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WHEAT AND MAIZE PRODUCTION IN HUNGARY UNDER DOUBLED ATMOSPHERIC CO2 CONCENTRATION

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Abstract

The present investigation aims at asseseing the impacts of three well known climate change scenarios - the carbon dioxide doubling scenarios from the **GISS, GFDL** and **UKMO** general circulation models - on wheat and maize yields in Hungary. For this purpose the monthly outputs for global radiation, temperature and precipitation of the above three GCMs were used to create daily weather time series for Hungary. Climatic data scenarios were chosen from the gridbox which covers the location of Keszthely. Historical weather data of 16 years from Keszthely were used as baseline. These were used together with the CERES-Wheat and CERES-Maize crop growth simulation models. The validation of crop models is based on field experiment data from Keszthely. Statistical analysis of simulated crop data is presented. Comparing to the baseline the average wheat yield shows 13-25 % decrease in spite of the slightly increase of total biomass production according to different GCM scenarios. In case of maize the GISS scenario resulted in a small 8 % yield increase on the average, while the GFDL and UKMO resulted in 7% and 14 % yield decrease respectively. Yield decreasing mainly due to the shortened length of growing period.

1.THE CREATION OF THE CLIMATE CHANGE SCENARIOS

Outputs from three General Circulation Models were used to create climate change weather scenarios. These are: -GISS (Goddard Institute for Space Studies, New York,U.S.A. [1], -GFDL (Geophysical and Fluid Dynamics Laboratory, Princeton, U.S.A. [2], - UKMO (United Kingdom Meteorological Office, Bracknell, U.K. [3]. All the three applied GCM are so called equilibrum models and they have their limitations regarding spatial resolution. The GISS handles the earth's surface as gridboxes of the size 10^{o} latidude x 7.9^{o} longitude. The climate of each gridbox is considered to be homogeneous, and the climate characteristics are allocated to the gridbox centre. The GFDL works similarly with gridboxes of 4.5^{o}latitude x 7.5^{o}longitude, and the UKMO with gridboxes of 5^{o}latitude x 7.5^{o}longitude. In the present study the gridbox covering the location of Keszthely (46.4^{o}N;17.3^{o}E) was used with each

GCM, thus for GISS the gridbox with the centre 50°N;20°E, for GFDL the gridbox with the centre 46.7°N;15°E, for UKMO the gridbox with the centre 47.5°N;18.8°E. Regarding temporal resolution, the three GCMs are capable of calculating the weather of a year as monthly average values at most detail. Since the GCMs are inaccurate in simulation of the present climate , so the climate charactherstics simulated under changed greenhouse gas concentrations are also rather unreliable. Therefore we used the rate of changes instead of the absolut values of predicted climatic variables. The "baseline" weather was taken from the location of Keszthely from the period 1975-1990. The change factor was calculated as the difference between the 'future' and 'present' values for temperature, and as the ratio for radiation and precipitation, in agreement with the recommended methodology of many similar impact assesment studies [4],[5],[6].
As the crop growth simulation models require daily weather data and the climate model outputs present the results only in monthly resolutions, the baseline daily weather data were modified by the change factor of the corresponding month to create climate change scenarios with daily resolutions.

2. CROP GROWTH SIMULATION MODELS

The growth and development of the winter wheat and maize crop were assesed using the CERES Wheat and CERES Maize models [7],[8]. Soil and plant characteristics required as input data were chosen according to typical ones for the location of Keszthely as well as the agrotechnology data like the date of sowing. Before starting the climate change experiment the validation of the models had been carried out. In the case of CERES Maize the average differences between the predicted and observed plant variables were less than 4 % [9] and for CERES Wheat the average difference is about 6 % [10].

In order to compare the impact of the changed weather on the crops the agrotechnology was assumed constant for all simulation experiments. In the simulation runs the following agrotechnology parameters were used: sowing on 10 October with MV-4 winter wheat variety for the wheat model, and sowing on 20 April with Pioneer 3901 variety for the maize model. For both crops optimal nitrogen supply was assumed, and no irrigation was applied.

3. RESULTS

The outputs from the CERES crop models were used for the impact assessments, that is, for both wheat and maize the simulated values of resultant variables under the baseline weather were compared to the simulated values of the same variables under the climate change weather scenarios generated from the three GCMs. The following resultant variables were considered in the assessment: the grain yield (t/ha), the amount of above ground biomass (t/ha), maturity date.

3.1 MAIZE

In the maize experiments altogether 16 baseline weather years were available together with 16 GISS-years, 16 GFDL-years and 16 UKMO-years.

The climate change scenarios resulted in maturity occuring much earlier, and thus the growing season became significantly shorter for all the three different GCMs. Biomass and grain yield show somewhat less unanimous results. The GISS scenario resulted in a small, 8% yield increase on the average, while the GFDL resulted 7%, and the UKMO in a 14 % yield decrease.

In biomass production the GISS and the GFDL scenarios resulted small increase while the UKMO scenario resulted small decrease. For all the three GCM scenarios the standard deviations of the yield are somewhat smaller than for the baseline weather (table 1.).

Table 1
The averages and the standard deviations of the simulated resultant variables of maize for different scenarios

	Maturity date (day of the year)		Grain yield (t/ha)		Biomass (t/ha)	
	avg.	std.	avg.	std.	avg.	std.
Base	248	18.0	8.57	3.35	15.95	3.89
GISS	225	5.3	9.29	1.07	17.29	1.20
GFDL	212	3.8	7.96	0.90	16.10	1.16
UKMO	207	7.0	7.35	2.20	15.25	3.25

3.2 WINTER WHEAT

In the wheat experiments altogether 15 baseline weather years were available together with 15 GISS-years, 15 GFDL-years and 15 UKMO-years. Results showed that similar to maize the maturity dates occured earlier and the growing season became significantly shorter for all of the climate change scenarios. The fastest crop development occured in the case of the UKMO scenario, with an average of 42 days shorter period from sowing to maturity in comparison to the baseline, while under the GFDL scenario maturity occured 25 days earlier on the average, and under GISS scenario 22 days earlier in average than under the baseline weather. The average biomass production slightly increased for all the three climate change

scenarios, and the standard deviation decreased. In the case of grain yield the GISS scenario resulted in a yield decrease of 13 %, the GISS scenario resulted 28 % decrease and the UKMO scenario 25 % decrease. Standard deviation of crop variables decreased for all the three GCM scenarios comparing to the baseline. (see table 2.)
Summarizing that equilibrium GCM scenarios give a significant warmer climate with moderately higher precipitation amounts. These conditions seem to be favourable for total biomass production but unfavourable for grain filling processes.

Table 2
The averages and standard deviations of the simulated resultant variables of winter wheat for different scenarios

	Maturity date (day of the year)		Grain yield (t/ha)		Biomass (t/ha)	
	avg.	std.	avg.	std.	avg.	std.
Base	193	5.5	6.28	0.85	17.45	2.02
GISS	171	5.5	5.44	0.62	18.34	1.47
GFDL	169	5.1	4.49	0.50	17.75	1.82
UKMO	151	5.3	4.73	0.68	18.58	1.21

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