Climate Change Impacts on the Agricultural Potential of Hungary

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ABSTRACT

This paper conducts a socio-economic evaluation of climate risks on crop production in Hungary, using panel data models. The country has a special location in the Carpathian basin. The spatial distribution of the precipitation is highly varied, from humid conditions in the western part to semiarid conditions over the eastern regions. Under the current conditions crop systems are mainly rainfed and water licenses are completely underexploited. The potential future climatic conditions were examined based on the RegCM3 model with A1B scenario, and compared to last ten years (2002-2011), which was a warm period. Results show, that in the near future (2021-2050) most of the crops examined could have the same or better climatic conditions, while at the end of the century (2071-2100) lower yields are expected.

Keywords: Climate change, statistical models of yield response, panel data analysis, adaptation, irrigation, Hungary.

1. INTRODUCTION

Agriculture plays an important role in Hungary's economy. The farm structure is bipolar and fragmented, with large-scale and small-scale farms. The number of small individual farms (many of them only 1-2 hectares) is disproportionately high, but these farms contribute to a secure livelihood and a modest income for many families (Tóth, 2012).

Hungary owns many fertile soils and basically good climatic conditions for agricultural activities. However, in the last years, as a consequence of the extreme weather events, crop yields were very varied. For example the year 2003 was extreme hot and dry, the period from May to August was the warmest in the last 100 years (Bella et al., 2007). In 2007, Hungary had to face spring frost, heat waves, wind storms, hail and heavy rains (Ladányi et al., 2009), in summer 2009, storms and hail events devastated during nearly a month across the whole country (Szenteleki et al., 2009), while 2010 was an extremely wet year.

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According to Jacquin et al. (1998), the quantity of flowing water per inhabitant in Hungary seems to be the largest in the world, however the ratio of the irrigated areas is very low and the irrigation schemes are inefficient. Water licences are completely underexploited; around 98% of the agricultural areas are non-irrigated arable land. Floods and excess surface water are also regular problems.

The aim of this study was to analyse the agricultural production of the Hungarian counties and the expected changes due to the climate change.

2. MATERIALS AND METHODS

Five important crops with different needs were selected for the analyses. Green peas and potato have the highest proportion of irrigated areas (about 20% and 13%, respectively), while maize, sunflower and grapevines are primarily rainfed crops. The crop response was analysed using panel data regression, taking into account climatic and socio-economic variables.

2.1 Data

The study focuses on the 19 counties of Hungary. Historical data were obtained for the period of 2002-2011 from the Hungarian Central Statistical Office, the Research Institute of Agricultural Economics and from the Hungarian Meteorological Service.
To characterize the climatic conditions seasonal average temperature and precipitation sum values were applied. Drought events are difficult to characterize, in this study we used the well-known Standardized Precipitation Index (SPI) developed by McKee et al. (1993). Based on the 12 month SPI values a dummy variable was constructed, which equals to 1 if a given year is a drought year (SPI <= -1) and 0 in other cases.

The variables net income per capita, income per capita from small-scale agricultural production and the number of taxpayer small-scale agricultural producers were considered as socio-economic variables. Small-scale agricultural producers have an important role in Hungarian agriculture (there are many small farms), so these variables can characterize the human resources of the counties. Attempts were made to involve other variables, e.g. total employment, employment in agriculture, but these were not significant in the models, or showed correlation with the previous ones.

Irrigation activities were characterized by the following variables: area with irrigation license, irrigated area by crop type, amount of irrigated water by crop type; and from these values the ratio of the irrigated and harvested area, as well as the amount of irrigated water amount per harvested area were calculated, too.

Climate scenarios applied in the study were provided by the Department of Meteorology of the Eötvös Loránd University. They used the high-resolution version of the Regional Climate Model (RegCM3) over the Carpathian basin using the A1B scenario (Torma et al., 2011). Two future time-slices were applied: 2021-2050 and 2071-2100. Usually the period of 1961-1990 provides a standard reference for the impact studies; in the present study the forecasted results were compared to the observations in the last ten years (2002-2011). According to the World Meteorological Organization (2011), the decade 2001-2010 was the warmest ever recorded. Moreover, this decade was marked by numerous weather extremes, unique in force and impact.

