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Territorial differences of climate change impact on Romanian crop production

Abstract. Effects of the climate change appear in several fields of the economy and agriculture can be considered as one of the most affected among them. In a country, where almost 10% of the total GDP is produced by the agricultural sector and more than 30% of the total work force is employed in this field, these changes may have severe economic impacts. As in Romania almost 65% of the agricultural production is represented by vegetal production, we concentrate our investigations on this agricultural sector. Our aim is to present, basing on econometric modeling, how the climate changes will affect the Romanian crop production in the next 20 years, highlighting the territorial differences which appear between the Romanian NUTS2 development regions. This paper presents some of the first results of the FP6 research project "CLAVIER – Climate Change and Variability: Impact on Central and Eastern Europe", contract no. 037013 (2006-2009).

Key words: climate change, crop yields, regional differences

Introduction

Agriculture is one of the sectors of economy which is the most affected by climate change [Cuculeanu 2003]. Compared to other European countries in Romania a relatively high share of GDP creation and a relatively high share of employment belongs to this sector. For thes reasons Romania may be highly affected by the climate change.

The aim of this paper is to estimate the effects of the changing climate parameters, as temperature, precipitation and relative humidity on the Romanian agriculture, concentrating on crop production. Due to the differences which occurf the land relief, climate, level of development and so on, the crop production in different regions of the country is affected in different way by the climate change.

The meteorological factors which are significant in production of the main crops in Romania, like wheat, maize, barley, potato, sunflower, lucerne and clover, will be identified by means of econometric modeling and there will be forecasts made of their yield until year 2030. Territorial differences among the development regions of the country are also going to be highlighted.

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Methods applied and data sources

Regression analysis

Agricultural productivity is dependent on many factors, as genetics, agricultural technology, adaptation capacity and regional climate [Harnos 2005]. In order to identify the most important meteorological factors in crop production and to estimate the evolution of the crop yields in the future regression analyses were applied separately for each of the representative crops in the region.

Two scenarios were created. Firstly, the baseline scenario assumed that the crop yield depends only on a single trend variable:

$$Ytrend_i = a_0 + a_1 * trend_i + e_i \qquad (1)$$

where:
- Y: predictant, the crop yield
- trend: predictor, a variable having value 1 for the first observation, 2 for the second one etc., and having linear, logarithmic or reciprocal form depending on the models' adjusted R square
- a_0: intercept
- a_1: slope coefficient of trend
- i: time step
- e: unexplained noise.

We suppose that the trend fitted for the past period will be the same in the case of the future periods too.

Scenario 1 assumed that deviations of the observed values of crop yields from the baseline scenario depend on the meteorological parameters which may affect the crop.

$$Deviation_i = Yobserved_i - Ytrend_i \qquad (2)$$

In the next step deviations were estimated by the relevant meteorological parameters, supposing linear relation between the predictant and predictors.

$$Deviation_i = b_0 + \sum_{k=1}^{m} b_k X_{ki} + u_i \qquad (3)$$

where:
- deviation: predictant (calculated using equation (2))
- X: relevant meteorological parameter (different for different crops)
- b_0: intercept
- b_k: slope coefficient of X_k
- m: number of predictors
- u: unexplained noise.

Estimated crop yields for the future period according to Scenario 1 were calculated using the results of equations (1) and (3):

$$Y'sce_i = Y'trend_i + Deviation'_i \qquad (4)$$

where:

- Y'sce: yield according to the Scenario 1
- Y'trend: yield according to the baseline scenario (estimated by (1))
- Deviation': deviation estimated by (3)

Results of the Baseline scenario and Scenario 1 represented a base for the further analysis in the study.
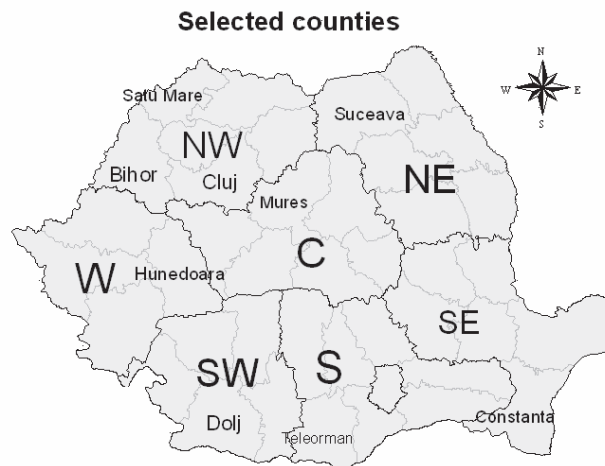
Data sources

