Climate Changes and Its Impact on Agriculture – The Case Study of Bulgaria

Nedka Ivanova and Plamen Mishev

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/50861

1. Introduction

The Republic of Bulgaria is situated on the eastern Balkan Peninsula with Black See on the east, Turkey and Greece on the south, Macedonia and Serbia on the west and the Danube River and Romania on the north. Bulgaria spreads on a territory of 111 thousand sq. km. with 6 NUTS2 administrative regions (Figure 1): North West Region (NWR) with 5 major towns (Vidin, Vratza, Lovech, Montana and Pleven); North Central Region (NCR) with 5 major towns (Veliko Tarnovo, Gabrovo, Razgrad, Ruse and Silistra); North East Region (NER) with 4 major towns (Varna, Dobrich, Targoviste and Shumen); South East Region (SER) with 4 major towns (Burgas, Sliven, Jambol and Stara Zagora); South Central Region (SCR) with 5 major towns (Kardgali, Pazardgik, Plovdiv, Smoljan and Haskovo) and South West Region (SWR) with 5 administrative centres (Blagoevgrad, Kjustendil, Pernik, Sofia-town and Sofia-district).

The basic climatic characteristics of Bulgaria are: temperately continental and subtropical (in the south) climate with four seasons and high variation in the temperature, precipitation and humidity among the country regions. Mountains cover 60% of the country territory as the rivers are short, low-water and unevenly allocated through the country.

Bulgaria has a moderate continental climate, with the Black Sea influencing the weather conditions in the coastal area (30-35 km along the sea shore, NER, SER). The average temperatures in the country vary between years and among the regions. The physic and geographical conditions in Bulgaria are very favourable for the development of agriculture, but there are substantial differences in climatic conditions among regions.

Due to the continental climate the summer in Bulgaria is hot and the winter – dry and cold. There are dry spells in summers in July and August. The amount of precipitation is generally low with variations among the regions. The lowest precipitation is observed in

SWR. West and northeast winds dominate and in the winter there are strong north and northeast winds. Because of the strong and steady winds the snow cover is often blown away from the flat areas and the soil gets frozen.

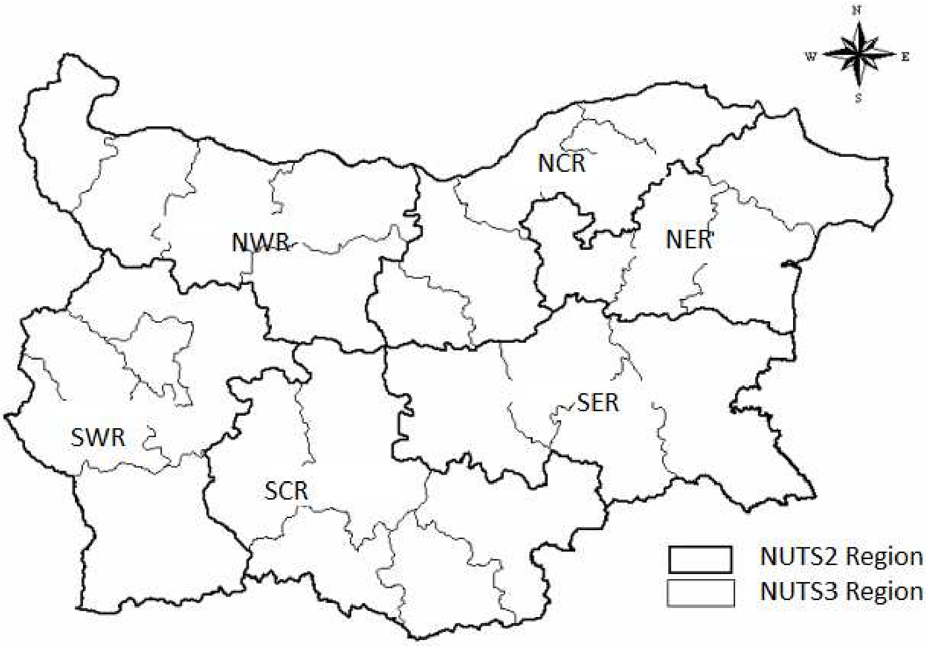


Figure 1. Administrative structure of Bulgaria

The irrigated areas in the country are about 8% of the cultivated land. Concerning water use for irrigation it should be mentioned that it is accounted about only 3% of the total water used in the country which make crop production highly dependent on climatic conditions.

In conclusion, Bulgarian agricultural production is rain-fed, crucially depends on precipitation regimes and climate changes are a very important factor for agricultural development of Bulgaria.

Agriculture plays a crucial role for the economy in Bulgaria. About 5% of GDP and 17.2% of total export of the country in 2009 were provided by agriculture. The sector is the major activity in the rural regions of the country ensuring employment and development of these regions. Over the last years crop production reached to 70% of GAO thus making agriculture highly dependent of crop output. Crop pattern and crop productivity are affected substantially by the regional climate as weather and climate factors are regarded as key factors for the crop output. Having in mind that approximately 49% of the country's territory is agricultural land and that more than 60% of it is the arable land, it is obvious that crop production plays an important role in Bulgarian economy and is crucial for the development particularly of the rural regions.

Agricultural productivity and in particular crop productivity plays an important role for the development of Bulgarian agriculture. Although technological advances such as improved seeds, cultivation methods, fertilization etc. play a major role, weather and climate can still be regarded as key factors for agricultural productivity [e.g., Anderson and Hazel, 1989;

Alexandrov and Hoogenboom, 2001; Sun et al., 2007]. Alexandrov and Hoogenboom [2000] demonstrated the importance of monthly temperature and precipitation conditions for yields of maize and winter wheat for Bulgaria, but the authors do not cover economic aspects of the observed impact of the mentioned climatic indicators. Some attempts to cover economic aspects of the climatic impact on crop yields are made under the CLAVIER project[1] as the study covers only North-East Region of the country (Mishev Pl., Ivanova N., Mochurova M., Golemanova A.,2009).

Having in mind the importance of the climatic factors for crop yields and crop production for agricultural development in Bulgaria as well as the importance of the agriculture for the national economy the main goal of this study is to evaluate the economic impacts of climate changes on Bulgarian agriculture and through then on the national economy.

2. Some national peculiarity

As mentioned above the climate in Bulgaria is temperately continental and subtropical in the south part of the country with high variation in the temperature, precipitation and humidity among the country regions. These differences in the climatic conditions reflect in different structure of land use, pattern of production and crop yields among the regions. The allocation of territory by regions, some basic climatic indicators and the share of agricultural land by regions are shown in Table 1.

indicators	Bulgaria	NWR	NCR	NER	SER	SCR	SWR
Area, ‘000 sq. km	111	19,1	14,8	14,4	19,7	22,3	20,7
% of UAA in total territory	49%	59%	58%	65%	50%	31%	42%
% of arable land in UAA	62%	68%	78%	81%	64%	59%	19%
% of grains and sunflower in UAA, 2009	75%	81%	83%	80%	73%	57%	47%
Climate indicators							
Average air temperature, degrees C, 2009	13,1	11,9	12,7	12,8	13,4	12,0	15,7
Annual amount of precipitation, l/m^2, 2009	1,0	1,4	1,1	1,0	0,9	1,1	0,7
Average humidity	56,2	57,0	57,2	61,5	56,2	51,6	54,1
Share of agriculture in GDP, 2009	4,8%	11,7%	9,2%	7,2%	5,8%	7,5%	1,5%

Source: National Statistical Institute, Statistical Yearbook different years; MAF, Agrostatistics, BANSIK different years

Table 1. Geographic Indicators

The data in the table show that the agricultural land in the country covers nearly half of the country’s territory as in some regions reaches 60% - 65% of region’s territory (NER, NWR,

[1] CLAVIER project (Climate Change and Viability: Impacts on Central and Eastern Europe): http://clavier-eu.org/

NCR). The arable land is 62% of the agricultural land but generally it is unevenly allocated among regions (between 81% in NER and 19% in SWR). The importance of the agricultural sector in for the economic development the regions varies between 1,5% of the regional GDP in SWR and 11,7% in NWR (Table 1). In all regions with exception of SWR the share of agriculture in GDP is higher than the national average which shows that the importance of the sector in these regions is even stronger for the regional development than at national level.

Grains and sunflower seeds have always been most important crops cultivated in the country as the importance of these crops increases. Over the last decade the share of grains and sunflower seeds in total arable land increased from 74,5% in 2001 to 82,1% in 2009, which practically means that Bulgarian crop production depends highly on 4 crops only. The grains and sunflower seed are also important for the country in respect to the export. These 4 crops provide 30,6 % (in this number wheat 13%, sunflower and oil 13%) of total agricultural trade and are the main export oriented products.

