Climate change impacts and the adaptation options in agriculture in Slovakia

Pavol Nejedlík[1], Bernard Šiška[2]

[1]Slovak Hydrometeorological Institute, Jeseniova 17, 833 15 Bratislava, Slovakia, pavol.nejedlik@shmu.sk
[2]Slovak Agricultural University, Trieda A. Hlinku 38, 949 76 Nitra, Slovakia, bernard.siska@uniag.sk

Abstract. Coping with climate change within the agricultural sector encompasses both mitigation and adaptation activities. On the mitigation side, the focus is on reduction of greenhouse gas emissions: the time span of any effect of this effort goes beyond decades. Adaptation activities focus on the potential to build resilience to climate and to increase adaptive capacity through sustainable management of agriculture and other complementary factors. There are usually no firm time schedules for applying the adaptations in the general plans of the countries but implementing effective adaptation can 'buy time' until an effective mitigation response can be mounted.
The climate change impacts appear in different ways and will influence the agroclimatic regionalisation of the country. Productive potential of individual crop in the particular region will change and the changes in precipitation amount will influence the water use for irrigation both in areas and rate (Olesen, 2007). The suggestions for adapting measures to these changes in agricultural sector include change of structure of crops grown in Slovakia and the change of variety structure, adaptation of agro technical terms (mainly sowing) to changed agro climatic conditions and the completion of the construction of irrigation system and ensuring sufficient amount of irrigation water in cooperation with water service (Šiška, Takáč, 2008).

Key words

climate change, agriculture, adaptations, carbon dioxide,

Introduction

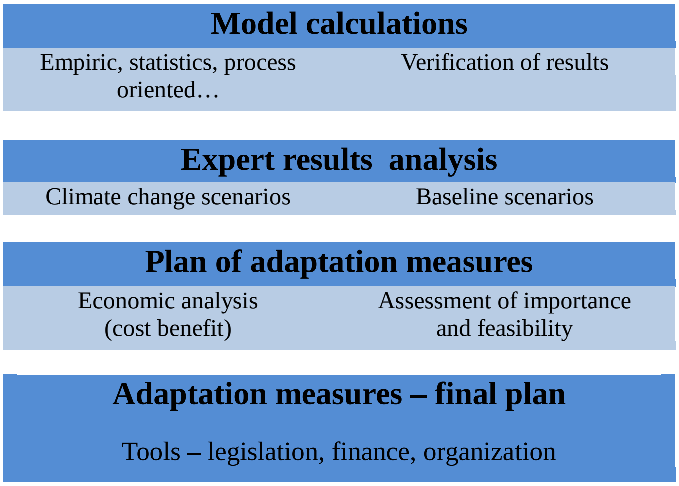
Solving problems of climate change impacts changed from scientific character to social and political ones and also to practical level in last decade.
Coordination of sources and activities is very important in this situation especially at the national level. A project on "Climate Change Impacts and Possible Adaptations in Different Sectors" (Final report, 2012), has brought some suggestions for the some solutions at the national level. The most important points for creating above mentioned project were:

- high level of uncertainty of impacts of climate change to individual sectors/human activity
- an absence of integrated knowledge concerned climate scenarios which would employ cross sectoral activities Slovakia
- fragmentation of conclusions of climate change impacts and in many sectors absenting definitions of possible adaptation measures
- an absence of any economical assessments of climate change impacts and economical assessment of adaptation measures
- an absence of a national adaptation strategy

The last point is of a special importancy as it should give a certain priority list before taking the practical planning for the particular adaptation measures as well as cross sectoral activities.
Agriculture was one of the basic sectors being subjected to the analysis regarding the Climate Change impacts. It is to be stressed that the major part of the agricultural production happens in the open air and is under a constant influence of surrounding conditions which are mostly formed by climate. Any of the changes in climate determine the future conditions for agricultural activities.