Fig. 1. Selected counties from the Romanian development regions

Source: own composition based on HDR database

Crop data were available since 1975 on a county level, with a gap in the period between 1986 and 1988. Their source was the Romanian Statistical Yearbook for the period of years 1976-2005 published by the Romanian National Institute of Statistics [Romanian... 1976-2005]. In the case of the North-West region, regional crop data were calculated as an arithmetic average of crop data from of three counties, Bihor, Cluj and Satu Mare, selected from the region. In the case of the other development regions one representative county was selected in each of them, and the analysis has been executed using their data. The following counties were selected: from the North-East region Suceava, the South-East region Constanța, South region Teleorman, South-West region Dolj, West region Hunedoara, Center region Mureș. Figure 1[2] shows the selected counties.

Gaps in the time series of the crop yields were filled in the following way: for year 1986 an arithmetic average of the period 1975-1985 was calculated, for year 1988 an average of the period 1989-2000 and for year 1987 the average for years 1986 and 1988.

Climate data we used was provided within the CLAVIER project and derived using REMO 5.7 regional climate model. Studies for the past were realized by specialists basing

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[2] Abbreviations used for the names of the regions: NW – North-West, NE – North-East, SE – South-East, S – South Munteania, SW – South-West Oltenia, W – West, C – Center.

on the ERA 40 re-analysis data. REMO 5.7 model using A1B scenario[3] was applied for future projections.

Climate parameters were available on NUTS3 level and, similarly to the crop data, the regional data were taken for the above mentioned counties.
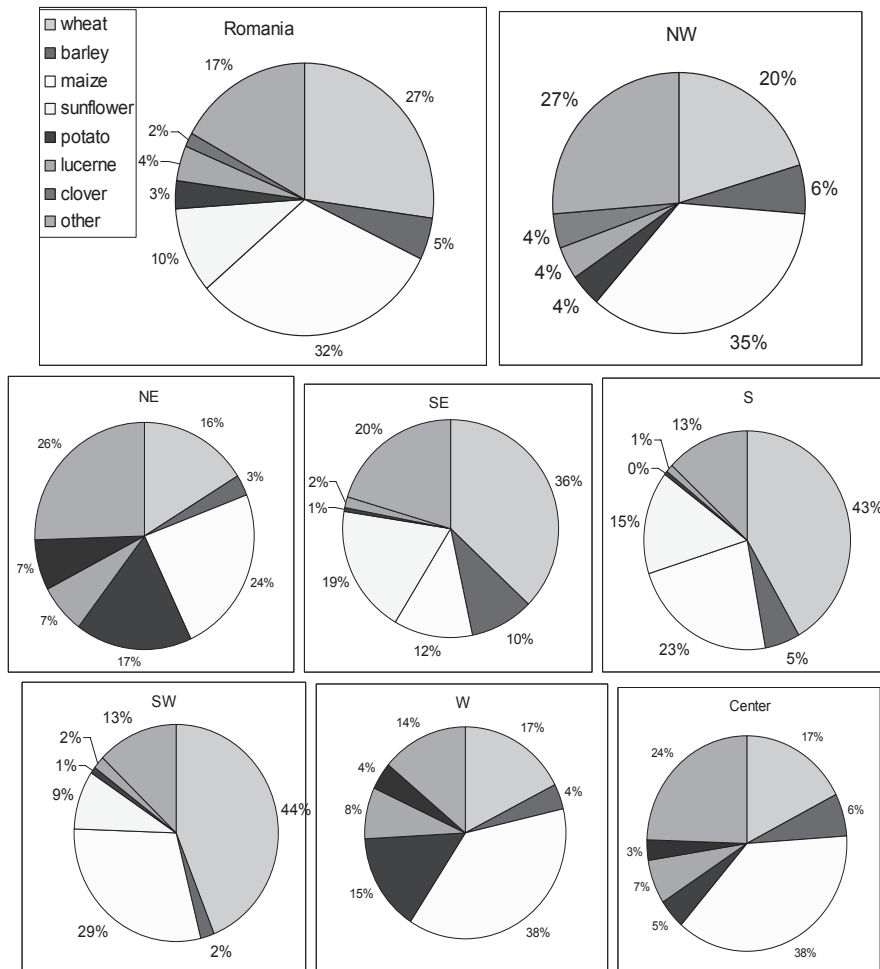

Fig. 2. Sowing pattern on the arable land in the development regions of Romania in 2008

Source: own calculations based on [National... 2009].

