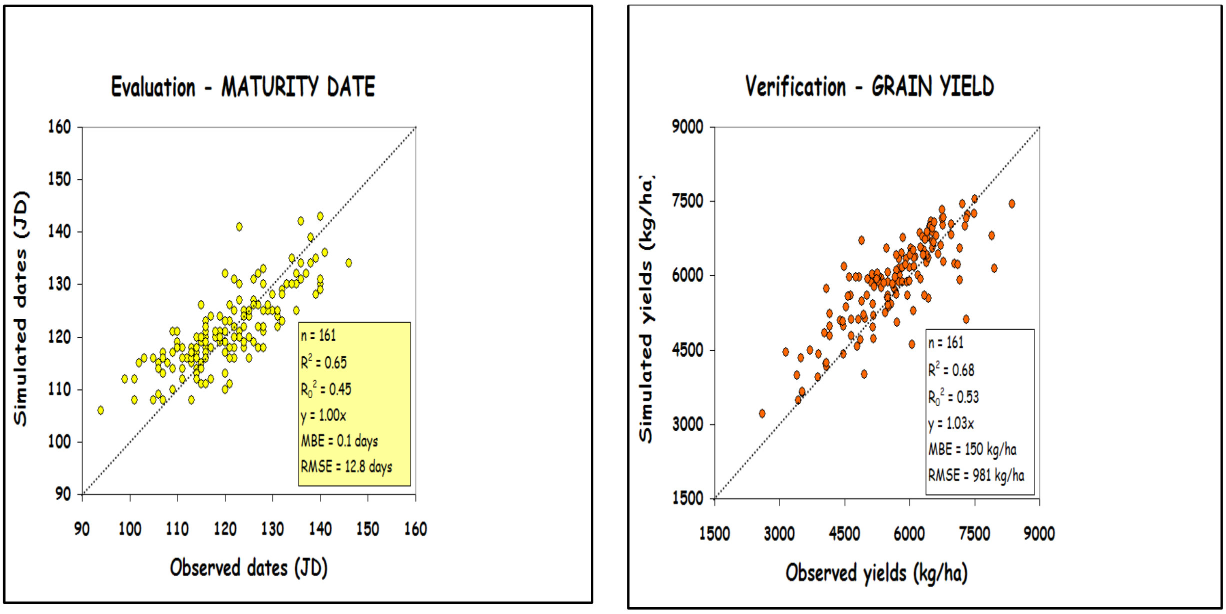

Fig. 4. Estimated vs. observed dates of maturity (left) and grain yield (right) as predicted by CERES-Barley model. Evaluation is based on 161 experimental years from 13 sites with cultivar ORBIT.

After the site based evaluation the model was run at the spatial mode and we have found that it reproduces realistically yield levels on the different soils and under varying climatic conditions (Fig 5). When the model runs were extended to the whole territory (Fig. 5) those areas where the present land use is known to be either forest or grasslands performed poorly with very low yield levels and low yield stability. In the same time yields tend to decrease in altitudes over 650 m, which adds to the model validity and integrity. Also the general spatial distribution of yields (in terms of mean and variability) is consistent with reality. However the mean production level (compared to the statistical yields) is about 30% higher as the farm level production is influenced by factors not considered by the model (e.g. substandard field practices, pests and diseases, local weather events etc.).

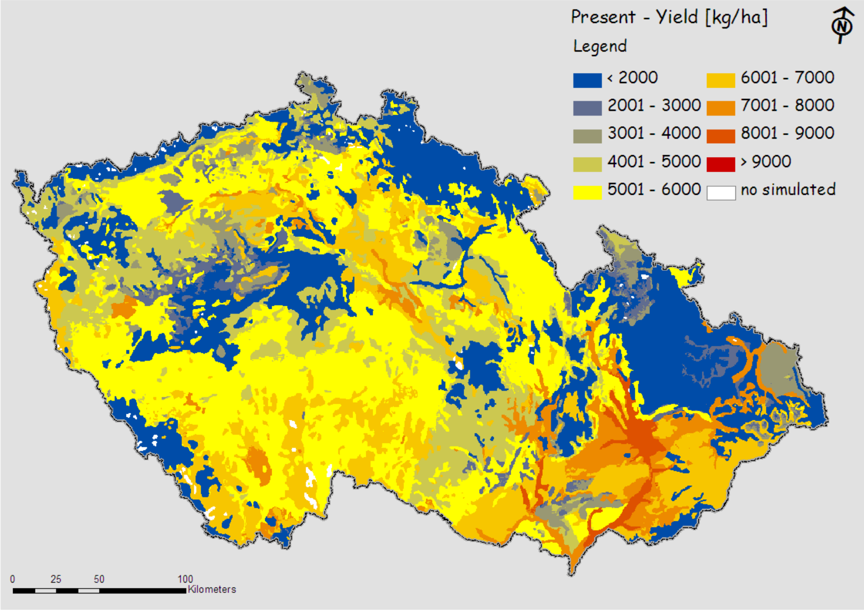

Fig. 5. Mean spring barley yield under the present climate on all soil polygons – average of 30 year simulation runs based on 1961-2000 climate.