Although the physic and geographical conditions in Bulgaria are very favourable for the development of agriculture, due to the substantial differences in natural and climatic conditions among regions (Table 1) the impact of climate changes would be different by regions. Due to this the regional approach for estimation of climate changes impact on crop yields have been used in the study as the results are aggregated at national level.

3. Case study framework: Brief methodological notes

The study covers three main aspects of the impact of climate on the economy:

1. Evaluation of the impact of climatic changes on crop yields;
2. Estimation of these effects in economic terms for agriculture;
3. Evaluation of the impact of changes in the sector on the overall economy.

In respect to the first aspect different methods have been developed to estimate the climate impact on crop yields. These methods can be grouped into two main groups: dynamic process-based crop models and empirical-statistical approaches [Feenstra et al., 1998; Hansen and Indeje, 2004]. For the study empirical-statistical techniques are applied to design climate-crop models in order to quantify the impacts of climate change on agricultural productivity. There are lots of publications focus on the climate factors impact on crop productivity and the statistical methods for estimating the impact of climate change on crop yields (Cline, W., 2008; Iglesias, A., L. Garrote, S. Quiroga, M. Moneo, 2009; Ciscar, Juan-Carlos, 2009; Alexandrov, V., 2008, etc.). In the studies generally multiple regression models with crop yield as dependent variable have been used. This approach has been used in the current study.

The problem of estimation the economic impact for agriculture of changes in yields caused by the climate changes is not widely considered in the literature. An approach for doing this has been developed under the CLAVIER project and this approach has been used in the study. The approach is based on constant process and no changes in land allocation thus excluding the economic factors impact on performance of the sector.

In respect to the third aspect of the study there are a lot of publication dealing with the evaluation of the impact of changes in a given sector on the economy (Johansen L., 1960; Pyatt & Round, 1985; Hertel T.W, Brockmeier M., Swaminathan P.V., 1997; Bach C.F., Frandsen S.E., Jensen H.G., 2000; Jensen H.G., Frandsen S.E., Bach C.F., 1998; Ivanova N., T. Todorov, A. Zezza, 2000 atc.). The approaches used can be classified into three main groups: input-output analysis, social accounting matrix analysis and General equilibrium analysis as input-output analysis is implicitly involved in the other two groups of analysis. For the purpose of this analysis the input-output models with multiplier analysis have been chosen.

In respect to the first aspect of the study in order to estimate the climatic factors impact on crop yields the crops to be examined should be selected first. The estimation of the climate changes impact on selected crops could be done following two possible approaches:

1. To estimate the impact of major climatic factors directly on average yields at national level for the selected crops;
2. To estimate the impact of major climatic factors on average yields of crops important for the regions and to aggregate the expected effect at national level.

The first approach is suitable to be used in case of no substantial differences in crop yields and climatic indicators among regions while the second approach could be used in case of differences in crop yields and climatic indicators among the regions. The second approach requires an additional analysis of the importance of selected crops at national level to the regions.

As seen from Table 1 the climatic factors differ substantially among the regions even on a yearly basis. Due to this the second approach is more suitable in the case of Bulgaria but in this case an additional analysis of the importance of selected crops by region should be done.. The second approach also requires more precise analysis based on differences in monthly data for temperature, precipitation and relative humidity by regions as well as the regional differences in crop yields of the selected crops. Due to this after selection of crops to be examined at national level the regional differences in yields and climatic indicators have to be analysed and on the basis of the results of this analysis to select the approach to be followed.

Following the selected approach for estimation the climate changes impact on crop yields the multiple regression crop models have to be developed for selected crops at regional level. The models use selected meteorological parameters as predictors and crop yields as the dependent variable.

To estimate the potential impact of climate changes on crop yields scenarios for the climate changes for the period 1951-2050 have to been produced. They are based on the post-processed climate simulations obtained in the VI FP project CLAVIER. For projections of climatic indicators error corrected daily data from highly resolved regional climate simulations (REMO version 5.7). Hemispheric synoptic-climatological studies were realised based on the ERA-40 re-analyses data (for the past) and the ECHAM 5 global climate model's results (for the past and the future as well)[2]. The scenario simulation (2010 – 2050) is

[2] CLAVIER project (Climate Change and Viability: Impacts on Central and Eastern Europe): http://clavier-eu.org/

based on greenhouse gas emission scenarios A1B REMO and B1 LMDZ and can be used to quantify climate change signals by comparing it to the control simulation (1951 – 2000) which is based on observed greenhouse gas concentrations. Based on these scenarios potential impact on crop yields by regions is estimated.

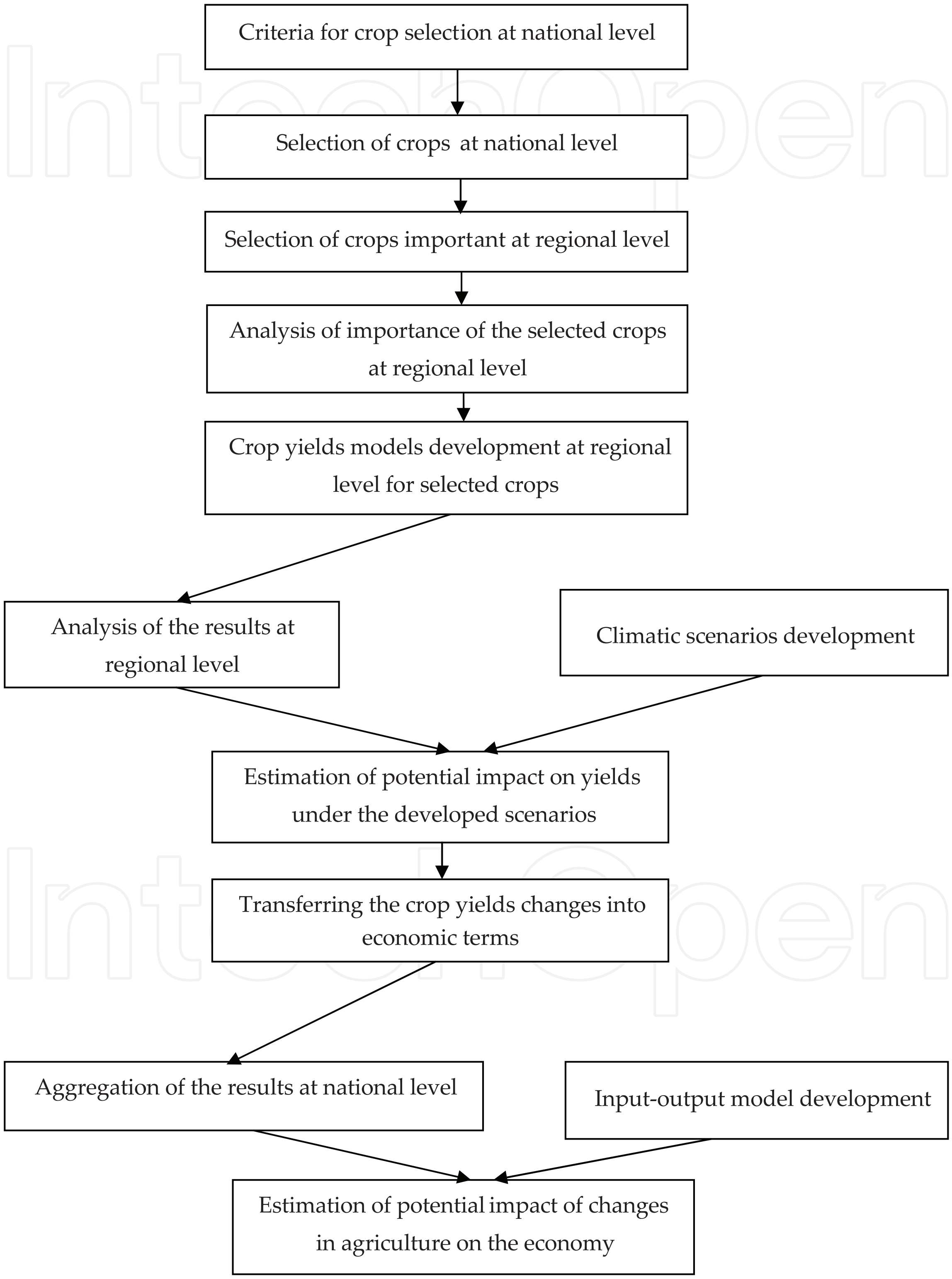


Figure 2. Methodology followed in the study

In respect to the second aspect the estimated changes in yields should be translated into economic terms. As the main economic indicator gross agricultural output (GAO) is used in the study. To avoid price changes impact the constant prices are used for estimation the yields changes in value terms. Additional assumptions used in transferring the climate changes impact on GAO are:

- no changes in land use structure;
- all other crops remain unaffected;
- value of livestock production and other activities in GAO remain constant.

