"KLÍMA-21" Füzetek

KLÍMAVÁLTOZÁS – HATÁSOK – VÁLASZOK

adam

FROM THE CONTENTS

WHAT IS THE ADAM PROJECT?

CLIMATE CHANGE AND SOME IMPACT ON THE ENVIRONMENT AND AGRICULTURE MODELLING CASE STUDY

USE OF THE SPATIAL ANALOGY METHOD TO ANALYSE TO POSSIBLE LANDUSE CHANGE IN HUNGARY

EXPECTED CHANGES IN CLIMATIC CONDITIONS OF MAIN CROPS

VITICULTURE CHALLENGES UNDER CHANGING CLIMATE IN HUNGARY

THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON MAIN FIELD CROPS AND THEIR YIELDS, CASE STUDIES IN HUNGARY

ENERGY CROPPING CONSIDERATIONS

INSTITUTIONS FOR ADAPTING TO CLIMATE CHANGE IN THE TISZA RIVER BASIN

ENGLISH
SPECIAL
EDITION

2008. No 55

„KLÍMA-21” FÜZETEK

KLÍMAVÁLTOZÁS – HATÁSOK – VÁLASZOK

“CLIMA-21” BROCHURES

CLIMATE CHANGE – IMPACTS – RESPONSES

„KLIMA-21” HEFTE

KLIMAÄNDERUNG – AUSWIRKUNGEN – LÖSUNGEN

«КЛИМА-21» БРОШЮРЫ

ИЗМЕНЕНИЕ КЛИМАТА – ВЛИЯНИЯ – ОТВЕТЫ

SZERKESZTŐ:

CSETE LÁSZLÓ
c. egyetemi tanár

SZERKESZTŐSÉG:

1093 Budapest, Zsil u. 3–5.
Tel.: 476-3295, Fax: 342-7571
E-mail: csetel@mail.datanet.hu

KIADJA:

MTA–BCE KUTATÓCSOPORT
KLÍMAVÉDELMI KUTATÁSOK KOORDINÁCIÓS IRODA, MTA KSZI

FELELŐS KIADÓ:

HARNOS ZSOLT
akadémikus, egyetemi tanár

ISSN 1789-428X

Készült:
AKAPRINT KFT. BUDAPEST – Felelős vezető: Freier László

CONTENTS

WHAT IS THE ADAM PROJECT?

HARNOS, ZSOLT

Funded by the European Commission and co-ordinated by the Tyndall Centre for Climate Change Research in the UK, ADAM (Adaptation and Mitigation Strategies: supporting European climate policy) is an integrated research project running from 2006 to 2009 that will lead to a better understanding of the trade-offs and conflicts that exist between adaptation and mitigation policies. ADAM will support EU policy development in the next stage of the development of the Kyoto Protocol and will inform the emergence of new adaptation strategies for Europe.

Why is ADAM important? The UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol provide the primary international policy context for the work to be undertaken in ADAM. ADAM will examine the extent to which existing policy trajectories in Europe will deliver Europe's commitments to these agreements and will co-develop with stakeholders portfolios of policy options where current trajectories are insufficient.

Most importantly, ADAM will also develop a Policy Appraisal Framework which will engage policy communities within Europe and allow policy advisors to examine and explore the effectiveness of different policy options against specific yet contrasting criteria.

Core ADAM objectives. To assess the extent to which existing and evolving EU (and world) mitigation and adaptation policies can achieve a tolerable transition to a world with a global climate no warmer than 2 °C above pre-industrial levels, and to identify their associated costs and effectiveness.

To develop and appraise a portfolio of longer term policy options that could contribute to addressing shortfalls both between existing mitigation policies and the achievement of the EU's 2 °C target, and between existing adaptation policy development and EU goals and targets for adaptation.

To develop a novel Policy-options Appraisal Framework and apply it both to existing and evolving climate policies, and to new, long-term policy options in the following four case studies: European and international climate protection strategy in post-2012 Kyoto negotiations; a re-structuring of International Development Assistance; the EU electricity sector; and regional spatial planning.

ADAM work programme. The ADAM work programme is structured around four overarching domains: Scenarios, Policy Appraisal, Mitigation and Adaptation.

Developing framing scenarios for adaptation and mitigation.

The Scenarios Domain will lay out four framing scenarios that will guide the ADAM analysis. They will span a range of climate futures from a 2 °C global warming outcome where the primary challenge is mitigation, to a 5 °C warming outcome where the primary challenge is adaptation.

Analytical and deliberative appraisal of climate change policy options.

The Policy Appraisal Domain will provide the central component of ADAM, namely the development of an innovative Policy-options Appraisal Framework (PAF). The PAF will be the key mechanism for interacting with stakeholders and for providing policy-relevant outputs from the project.

Analysis of mitigation policy options globally and for the EU.

The Mitigation Domain will evaluate the costs and effectiveness of different mitigation options at the EU level and estimate their corresponding contribution at the global level. These evaluations will address the main interactions between the EU and other world regions: international trade, development aid, technology transfer, and trade of used products and investment goods.

Analysis of impacts, vulnerability and adaptation options globally and for the EU.

The Adaptation Domain will develop a quantitative knowledge base on Europe's vulnerability to climate change. Social, technical and environmental factors that influence adaptive capacity will be analysed, and adjusted national accounts, incorporating the impacts of climate change, will be developed.

ADAM case studies. ADAM will conduct four specific case studies where climate mitigation and adaptation strategies have a crucial bearing on the objectives of international conventions. The Policy Appraisal Framework will be used in each case study to evaluate policy options. The four case studies will focus on:

The development of post-2012 policies for the UNFCCC. This will take a global perspective, but will appraise a range of possible architectures and policy options against multiple criteria as they apply to the EU.

The question of Europe's international development assistance and the ways in which more careful design and operation of such assistance can simultaneously meet the objectives of the Millennium Development Goals and the UNFCCC.

The electricity sector. Using the European electricity sector as a prism through which mitigation and adaptation options are examined, specific options for new measures and policies and their impacts will be assessed.

Three specific regions. The Policy Appraisal Framework will be applied in three localities (the Tisza Basin in eastern Europe, the Guadiana Basin in Spain, and Inner Mongolia) to develop and test regional policies which contribute to climate change mitigation and adaptation goals.

CLIMATE CHANGE AND SOME IMPACT ON THE ENVIRONMENT AND AGRICULTURE MODELLING CASE STUDY

HARNOS, ZSOLT

Keywords: climate change, impact, environment, agriculture, modelling.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

Climate change presents a double challenge today. First, severe climate change impacts can only be prevented by early, deep cuts of greenhouse gas (GHG) emissions. Swift transition to a global low-carbon economy is therefore the central pillar of the EU's integrated climate change and energy policy in order to reach the EU's objective of keeping global average temperature increase below 2 °C compared to pre-industrial levels. Beyond 2 °C change, the risk of dangerous and unpredictable climate change increases significantly and costs of adaptation escalate. That is why mitigation is such an imperative for the global community and why EU Heads of State and Government at the 2007 Spring Council unanimously agreed to reduce its greenhouse gas emissions by at least 20% by 2020 and, in case of a global and comprehensive agreement, by 30% by 2020 and called for a global reduction of up to 50% by 2050 compared to 1990 levels.

Second, with climate change already happening, societies worldwide face the parallel challenge of having to adapt to its impacts as a certain degree of climate change is inevitable throughout this century and beyond, even if global mitigation efforts over the next decades prove successful. While adaptation action has therefore become an unavoidable and indispensable complement to mitigation action, it is not an alternative to reducing GHG emissions. It has its limits.

Once certain temperature thresholds are exceeded, certain climate impacts are expected to become severe and irreversible (EU Green Paper).

WHAT IS THE CLIMATE CHANGE?

Climate change is any long-term significant change in the "average weather" that a given region experiences. Average weather may include average temperature, precipitation and wind patterns. It involves changes in the variability or average state of the atmosphere over durations ranging from decades to millions of years. These changes can be caused by dynamic process on Earth, external forces including variations in sunlight intensity, and more recently by human activities.

In the past the Earth's climate has changed as a result of natural causes in our atmosphere.

The changes we are witnessing and those that are predicted are largely due to human behaviour: we are burning fossil fuels, and heating up the planet at the same time. We blow exponential amounts of carbon dioxide (CO_2) into the atmosphere every year – 29 billion tonnes of it (2004) and rising – and this warms the globe.

Since the Industrial Revolution, humans have been burning fossil fuels on a massive scale. We use this energy, almost without care for the consequences, to run vehicles, heat homes, conduct business, and power factories.

Burning fossil fuels releases carbon dioxide stored millions of years ago as oil, coal or natural gas. In the last 200 years we have burned a large part of these stores, resulting in an increase in CO_2 in our atmosphere. Deforestation also releases CO_2 stored in trees and in the soil.

The increase of CO_2 in the atmosphere thickens the ‘greenhouse blanket’, with the result that too much heat is trapped into the Earth’s atmosphere. This causes global warming: global temperatures rise and cause climate change.

Overall, the concentration of CO_2 in the atmosphere has increased more than 30% since the Industrial Revolution (280 ppm – 380 ppm).

CO_2 emissions are now around 12 times higher than in 1900 as the world burns more and more coal, oil and gas for energy.

THE (NOT TOO DISTANT) FUTURE

We simply cannot continue pumping CO_2 into the atmosphere without curbs and controls. Even with the best case scenario for the increase in CO_2 emissions it is predicted that the concentration of CO_2 in the atmosphere will reach double the level of before the Industrial Revolution by 2100. The worst case scenario brings this doubling forward to 2045 – less than 40 years from now!

The weather in the XXIst century by the IPCC Fourth Assessment

The assessments require information on how conditions such a climate, social and economic development, and other environment factors are expected to change in the future (Fig. 1).

The IPCC used the scenarios of future greenhouse gas emissions accompanied by storylines of social, economic and technological development (Fig. 2).

By the end of this century the global temperature will increase at least by 2 °C (optimistic estimation) but the increment can achieve the 5–6 °C (Fig. 3).