Soil conditions are also responsible for the crop development and water availability, but were ignored during the analyses because of the spatial resolution. It is supposed that soil will not change in significant extent. Neither did we consider the further changes of the economic conditions.

2.2 Panel Data Regression

Panel data regression is a useful tool when the outcomes depend on both time and cross-sectional effects. Panel data models can be estimated by fixed effects (FE) or random effects (RE). The core difference between fixed and random effect models lies in the role of dummy variables. If dummies are considered as a part of the intercept, this is a fixed effect model. In this case the model examines group differences in intercepts, assuming the same slopes and constant variance across entities or subjects. In a random effect model, the dummies act as an error term and the difference among groups (or time periods) lies in the variance of these error terms, not in their intercepts (Baltagi, 2001; Hsiao, 2003). The decision on the FE or RE model was made based on Hausman's (1978) specification test. In case of favour to RE model, the model was tested with Breusch-Pagan Lagrange multiplier test, too (Breusch and Pagan 1980). In our crop-models the dependent variable was the natural logarithm of the crop yields, and the explanatory variables were described above. The logaritmization of the dependent variable was used in order to homogenize the variances. This transformation is widely used in economic studies (Quiroga and Iglesias, 2009). As a first step the correlation coefficients between the explanatory variables and the logarithm of the crop yields were calculated and only the significantly correlated variables were used in the models. In case of highly correlated explanatory variables the more important ones were kept in the models. The analysis was made using the STATA 11 statistical program.

3. RESULTS

3.1 Panel Regression Models

Estimation was carried out for the 19 counties of Hungary on the basis of the 10-year observed data. In case of maize, sunflower and green peas the fixed effect (FE), while in case of the potato and grapevine the random effect (RE) model proved to be the best one (Table 1). The *Rho* value shows the fraction of variance due to the differences of the counties, and varies from 26.63% (grapevine) to 56.76% (maize).

The models make good estimations for the average yields with less than 5% difference between the observed and the modelled values; however they underestimate the standard deviation.

Table 1. Estimated coefficients of the panel regression models
(19 regions, 10 years, dependent variable ln_Yield)

Variable	Maize (FE)	Sunflower (FE)	Potato (RE)	Green peas (FE)	Grapevine (RE)
Irr_area				0.0001*	0.0033**
Irr_ratio			0.0011**		
T_djf					0.0381*
T_jja	-0.1940***	-0.0550***		-0.1209***	-0.0428*
T_son	0.0864***	0.0263***			
P_mam			0.0006***	0.0013**	
P_jja	0.0004**				
P_son		-0.0006***	-0.0021***		
Dro			-0.0909***		
Net_income	0.0008***	0.0003**	0.0004**		
Agr_taxpay		0.0524***	0.0381***	0.0858**	
Constant	4.3614***	1.5165***	3.0247***	3.5897***	2.6768***
Rho	0.5676	0.4210	0.5631	0.2743	0.2663
R^2	0.82	0.65		0.37	
Adj. R^2	0.80	0.60		0.27	
Breusch-Pagan LM			183.11***		91.60***

Significance level of the robust t-statistics: *** p<0.01, ** p<0.05, * p<0.1

The results show that irrigation has a positive effect on the crop yield of green peas, potato and grapevine. It was expected in the case of potato and green peas, because these crops have the highest ratio of irrigated area among the examined ones. In contrast, the irrigation of the vineyards is not usual in Hungary.