Based on this assumptions changes in GAO by regions are estimated and the results are aggregated at national level and the estimated change in GAO is used as a proxy for economic impact of climate changes on agriculture.

The third aspect of the considered problem requires an input-output model at nationasl level to be developed. The model is based on make and use tables provided by the National Statistical Institute. In order to estimate direct, indirect and spillover impact of the changes in agriculture on the national economy the developed input-output model is shocked as the shock vector is constructed on the basis of change GAO. The impact of changes in agriculture on the national economy is estimated on the basis of multiplier analysis.

The methodology used in the study described above is shown on Figure 2.

4. Selection of crops to be examined

Selection of crops to be examined is based on the following criteria: share of crops in the arable land and the importance of crops in respect to the crop output. Results of the analysis of importance of crops in respect to the two criteria are shown in Table 2. As seen from the table the 4 crops mentioned above use nearly 70% of the arable land in the country and provide half of crop output. The shares of other crops, produced in Bulgaria are relative much lower than the shares of crops shown as in arable land as well as in respect to the crop output. Based on the results of the analysis the selected crops to be examined at national level are: wheat, barley, maize and sunflower.

As shown in the table the importance of the 4 crops analysed at regional level in respect to the land use and crop output is relatively high in all regions but NWR Having in mind that the share of the four crops in crop output and in arable land in SWR is relatively low in comparison with the other regions (Table 2) the SWR is excluded from the regional analysis. The same is valid for barley in NWR. Thus the analysed products by regions are the four selected products for SCR, SER, NCR and NER, and wheat, maize and sunflower for NWR. Thus the selected crops cover at least 50% of the arable land and above 40% of crop output at regional level.

Results of the analysis of crop yields at regional level are shown on Figure 3. As seen from the figure the crop yields differ quite substantially by regions as in cases of wheat, maize and sunflower the difference is quite substantial while in case of barley the yields differences are not so large. The differences in climatic factors by regions are obvious from

Table 1 although the annual data are presented in the table. The detailed analysis of the three selected climatic indicators based on the monthly data shows that the differences by the regions are even higher than on average for the year. The most substantial differences in temperature are observed in winter months when the differences reached to 90% of the country average and are the smallest in summer with deviation from the average accounted to 15%. In respect to the precipitation the most substantial differences are observed in spring and early summer as the deviation reached to 45% of the country average. The deviation in relative humidity is relatively smaller in comparison with the other two climatic indicators but during the summer the differences reached to 25% of the country average. These differences in climatic conditions as well as differences in yields are the reason for selecting the second approach for the study, i.e. analysing the impact of climate changes on yields by regions.

products	Bulgaria	NWR	NCR	NER	SER	SCR	SWR
Share in crop output							
Wheat	20%	21%	24%	23%	24%	11%	6%
Barley	5%	5%	7%	5%	9%	1%	1%
Maize	8%	12%	11%	11%	2%	3%	2%
sunflower	13%	18%	17%	16%	14%	5%	2%
Total	46%	57%	60%	55%	48%	20%	11%
Share in arable land							
Wheat	36,6%	37,7%	39,1%	37,1%	39,9%	29,9%	23,9%
Barley	7,6%	5,7%	9,1%	6,8%	11,5%	4,6%	3,6%
Maize	8,0%	10,6%	12,1%	11,6%	0,8%	3,4%	5,5%
sunflower	16,9%	22,9%	22,3%	22,9%	1,9%	13,3%	7,3%
total	69,1%	76,9%	82,6%	78,4%	54,0%	51,2%	40,4%

Source: NSI, Economic account for agriculture, 2009; MAF Agricultural Statistics Department

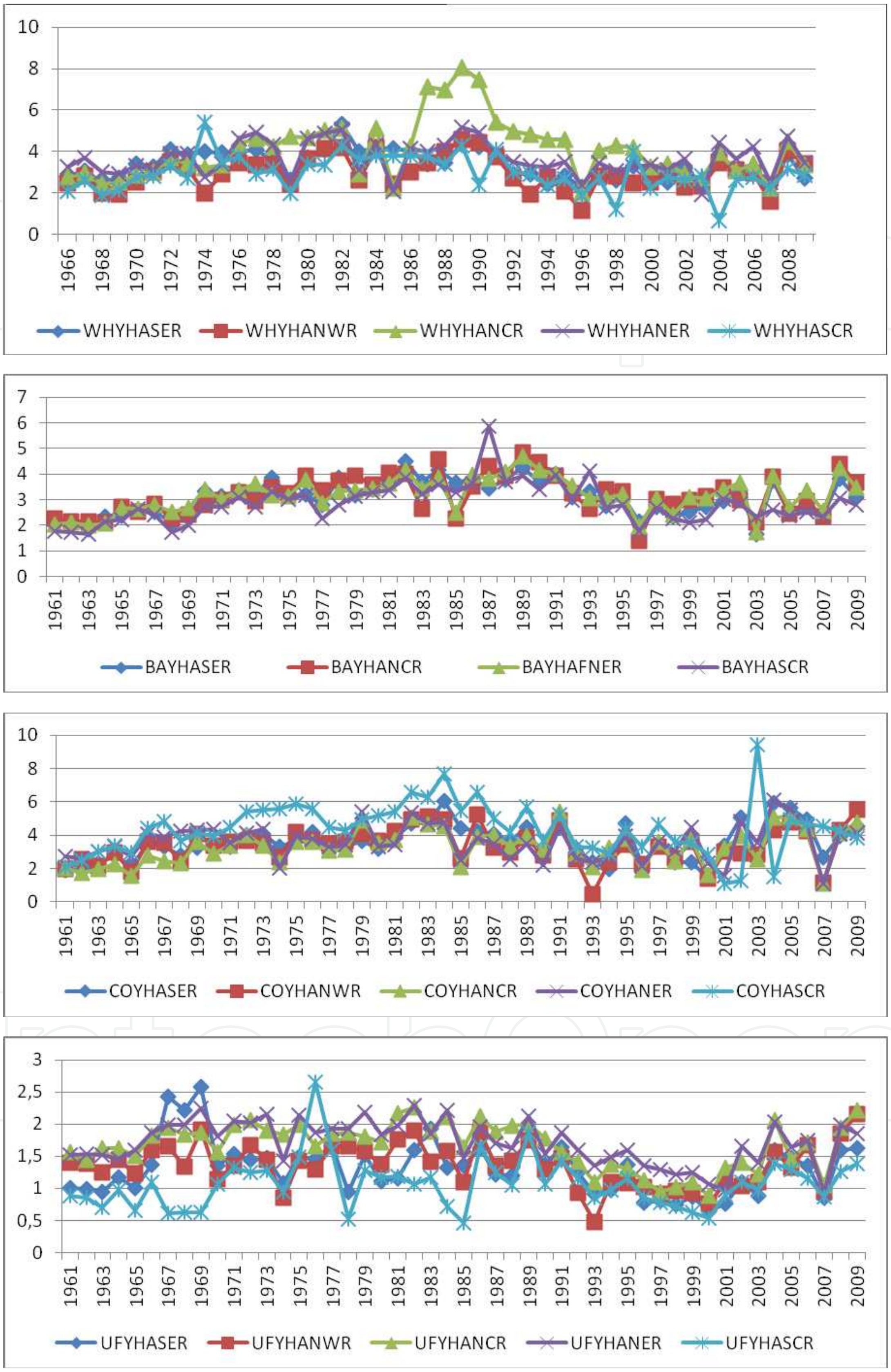
Table 2. Share of major crops in crop output and in arable land, 2009

5. Data and metadata used in the analysis

The source of crop yield data, historic meteorological data, prices and the national I-O table and all other economic data is the National Statistical Institute and Agro Statistics Department of MAF. The historic data used in the analysis covers the period 1961 – 2009, as for yields annual data are used, for temperature, precipitation and relative humidity average monthly data are used. For construction of I – O table Make and Use tables for 2005[3] are used.

As already mentioned for projections of climatic indicators error corrected daily data from highly resolved regional climate simulations (REMO version 5.7) are used and the scenarios run covers the period 1910 to 2050 (datasets STAT-CLIMATE-ECA-A1B and B1 LMDZ METEO REGION).

[3] Last available Make and Use tables, Source NSI, Revised Make and Use tables for 2005



Source: NSI for the period 1961 – 2001; MAF, Agricultural Statistics bulletins, different years for the period 2002 - 2009

Figure 3. Crop yields by regions

6. Analysis of the impact of climate changes on yields

The analysis of the relation between the climatic indicators (temperature, precipitation and humidity) and the crop yields for the crops cultivated in by regions is based on the multiple regression models with yield as a dependent variable. For the purposes of this analysis the following data are used:

- Weighted average yields by regions
- Average monthly data for temperature, humidity and precipitation by regions
- Hindcast simulation data for the scenarios covering the period 1951 to 2050 (data base STAT-CLIMATE-ECA-A1B and and B1 LMDZ METEO REGION).