One of the most vulnerable areas in Europe is Southern Europe and the entire Mediterranean Basin due to the combined effect of high temperature increases and reduced precipitation in areas already coping with water scarcity. Hungary is located on the boundary of this area (Fig. 4).

In the Carpathian basin has warmed by 1.5 times faster then the global average and this tendency will continue in the future. The expected changes are shown in the Fig. 5.

WHAT ARE THE POSSIBLE CONSEQUENCES OF THE CLIMATE CHANGE?

Many economic sectors depend strongly on climatic conditions and will feel the consequences of climate change on their activities and businesses directly: agriculture, forestry, fisheries, beach and skiing tourism, and health. Reduced water availability, wind damages, higher temperatures, increased bushfires and greater disease pressure will lead to damage to forests.

Increase in frequency and intensity of extreme events such as storms, severe precipitation events, sea floods and flash floods, droughts, forest fires, landslides cause damage to buildings, transport and industrial infrastructure and consequently impact indirectly on financial services and insurance sectors.

The effects of climate change in Europe are already significant and measurable. Climate change will heavily affect Europe’s natural environment and nearly all sections of society and the economy. Because of the non-linearity of climatic impacts and the sensitivity of ecosystems, even small temperature changes can have very big effects.

Over the last three decades climate change has already had a marked influence on many physical and biological systems worldwide:

– Water: Climate change will further reduce access to safe drinking water. Drought-affected areas are likely to increase.

– Ecosystems and biodiversity: Approximately 20–30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5–2.5 °C.

– Food: Climate change is expected to increase the risk of famine; the additional number of people at risk could rise to several hundred millions.

– Health: Climate change will have direct and indirect impacts on human and animal health. The effects of extreme weather events and an increase in infectious diseases are amongst the most important risks to be taken into account. Climate sensitive diseases are among the most deadly worldwide.

The Stern review on the economics of climate change concludes that adaptation could reduce the costs, provided policies are put in place to overcome obstacles to private action. Market forces alone are unlikely to lead to efficient adaptation because of a certain degree of uncertainty in the climate projections and lack of financial resources. Cost-effective adaptation is therefore the most appropriate solution.

In Hungary harmful impacts and financial expenditure of hazard management due to unfavourable meteorological extremities range between 150-180 billion HUF (600-800 million EUR). This is almost 1% of the GDP. In 2007 the loss of the agriculture was more than this amount.

Early action will bring clear economic benefits by anticipating potential damages and minimizing threats to ecosystems, human health, economic development, property and infrastructure. Furthermore competitive advantages could be gained for European companies that are leading in adaptation strategies and technologies.

Sufficient knowledge on time dimensions of impacts is important when setting priorities. The exact level of temperature increase is uncertain and will also depend on global mitigation action taken over the next few decades.

The predicted effects of global warming on the environment and for human life are numerous and varied. It is generally difficult to attribute specific natural phenomena to long-term causes, but some effects of recent climate change may already be occurring. Raising sea levels, glacier retreat, Arctic shrinkage, and altered patterns of agriculture are cited as direct consequences, but predictions for secondary and regional effects include extreme weather events, an expansion of tropical diseases, changes in the timing of seasonal patterns in ecosystems, and drastic economic impact. Concerns have led to political activism advocating proposals to mitigate, eliminate, or adapt to it.

The 2007 Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) includes a summary of the expected effects.

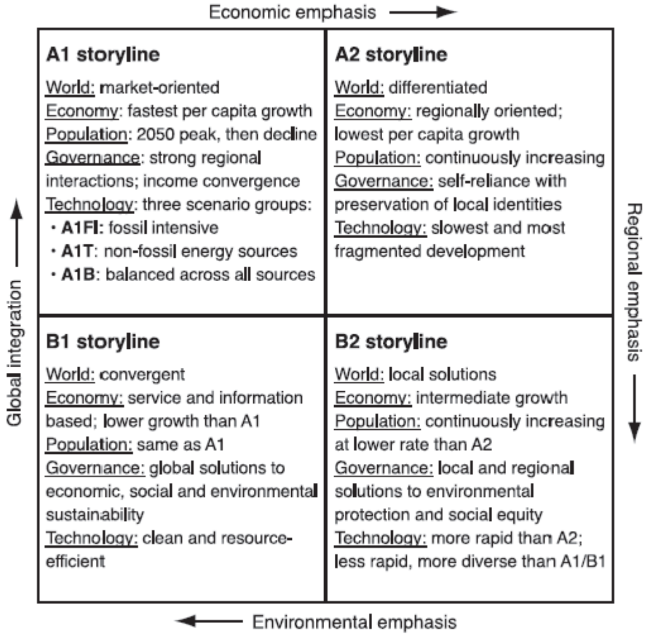
WHAT WE HAVE DONE AND WHAT WE HAVE TO DO?

In June 2003 the *Hungarian Ministry for the Environment and Water Management (KvVM) and the Hungarian Academy of Sciences* (MTA) have launched a joint research project of the title of “Global climate changes, Hungarian impacts and responses”. The name “VAHAVA” of this project is an abbreviation of the Hungarian first letters of the key words ”Changes-Impacts-Responses” (VÁltozás-HAtás-VÁlaszadás).

In preparing the thematic structure of the Project the participants relied on the recently increased role of *climate-policies.* In doing so they considered the need for mitigating the emissions of greenhouse gases and the must for the adaptation to the changes. In this context they formulated three phases; those of the prevention, defence and rehabilitation.

In the Project VAHAVA we formulated two strategic objectives:

Figure 1



A1 storyline

World: market-oriented
Economy: fastest per capita growth
Population: 2050 peak, then decline
Governance: strong regional interactions; income convergence
Technology: three scenario groups:
- **A1FI**: fossil intensive
- **A1T**: non-fossil energy sources
- **A1B**: balanced across all sources

A2 storyline

World: differentiated
Economy: regionally oriented; lowest per capita growth
Population: continuously increasing
Governance: self-reliance with preservation of local identities
Technology: slowest and most fragmented development

B1 storyline

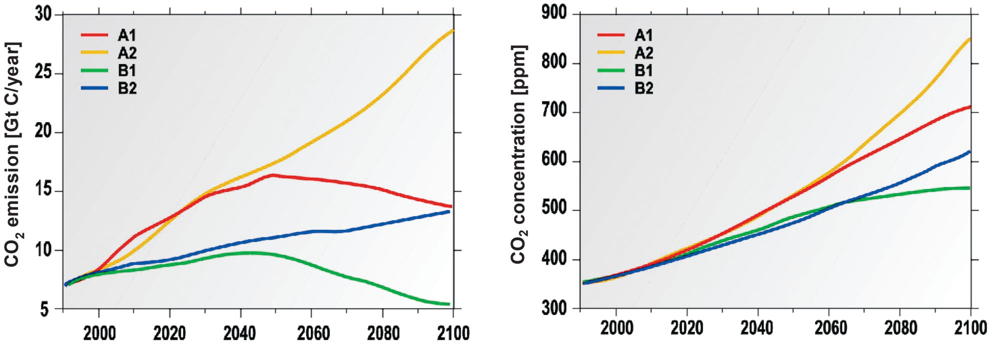
World: convergent
Economy: service and information based; lower growth than A1
Population: same as A1
Governance: global solutions to economic, social and environmental sustainability
Technology: clean and resource-efficient

B2 storyline

World: local solutions
Economy: intermediate growth
Population: continuously increasing at lower rate than A2
Governance: local and regional solutions to environmental protection and social equity
Technology: more rapid than A2; less rapid, more diverse than A1/B1

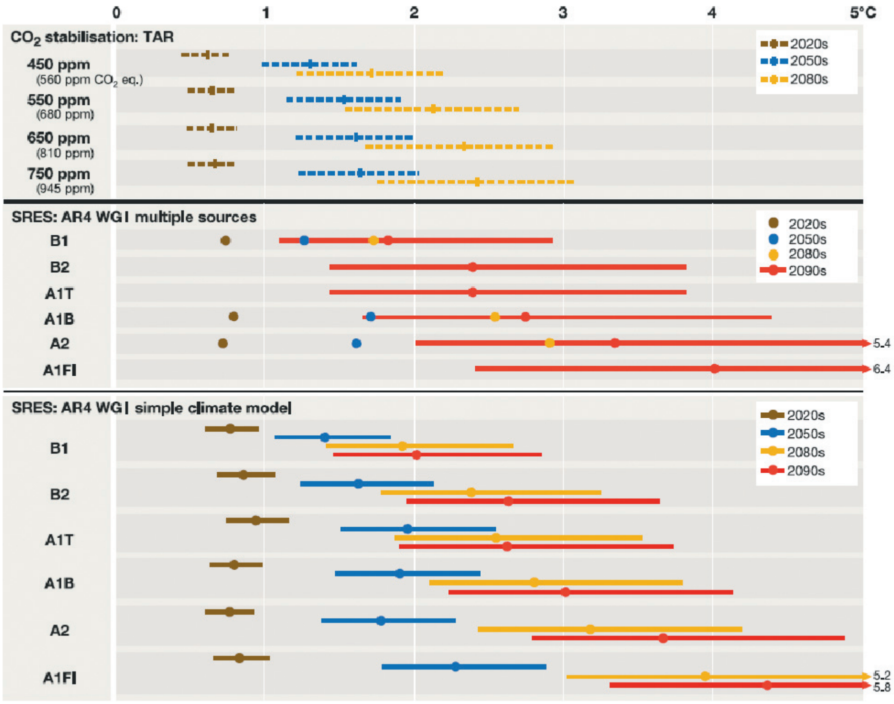
Summary characteristics of the four storylines

Figure 2



The CO_2 emission and the atmospherical CO_2 concentration

Figure 3



Change of global annual temperature

1. To get the Hungarian people and economy prepared to face the occurrence of the likely increased extreme weather events and to bear warmer and drier time periods and their expectable impacts.

2. To create and develop the organisational, technical, infrastructural and financial conditions that will be needed for a rapid response of people (of the society) to the harmful impacts of unexpectedly occurring extreme weather events.