Drought has a significant negative impact on potato. It can be seen that increasing summer temperature has a significant negative impact on the yield of all crops (except potatoes); however, the autumn temperature has a positive effect on the yield of maize and sunflower. In case of sunflower and potato the autumn precipitation is also crucial; high precipitation has a negative effect making the harvest difficult and reducing the crop quality. The positive coefficients of the net income indicate that in richer counties more yields are expected in case of maize, sunflower and potato; furthermore the number of small-scale agricultural taxpayers has a positive effect on the yield of sunflower, potatoes and green peas.

3.2 Expected Changes in Crop Yields

Based on the panel regression models obtained for the last ten years (2002-2011), the potential climate change effects were investigated. As the last decade was very warm, the applied A1B scenario indicates in the near future (2021-2050) lower temperature in summer and autumn, so most of the crops examined could have better climatic conditions. In the opposite way, if we look at the end of this century (2071-2100), due to the higher temperature and lower precipitation, lower yields are expected on country level. However, the variability of the yields, characterized by the standard deviations, could be greater in the near future. The counties have different conditions, so the expected changes of crop yields have a spatial variability (Figure 1).

Maize is a warm season crop, but a very hot and dry summer decreases its yield. In the near future, due to the temperature decrease in summer, higher yields are expected in all counties compared to the last ten years. However, looking at the end of the century, the significantly less summer precipitation can lead to considerable yield losses. Sunflower is well adapted to Hungary's agro-climatic conditions. Our results show that in the near future sunflower yields could be slightly higher, while in the far future the present amount of yield is expected in almost all regions, with a 5-10% decrease in the central part of the country. Potato has a high water demand and looking at the model estimations, it is the unique case, where the dummy variable indicating drought years was significant and negative. As we do not know whether the future years would be dry years or not, we assume the presence of drought in all cases; while considering the ratio of the irrigated area values of the year 2011 were applied. In the near future, in the northern part of the country, the expected yield decrease is approximately 10%. In these counties, the scenario forecasts increasing autumn precipitation; and precipitation in the harvest season can lead to yield loss. By the end of the century the yields are expected to decrease in almost the whole country, because of the decreasing precipitation in spring and increasing precipitation in autumn. In case of green peas the high summer temperature has a negative effect, while the precipitation in spring has a positive effect on the yield. For the period of 2021-2050 the scenario indicates on country level about 5% decrease in both the summer temperature and spring precipitation, but the summer temperature has a greater coefficient (greater effect) in the model. Therefore in most of the counties a slight increase of yield can be expected. For the period of 2071-2100 increase of summer temperature and decrease of spring precipitation is forecasted, and this combination leads to a significant yield loss, especially in the southern counties. The grapevine model has very few significant variables, however the whole model and all the coefficients are significant and its capacity of prediction is good. In the near future, the model forecasts slightly higher yields for almost the whole country, while for the far future, we can observe almost the same yield as at present.