Structure of the Romanian crop production

The crop production has generally a share of about 60-65% in the total agricultural production in the Romanian development regions [4]. Wheat, maize, barley, potato, sunflower, lucerne and clover can be considered as being the main crops in the country as they together occupy more than 74% of the total arable land in all of the regions[5]. Thus any change which occurs in their production could have a significant impact on the country's agricultural production.

Figure 2 shows the sowing patterns on the arable land in Romania in general and in the 7 development regions[6]. Wheat and maize are the most important crops in all of the regions, being followed by sunflower in the southern regions of the country and by potato in the northern part. It is easy to observe the regional differences in crop production. While in some regions wheat is produced on more than 40% of the total arable land, in other regions its share is only about 16-17%. Share of sunflower in the southern regions varies from 9% to 19%, while in the case of the Center, West and North-East regions its share is almost negligible, less than 1%. Position of potato is the opposite. Its share is high in the Transilvanian part and in the North-East region and relatively low in other parts of the country. Share of lucerne and clover is relatively high in the North-East region and low in the southern part of the country.

Sowing patterns differ from one region to the other and the situation is the same in the case of crop yields. When looking at Table 1 it can be observed that while the yield of one crop is high in one region, the area share of another crop is lower, due mainly to the regions' geographical position and soil type, but to the level of development as well. For example, in spite of the fact that southern regions are the main maize producers, maize yield (t/hectare) in 2008 was the highest in the Transylvanian and North-East regions. In the case of potato, yields are the highest in those regions where share of this crop in the sowing pattern is also the highest (Table 1).

Table 1 Crop yields in the development regions of the country in 2008, t/hectare

Crop	Region							
	Romania	C	NE	SE	SW	W	S	NW
Wheat	3.40	3.29	2.87	3.92	2.94	2.98	3.40	3.40
Barley	3.07	2.55	2.48	3.67	2.54	2.40	3.54	2.54
Maize	3.22	4.15	4.32	2.55	3.45	3.86	2.25	4.18
Sunflower	1.44	-	-	1.52	1.49	-	1.17	1.99
Potato	14.11	15.06	11.90	14.52	12.25	11.58	11.06	15.61
Lucerne	4.28	4.34	5.52	5.03	4.58	4.08	2.91	4.38
Clover	3.73	4.62	4.05	-	-	2.89	-	3.37

Source: [National... 200].

Econometric models of the selected crops

Vegetation period differs from one crop to the other. Thus, when estimating econometric models, only the climatic parameters of those months which belong to the vegetation period of the respective crop were taken into consideration. Table 2 reflects the vegetation period (starting with sowing time, ending with harvesting period) of each analyzed crop.

Table 2. Important periods in crop cultivation

Crop	Optimal sowing time	Optimal harvesting period
Winter wheat	20 September - 20 October	July
Maize	15 April - 10 May	September - October
Winter barley	10 September - 1 October	June - July
Potatoes	5 - 20 March	September
Sunflower	March	September
Lucerne, clover	March	1. May -June
		2. August - September

Source: [Erdélyi 2007; Gaál 2007], information from local agronomist experts.

The statistical relationship was determined by a multiple linear regression, separately for the main crops of the country: wheat, maize, barley, potato, sunflower, lucerne and clover, where dependent predictant was a crop yield and independent variables were selected from the meteorological parameters represented in Table 3.

Table 3. Meteorological parameters used in estimation of the crop yields

Meteorological parameters	Short cut	Unit
Monthly air temperature (2m above ground level)	T	Celsius degree
Monthly precipitation sum[7]	P	Mm
Monthly relative humidity	H	%

The models used for the different crops in order to estimate their evolution in the period between 1975 and 2030 are based on a dataset for the period between 1975 and 2000 and yields are projected for the period between 2001 and 2030. The regression analysis was carried out by using the ordinary least squares method and the model quality was reflected by the adjusted R squared and F statistic. Climate parameters were statistically significant at minimum 10%, presence of heteroschedasticity and autocorrelation of the regression results were tested and corrected if necessary.