The most highlighted recommendations launched by VAHAVA towards decision makers, stake holders and the society as a whole:

1. Establishment of *national climate policy* integrated to present social, economic and environmental policies (mitigation and adaptation).

2. Attempts for political decision: a *National Strategy on Climate Change* approved by the Parliament of Hungary. (In March, 2008 the Parliament accepted it.)

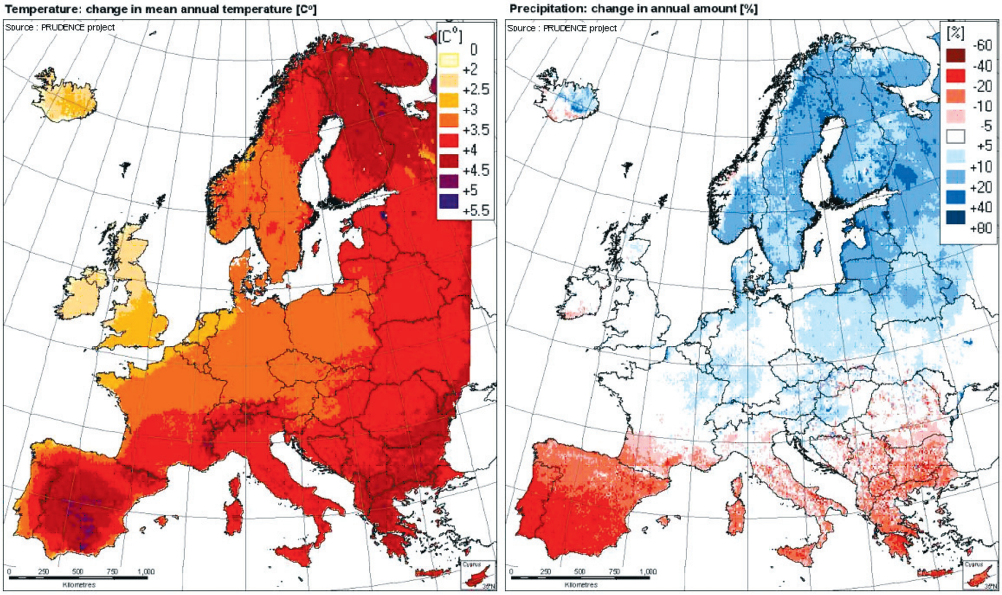
3. Establishment of a *National Hazard Management Fund* with both government and public participation integrating assurance activities.

4. *Education, extension and training* issues that enable the population to prevent, or handle the damaging effects of foreseen or unexpected extreme weather events.

5. Priorities in funding of *scientific research and development* regarding the field of climate change and meteorological phenomena.

The VAHAVA project has a follow-up within the framework of a national research project titled: “Preparation for climate change: environment – risk – society” and an EU

Figure 4


Temperature: change in mean annual temperature [C°]

Source : PRUDENCE project

Precipitation: change in annual amount [%]

Source : PRUDENCE project

Temperature and precipitation change in Europe

research project: ADAM – Adaptation and mitigation strategies: supporting European climate policy.

The range of the research areas are very branching out however here we deal with the problems of environment and the agriculture.

In the frame of ADAM we elaborate a case study on *Upper Tisza Region*.

Climate change can be investigated from two aspects

- it is a continuous, linear and slow change of mean temperature and precipitation;
- it is a nonlinear change with more frequent and serious anomalies.

The latter type of change causes increasing risk and catastrophic events the provision against of which is much more expensive than the prevention and socio-economic preparations.

1. Considering the first (slow) type of change we expect the following changes in crop production and, indirectly, in food production:

- The crop development is accelerated by the higher temperature assuming no nutrient and water stress. Much higher temperature than optimal, however, can danger the crop growing and survive.
- High temperature increases evapotranspiration which can rapidly dry up the soil.
- Increasing CO_2 concentration has a positive effect to the biomass accumulation.
- Water use in agriculture is expected to be much more expensive and so strictly limited because of increasing private and industrial water use under warmer temperature conditions.
- Soil productivity is also expected to be changed because organic matter brakes down more intensively at high temperature.
- Warming up has a positive effect on the reproduction and winter mortality rate of pests which makes the invasion easier. Thus, the protection against pests becomes more expensive.

Depending on climate change land use can also alter significantly. According to the assessments ecological zones can be shifted to north at a rate of 150-250 km with global warming of 1 ºC. For Hungary it means that a temperature increase of 2 ºC can involve such great changes in climate conditions which demand totally different land use.

The changes in the structure of production, in agricultural land use, in capability of old varieties and improvement of new varieties as well as in the production prices can change the life of villages and all economic conditions of production.

Warming and altered water circulation caused by climate change has a great influence on natural ecosystems regarding to biodiversity and land use.

Besides direct effects of climate change indirect socio-economic impacts have to be considered as well.

2. Considering the second (changeable) type of climate change we can establish that anomalies make the production uncertain, extreme events can cause catastrophes which have serious social and economic effects.

Some kinds of extreme situations (drought, flood, inland water, wind storm) were observed in Hungary, too. The analysis of these events and the elaboration of an adaptation strategy are the main points of the investigations.

What are the most important problems?

- Developing the regional scenarios regarding to climate change (i.e. to downscale the most widely accepted climate scenarios).
- Characterization of the change of soil productivity depending on climate change.
- Exploring the hydrologic relations – agricultural versus non-agricultural water use.
- Modelling and analysing crop-soil-water-nutrient-plant protection systems.
- Biodiversity analysis.
- Land use approach from the aspect of socio-economic consequences of climate change.
- Risk assessment of crop production.
- Description of extreme events with their frequencies and consequences.
- Approach on CO_2 balance of natural and agricultural ecosystems.

The factors of the adaptation strategy are the following

- new varieties (adaptation to new vegetation periods, resistance, water-use, etc.);
- new agrotechnics;
- land use;
- risk reducing techniques;
- catastrophe analysis, elaboration of an adaptation strategy;
- socio-economic consequences.

The structure of the research on agriculture and environment is represented in Fig. 7.

MODELLING OF PLANT CULTIVATION

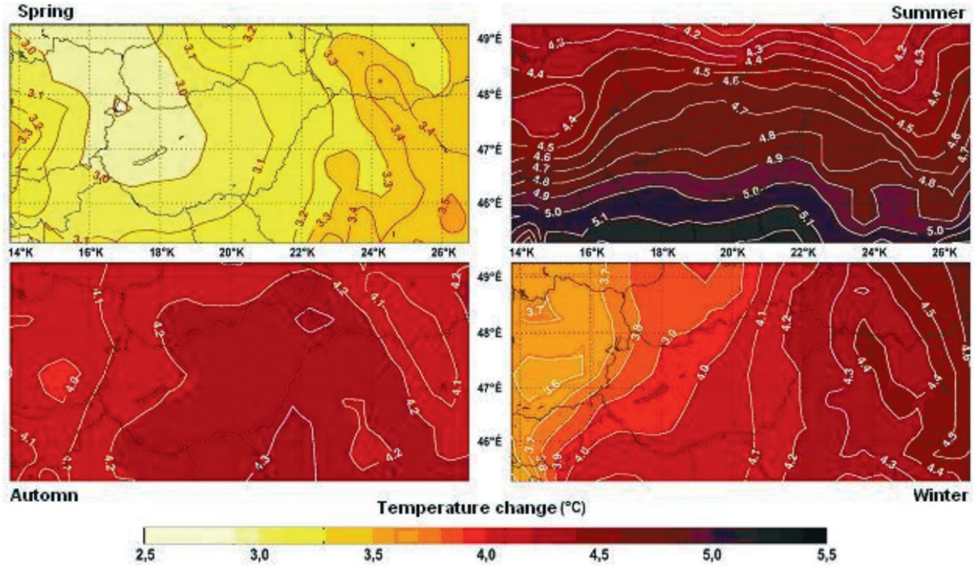
Assessment of agroecological potential of Hungary

The basic goals of the project were to determine the maximal amount of production that, given the natural environment, meteorological effects, soil properties, water supply, the genetic properties of plants, and the partial modification of environmental factors (amelioration, irrigation), can be obtained around the turn of century. The agroecological potential was calculated based on the hypothesis that it is basically the presently known advanced procedures that will be used to produce the primary food materials in 20 to 22 years’ time. No fundamental or completely new results in plant production on a completely new basis were taken into consideration.

Any major unexpected or unpredictable scientific achievement will only improve the examined situation. The procedure used for the survey is shown in Fig. 8.

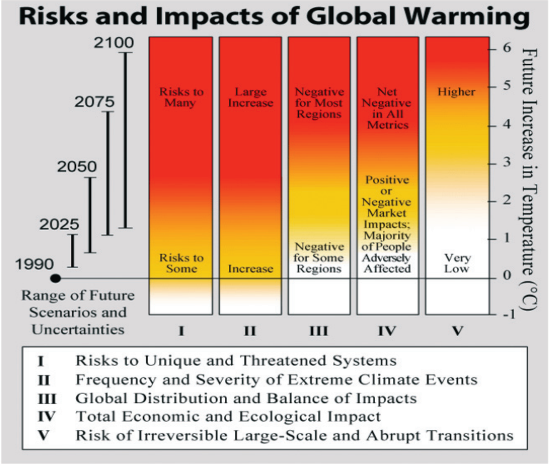
The prognosis of yields was carried out for every branch of cultivation, but here we dealt with only the production of field crops, because this plays a fundamental role in the planned work the analysis of the impacts of