Material and methods

The frame method used for the evaluation the impacts of changing climate were arranged in following steps:



Climate scenarios
Outputs of four models of general circulation of the atmosphere (GCMs) were used as a source data for preparation of scenarios. Two of them (Canadian CGCM3.1 and German ECHAM5) are global and two of them (Dutch KNMI and german MPI) are regional. All models produce the daily values of a number of atmospheric parameters from 1951 to 2100. Two emission scenarios A2 (rather pesimistic) and B1 (rather optimistic) were applied. The calculation has been performed according to the original methodology (Lapin et al., 2004 and 2006).

The area of the agricultural land used for growing crops in Slovakia is reduced in the long term. Nowadays it occupies approximately 1.9 million hectares. Reduction of the area of the agricultural land is related to the urbanization and the infrastructure building as well as to the forestration especially in mountains and area under mountains what is the result of agriculture activities in the land.

The structure of the production has been changed by application some principals of common agriculture politics in European Union. Generally, the quantity of technical crops is rising, mainly oil crops, potatoes, legumes while the area the production of vegetables is reducing. The unbalance of commodity of agricultural produce market effects significant inter-annual changes in area under crops. Big part of vegetable production is used by animals that means animal husbandry is energetically harder.

To evaluate the sensitivity of the particular region of Slovakia to climate change the water balance (E_0-R [mm]), and evapotranspiration deficit (E_0-E [mm]), where E_0 is potential evapotranspiration E is real evapotranspiration and R represents precipitation.

Meteorological and phenologiccal data vere evaluated for 2 periods for defined levels of CO_2 in the atmosphere.

Tab. 1. *Foreseen changes in CO_2 concentration*

CO_2 level		Period
1xCO_2	330 ppm	1961–1990
2xCO_2	660 ppm	2061–2090

Climate change and agriculture

The agriculture is very sensitive to variability of the climate and the weather extremes, as draught, strong storms and floods. Human activity affects chemical and physical atmospheric properties, such as temperature, precipitation, concentration of carbon dioxide (CO_2) and near-ground ozone and this trend is expected to continue. The warmer climate is good for vegetable production, but appearance of the drought, floods and heat waves represents a challenge for growers.

Expected global climate change in Slovakia will be reflected mainly in temperature and moisture assurance of vegetable production. This will affect, phenological changes, physical and chemical soil properties, wintering conditions, pests and weeds occurrence as well as the start and the length of vegetation period. Prolongation of the vegetation period in the areas with relatively cold spring and autumn will negatively affect the harvest. In areas where summer heats limit production, increasing intensity of soil evaporation and will bring strong drought. The response of results of the climate change in agricultural sector can be understood in positive or negative way.

The role of agriculture in respect to climate change has two levels:

1. source of emission of some green-house gasses
2. sector which is affected by negative climate change impacts

We have two groups of measures to deal with climate change negative impacts:

1. Mitigation measures - decreasing of green-house gases emission
2. Adaptation measures - the main goal is to adapt and prepare to climate change conditions.

Results

Projections of some relevant agroclimatic parameters

The agriculture production is determined by certain climatic parameters. Tab. 2a, 2b and 2c characterize the productive regions by the basic agroclimatic parameters – temperature sums over 5°C over the vegetative period /TS5/, photosynthetic active radiation /PAR/ precipitation /R/, potential evapotranspiration / E_0/ and climatic water balance / E_0-R/.