In order to make the climate data used for predictions be statistically equal with the climate data used for building the econometric models some adjustments were required. Thus, future climate data were adjusted for the difference between the averages of two

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[7] Calculated as a sum of the daily means in the respective month.

datasets for the historical period (1975-2000): REMO 5.7 ERA40 climate data used for the regression analysis and REMO 5.7 A1B scenario data used for projections.

Relevance of the climatic factors and their evolution in the period between 2001 and 2030

Impact of the three most important meteorological factors, temperature, precipitation and humidity, according to the econometric models shows significant discrepancies among the selected crops. In some cases a change in one meteorological factor could have even an opposite effect on different crop yields. This is the reason why weather in one year is favourable for some crops and unfavourable for the other.

Table 4. Important meteorological factors in the case of selected crops according to the econometric models

Sign	Month							
	March	April	May	June	July	August	September	October
Temperature								
+	barley		clover, potato				wheat, barley, sunflower	
-		barley, potato		barley, potato	potato, sunflower			wheat
different			wheat					
Precipitation								
+			lucerne	clover			potato	wheat, barley
-	potato, clover				wheat, maize, lucerne, sunflower			
different							wheat, barley	
Humidity								
+	lucerne				wheat			
-	wheat	potato	wheat, maize, lucerne, sunflower	potato			wheat	barley
different	sunflower	wheat				potato, maize		

Source: own calculations based on regression analysis results.

Table 4 shows the importance of meteorological parameters for the crop production of the country according to the econometric models. Signs refer to the regional econometric models and they reflect on the country level a general 'behavior' of the crops facing an

increase or a decrease of a certain meteorological factor. We took into consideration those effects which appear in at least 3 development regions. Sign '+' means that an increase of the relevant factor will increase the yield of the crop which appears in the cell. Sign '-' means the opposite and reflects that a decrease of the respective factor will increase the yield of the crop in the cell. 'Different' suggests regional differences. Crops which enter in these categories in some regions react in a positive way to an increase of respective parameter, while in the other regions in a negative way.

In the case of monthly temperature values only the reaction of wheat shows significant territorial differences. In some regions a temperature increase in May is beneficial for wheat production, while in other regions it has a negative impact on wheat yields. Wheat needs high temperature in September and a low one in October. For barley it is advantageous to have the temperature of March and that of September relatively high, while it is disadvantageous to have the temperature of April and June high as well. A temperature increase of April, June and July has a negative effect on potato yields, and, contrarily to this, an increase of temperature in May has a positive effect.

In the case of precipitation there are significant territorial differences for wheat and barley in September, when they have the sowing time. An increase of precipitation in October appears with a positive sign in most of the regions for these two crops. Potato likes high precipitation in September, when it is harvested, and it does not like that in March. Precipitations in July in most of the regions and in the case of most crops have a significant effect on yields but with a negative sign.

Relative humidity shows the highest regional differences. Its mean value in some months and in some parts of the country affects in different way the yield of the wheat, maize, potato and sunflower. Wheat does not like generally a high relative humidity in the spring months and it needs more humidity in the harvesting period. In the case of humidity it can be observed that a change in one month may affect differently different crops. For exemple an increase in March affects positively lucerne yields and negatively wheat yields, in the case of sunflower there appear territorial differences. Humidity in May is better if low in the case of several crops: wheat, maize, lucerne and sunflower.

After analyzing their relevance, we continue with estimating the trends of the relevant regional meteorological parameters in the period 2001 – 2030. When looking at Table 5 again the existence of territorial differences can be deduced in the evolution of the climate factors. Monthly average temperatures generally show an upward tendency except for the temperature of July and that of March in the North-East, South-East, West and Central regions of the country. These conditions will generally increase the sunflower and clover production.

The highest territorial differences appear in the case of precipitation. Only the amount of precipitation in June shows an upward trend in all of the regions and that of April and May a downward tendency. Direction of the other months' precipitation trends differ from one region to the other. While summer months generally are characterized by upward trends, in spring months and in October precipitation will be lower.