Figure 5



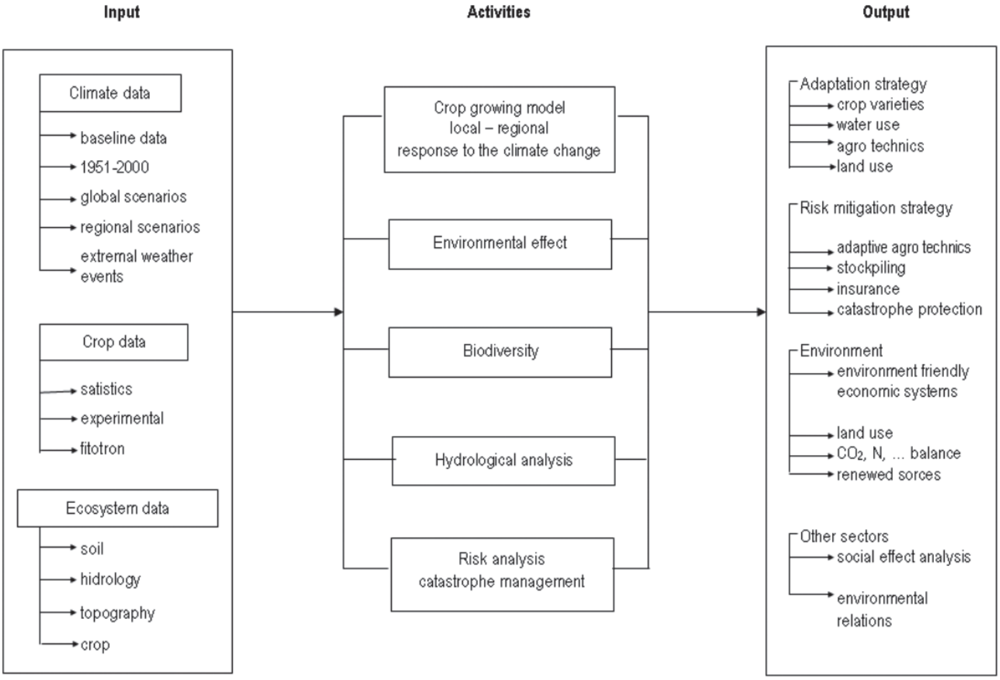
The expected temperature changes in Carpathian basin

Figure 6



Risk and impacts of global warming

Figure 7



Project approach

technological development on production and the environment.

The ecological factors that were taken into consideration for the yield prognosis are as follows

a) characteristics of natural geography;
b) meteorological conditions;
c) soil properties;
d) hydrological conditions;
e) genetics.

The most important field crops were selected, among others: wheat, maize, winter and spring barley, sugar beet, potato, sunflower etc.

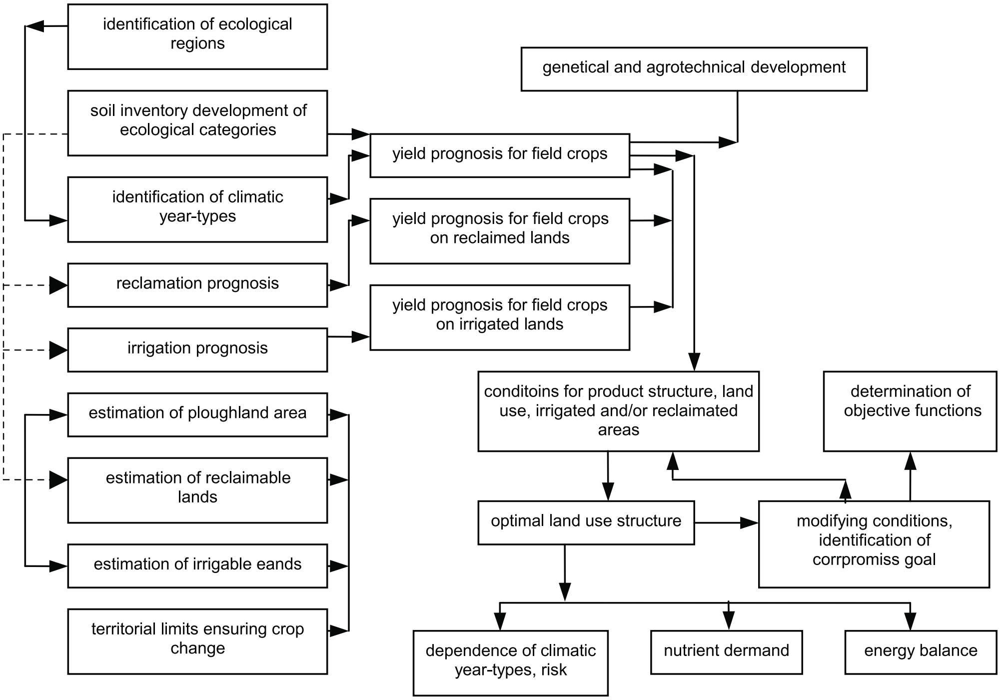
Production data of these crops for the 25 years period were also collected. Statistical analysis and some non formalized procedures were used in the selection of the characteristic meteorological parameters. Using production and meteorological data we determined climatic year types for each region. The parameters of the climatic year types are cluster centres of the group. The concept of climatic year types enabled us to account for the variability of weather in time in a relatively simple way. Individual year types are usually characterized by parameters relating to precipitation and temperature in certain parts of the vegetation period and by their probability of occurrence (Table 1).

By the climate scenarios the climatic year types will modify as the Table 2 shows.

Ecological regions were further divided into soil mosaics according to the quality of the habitat, which we characterized by soil and hydrological conditions (Table 3).

A special study was prepared on the expected development of the genetic potential of the main crops. The yield prognosis is based on this study, and it gives the expected

Figure 8



The model structure

yield of all the 13 main crops for each types, the expectation of the yield with respect to weather was also determined.

The main goals of the computations were

- the analysis of the relationships between land use pattern complying with natural conditions on one hand, and the required total production (social demand), on the other hand;
- the analysis of the dependence of land use patterns and total production on the amount of investments into land reclamation and irrigation and on their realization in time.

To solve this problem, we used a two-level hierarchical model. The first, so-called regional model describes the problem in an aggregated form. In this case the region constituted the land units. The social demand (with respect to the production structure), land reclamation investment conditions and others are formulated in this model.

The results give a regional allocation on investments and land use. A global analysis of the crop production system and that of the interdependence of land use and product structure can be carried out by using this model.

The second model served for a detailed analysis. It consisted on fact of four separate models. The country was divided into four large regions, and the crop production activity was described by separate models in each of them. Its structure is similar to that of regional model, but the constraints (like the product structure, the allocation of land reclamation investments and goals) were formulated on the basis of the results of the regional model.

The possible land use patterns are represented by the solutions of the system.

Risk analysis of yield loss

(Adaptive agricultural systems)

It's obvious that the natural conditions of the agricultural production are worsening by the GCM scenarios

- the agricultural zones would be pushed further to north. It means that Hungary will be in the Mediterranean climatic zones;
- the aridity of climate would strengthen, which may cause increased risk of cultivation.

The change of average temperature and precipitation are shown in the Table 4.

By the UKTR scenario the temperature increases by near 2 °C during the next tree decades while precipitation remains at the recent level.

The effective temperature sum of May and June is one of the deterministic parameter of wheat production. Fig. 9 shows the great change by the UKTR scenario.

The maize production depends on the summer effective temperature. Fig. 10 shows the change of it. 1983 was a catastrophical year. The yield loss exceeded 50% in some of region. The effective temperature can be more then it was in 1983. If it is followed by drought the maize production will be almost impossible in Hungary.

We try to characterize the risk of yield in the following manner:

If we know the $\eta(x,\xi,u)$ yield function, where

x state variable describe the properties of land,
ξ stochastic variable represent the weather,
u control variable (agrotechnique)

then we can express the distribution of yield by the function

$$F(y) = P(\eta\ (x,\xi,u) < u)$$

and the yield loss by

$$F\gamma(\alpha) = P(\eta^{-}(x,\xi,x) > \alpha E(x,\xi,u))$$

Fig. 11 shows the risk function of wheat and maize for Csongrád and Hajdú-Bihar countries. The results are supported by the empirical observations.

Simulation modelling

(CLIVARA project)

In our research work we used the AFRCWHEAT2 model to simulate the winter wheat production depending on the weather. This is the adapted version of AFRCWHEAT developed by *John Porter et al.*

The results of the validation of the AFRCWHEAT are shown on Fig. 12 which is tolerably good.

Using this model we simulated the expected yield for two regions: Győr-Moson-Sopron and Hajdú-Bihar. The results are shown on Table 5 and Fig. 13. We also made statistical analysis and we have got similar results.

We also have determinated the risk functions of winter wheat showing in Fig. 14.

The conclusion: the production condition of winter wheat is likely to worsen under the future climate. The production risk will be similar.

Tisza project – modelling plan

In the project we improved the presented methodology for the Tisza region.

The basic goal of the modelling work is to determine an optional (or adaptive) land use structure in the Tisza river basin depending on the soil properties, hydrological conditions, climatic factors, the genetic properties of plants, and economic and social background.

The main steps of the work:

- To determine the homogenous soil mosaics and their characterization according to meteorology, hydrology and productivity.

The basis of this steps is the soil map of HAS RISSAC (Research Institute for Soil and Agricultural Chemistry of the Hungarian Academy of Sciences).

- To select the climate scenarios is in accordance with ADAM.