Tab. 2a *Agroclimatic parameters over the vegetative period*

Production region	**Elevation [m]**	***TS5* [°C]**	
		1xCO_2	**2xCO_2**
Corn	<200	3200 – 3400	4000 – 4400
Beet	200 – 350	2900 – 3200	3650 – 4000
Potato	300 – 650	2300 – 2900	3150 – 3650
Mountains	>600	<2300	<3150

Tab. 2b. *Agroclimatic parameters over the vegetative period*

Production region	***PAR* [kWh.m^{-2}]**		***R* [mm]**	
	1xCO_2	**2xCO_2**	**1xCO_2**	**2xCO_2**
Corn	460 – 500	510 – 560	400 – 460	500 – 530
Beet	435 – 460	485 – 510	460 – 510	530 – 580
Potato	400 – 435	465 – 485	510 – 560	580 – 650
Mountains	<400	<465	>560	>650

Tab. 2c. *Agroclimatic parameters over the vegetative period*

Production region	E_0 [mm]		E_0-R [mm]	
	1xCO_2	2xCO_2	1xCO_2	2xCO_2
Corn	600 – 660	720 – 810	150 – 220	200 – 300
Beet	550 – 600	650 – 720	50 – 150	110 – 200
Potato	450 – 550	570 – 650	-80 – 50	-50 – 110
Mountains	<450	<570	<-80	<-50

All the parameters in all productive regions will increase from the present situation 1xCO_2 to the projected 2xCO_2 in the future. This indicates a partial shift of the productive regions from the south to the north and from lower to higher elevations. The duration of the vegetation period eg. The period with the daily mean temperatures over 5°C will naturally increase and despite of the increase of the precipitation even in the lowlands we have to expect higher frequency of drought because of the increase of potential evapotranspiration which impacts on the climatic water balance. /See Fig. 1/. Further to that the pattern of the precipitation will change and much more precipitation will come in heavy rains during the vegetation period which will increase the run of and decrease the effectivenes of watering efect.

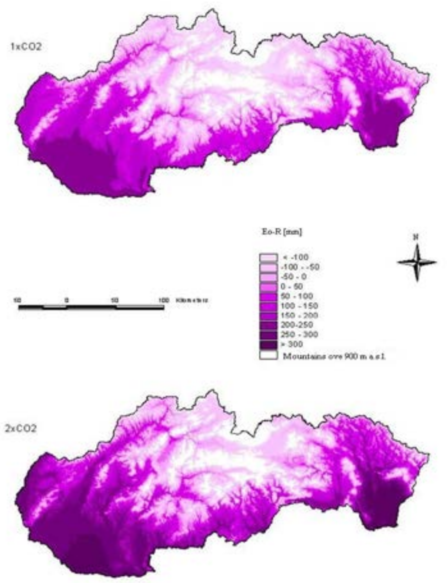


Figure 1. *Climatic water balance during the vegetation period for 1xCO_2 and 2xCO_2 in Slovakia.*

Projections of the impacts of changing agroclimatic parameters on the production

The simulation of the impacts of the changing agroclimatic parameters on the growth and yields of some cultivated plants was done by DAISY model. It is an one dimensional agroecologic model accounting water balance, thermic balance as well as the type of the soil and dynamics of the nutrients in the soil. Within the water balance the accumulation of the water from the snow, interception, surface run off and water flow in soil matrics are simulated.

The simulations for different cultivated plants have brought different results in yields. They were compared in for the Podunajska lowland which is the most productive region in Slovakia over the periods 1971– 2000 and 2071–2100 for winter wheat, spring barley and corn.

General expectation of the increase of the biomass production because of the higher rate of the photosynthesis due to the increased 2xCO_2 is modified by the influence of the water availability and also by the effectivity of the use of the 2xCO_2 by C_3 and C_4 plants and shows different results at different soil types.

The yields of the winter wheat showed the increase until the end of the century over the major part /75%/ of the selected area. Similar result was brought by simulating the yoilds of spring barley. This showed the increase on 72% of the selected area. The yields of the corn increased only on 3% of the area while the rest of the selected area has shown the decrease. The variability of the yields is influenced by the water availability but also by the type of the soil. The increase, the decrease of the yields at different types of soil showed quite different results as the different types of soil have different influence on water and regime.