Relative humidity is characterized by a general downward trend in May and in October in the whole country and that is why there are expected increasing barley yields. Increasing tendency of relative humidity observed in March and September will affect negatively the wheat production. General downward trend of April humidity will affect positively potato yields while the upward trend of June will have an opposite effect on potato yields in the country except for the South-East and South regions.

Table 5: Linear trends of the regional meteorological data in the period 2000-2030

| Type of trend	Parameter	Region						
		NW	NE	SE	S	SW	W	C
Trend +	T	T3,T4,T5, T6, T8, T9, T10	T4, T5, T6, T8, T9, T10	T3,T4,T5, T6, T8, T9, T10	T4, T5, T6, T8, T9, T10	T3,T4,T5, T6, T8, T9, T10	T4, T5, T6, T8, T9, T10	T4, T5, T6, T8, T9, T10
	P	P6	P3, P6, P7, P9	P3, P6, P7, P9	P3, P6, P7, P8, P9	P3, P6, P7, P9	P6, P7, P8,	P6, P7
	H	H3, H5, H6, H7, H8, H9	H3, H5, H6, H7, H8, H9	H3,H4, H6, H8, H9, H10	H3, H4, H7, H8, H9	H3,H6, H8, H9	H3, H6, H7, H8, H9	H3, H6, H7, H8, H9
Trend -	T	T7	T3, T7	T7	T3, T7	T7	T3, T7	T3, T7
	P	P3, P4, P5, P9, P8	P4, P5, P8, P10	P4, P5, P8, P10	P4, P5, P10	P4, P5, P8, P10	P3, P4, P5, P9, P10	P3, P4, P5, P8, P9, P10
	H	H4, H10	H4,H10	H5, H7	H5, H6, H10	H4, H5, H7, H10	H4, H5, H10	H4, H5, H10

Source: own calculations based on the REMO57 A1B model data

Expected changes in the Romanian crop production

In previous chapter the evolution of the relevant meteorological factors and their impact on different crop yields in the 7 development regions of the country could be observed. Then, based on the forecasts made by means of the econometric models, the percentage changes in the crop yields by region were estimated. Crop yields estimations refer to the year 2025, calculated as an average of years 2020-2030[8], and they are compared to crop yields from the period between 1975 and 2000.

From Figure 4 it can be deduced that significant territorial differences appear between regions in the case of all crops. According to the baseline scenario wheat yields will increase in the Transylvanian region and in the North-East region; in the southern part of the country a decrease will appear. With regard to maize situation is almost the same: only in Transylvania a general upward tendency of the maize yields will appear. Barley yields will only decrease in South-Muntenia region. In other regions an increase of less than 10% can be forecasted. In the case of potato a decreasing tendency appears only in the North-East region, which is one of the main potato producers of the country. In other regions an increase of less than 10 % will appear. In the case of lucerne a significant decrease appears in the North-West, South-East, South and South-West regions. A decrease of clover yields appears in the southern part of the country, in the other regions a relatively slow increasing tendency will be present.