Table 1

Climatic year types Hajdú-Bihar county – Debrecen

Maize			
	precipitation	effective temperature sum	frequency
	summer half year		
A dry – cold	300	1260	28
B dry – warm	200	1400	12
C wet – cold	530	1210	16
D wet – warm	300	1500	44
Winter wheat			
	April-May	May-June	
A dry – cold	70	450	40
B dry – warm	65	550	16
C wet – cold	140	365	12
D wet – warm	120	490	32

Table 2

Climatic year types modify in Debrecen

	Summer half year Effective temperature sums (°C)		**Summer half year Precipitation (mm)**	
1961–90	**1253**		**354.0**	
	A2	B2	A2	B2
2015	1494	1570	327.8	317.5
2030	1661	1771	324.2	309.7
2045	1865	1962	313.4	298.8
2060	2023	2125	289.6	278.0
2075	2141	2174	280.2	273.6

Table 3

Crop productivity by soil and climatic year types in Hajdú-Bihar county

Maize					
soil types	climatic year types				expected value t/ha
	A	B	C	D	
14	7.4	7.1	9.1	9.6	8.6
16	7.4	7.1	9.1	9.6	8.6
17	6.1	5.9	7.3	7.9	7.1
23	4.8	4.7	5.8	6.4	5.7
24	4.8	4.7	5.8	6.4	5.7
25	6.1	5.9	7.3	7.9	7.1
Regional average					8.0
Winter wheat					
2	3.5	3.3	4.0	4.0	3.7
14	6.0	5.9	6,7	6,8	6,3
16	6.0	5.9	6.7	6.8	6.3
17	5.7	5.6	6.4	6.5	6.0
22	4.2	4.1	4.7	4.7	4.4
23	4.9	4.9	5.5	5.5	5.2
24	4.9	4.9	5.5	5.5	5.2
25	5.7	5.6	6.4	6.5	6.0
Regional average					6.1

Table 4

Change of average temperature and precipitation

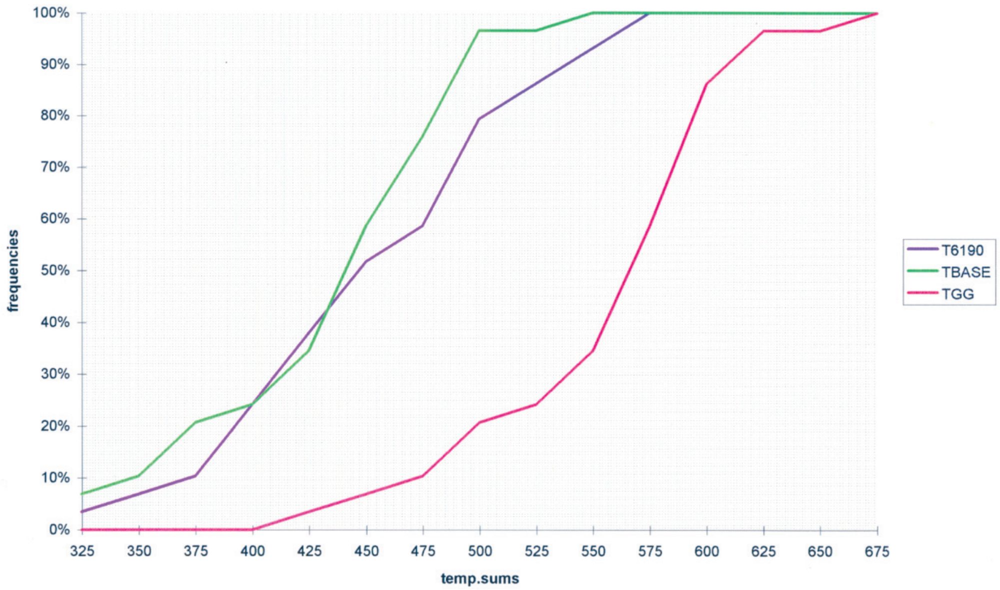
	I-III month	IV-VI month	VII-IX month	X-XII month	yearly average
1951-1991 average	96	179	155	126	556
minimum	39	80	35	43	321
maximum	208	333	376	272	950
GCM					
I. period	160	170	90	150	570
II. period	130	190	150	155	625

Debrecen precipitation (mm)

	I-III month	IV-VI month	VII-IX month	X-XII month	yearly average
1951-1991 average	0.9	15.2	18.9	5.1	10
minimum	–3.3	13,2	16.7	2.8	8.8
maximum	4.2	16,8	21.2	8.2	11.8
GCM					
I. period	4.1	16.3	20.4	7.0	11.9
II. period	5.6	17.1	21.8	9.1	13.4

Debrecen mean temperature (ºC)

Figure 9



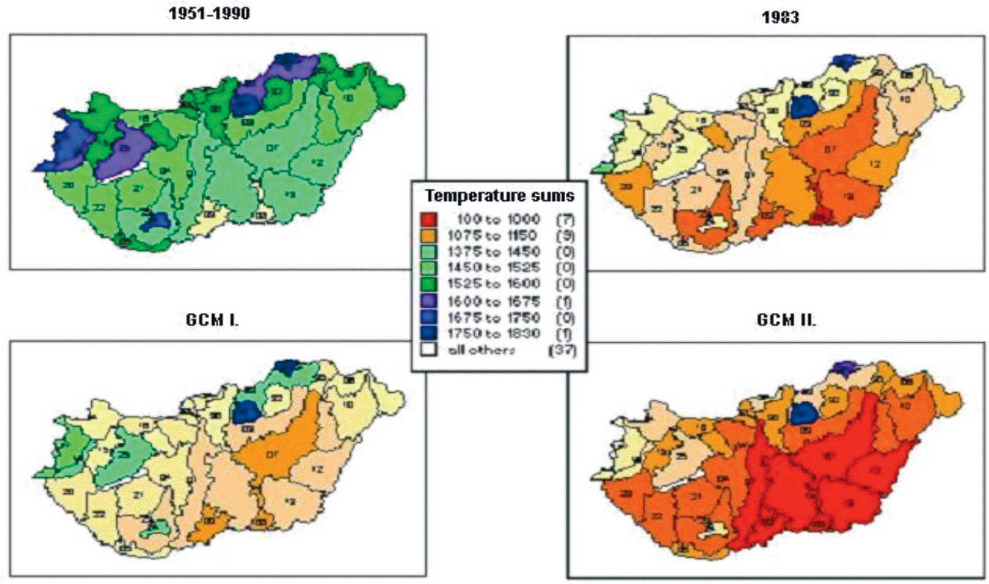
Distribution of effective temperature sums of May and June

According to need we downscale the scenarios to the Tisza basin.

- Knowing the climate scenarios the hydrological conditions are going to be worked out. In this steps we use the Koncsos's model system.
- To determine the distribution function of crop yield depending on the changing climatic conditions by simulation technique.

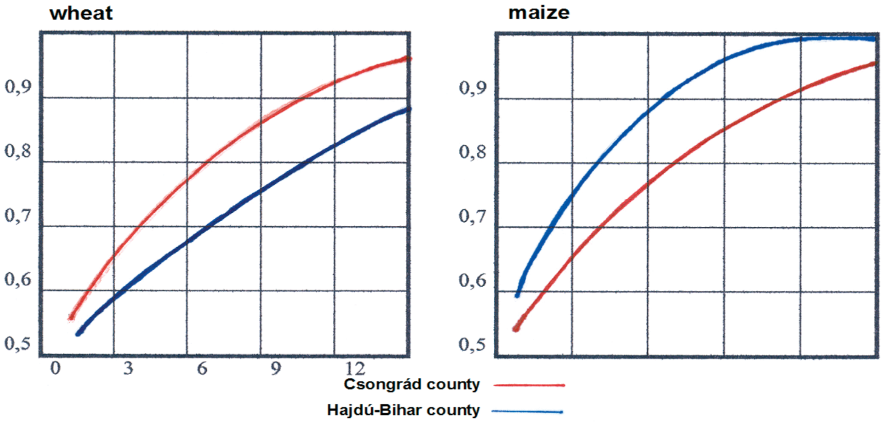
The possible crops are: winter wheat, maize, sunflower, barley, alfalfa and some kinds of energy crops.

Figure 10



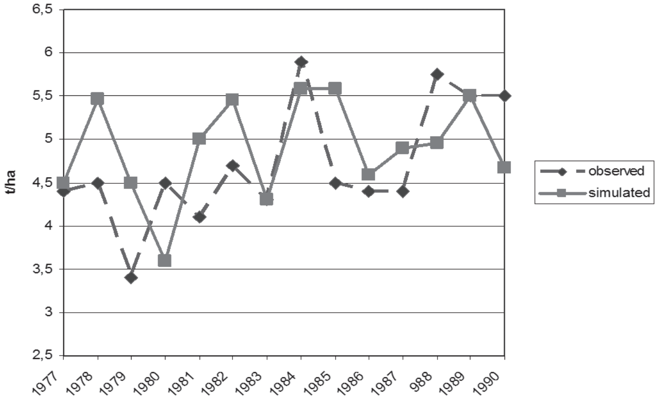
Effective temperature sums in summer

Figure 11



The distribution of relative loss of yield

Figure 12



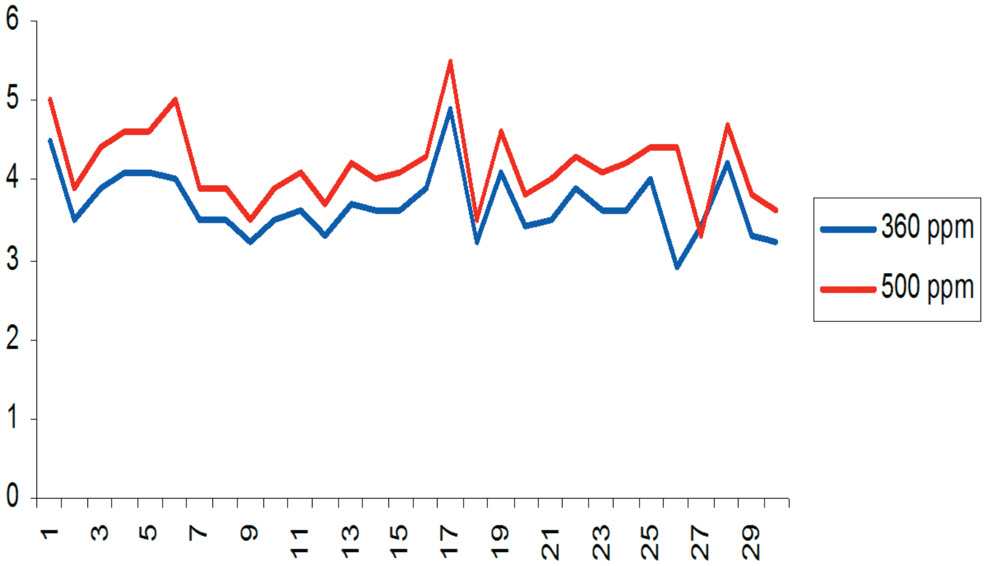
Observed and simulated winter wheat production Hajdú-Bihar county, Hungary