The mnemonic used in the figures as well as in the regression analysis is shown in Table 3.

	Data from NSI
Average monthly temperature	Tnn
Average monthly temperature changes(i.e. for the first difference of the indicator)	DTnn
Relative Humidity	RHnn
Relative Humidity changes(i.e. for the first difference of the indicator)	DRHnn
Precipitation	Rnn
Precipitation changes(i.e. for the first difference of the indicator)	DRnn
Wheat yield	WHYHA
Barley yield	BAYHA
Maize yield	COYHA
Sunflower yield	UFYHA

Note: nn is used for the month

Table 3. Mnemonics used

Generally there are three groups of factors affecting crops yields: technological development, economic factors and climate factors. In long run the first two groups of factors are associated with the trend while the third group of factors are associated with the deviation from the trend. Since the purpose of this analysis is to evaluate the impact of the third group of factors only the crop yield data are analysed more detailed. From the Figure 2 it is obvious that over the period up to 1990 there is an increasing trend in the yields, followed by a decreasing trend over the period of 90th and then with the stabilization of the economy the trend in yields became again positive for all crops analysed. Because of this in the analyses of the crop yields data either three sub-periods should be considered or a transitional dummy should be used to capture the economic factors impact on yields. For this study the second approach has been chosen.

To be able to exclude the impact of technological and economic factors the three type of trend models for yields are studied: linear trend models, logarithmic trend model and reciprocal trend model for all analysed crops by regions. In all models a transitional dummy is also used to absorb the effect of transition. It has to be mentioned that neither of the trend examined is statistically significant if the effect of transition is not taken into account. Results also show that in all cases analysed trend is not statistically significant even if the transitional dummy is included. Because of this the traditional approach for estimation of the impact of climatic factors on yields based on the two steps procedure of estimation (exclusion of trends first and them estimation of the climate impact on de-trended yields) could not be used. To solve this problem we chose to analyse the impact of climate factors change on the change in yields thus trying to exclude the impact of technological and economic development factors. This practically means that all the data (yields, temperature, relative humidity and precipitation) are transformed and the first differences of the series instead of the series alone are used in the further analysis. Further examination of the transformed yields data includes statistical properties of the data i.e. testing whether the adjusted yield series are stationary or integrated. Both tests (augmented Dickey-Fuller (ADF) tests, and the Phillips-Perron (PP) test[4]) proved that the time series of the first differences of transformed yields are stationary series at 99% confidence level, according to both, ADF tests and PP tests. Having in mind this, there was no need of further adjustments in the yields data or considering the autoregressive process (AR models) in modelling the impact of climate variables on yields.

7. Regression analysis for yields

In order to estimate the climate factors impact on transformed yields the correlation between the changes in yields and changes in climate factors has been checked for all crops and all regions analysed. The analysis of the correlation coefficients shows that in general the estimated coefficients are low (below 0,5). Never mind low correlation on the basis of the results the factors with highest correlation coefficients for any crop has been chosen. To avoid the potential multicollinearity problem that might appear in the transformed crop yields models in case of high correlation among the factors, only one of them has been chosen. The selection of factors is based on the correlation coefficients. Never mind that the number of observations is small more than 4 factors have been chosen to be tested in the regression models. Following this procedure the following factors have been chosen for the crops analysed (Table 4).

As seen from the table the change in climatic factors having impact on the change in yields of a given crop differs among the regions which confirms that the analysis should be done by regions but not at national level.

After testing various functional forms (linear, quadratic, log-linear etc.) and the significance of the variables, linear function has been chosen for modelling the change in crops yields. In the process of testing the regression models for the four crops analysed by regions combinations of the mentioned factors are used as some of them appeared to be statistically insignificant at 95% confidence level and do not improved the explained variation in change in yields or do not comply with theoretical requirements. As a consequence those factors have not been included in the models. The selected models are the ones with highest R

[4] Tested with a constant and a linear time trend

square that comply with the regression theory properties. Results for the best fitted models are shown in Table 5.

crop	NWR	NCR	NER	SER	SCR
	factors				
wheat	DT10(-1) DT6 DR5 DRH3 DRH2	DT7 DR3 DR4 DR5 DRH3	DT7 DT10(-1) DR3 DR4 DR5	DT7 DT5 DR3 DR4 DR6 DRH10(-1)	DT12(-1) DT5 DR3 DR7 DRH11(-1)
Barley		DT2 DT5 DR3 DRH2 DRH4	DT2 DT7 DR3 DR5 DRH2 DRH3 DRH10(-1)	DT2 DT7 DR3 DR5 DRH7	DT2 DT3 DR2 DR5 DRH6
Maize	DT5 DT8 DR4 DR6 DRH10	DT6 DR3 DR7 DRH5 DR9	DT5 DT7 DRH3 DR6 DR8 DRH10	DT6 DT11 DRH3 DRH6 DRH10	DT2 DT3 DR5 DR11 DRH10
Sunflower seeds	DT6 DT7 DR5 DR10 DRH7	DT3 DT6 DR5 DR10 DRH8	DT5 DT7 DR3 DR6 DRH5 DRH7	DT5 DT10 DT11 DR5 DRH7	DT8 DT5 DR5 DR6 DRH11

Source: Own calculations

Table 4. Climate factors with significant impact on yields

As seen from the results the explained variation in the changes in yields is relatively reliable. In some cases factors not statistically significant at 95% confidence level have been left in the model since they improve the explained variation (based on adjusted R-squared). The selected models have been tested for stability (QSUM and QSUMSQ tests) and proved to be stable.

As seen from the results the change in climatic factors explains 30% to 50% of the variation of crop yields as the less affected crop is maize (the climate factors explains between 22% and 36% of the variation in yields) and wheat is the most sensitive to the climatic changes (between 36% and 50% of the yield changes are explained by the changes in climatic factor). Results also show that climate changes affect more substantially yields in NER and SER and not so much the other regions.

crops	NER			NCR			NWR			SER			SCR		
	Variables and estimated coef.	Stat. signifi-cance (p-value)	R square	Variables and estimated coef.	Stat. signifi-cance (p-value)	R square	Variables and estimated coef.	Stat. signifi-cance (p-value)	R square	Variables and estimated coef.	Stat. signifi-cance (p-value)	R square	Variables and estimated coef.	Stat. signifi-cance (p-value)	R square
wheat	0,06	0.0000	0.469	0,03	0.8204	0.407	0,05	0.609	0.356	0,04	0.5786	0.503	0,03	0.9503	0.411
	-0,31DT7	0.0040		0,87DR3	0.0000		-0,10DT10(-1)	0.0129		-0,14DT7	0.0001		-0,68DT12(-1)	0.0003	
	-0,40DR4	0.0069		-0,24DR4	0.0363		0,03DRH3	0.0025		-0,23DR4	0.0019		1,18DR3	0.0344	
	-0,23DR5	0.2200		-0,25DR5	0.0806		-0,26DR5	0.0182		0,02DRH10(-1)	0.0405		-1,70DR7	0.002	
				0,08DT3	0.1880					0,15DR6	0.2183		-0,08DRH11(-1)	0.1138	
barley	0,02	0.7863	0.379	0,02	0.8266	0.432				0,03	0.7172	0.453	0,02	0.8302	0.279
	-0,10DT7	0.0411		0,70DR3	0.0000					-0,07DT2	0.0017		-0,05DT2	0.0434	
	0,32DR3	0.0296		-0,06DT2	0.0283					-0,24DT7	0.0004		0,08DT3	0.0385	
	-0,19DR5	0.0837		-0,03DRH4	0.0337					0,21DR3	0.0891		0,13DR2	0.0852	
	0,02DRH2	0.0073								-0,04DRH7	0.0029				
maize	0,04	0.8458	0.294	0,07	0.6698	0.335	0,05	0.8008	0.217	0,05	0.722	0.365	0,04	0.8652	0.292
	0,60DR6	0.0358		-0,29DT6	0.0064		0,77DR4	0.0039		0,16DT11	0.0055		0,27DT3	0.0201	
	0,43DR8	0.0207		0,67DR3	0.0107		-0,40DR6	0.0632		-0,29DT6	0.0351		-0,35DR11	0.0396	
	-0,07DRH10	0.0031		0,27DR7	0.0717		0,09DT8	0.2104		0,07DRH3	0.0001		0,07DRH10	0.0168	
				-0,05DRH5	0.0927					-0,06DRH6	0.0408		0,12DT2	0.0752	
sunflower	0,01	0.8395	0.350	0,01	0.8059	0.324	0,02	0.7881	0.383	0,01	0.8004	0.389	0,01	0.8121	0.302
	-0,04DT7	0.1365		-0,05DT3	0.0049		-0,08DT6	0.0847		0,06DT11	0.0024		0,26DR6	0.0116	
	0,25DR3	0.0018		-0,12DR5	0.005		0,13DT7	0.0222		0,03DT10	0.0939		-0,01DRH11	0.0219	
	0,16DR6	0.0299		0,01DRH8	0.0711		0,15DR10	0.0603		-0,19DR5	0.0083		0,03DT8	0.2275	
	-0,02DRH5	0.0175		-0,06DR10	0.0754		0,04DRH7	0.0078		0,02DRH7	0.0022				

Table 5. Estimated model results

Having in mind that 41% of wheat, 47% of barley and 43% of sunflower and 30% of maize are produced in the east part of the country (NER and SER) the obtained results stress on the fact that grains and sunflower production in the country would vary quite substantially die to the changes in climate. Furthermore, taking into account that crop production is two third of GAO, this would mean that strong variation in GAO could be expected, i.e. variations in GAO observed by now would continue.