[8] The reason why for year 2025 we calculate crop yields as an average of years 2020-2030 is that the climate data being model data can not be used as annual data. It is advisable to use for calculations the forecasts averages for a certain period, at least 10 years, instead of one year data.
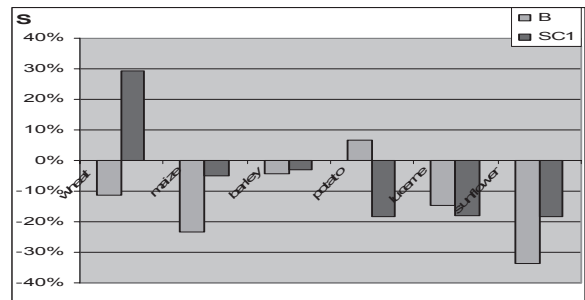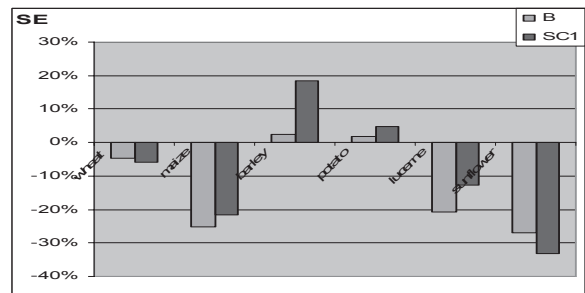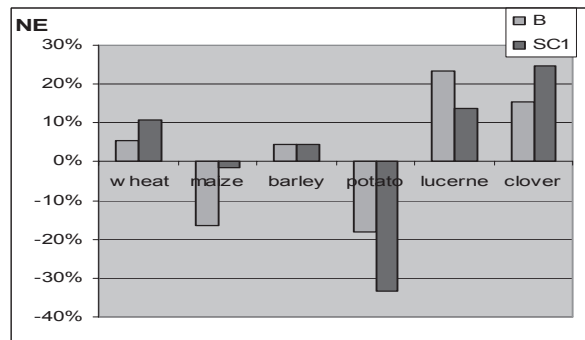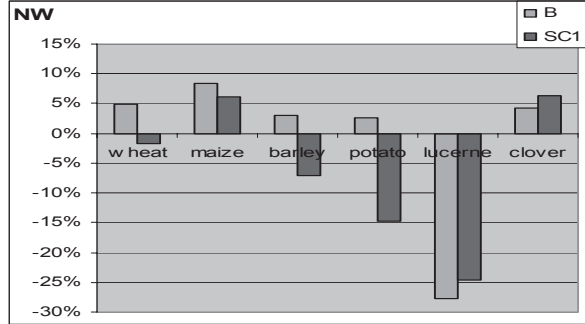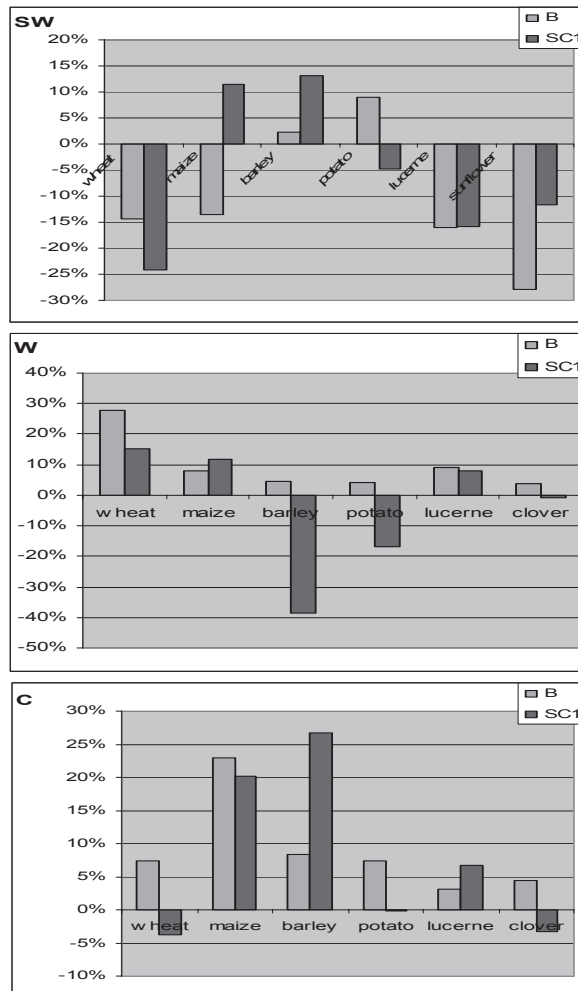
Figure 3: Changes in crop yields in 2025 with respect to the 1975-2000 by development regions (B – baseline scenario, SC1 – Scenario 1), %

Source: own calculations.

According to the Scenario 1, which models the climate impact on the crop yields, the following aspects can be noticed (Figure 4.).
• Concerning wheat: the highest increase (about 30%) appears in the South region, being followed by the North-East region (with about 10% increase). It is interesting to mention that in the first region the share of wheat in arable land is the highest, and in the second one it is the lowest as compared to the country average. However in the West region, according to this scenario, wheat yields will be higher than in the past period. It has to be observed that the baseline scenario forecasted higher yields. In this case the climate change affects negatively the production of this crop.