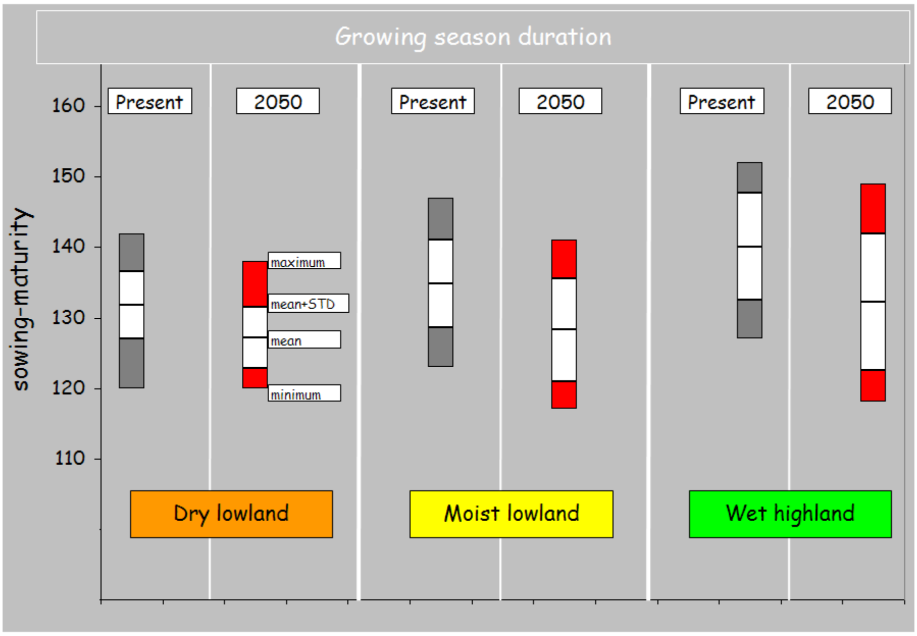

Fig. 6. An example of the anticipated change in the growing season duration (the shift of the sowing date toward beginning of the year is already included). The individual bars represent present (gray)

vs. 2050 according to A2-SRES and HadCM3 (red) conditions. The three types of stations were taken into account.

The impact of climate change on the spring barley production is multifaceted and only selection of them is presented here. The **mean growth duration** (sowing-maturity) will **decrease**. HOWEVER the variability will slightly increase especially in wetter regions and on heavier soils (Fig. 6). According to the model estimates **sowing** dates will be **shifted** by 5 to 20 days to the beginning of the year depending on the type and season. However at some soils achieving early sowing will remain problematic due to the excessive soil water content (mostly due to higher winter precipitation).

The impact of the changed climate conditions would **benefit** mainly **lowland areas** on **good soils** where mean yield increase might be expected (Fig. 7A). The change of climate alone would have almost uniformly adverse effects regardless of soil or location (Fig. 7B). **When** the change of **weather variability** is **considered yield variability** would **increase dramatically** (not shown).