7.1. Expected climate change

Climatic changes scenarios used in the study for projections are developed under the VI FP CLAVIER project. Climate scenarios describe the mean conditions over a longer period and hence, comparing the mean conditions in future periods (e.g., 2021 to 2050) to those in a reference period (e.g., 1961 to 1990) allows deducing the influence of climate change.

The following two scenarios and climate models are applied in the study:

1. A1B - REMO
2. B1 - LMDZ

These scenarios are based on the different CO2 emissions in the future (the so called A1B and B1). The Emission Scenarios have been developed by the Intergovernmental Panel of Climate Change (IPCC).

The A1B storyline and scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies (reference to Clavier WP). Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. A1B scenario is a balance across all energy sources: fossil intensive and non-fossil energy sources.

Scenario/ model	Yearly mean of the mean daily temperature /°C/	Yearly mean of the daily precipitation amount /mm/
A1B - REMO	+1.0	0.0
B1 - LMDZ	+1.8	-0.5

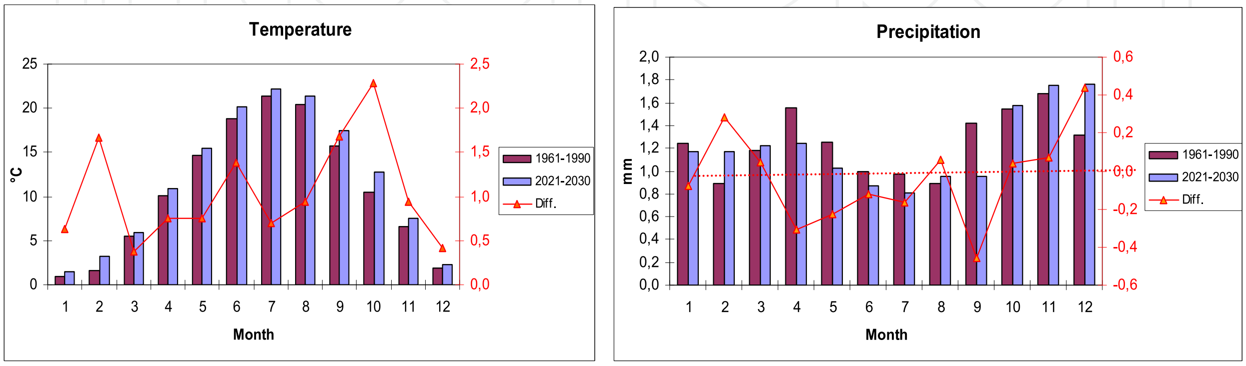
Source: own calculations based on CLAVIER database

Table 6. Differences in the climate parameters in the future 2021-2030 as compared to the past climate 1961-1990 in Bulgaria

The B1 storyline and scenario describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies (reference to Clavier WP). The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives. B1 – LMDZ scenario do not provide relative humidity data, due to which humidity projections obtained from scenario A1B – REMO are used in the second scenario.

The changes expected in the future 2021-2030 as compared to the past climate 1961-1990 over the territory of Bulgaria under the two scenarios are presented in Table 6.

The changes expected in the future 2021-2030 according to scenario A1B - REMO as compared to the past climate 1961-1990 over the territory of Bulgaria under the first scenario are presented in Figure 3.

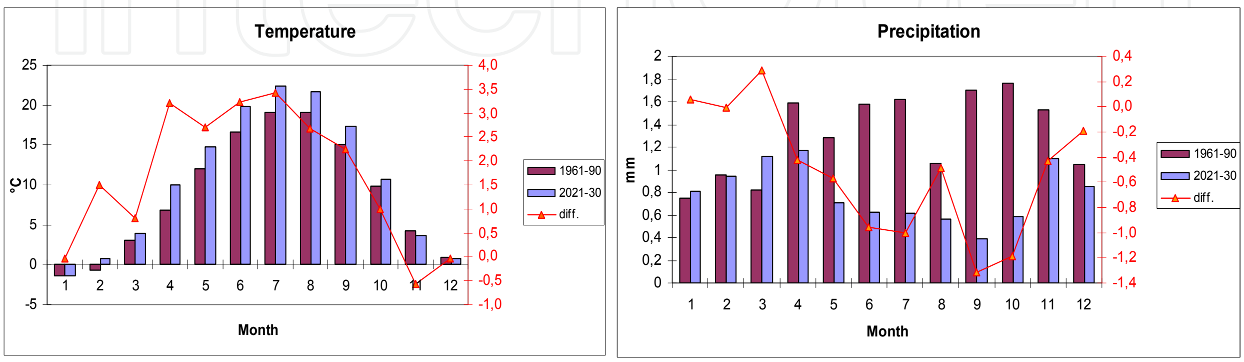


Source: own calculation based on data base STAT-CLIMATE-ECA-A1B

Figure 4. Expected climate changes over the territory of Bulgaria, A1B REMO scenario

While it is expected the mean monthly temperature to increase by 1 °C on average, the difference between the past and future climate reaches about +2 °C in autumn (September and October) and in February. There is almost no change in the mean yearly precipitation (-0.04 mm). However, a decrease in the mean monthly precipitation the can be observed during most months, especially in September, as an increase could be expected in winter.

Under scenario B1 LMDZ a moderate increase in the temperature and a decrease in the precipitation in Bulgaria is expected as compared to the A1B - REMO scenario. The most noticeable raise in the mean monthly values of the daily mean temperature is expected in spring (+2.2 °C) and in summer (+3.1 °C). A decrease in the average precipitation is projected, especially in June, July, September and October.



Source: own calculation based on data base B1 LMDZ METEO REGION

Figure 5. Expected climate changes over the territory of Bulgaria, B1 LMDZ scenario

8. Crop yields projections by regions

The changes in climatic factors used in the models (temperature, precipitation and relative humidity) for the historic period as well as Hindcast simulation data for the period 1950 – 2009 were tested for statistical equity. The equity tests for mean, median and variance have been performed for the month temperature data, precipitation data and relative humidity data used in the crop models. Results show that the null hypothesis is not rejected in all cases analysed and therefore there are no statistically significant differences at 95% confidence level for all climatic variables used in model and no adjustments in the data are needed.