Nevertheless, the simulations over all soil types have shown the shift of the date of the full ripeness, harvest respectively by 5 days with spring barley but 14 and 17 days with corn and winter wheat. This brings the water demand closer to the spring months and the irrigation need concentrates to April May and June.

Simulation of the water availability by DAISY showed us the irrigation need during the vegetation period. The demands for the irrigation increases in all regions step by step until te end of the century /see Tab. 3/.

Tab. 3. *The mean duration of the irrigation period in days of the main crops in Podunajska lowland in 1966–1990 and in the future according to the scenarios.*

Scen -ario	Period	Spring barley	Winter wheat	Corn	Sugar beet
	1966 – 1990	24	30	41	64
SRES A2	2011 – 2040	26	41	46	67
	2041 – 2070	30	40	60	89
	2071 – 2100	33	40	67	108
SRES B2	2011 – 2040	26	41	50	67
	2041 – 2070	31	41	59	88
	2071 – 2100	31	34	64	96

The combination of the factors influencing the agricultural production in the past and in the future together with the geographical and soil parameters of different regions enabled us to estimate the risk of the negative climate change impact on agricultural sector in selected geomorphologic units (Tab. 4).

Tab. 4. *Risk of the negative climate change impact on agricultural sector in selected geomorphologic units*

Region	Geomorphological units	Risk
1	Malé Karpaty, Biele Karpaty, Považský Inovec, Záhorská nížina, Podunajská nížina, Považské podolie, Podunajská pahorkatina, Pohronský Inovec	***
2	Lučensko-košická zníženina, Krupinská planina, Javorie, Matransko-slanská oblasť a priľahlé kotliny	**
3	Východoslovenská nížina, Vihorlatské vrchy	**
4	Poloniny, Nízke Beskydy, Východné Beskydy, Spišská Magura	0
5	Stredné Beskydy, Západné Beskydy, Javorníky	0
6	Tatry, Nízke Tatry, Chočské vrchy, Malá Fatra- Kriváanska a priľahlé kotliny	0
7	Slovenské Rudohorie, Branisko a priľahlé kotliny	0
8	Veľká Fatra, Malá Fatra-Lúčanská, Kremnické vrchy, Štiavnické vrchy, Starohorské vrchy, Poľana a priľahlé kotliny	0
9	Vtáčnik, Tríbeč, Strážovské vrchy, Žiar	0
The risk of negative impact of CCH 0 – minimal risk, *medium risk **high risk ***very high risk		

Conclusions

The adaptation options are not identical for each region. Nevertheless, it was possible to identify four agrotechnic measures which can be applied in general:

1. to change the structure of grown crops in Slovakia a
2. to change the structure of the varieties
3. to adaptat the agro technical terms (mainly sowing) to changed agro climatic conditions
4. to support the construction of irrigation systems and to ensure sufficient amount of irrigation water in cooperation with water service sector

The first three measures can represent the green options for adaptations while the fourth one represents the artificial infrastructure.

The first option represents a radical step mainly in the regions with higher elevation where we expect the biggest change of thermal comfort for the plants. Corn sugar beet and some other more thermophilic plants will be accommodated in higher elevated basins and in the highlands.

The second option is ever ongoing process which is in the recent decades influenced by widening of the vegetation period in general but also by the fact that the crops ripen sooner. This brings less photosynthetically active radiation /PHAR/ during the period of vegetation and changes the agrobiological potential. The scenarios show relatively quick start of the temperatures over 5°C. The varieties with the longer vegetation time enable better use of PHAR. Nevertheless, it looks that what will mostly determine the growing conditions is water availability. Therefore, the irrigation systems are becoming an inevitable facility in almost all grooving regions in Slovakia.

Acknowledgements. This study follows the project OPŽP-PO3-08-5 ITMS 24130120015 supported by the Ministry of environment of Slovak Republic.

This work was supported by the project VEGA 2/0117/13: Evaluation of state an dynamics of biotps using modeling and remote sensing.

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