Table 5

Simulated and observed winter wheat yield

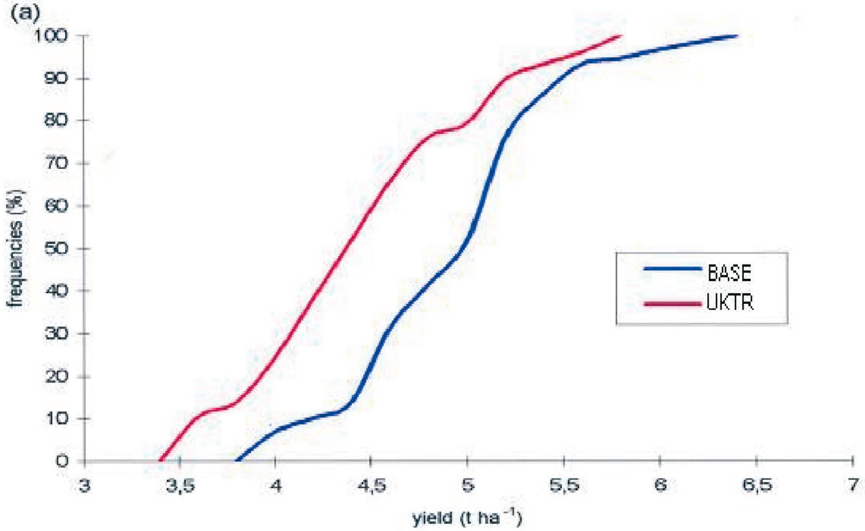
Country	Observed yield (t/ha)		Simulated yield (t/ha) AFRCWHEAT	
Győr				
Observed weather	4.88	0.63	4.9	0.5
Generated weather				
CO_2 conc.: 360 ppm			3.7	0.4
CO_2 conc.: 500 ppm			4.2	0.5
Debrecen				
Observed weather	4.69	0.69	4.8	0.6
Generated weather				
CO_2 conc.: 360ppm			3.8	0.4
CO_2 conc.: 500 ppm			4.4	0.5

Figure 13



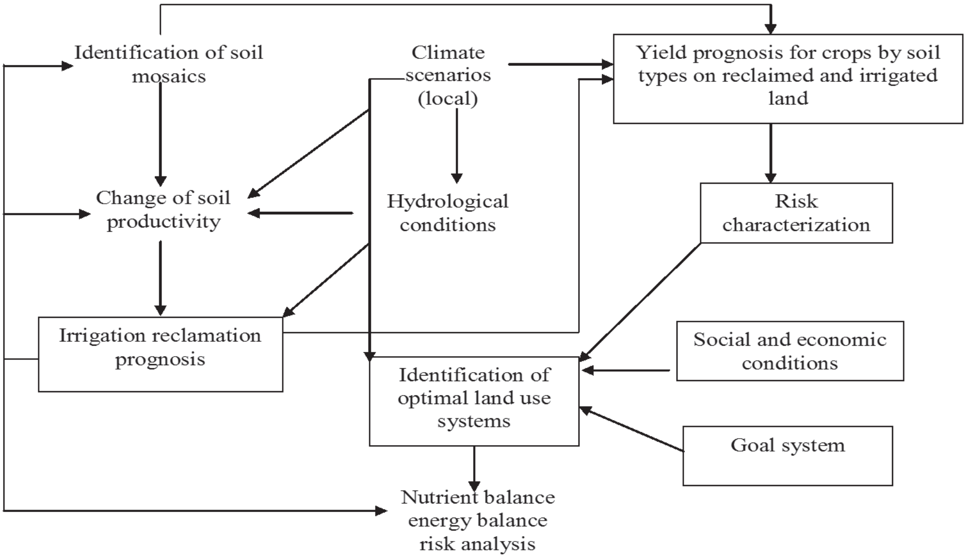
Winter wheat yield simulation under the HadCM2 scenario Győr-Moson-Sopron county

Figure 14



Distribution of yield and loss of the winter wheat

Figure 15



Structure of the model describing of land use

Figure 16

$Fz \le x$	land use pattern
$Az \le b_1$	crop rotation
$H(u,z) \le b_2$	agrotechnical conditions
$Y = Gz$	output
$y_0 \le y \le y_1$	product structure
$(z,u) \in \Omega_p$	risk condition
$\Theta(y, u) \to opt$	objective condition

Risk conditions

$$\Omega_p = \{u \mid 1 - F(y; x; u) \le p;\ y \ge \alpha E(x, \xi, u)\}$$

The mathematical model

Directly we don't calculate with genetic and agrotechnical development, i.e. new varieties and agrotechnique, however we assume a general yield growth.

If the distribution is known, we can determine the expected value and the risk of yield possible.

• Finally, we determine the social and economic conditions. We don't carry out a detailed analysis, we only form a condition system to the model (consumption, lower and upper bounds for the production, energy balance etc.).

The structure of the model is shown in the Fig. 15.

Methodologically, the model system is linear, but it contains

- real and integer variables;
- quasi stochastic elements (some risk conditions are formulated);
- multiobjective factors.

The mathematical form of the model is shown in Fig. 16.

REFERENCES

(1) Bartholy J. – Dunkel Z. (2006): A növénykultúrák fejlődését befolyásoló éghajlati paraméterek tendencia elemzése. A klímaváltozás kockázata: kihívások és teendők, MTA Budapest, 2006. október 20. (2) Csáki, Cs. – Harnos, Zs. – Láng, I. (1984): Agricultural Development and Ecological Potential: The Case of Hungary. Kieler Wissenschaftsverlag Vauk, 130 p. (3) Harnos, Zs. (1981): The Mathematical Model for the Determination of the Optimal Crop. Production Structures "Large-Scale Linear Programming" Vol.2. (G.B. Dantzig, M.A.H. Dempster and M.I. Kallio, Editors (4) Harnos, Zs. (1991): Adaptive agricultural systems (in Hungarian). AKAPRINT, Budapest, 1991 (5) Harnos, Zs. (2000): Analysis of risk factors in crop production (in Hungarian). MTA közgyűlési előadások (6) Harnos, Zs. (2004): Potential impact of climate change on wheat production in Hungary. SICCIA Conference, June 28-July 2, 2004 Grainau, Germany (7) Harnos, Zs. (2005): Preparation for climate change: environment – risk – society (in Hungarian). Research proposal, Budapest, Hungary (8) Harnos, Zs. (2006): Climate change and climatic variability. A Hungarian case study. TIES 2006, Kalmar Sweden (9) Harnos, Zs. – Bussay, A. – Harnos, N. (1999): Modelling climate change impacts on wheat and potato in Hungary (Ch. 19) in Climate change, climatic variability and agriculture in Europe. In: P. A. Harrison, R. E. Butterfield and T. E Downing (eds.): Environmental Change Unit, University of Oxford, 249-260. pp. (10) Jolánkai, M. – Láng, I. – Csete, L. (2005): Impacts and Responses Concerning Global Climate Change in Hungary – an introduction to VAHAVA project. International Conference on Climate Change: Impacts and Responses in Central and Eastern European Countries, Pécs, Hungary, 2005 (11) Láng, I. (2005): Review of the adaptation to climate change in Hungary (VAHAVA project). Budapest, Hungary (12) Láng, I. (2006): Impacts and Responses Concerning Global Climate Change in Hungary. Executive summary, Budapest, Hungary 2006 (13) GREEN PAPER: From the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Adapting to climate change in Europe – options for EU action, Brussels, 29.6.2007 (14) Climate change 2007, IPCC Fourth Assessment Report: Impacts, Adaptation and Vulnerability (15) Getting prepared to (combat) climate change in Hungary: Changes – Impacts – Responses (The Project "VAHAVA"), Ministry for the Environment and Water Management, Budapest, March 2007

USE OF THE SPATIAL ANALOGY METHOD TO ANALYSE TO POSSIBLE LANDUSE CHANGE IN HUNGARY

HORVÁTH, LEVENTE

Keywords: climate change, spatial analogy, landuse.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

With the method of spatial analogy we are searching for regions which at present have the same climate as the scenarios indicate for the future. With the spatial analogy we can make the climate scenarios easier to understand. In this research the analogue regions for Debrecen, which is an agriculturally important region for Hungary, were examined. From the result we can say – according to international results – that our climate will be similar to regions south to Hungary. This shifting will be 250-450 km in the next decades (2011-2040), and it could be 450-650 km in the middle of the century, and maybe there no spatial analogues in Europe to the end of the century. Different methods were used to calculate the analogues, but they indicate the same regions. These analogue regions are North-Serbia, Vojvodina regions and South Romania and North Bulgaria in the next decades, and South Bulgaria and North Greece in the middle of the century. We developed the inverse analogy method, with these we can searching for regions which at future have the same climate as in the present in Debrecen. If we accept the results of spatial analogy, we can identify the analogue regions and compare they data. The data collected from the EUROSTATs database and from the CORINE database. We collected all the data for land use, crops and natural vegetation. These data shows us, that the land use may change to more diverse which is better against climate change in adaptation. The ratio of forest and paisture may be higher. In the next decades the maize and the wheat will be more important, because the climatic condition will be better (because of the ”cornbelt”).

INTRODUCTION

The tendency of a potential global climate change is still not obvious, but the most accepted models predict warming and increasing of the extreme weather events. As the climate change has an overall impact on human health, natural systems, on agricultural production and also has socio-economic impacts it is very important to predict the potential changes to have enough time for the appropriate decision-making. Analogue scenarios involve the use of past warm climates as scenarios of future climate (temporal analogue scenario), or the use of current climate in another location (usually warmer) as a scenario of future climate in the study area (spatial analogue scenario). Our aim was to find spatial analogues to describe the potential future climate of Hungary. However we must note that climate depends also on other effects, especially on elevation, topography and storm-track conditions, which can not be considered in this kind of analysis

MATERIALS AND METHODS

Climate scenarios can be defined as relevant and adequate pictures of how the climate may look like in the future. Our work is based on General Circulation Models (GCMs) downscaled to Debrecen, an important centre of agricultural production in Hungary and we used the method of geographical analogies to explain the results. We used different GCM scenarios (GFDL5564, GFDL2534, UKTR, HadCM3) the IPCC CRU Global Climate dataset and the Hungarian meteorological database for 30 years (1961-1990). To find the analogues, monthly data were used. The monthly temperature averages and precipitation sums for 4 different time periods, which were for the base period 1961-1990, and for the future 2010-2019, 2020-2029, 2020-2039 and 2040-2069. To calculate and find the analogue regions we used the Climex method, which was improved by us.