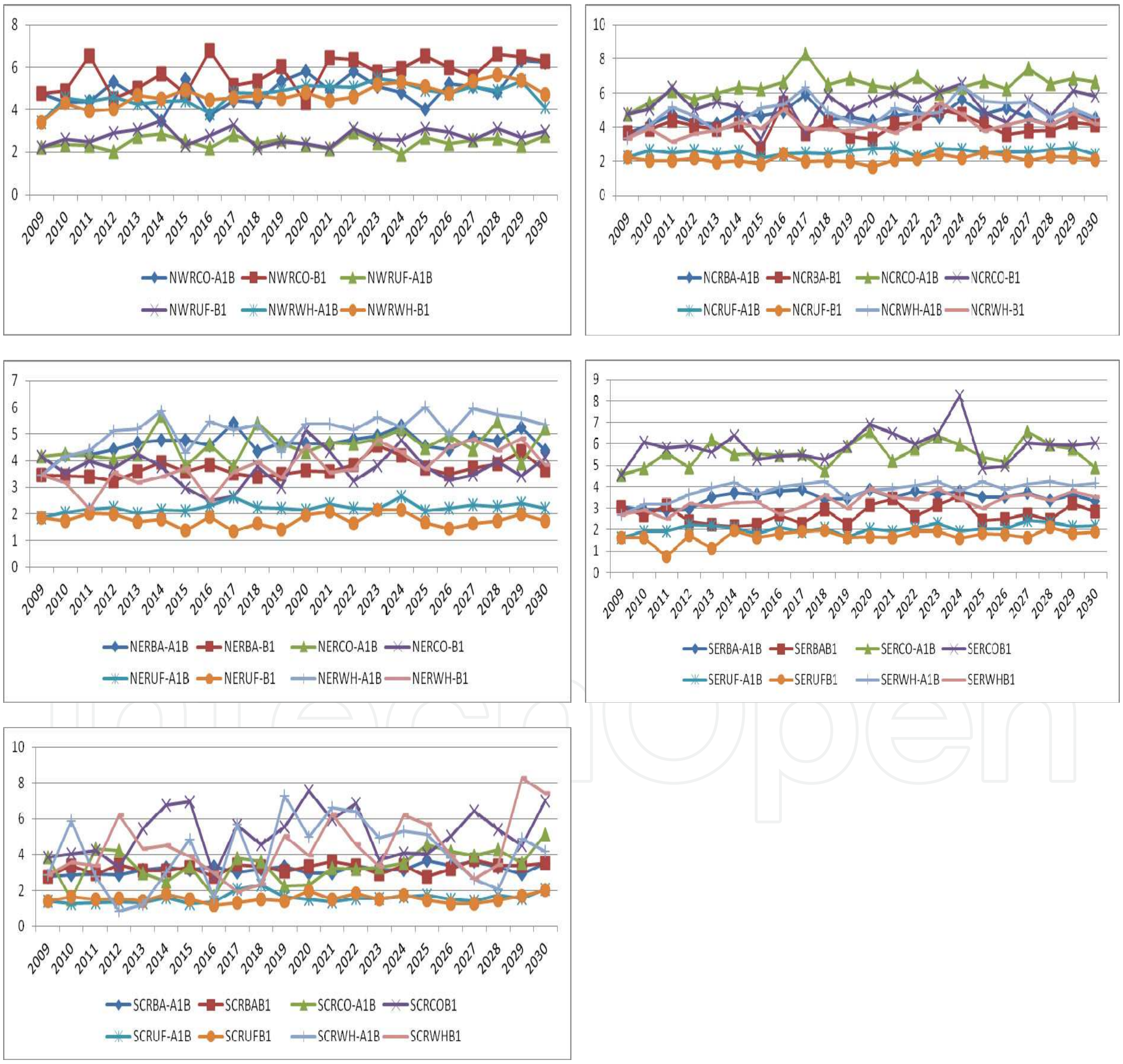
Projections of crop yields are based on projections of changes in crop yields due to the changes in climatic factors and observed yields in 2009 (the last year in the historic period). Projected yields under scenario A1B - REMO and scenario B1 - LMDZ for the four crops analysed by regions are shown in Figure 5.

As seen from the figure the expected yields by products differ quite substantially by regions under the both scenarios. The expected variation in yields due to the changes in climate is substantial for all products and all regions. The most important is the variation in maize yields in SCR (scenario B1 – LMDZ) reaching above 85% and wheat yields (scenario A1B REMO and B1 – LMDZ) in SCR estimated at 79% and 88% followed by maize yields (scenario B1 – LMDZ) in all regions varing among the regions from 55% to 67%. The variation of yields in case of barley and sunflower is relatively smaller under both scenarios compared to maize and wheat varying among the regions between25% to 43% for barley and from 18% to 37% for sunflower .

Further analysis of the results obtained shows that the potential impact of climate factors on yields for the period 2010 – 2030 is generally positive for wheat yields in all regions under both scenarios but high deviation is expected through the years. Potential impact of climate changes on barley yields is also positive under both scenarios in all regions with exception of barley yields in SCR under scenario B1 – LMDZ where slight reduction in yields is expected. Generally the impact of climate changed on maize yields is positive much lower than the impact on wheat. For this crop slightly negative impact could be expected in SRC under scenario A1B – REMO and in NER under scenario B1 – LMDZ. At national level the impact of climate changes of sunflower yields is also positive under both scenarios, but at regional level slightly negative impact could be expected in NER and NCR under scenario B1 – LMDZ.

In estimation of the climate impact on yields towards 2025 two approaches are possible: to use the yields projected for year 2025, or to use a simple 3-year, 5-year or 10-year averages. Having in mind that climate factors projections are long run projections and are not so precise on a year by year base, a 10-year averages (from 2020 to 2029) are used as a proxy for change in yields in 2025 in the two scenarios considered.

Since change in yields in 2025 is estimated only on the basis of climate changes the change could be directly compared with yields in the last observed. Yields in 2025 are obtained on the basis of changes in yields estimated and observed yields in 2009. They are shown in Table 7. As seen from the table in 2025 the impact of climate on wheat is positive under the both scenarios showing on increase in yields between 29% (NCR under scenario B1 – LMDZ) and 86% in SCR under the same scenario. The same is valid for barley with exception of yield in SER under scenario B1 - LMDZ where a reduction in yields amounting to 6% is expected. The sunflower yields in 2025 are higher than in 2009 for all regions with exception of NER and NCR under the scenario B1 – LMDZ with reduction in yields by 1% and 2% respectively. Potential impact of climate on maize yield in 2025 is positive with exception of SCR under scenario A1B – REMO with reduction estimated at 3% and in NER under scenario B1 –LMDZ with reduction in yields by 5%.



Source: own calculations

Figure 6. Projected crop yields for analysed products by regions

Yields in 2009					
	NER	NCR	NWR	SER	SCR
Wheat	3,45	3,38	3,4	2,7	2,86
Barley	3,46	3,67		3,08	2,79
Maize	4,15	4,76	5,51	4,53	3,85
Sunflower	1,85	2,21	2,15	1,62	1,39
Scenario A1B - REMO					
	NER	NCR	NWR	SER	SCR
Wheat	5,284	4,909	4,875	3,909	4,768
Barley	4,775	4,714	0,000	3,599	3,279
Maize	4,727	6,589	6,048	5,782	3,743
Sunflower	2,277	2,606	2,401	2,131	1,599
Scenario B1 - LMDZ					
	NER	NCR	NWR	SER	SCR
Wheat	4,268	4,348	5,046	3,538	5,312
Barley	3,870	4,113	0,000	2,910	3,326
Maize	3,937	5,544	6,786	6,168	5,507
Sunflower	1,835	2,173	2,691	1,790	1,610

Source: Own calculations

Table 7. Projected yields

9. The economic meaning of climate changes at sectoral and economy level

As mentioned above the economic impact of climate changes is analysed at two levels: impact on agricultural sector performance and impact on the Bulgarian economy. Following the selected methodology the physical changes in yields are transformed into value terms based on the following assumptions:

- the area cultivated is not affected by the relative change in yields
- to exclude price impact on agricultural output constant prices are used
- all other crops remain unaffected
- value of livestock production and other activities in GAO remain constant

Based on these assumptions the impact of climate on agriculture in value terms is shown in Table 8.

Table 8 shows that the estimated economic impact of climate changes on yields by regions is positive under both scenarios but differed substantially by regions. The expected changes in agricultural development under scenario A1B REMO are more favourable for NCR, NER and SER while the changes under scenario B1 MLDZ are more favourable in NCR and NWR.

As seen from Table 8 at sectoral level the expected changes in crop output and GAO due to the climate changes are positive under both scenarios as changes in climatic factors under scenario A1B REMO are more favourable to the sectorat national level then those under scenario B1 MLDZ. The estimated impact of climate changes toward 2025 under scenario A1B REMO is increase by nearly 15% of the total crop output and increase in GAO by 9,5%. The increase in total output under scenario B1 LMDZ is estimated at 10% and in GAO at 6,6%.

Change in	NER	NCR	NWR	SER	SCR	National level
Change in value of crops analysed (million leva)	162,19	153,15	116,66	97,65	55,95	585,6
change in total crop output	19%	19%	16%	15%	10%	14,9%
change in GAO	11%	11%	8%	7%	5%	9,5%
Change in value of crops analysed (million leva)	47,46	71,07	159,3	53,60	77,01	408,5
change in total crop output	6%	9%	22%	8%	14%	10,4%
change in GAO	3%	5%	10%	4%	7%	6,6%

Table 8. Economic impact of climate changes

Following the chosen methodology in order to find the effect of climate changes on the economy, obtained results for agriculture are incorporated in the input-output (I-O) model by adjusting the vector of agricultural sector. For this purpose I-O model with 20 sectors has been constructed as agriculture, forestry and food industry are considered separately, while other sectors are aggregated. Based on the constructed I-O model, gross output multipliers (type II B), income multipliers as well as employment multipliers are estimated following the commonly used methodology of multiplier analysis. This allows direct as well as indirect and induced effects caused by the change in agricultural output due to the changes in climate to be taken into account by simulating a shock in final demand. The changes in final demand are based on estimated impact of change in climate factors on GAO. In addition the multiplier analysis is used for analysis of the importance of the economic sectors for generating growth in the national economy.