- Maize: only in the North-West and Center regions negative climate effects will appear. Besides the above mentioned regions, the West region can be charecterized by an increasing tendency when compared to the yields of the past period. In other regions a decreasing tendency in maize yields will be moderated by the climate change.
- Barley: a considerable increase appears in the case of the Center, South-West, South-East and North-East regions, the highest dercrease in the West and North-West regions.
- Potato yield decrease will appear mainly in those regions where the share of this crop in the sowing pattern is the highest: in the North-East and North-West regions, a slow increase appears only in the case of the South-East region. It can be observed that the negative impact of climate change is most significant in the case of this crop.
- Sunflower yields show a decrease in the case of all three regions in the Southern part of the country.
- Lucerne and clover yields show an increase in the North-East region, where their share is the highest, however lucerne yields will be lower than in the case of the baseline scenario. Apart from this region a lucerne yield increase is expected only in the Center and West regions; the clover yield increases only in the North-West region.

Related to Figure 4, Table 6 shows a comparison of the regions regarding the size of the change which appears in the crop yield in the period 2020-2030, when taking as a base the mean yield of the period 1975-2000. The following aspects can be highlighted: a decrease of some crop yields is the highest in those regions where the crop share in the sowing pattern is also the highest: wheat in the South-West region, potato in the North-East region. At the same time, compensating these negative aspects, some crop yields will increase due to the climate change in those regions where their share in the cropping pattern is relatively high: maize in the Center, lucerne and clover in the North-East, sunflower in the South-West region.

Table 6: Regions with the highest and the lowest yield increase/decrease in 2025 as compared to the level of 1975-2000

Scenario	Change	Crop						
		wheat	maize	barley	potato	lucerne	clover	sunflower
2020-2030 baseline	increase	W	C	C	SW	NE	NE	SE
	decrease	SW	SE	S	NE	NW	W	S
2020-2030 scenario 1	increase	S	C	C	SE	NE	NE	SW
	decrease	SW	SE	W	NE	NW	C	SE

Source: own calculations based on the regression analysis results.

Which regions will have the highest crop yields in 2025 taking into consideration the climate change effects? In some cases it has no connection with the size of the above mentioned regional yield increases. For example, however the highest barley yield increase appears in the case of the Central region, according to the scenario 1 in 2025 still the South-East region will have the highest barley yield.

In a lot of cases the baseline scenario and the scenario 1 show the same results in ranking of the regions by the height of crop yields. But there are still cases where the scenarios show different results, suggesting a significant effect of the climate changes. For example, according to the baseline scenario the highest wheat yields would be expected in the West region, but due to the favourable climate conditions the South region will move to the first place, as it was in the past period too. the situation is similar in the case of lucerne and sunflower too, where the Center and the South regions will benefit from the climate change. In the case of maize and clover the 2 scenarios show the same results.

Table 7: Regions with the highest and the lowest crop yields in 2020-2030

Scenario	Position	Crop						
		wheat	maize	barley	potato	lucerne	clover	sunflower
1975-2000 observed	first	S	SE	S	NE	SE	NE	SW
	last	W	NE	NE	SW	W	W	SE
2020-2030 baseline	first	W	C	SE	C	NE	NE	SW
	last	SW	NE	NE	SW	NW	W	SE
2020-2030 scenario 1	first	S	C	SE	C	C	NE	S
	last	SW	NE	W	S	NW	W	SE

Source: own calculations based on the regression analysis results.

Conclusions

Climate change is an inevitable phenomenon which causes modifications in the meteorological factors important for crop cultivation. Crop yields will change and therefore `the volume of production in the agricultural sector will also change. But climate impact on yields differ from one crop to the other, thus there will be crops which will be affected negatively while the others positively by the same impact. Forecasted climate change will not be the same in all parts of the country. In Romania there are some territorial differences between the crop production in the 7 development regions due to the land relief, the climate, the agriculturl development level and they will persist.

According to the REMO 5.7 regional climate model using A1B scenario significant yield decreases in the case of most important crops will appear in the next 20 years in most of the regions. Agricultural sector has to adapt somehow to these changes. Many adaptation techniques are known, one being a change in the cropping pattern. Maybe an increase in production of those crops which probably will have increasing yields, taking into consideration the regional differences, would be a good solution for mitigating the negative effects of the climate change.

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