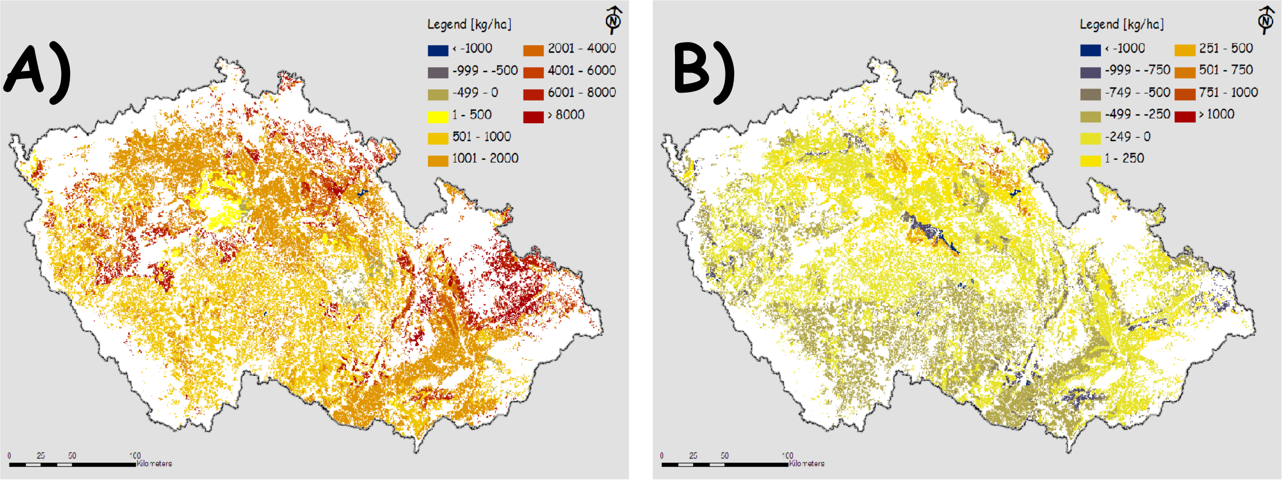

Fig. 7. Relative yield change vs. present mean levels when **(A)** both CO_2 fertilization and changed climates are considered and **(B)** yields without CO_2 fertilization included.

Acknowledgement: This study was conducted with support of Grant Agency of the Czech Republic project No. 205/05/2265- Calim&Ro and National Agency for the Agricultural Research (project 60051 – *"Impact of climate change on growth and development of the selected crops"*).

References:

Alexandrov, A., Hoogenboom, G., 2000. The impact of climate variability and change on crop yield in Bulgaria. Agric. For. Meteorol., 104, 315-327.

Aggarwal, P.K., 2000. Application of systems simulation for understanding and increasing yield potential of wheat and rice. PhD Thesis, Wageningen Agriculture University, 176 pp.

Diepen van, C.A., 1992. An Agrometeorological model to monitor the crop state on a regional scale in the European Community: Concept implementation and first operational outputs. In: Proceedings of the Conference on Application of Remote Sensing to Agricultural Statistics, Belgirate, Italy, pp. 269-277.

Giorgi F., 2006. Climate change hot spots, Geophysical research letters, 33, L08707, doi:10.1029/2006GL025734, 2006

Hlavinka P., Trnka M., Semerádová D., Žalud Z., 2006. Vztah mezi výnosy jarního ječmene a výskytem sucha hodnoceného pomocí Palmerova Z-indexu v podmínkách České republiky, XIV. Posterový deň s medzinárodnou účasťou, Bratislava

Izaurralde, R.C., Rosenberg, N.J., Brown, R.A., Thomson, A.M., 2003. Integrated assessment of Hadley Center (HadCM2) climate change impacts on agricultural productivity and irrigation water supply in the conterminous United States Part II. Regional agricultural production in 2030 and 2095. Agric. For. Meteorol., 117: 97-122

Kalvová J., Kašpářek L., Janouš D., Žalud Z., 2002. Zpřesnění scénářů projekce klimatické změny na území České republiky a odhadů projekce klimatické změny na hydrologický režim, sektor zemědělství, sektor lesního hospodářství a na lidské zdraví v ČR. Praha, 151s.

Perdigão V., Suppit, I. (eds), 1999. An Early Crop Yield Estimation Metho for Finnish Conditions: The crop growth monitoring system of the Joint Research Centre with and without Remotely Sensed and other Additional Input data, EUR-18975 EN, p. 144.

Trnka, M., Dubrovský, M., Semerádová, D., Žalud, Z., 2004a. Projections of uncertainties in climate change scenarios into expected winter wheat yields. Theoretical and Applied Climatology, 77, 229-249.

Trnka, M., Dubrovský, M., Žalud, Z., 2004b. Climate change impacts and adaptation strategies in spring barley production in the Czech Republic. Climatic Change Vol. 64, 227-255.

Wit de, C.T., Penning de Vries, F.W.T., 1985. Predictive models in agricultural production. Phil.Trans.R.Soc.,London, B 310, 309-315.

Wolf J., Evans L.G., Semenov M.A., Eckersten H. and Iglesias A.: 1996. Comparison of wheat simulation models under climate change. I. Model calibration and sensitivity analyses. Climate Research 7, 253-270.

Žalud Z., Dubrovský M. (2002) Modelling climate change impacts on maize growth and development in the Czech Republic*, Theoretical and Applied Climatology,* **72,** 85-102.