Traditionally, the impact analysis within input-output models is done with the use of the backward linkages proposed by Rasmussen (1956) and Hirschman (1958) and forward linkages proposed by Augustinovics (1970). These linkages show the size of structural interdependence in an economy as well as the degree in which the enlargement of a sector can contribute directly or indirectly in the enlargement of other sectors in the model. On the basis of I-O table for year 2005, both backward and forward linkages for output, value added, income and employment for the 20 sectors are calculated (Table 9).

	Chenery & Watanabe		Rasmussen & Hirschman								Elastisity				Augostinovich FL			
		rank	OBL	rank	VABL	rank	IBL	rank	EBL	rank	BOE	rank	FOE	rank	OFL	rank	VAFL	rank
Agriculture	0,517	8	1,558	7	0,504	13	1,586	9	1,750	9	0,064	8	0,003	7	1,925	6	0,558	14
Forestry	0,455	9	1,426	9	0,433	16	1,572	13	1,578	14	0,003	20	0,001	20	1,634	10	0,397	18
Mining and quarrying	0,123	20	0,745	20	0,185	20	1,454	15	1,783	8	0,004	17	0,001	17	1,837	7	0,334	19
Food and beverages	0,419	13	1,338	14	0,645	7	1,574	12	1,861	6	0,074	6	0,003	6	1,363	12	0,609	9
Tobacco industry	0,216	19	0,874	19	0,207	19	1,506	14	1,564	15	0,029	14	0,001	14	1,123	17	0,301	20
Textile; leather products	0,438	12	1,364	12	0,469	14	1,584	11	1,964	5	0,055	9	0,003	9	1,406	11	0,560	12
Chemic industry	0,633	2	1,650	5	0,353	18	2,707	1	2,619	1	0,096	2	0,003	3	2,534	1	0,996	2
Machinery & equipment	0,396	16	1,295	16	0,806	4	1,715	5	2,271	2	0,089	3	0,003	5	1,954	4	0,514	15
Furniture & secondary raw materials	0,585	5	1,729	4	0,452	15	1,452	16	1,528	16	0,017	16	0,001	16	1,336	14	0,404	17
Electrical energy, gas, water	0,581	6	1,492	8	0,829	3	1,656	7	1,617	11	0,036	12	0,002	12	1,945	5	0,807	4
Water supply services	0,396	15	1,326	15	0,630	8	1,252	19	1,492	18	0,003	18	0,001	18	1,098	18	0,681	7
Construction	0,598	3	1,784	2	1,050	1	2,030	3	2,036	4	0,081	4	0,004	2	2,433	2	0,919	3
Transport, hotels restaurants	0,595	4	1,760	3	0,950	2	2,488	2	1,842	7	0,168	1	0,008	1	1,956	3	1,481	1
Financial intermediation	0,413	14	1,349	13	0,647	6	1,595	8	1,604	13	0,077	5	0,003	8	1,792	8	0,681	6
Public administration	0,449	10	1,397	11	0,610	9	1,377	17	1,498	17	0,073	7	0,003	4	1,179	16	0,701	5
Education	0,235	18	0,987	18	0,695	5	1,162	20	1,236	20	0,037	11	0,002	11	1,022	19	0,566	11
Health services	0,446	11	1,422	10	0,363	17	1,585	10	1,400	19	0,042	10	0,002	10	1,019	20	0,496	16
Other governmental services	0,675	1	1,934	1	0,598	10	1,898	4	2,119	3	0,027	15	0,001	15	1,347	13	0,633	8
Other services	0,298	17	1,122	17	0,596	11	1,333	18	1,616	12	0,003	19	0,001	19	1,330	15	0,560	13
Trade	0,560	7	1,622	6	0,562	12	1,674	6	1,711	10	0,031	13	0,001	13	1,741	9	0,584	10

Table 9. Estimated Multipliers and its rang

According to the estimated output backward and forward linkage coefficient (OBL & OFL) the forward linkages are generally higher than the backward linkages. The exceptions are: “Furniture and secondary row materials”, “Water supply services”, “Public administration”, “Health services” and “Other governmental services”. It is seen from the table that induced impact by the sectors is much higher than the direct impact of a change in the sector. The results also show that in total, the average of the forward linkages is higher than the total of the backward linkages (1.59 vs. 1.41).

“Other governmental services”, “Construction” and “Transport, hotels & restaurants” are the sectors with the highest backward linkages in respect to the output. This implies that decreases in demand in the above three sectors, compared with all other sectors, may result in the greatest losses to the national economy. Contrary, increases in investment, export or consumption in these sectors may have the biggest potential power to augment the economy by requiring large quantities of goods and services from other sector. Since “Construction” and “Transport, hotels & restaurants” are among the most important “buyers” of agricultural inputs, potential positive climate change effect could boost the general economic development. At the same time “Agriculture” takes the 7th place (backward) and 6th place (forward) which means that the impact of changes in the sector alone will not cause strong changes in output of the economy.

Since the impact of a change in a given sector on the economy depends not only on the multiplier effect but also on the share of the sector in national economy the weighted average of both linkages were calculated (BOE, FOE). The weighs are calculated on the basis the share of each sector’s input/output out of total input/output. Agriculture has the rank 8 in case of backward elasticity and rank 7 in case of forward elasticity with means that the there are sectors leading to much higher impact on the economy than agriculture and even strong impact of climate change on the sector will not cause significant impact on the economy

Looking at estimated value added backward and forward linkage coefficient (VABL & VAFL) the conclusion is again that the forward linkages are generally higher than the backward linkages, but with more exceptions than in case of output. Concerning the backward value added linkages, the first three places are taken from: “Construction” (1,05), “Transport, hotels & restaurants” (0,95) and “Electrical energy, gas, water” (0,83). As a result any external impact on the economy concerning these three sectors would cause the highest changes in value added of the economy of the country. Agriculture takes 13th (backward) and 14th (forward) places in respect to the generation of value added meaning that agriculture is not important sector in respect to the value added. But since “Agriculture” is again tightly connected with “Transport, hotels & restaurants”, the impact of climate changes on agriculture might appear in the economy through this sector.

“Transport, hotels & restaurants” (2,49) and “Construction” (2,03) are again one of the most important sectors in the economy in respect to the income generation. Agriculture takes 9th place. Because of the low wages in the sector climate changes impact on the total regional economy as a whole will not be that crucial. However, in terms of social stability and source of income for the poorer parts of the population agriculture could be influential.

Regarding employment generation "Chemic industry", "Machinery and equipment" and "Other governmental services" are having the highest potential. Agriculture again is ranked at the middle that means its impact on job creation is not important in the economy but having in mind that the agriculture is a major sector in the rural areas, even not so strong impact on the national employment is important for the employment in the rural areas.

Multiplier analysis in respect to the output, value added, income and employment leads to a conclusion that the most important sectors having crucial impact on the Bulgarian economy are "Construction", "Transport, hotels and restaurants", "Chemic industry" and "Machinery and equipment". Agriculture alone does not have such a strong impact on the national economy but as mentioned above since "Construction" and "Transport, hotels & restaurants" are among the most important "buyers" of agricultural inputs, the impact of changes in the sector would be transferred to the economy via these sectors also.

9.1. Climate scenarios simulation results

To estimate the impact of the climate changes on the national economy, the simulated yields impact in value terms to GAO under both scenarios considered is incorporated into the national I – O model by adjusting the vector of agricultural sector. The simulated changes caused by the change in GAO in respect to the output, income and employment under the considered scenarios are shown Table 10. The expected magnitude of the impact of changes in GAO on the economy output is modest. The total output is expected to increase by 1% - 1,5% as the effect from scenario A1B REMO is higher than under the scenario B1 MLDZ. As seen from the table the indirect and induced impact of climate changes on agricultural output is much higher than the direct impact only (15,1% against 9,5% and 8,6% against 6,6% respectively). Results also show that in both cases the expected changes in all other sectors are less than 1%, as the highest impact is expected for sectors "Food and beverages", "Transport, hotels and restaurants" as well as "Construction". As could be expected due to the insignificant change in the economy results show no changes in the structure of the economy under scenario B1 MLDZ and an increase in the share of agriculture by 1% at the account of industry under scenario A1B REMO.

Results also show model impact on the compensation of employees due to the climate changes (Table 10). The overall changes in incomes are around 1% - 2%, as again the expected changes under scenario A1B REMO are higher. It should also be mentioned that the expected increase in income is slightly higher than the expected increase in output under both scenarios. As in the case of output the induced impact in income is higher than the direct impact on income only. As could be expected the highest increase in income is observed in agriculture, followed by the increase in "Food and beverages", "Transport, hotels and restaurants" and "Construction" sectors.