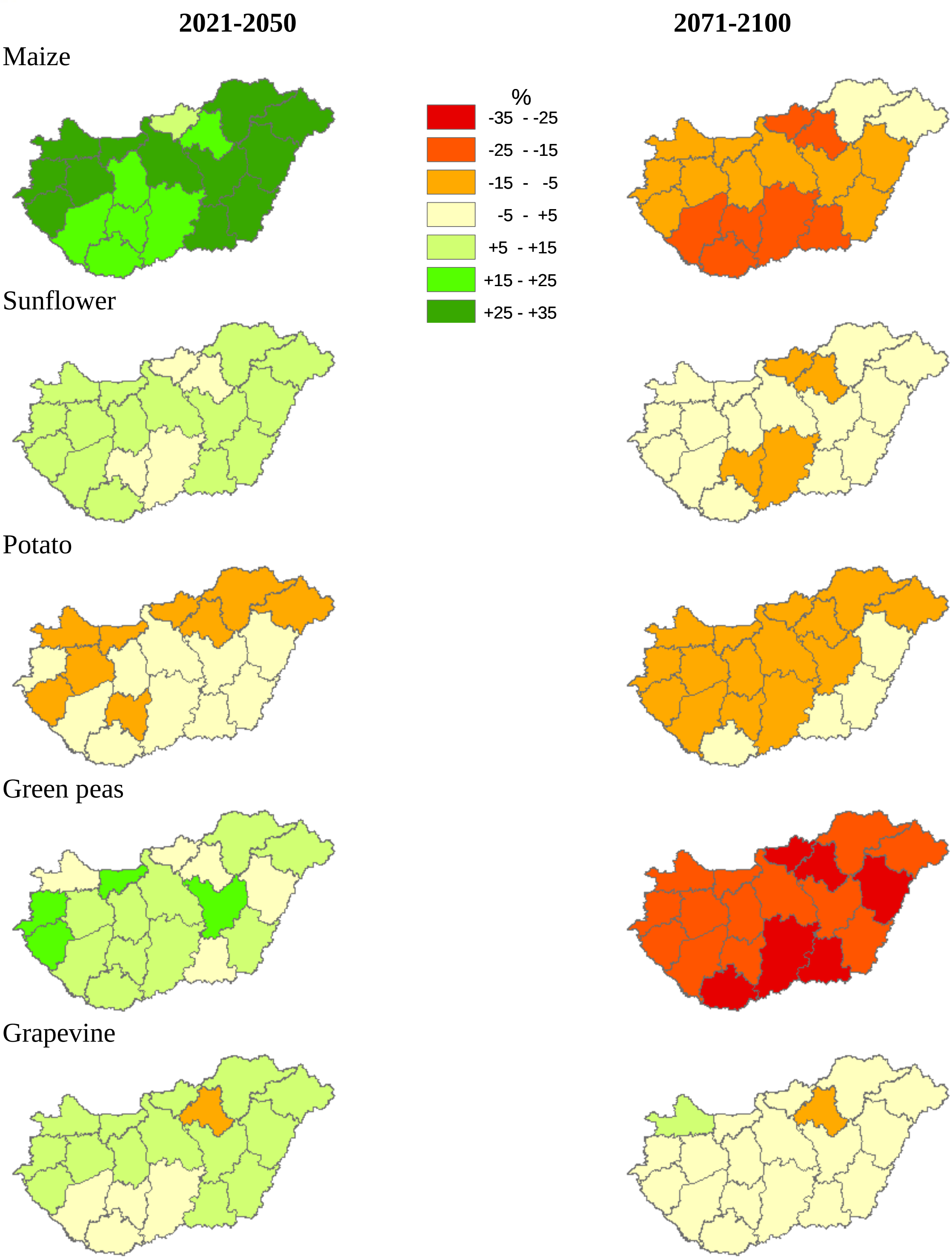

Figure 1. Expected changes (%) of crop yields compared to the average yields in 2002-2011

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4. DISCUSSION

Climate change impacts on the Hungarian agriculture were evaluated by county level, considering climatic and socio-economic variables. In this study the reference period was the last ten years (2002-2011), which was a warm period and had many extreme weather events. It was found that in the near future (2021-2050) maize can have better climatic conditions, the yield of sunflower, green peas and grapevine is expected to remain around the present level, while a slight decrease in potato yield is expected. However, the variability of the yields, characterized by the standard deviations, could be greater in the near future.

Several former researches stated that in long-term climate change would have prospectively mainly negative effects on the Hungarian agriculture (Aaheim et al,. 2009; Gaál, 2008). The present results confirm this. By the end of the century (2071-2100) all crops examined show yield loss, and green peas can suffer the most among them.

The presented results call the attention to the importance of the irrigation, especially in case of green peas and potato production. At present crop systems are mainly rainfed and water licenses are completely underexploited. The adequate use of the surface water resources could make Hungarian agriculture more stable and intensive (Kapronczai, 2010). To avoid great yield losses, the installation of irrigation systems would be essential, but there are economic impediments (Bella et al., 2007). According to Biro et al. (2011) the present farm structure with small farms, raise difficulties in the expensive irrigation development and also a strong state involvement would be needed.

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