Climex method

$$T_{dj} = \frac{1}{12} \cdot \sum_{i=1}^{12} \left| TEMP_{ji} - T_i \right|$$

$$P_{dj} = \frac{1}{12} \cdot \sum_{i=1}^{12} \frac{\left| PREC_{ji} - P_i \right|}{1 + a \cdot (PREC_{ji} + P_i)}$$

$$I_{Tj} = e^{-\lambda \cdot k_T \cdot T_{dj}}$$

$$I_{Pj} = e^{-(1-\lambda) \cdot k_P \cdot P_{dj}}$$

$$CMI_j = I_{Tj} \cdot I_{Pj}$$

Where:

j: grid point identity number (j = 1–31143)

i: month (i = 1–12)

TEMPji: monthly temperature of the gridpoint j for the base period

Ti: monthly temperature of the gridpoint j for the scenario

PRECji: monthly precipitation of the gridpoint j for the base period

Pi: monthly precipitation of the gridpoint j for the scenario

Tdj: average of the temperature differences

Pdj: average of the precipitation differences

ITj: similarity of the climate for the scenario by temperature

IPj: similarity of the climate for the scenario by precipitation

CMIj: ”Composite Match Index”, if CMI > 90%, we can call the grid point as the analogue for the scenario

ANALOGUE REGIONS

First we look for the analogue regions for the base period. We find, that we kept back our regions, after we look for the analogues for the future. We find that the analogue regions are south to Debrecen. This climate shifting was the same for different scenarios, because for the first decades they not differ very much but we can see more differences for the middle of the century. Finally we defined the analogue regions for the scenarios and time periods. We find that the climatic shifting will be 250–450 kms for the next decades and 450–650 kms for the middle of the century. Unfortunately we can’t find any similar region for the end of the century, but some analogues can be find in North-Africa (Fig. 1).

We developed a new method to find inverse analogue regions, these are the regions which climate will be similar in the future like our study area now. We find a same shifting amount to the north. These analogue regions are is Poland (Fig. 2). These analogue regions are defined for the A2 scenario.

It can be seen that analogue regions are south-east to Debrecen, with a distance of about 250-450 kms, but later this distance is larger. The analogue regions are Vojvodina in Serbia, the RO04 (Sud-Vest) and the RO03 (Sud) NUTS regions in Romania. For further analyzes only these regions were taken into consideration (Fig. 3). We calculated the diversity of cropping areas and the land use and we find opposite changes. While that the diversity of crops is lower than in Hungary, the diversity of land use is higher. Its mostly because the mean crops. The ratio of the wheat and the maize is higher to the south, so it is more often used crops. Just because the climatic condition are better for that kind of crops. Meanwhile the yield is lower, it more economic to use these crops because the better condition needs less agronomic techniques.

DISCUSSION

Debrecen, the basic object of our calculations is an important centre of agricultural production in Hungary, so we would like to interpret the results in this aspect.

Climate – especially temperature and precipitation – basically determines agricultural production. Results show that in Hungary we must count with an increase of temperature and decrease of precipitation. The possible future climate – predicted by the scenarios – would be similar to the present climate of South-Southeast Europe. Of course climate depends also on other effects, especially on elevation, topography and storm-track conditions, which can not be considered in this kind of analysis. But it seems that the method of spatial analogies is a good tool to understand and interpret the results of the GCM scenarios and the effects of climate change. This method with additional data of the analogue regions can provide information on impacts of climate change on ecosystems or on agricultural production, such as the changes in land use or cropping system, or in yields.

Increased mean annual temperatures in our region, if limited to two or three degrees, could generally be expected to extend growing season. In case of crops (or animals), where phenological phases depend on an accumulated heat unit, the phenophases could become shorter. Whether crops respond to higher temperatures with an increase or decrease in yield depends on whether their yield is currently strongly limited by insufficient warmth or it is near or little above the optimum. In Central Europe where temperature are near the optimum under current climatic conditions, increases in temperature would probably lead to decreased yields of several crops. Increased temperature could be favourable for example for pepper and grapes however it is unfavourable for green peas and potato. Decrease of precipitation could be a great limiting factor in agriculture.

Results show that in Hungary we must count with an increase of temperature and decrease of precipitation. The possible future climate – predicted by the scenarios – would be similar to the present climate of South-Southeast Europe. Geographical analogues can provide information on impacts of climate change on ecosystems or on agricultural production, such as the possibilities for disappearing or introducing new crops or weeds and pests into an area. Of course climate depends also on other effects, especially on elevation, topography and storm-track conditions, which can not be considered in this kind of analysis. But it seems that the method of spatial analogies is a good tool to understand and interpret the results of the GCM scenarios and the effects of climate change, so we want to go ahead in this research. If we accept the results of the GCMs, according to the A1FI scenario for the 2011-2040 periods, the analogue regions of Debrecen will be at Vojvodina region in Serbia, and South-Romania. It means about 250-450 km shifting to south, which correspond to other international results.

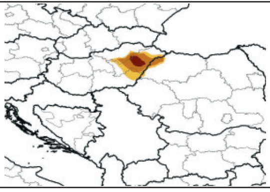
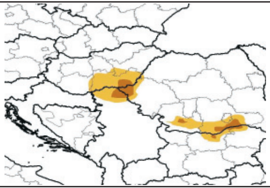
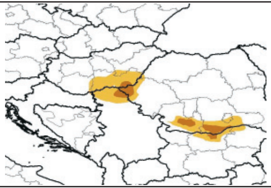
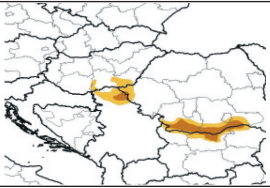
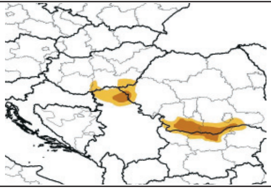
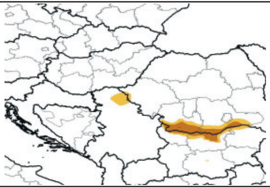
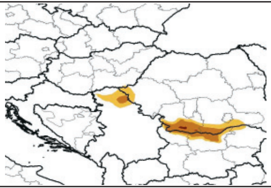
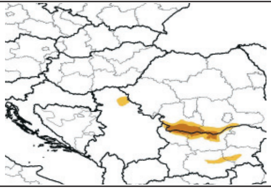
The detailed analyses of the analogue regions can help us to adapt to the changing climate. From the analogue regions we should collect all kind of available ecological, agricultural, economical, social or public sanitation data. We can study what kind of problems are there, and what are the solutions. We can learn from there how to solve the possible problems and develop strategies. This will be a good base for further research and an important base for decision makers.

With the method of spatial analogy we can build a new way of knowledge transfer from where learn adaptation techniques and to where transfer our knowledge.

REFERENCES

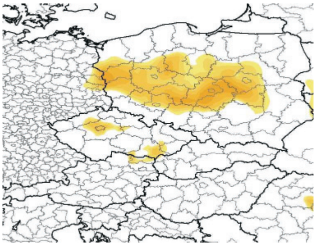
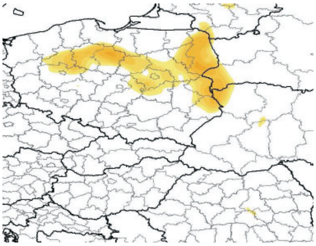
(1) IPCC (2007): The Fourth Assessment Report "Climate Change 2007" Cambridge University Press 2008 ISBN-13:9780521705974 (2) Mitchell, T.D. – Carter, T.R. – Jones, P.D. – Hulme, M. – New, M. (2003): A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Journal of Climate (3) Szenteleki K. (2007): A Környezet-Kockázat-Társadalom (KLIMAKKT) Klímakutatás adatbázis-kezelő rendszerei. "Klíma21" Füzetek vol 51. 89-115. pp. (4) Solymosi, N. – Kern, A. – Horváth, L. – Maróti-Agócs, Á. – Erdélyi, K. (2008): TETYN: An easy to use tool for extracting climatic parameters from Tyndall datasets. Environmental Modelling and Software 948-949 p.

Figure 1

TIME	Baseperiod	
1961-1990		For validating the method, similarity for the observed climatology were calculated. As a result we got back the region of Debrecen.
	A1FI	B2
2010-2019		
2020-2029		
2030-2039		
2040-2069		

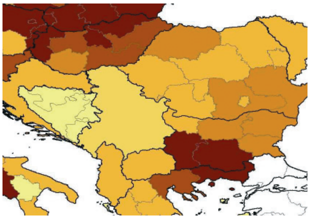
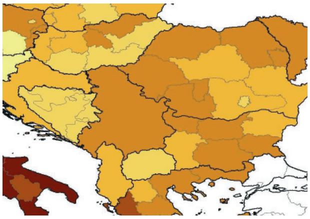
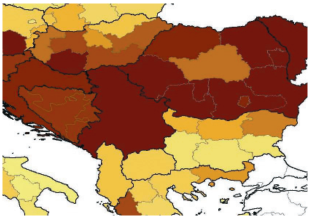
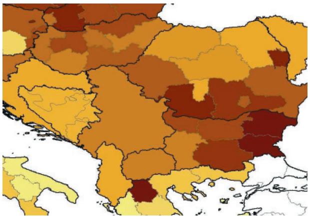
Analogue regions for the next decades and for different climate scenarios Debrecen

Figure 2

Similarity (%)	2011–2040	2041–2070
☐ - 90 🟨 90,01 - 91 🟨 91,01 - 92 🟨 92,01 - 93 🟧 93,01 - 94 🟧 94,01 - 95 🟧 95,01 - 96 🟫 96,01 - 97 🟫 97,01 - 98 🟫 98,01 - 99 🟥 99,01 - 100		
	Analogue regions: PL11, PL43, PL41	Analogue regions: PL61, PL12, PL31

Analogue regions for the next decades and for different climate scenarios Debrecen

Figure 3

	Diversity of the cropping areas. In the analogue regions the diversity is lower, so the structure of the crop fields in Hungary will probably change, too.
	Diversity of the land use types is higher in the analogues regions, but it could be also the effect of the topography.
	Ratio of the maize area in the arable land is higher in the analogue regions than in Hungary. Climate change would have a positive effect in Hungarian maize grow, too.
	The ratio of the wheat area in the analogue regions is similar to the present situation in Hungary. Climate change maybe will not have an effect on it.