Practically the same changes are observed in respect to the employment but it should be mentioned that increase in employment in the economy is even smaller that the increase in output (around 1% under both scenarios). Increase in labour above 1% except in agriculture could be expected in "Food and beverages" and "Transport, hotels and restaurants" sectors under both scenarios and "Trade" sector under scenario A1B REMO.

	change in output		change in income		change in mployment	
	A1B REMO	B1 MLDZ	A1B REMO	B1 MLDZ	A1B REMO	B1 MLDZ
Agriculture	15,1%	8,6%	14,1%	7,9%	10,6%	7,3%
Forestry	0,1%	0,1%	0,2%	0,1%	0,2%	0,2%
Mining and quarrying	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Food and beverages	0,8%	0,6%	2,6%	1,8%	1,7%	1,2%
Tobacco industry	0,1%	0,1%	0,1%	0,1%	0,1%	0,1%
Textile; leather products	0,1%	0,1%	0,2%	0,1%	0,2%	0,1%
Chemic industry	0,1%	0,1%	0,1%	0,1%	0,0%	0,0%
Machinery & equipment	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Furniture & secondary raw materials	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Electrical energy, gas, water	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Water supply services	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Construction	0,3%	0,2%	0,3%	0,2%	0,4%	0,3%
Transport, hotels restaurants	0,4%	0,3%	0,5%	0,4%	1,3%	1,1%
Financial intermediation	0,1%	0,1%	0,3%	0,2%	0,2%	0,2%
Public administration	0,3%	0,2%	0,4%	0,3%	0,4%	0,3%
Education	0,5%	0,4%	0,6%	0,4%	0,6%	0,4%
Health services	0,6%	0,4%	0,7%	0,5%	0,5%	0,3%
Other governmental services	0,1%	0,0%	0,1%	0,1%	0,1%	0,1%
Other services	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Trade	0,7%	0,5%	1,0%	0,7%	1,1%	0,8%
For the economy	1,4%	1,0%	2,1%	1,5%	1,1%	0,8%

Source: Own calculations

Table 10. Impact of changes in GAO on the national economy

Considering the very insignificant impact on the Bulgarian economy it should be stressed that no other effect is taken into account except impact of climate changes on production of the 4 major for the Bulgarian agriculture crops.

10. Conclusion

This chapter tries to quantify the effects of the climate changes at two levels: sectoral level(on Agriculture) and national level (on the economy of Bulgarian) using and Input-output methodology. Additionally, some comparative analysis about the magnitude and distribution effects of the two climate scenarios was made. In this respect, the following conclusions can be derived:

- The analysed two scenarios can bring a modest contribution to the overall output increase of the national economy.
- Scenario A1B REMO provides a benchmark of the potential maximum impact of the analysed case study. If this climate situation is accomplished and crops by regions reach relevant yields, the total output of the region would be increased by 1,4%.
- Sectors with highest potential to generate output, value added, incomes and employment are: "Construction", "Transport, hotels & restaurants", "Chemic industry" and "Machinery and equipment". They may be affected by the climate changes in the agricultural sector through their linkages with the latter. This is especially important for "Transport, hotels & restaurants".
- The favourable climate effects, however, should be regarded with certain caution. There are several factors that could worsen or even completely change the optimistic view from the climate scenarios. These factors range from technological ones to global ones (financial crises, food security, trade issues). The abovementioned factors could significantly deteriorate favourable results.
- Limitations of the undertaken research have to be acknowledged, as well. First of all, it has to be taken into consideration that climate changes represent only one dimension of the potential future impacts on the national economy. From one side, even though the regions are well specialised in agricultural activities, potential shortages of agricultural goods might be solved by importing goods in order to reach market equilibrium. From the other, if the agricultural production highly exceed due to the climate change it is unlikely that it could bring significant incomes to the agricultural producers due to increased supply. When it comes to analysis of economic impact, another important issue that is not tackled in the current analysis should be borne in mind. This is the behaviour of the agricultural producers after applying the instruments of the Common agricultural policy, which might significantly guide their decision in direction of increasing or decreasing the agricultural production. Secondly, limitations of the adopted I-O methodology should be considered: no substitution among factors of production, no change in technique, constant import coefficients. However, provided that I-O table is estimated accurately, theoretically implausible assumptions of the model are in some respect overshadowed by its empirical realism and simplicity.

Author details

Nedka Ivanova and Plamen Mishev
University of National and World Economy, Sofia, Bulgaria

11. References

Alexandrov, V., 2008, Climate Change, Vulnerability and Adaptation in Agriculture: the Situation in Bulgaria, Presentation, Adagio project

Alexandrov, V.A, G. Hoogenboom, 2001: Climate variation and crop production in Georgia, USA, during the twentieth century, Climate Research, Vol. 17, pp. 33-43.

Alexandrov, V.A, G. Hoogenboom, 2000: The impact of climate variability and change on crop yield in Bulgaria, Agricultural and Forest Meteorology, Vol. 104, pp. 315-327.

Anderson, J.R, Hazell, P, 1989: Variability in Grain Yields; Implications for Agricultural Research and Policy in Developing Countries, John Hopkins University Press, Baltimore and London, 416 pp.

Bach C.F., Frandsen S.E., Jensen H.G. 2000. Agricultural and Economy-Wide Effects of European Enlargement: Modelling the Common Agricultural Policy. *Journal of Agricultural Economics*, 51, 2: 162-180.

Binswanger H.P. & Deininger K. 1997. Explaining Agricultural and Agrarian Policies in Developing Countries, *Journal of Economic Literature*, Vol: 35, pp: 1958-2005.

Haggblade S., Hammer J., Hazell P., 1991, Modelling Agricultural growth multipliers, American Journal of Agricultural Economics, 73 (2): 361 – 374

Ciscar, Juan-Carlos (ed.), 2009, Climate change impacts in Europe, Final report of the PESETA research project, Joint Research Centre, European Commission, p. 103, 109

Clavier project (Climate Change and Viability: Impacts on Central and Eastern Europe): http://clavier-eu.org

Clavier project deliverables, WP2 and WP4

Cline, W., 2008, Global warming and agriculture, Finance & Development, issue March, p. 23-27

Feenstra, J.F., I. Burton, J.B. Smith, R.S.J. Tol, 1998: Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies, United Nations Environment Programme, Institute for Environmental Studies, Version 2.0, pp. 464.

Hansen, J.W., A. Challinor, A. Ines, T. Wheeler, V. Moron, 2006: Translating climate forecasts into agricultural terms: advances and challenges, Climate Research, Vol. 33, pp. 27-41.

Hansen, J.W., M. Indeje, 2004: Linking dynamic seasonal climate forecast with crop simulation for maize yield prediction in semi-arid Kenya, Agricultural and Forest Meteorology, Vol. 125, pp. 143-157.

Hertel T.W., Brockmeier M., Swaminathan P.V. 1997. Sectoral and economy-wide analysis of integrating Central and Eastern European countries into the EU: Implications of alternative strategies. European Review of Agricultural Economics, 27: 359-386.

Iglesias, A., L. Garrote, S. Quiroga, M. Moneo, 2009, Impacts of climate change in agriculture in Europe. PESETA-Agriculture Study, JRC-IPTS, European Communities, Luxemburg, p. 32

Ivanova N., T. Todorov, A. Zezza, (2000), "The role of agricultural sector in the transition to a market economy: Bulgarian case study", в *Perspectives on Agriculture in Transition: Analytical Issues, Modeling Approaches, and Case Study Results*, (editors Witold-Roger Poganietz, Alberto Zezza etc), Wissenschaftsverlag Vauk Kiel KG, ISBN 3-8175-0323-7, c. 78-139

Jensen H.G., Frandsen S.E., Bach C.F. 1998. Agricultural and economy-wide effects of European enlargement: Modelling the Common agricultural policy. SJFI - working paper No. 11/1998. Kopenhagen, SJFI: p. 40.

Johansen L. 1960. A multi-sectoral study of economic growth. North-Holland, Amsterdam.

Ministry of Regional Development and Public Works, 2005, Northeast Planning Region – Regional Development Plan 2007 – 2013, Sofia

National Statistical Institute, 2008, Regions, Districts and Municipalities in Bulgaria 2006, Sofia

Pyatt & Round, 1985, "Social Accounting Matrices: A Basis for Planning", The World Bank.

Republic of Bulgaria, 2007a, National Strategy Plan for Rural Development 2007 – 2013

Republic of Bulgaria, 2007b, Rural Development Programme 2007-2013

Sauberei, W., P. Royston, H. Binder, 2007: Selection of important variables and determination of functional form for continuous predictors in multivariable model building, Statist. Med., Vol. 26, pp: 5512-5528.

Sun L., H. Li, M.N. Ward, D.F. Moncunill, 2007: Climate Variability and Corn Yields in Semiarid Ceará, Brazil, Journal of Applied Meteorology an Climatology, Vol. 46, pp. 226-240.