Landuse and cropfield ratio of the analogue regions

EXPECTED CHANGES IN CLIMATIC CONDITIONS OF MAIN CROPS

GAÁL, MÁRTA

Keywords: maize, wheat, climate scenarios, climatic year types.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

It is well-known that climate basically determines agriculture therefore it is important to analyze the possible changes in it. The potential future climatic conditions of main crops in Hungary were examined based on the Hadley Centre's HadCM3 model with A2 and B2 emission scenarios in different time periods. The scenario data set contains monthly data, which was a limiting factor of this work. There was no possibility to analyze for example the risk of spring frost, summer hot days or extreme precipitation events. Results show a significant increase in the length of the potential vegetative period (temperature higher than 10 °C), a drastic increase of the heat units and decrease of precipitation. The unfavourable effects of the increasing temperature and decreasing precipitation could be characterized well by aridity indices. Attempts were done also to cluster the years from 1951 to 2100 looking for climatic year types. These results show the continuous shifting, too, and it can be observed that from about 2030 the minimum heat unit values become equal to the formerly high values. Results call the attention to the interpretation problems, as the heat unit values are going out of the formerly normal scope. It is problematic also in simulation modelling, as we can get easily false results.

MATERIALS AND METHODS

Climate scenario data were taken from the Tyndall scenario data-sets TYN SC 1.0 (*Mitchell et al., 2004, 2005*). Data is supplied from 2001 to 2100 at a monthly time-step, on a 10' grid covering European land only. This paper focuses on the Hadley Centre's HadCM3 model with the A2 and B2 emission scenarios (*IPCC, 2001*). The tendencies are similar based on the two scenarios, but until the middle of the century the B2 scenario indicate larger warming, while at the end of then century the A2 scenario. The baseline (1961-90) data were obtained from the CRU CL 2.0 database (*New et al., 2002*), which has – according to the scenarios – 10' grid spatial resolution. As the scenarios are not correct forecasts for each year, results are presented in moving 30-year time periods. For the primary data management the KKT program was used (*Szenteleki, 2007*).

To interpret the results GIS methods were used, too, using the ArcGIS program. Raster data were represented as ESRI grid with bilinear interpolation. For some calculations overlay functions and zonal statistics were applied.

Climatic year types were defined – in case of maize – by cluster analysis, using the precipitation and effective heat units (above 10 °C) of the summer half year (April-September). Ward method with Euclidean distances was used, for standardized data. For this analysis long-term historic data since 1951 were used, too, from the database of the Hungarian Meteorological Office. In this case data of the meteorological station of Debrecen were used, which is the nearest available one to the Upper-Tisza region (the target area of the ADAM project), and is of great agricultural importance.

RESULTS

Potential vegetative period

Beginning and end of the vegetative period were specified with the day number, when mean temperature across the 10 °C limit. The length of the potential vegetative period is the number of days between the beginning and the end day. As the database contains only monthly data, calculation was made by linear interpolation between the monthly averages. The disadvantage of this method is that can not take into consideration the late spring or early autumn frosts. However, many researches proved that extreme events, also late spring frost, have increased in the Carpathian basin and are expected to increase more in frequency (*Bartholy – Pongrácz, 2006*).

Results show that the potential vegetative period could be longer with approximately 12-17 days in the middle of the century and with about 40 days at the end. Expected changes in the 10 °C crossing days are summarized in Table 1.

The spatial pattern of the changes is very defined, but different in the examined periods. Usually it shows an east-west division or a V form (smallest values in the centre of the country). The Upper-Tisza region belongs to the regions with major changes.

The longer potential vegetative period would be favourable for the warm season crops, species and varieties with longer growing season. However – considering the expected increase of extreme events – it can hold a higher risk of production.

Many researches proved (*Varga-Haszonits – Varga, 2006; Erdélyi, 2008*) that in case of warming the effective vegetative period of the plants become shorter. Therefore, another possible advantage could be the use of the double-cropping systems, with adequate preplants or second crops.

Effective heat units and precipitation

Effective heat units – also called as degree days or temperature sum – are the seasonal temperature accumulations above a base temperature, 10 °C in this case. It is a very deterministic parameter of thermal suitability and often used for example in maize, soya bean and green peas growing. Effective heat units and precipitation values in the Upper-Tisza region are summarized for maize (Table 2) and winter wheat (Table 3).

In both cases (maize and wheat) can be seen that the values of the heat units were increasing now in the last years. This tendency will continuo, but in greater extent.

In case of precipitation the changes do not have so monotone system, in some periods (e.g. April – May) or regions a slightly increase could expected. Unfortunately even in these cases we must count with relative decrease, as the temperature will increase in greater degree. The combined effects of warmer temperatures and reduced mean summer precipitation would enhance the occurrence of heat waves and the risk of drought.

Regarding the precipitation, not only the seasonal amount, but also its distribution is very important for plant development. From monthly data it is not possible to draw conclusions about it, but many researches proved now that extreme precipitation events have increased in the Carpathian basin and are expected to increase more in frequency (*Bartholy – Pongrácz, 2006; Bartholy et al., 2007*).

Aridity index

The unfavourable effect of the increasing temperature and decreasing precipitation could be characterized well by aridity indices. In this work *Ángyán's* aridity index (*Ángyán, 1987*) was used, which was developed especially for maize growing. The index can be calculated from the effective heat units in April – September divided by the annual precipitation. The index was elaborated for the effective heat units of 1250–1750 °C, while the precipitation was between 500–720 mm.

The optimal values are around 2.5 and above 3.11 growing is advised only with irrigation. Looking at the Fig. 2 it can be seen that in the baseline period the whole country was climatically suitable for maize growing (some parts are not suitable due to the relief, but it is not indicated in the maps), and the great plain areas were near the optimum value. Going ahead in time areas with the need of irrigation become more and more great. In the near future the longer potential vegetative period and increasing effective heat units would be favourable to grow maize varieties with 2–3 further FAO groups, which have a higher potential yield, but the precipitation could be a serious limiting factor.

For the better understanding results are quantified with the ratios of the areas according to the aridity index values (Table 4). It can be seen that the ratio of the areas, where maize growing is possible only with irrigation would increase from zero to almost hundred percent to the end of the century.

At about 2030 the appearance of the values above 3.51 can be observed and it indicates a new problem, as it means that the values of the effective heat units are going out of the normal range. Further research needed to analyze, whether it means that these areas become unsuitable for maize growing at all (turn into desert), or with new varieties and irrigation methods the cultivation could go on.

Climatic year types

Any map based on the use of long-term means of climatic elements has the disadvantage of masking variability. Therefore, attempts were done to cluster the years from 1951 to 2100 looking for climatic year types. Analysis was done only for the region of Debrecen, which has a great importance in Hungarian agricultural production. Clustering the years from 1951 to 2100 (Fig. 3) we can divide four groups, and we can call them as wet-cold (1), dry-cold (2), wet-warm (3) and dry-warm (4).

Identifying the years a separation can be seen around 2030 – years before it belong to the first „cold" group and the future belongs to the „warm". Of course – due to the variation – in the middle the consecutive years can be different, but the first 23 years (except 1965 and 1970) belong to the wet-cold group and the last 15 years (2086-2100) belong to the dry-warm.

Clustering results for 30-year periods can be seen in Fig. 4, but for the better visibility the first (1951-75) and the least (2061-90) periods are omitted. The long term tendencies indicate increase in the heat units and decrease in precipitation, as it was partially presented now, but in this case also the variability can be seen. In the different periods the meaning of the four sub-groups can be the same (wet-cold, dry-cold, wet-warm and dry-warm), but the values are different. The separation of the groups is usually clear, in ambiguous situations the definition was made first according to the heat units (cold or warm) than based on the precipitation (dry or wet). To be easier to compare, the scaling of the figures and the colours of the groups are always the same.

It can be observed that from about 2030 the minimum heat unit values become equal to the formerly high values. Together with the increase of the average heat units the variation of it seems to be increasing, too.

The period 2031-2060 is interesting in such point of view, that it has the greatest variation in the heat units and the smallest variation in precipitation.

ACKNOWLEDGEMENTS

This work was supported by the NKFP 6-00079/2005 and ADAM projects.

REFERENCES

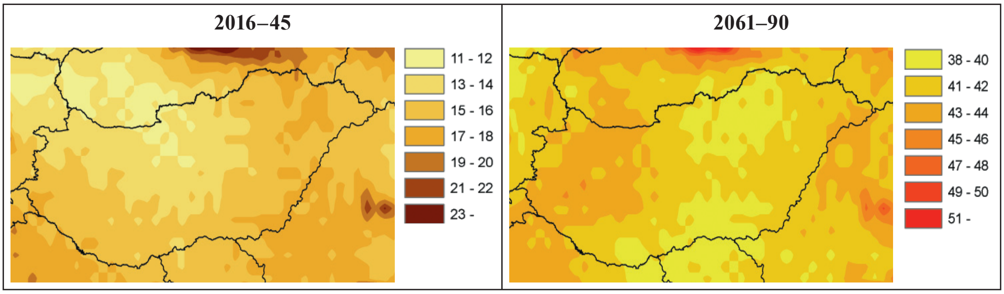
(1) Ángyán J. (1987): Agroökológiai hatások a kukoricatermesztésben. Az agroökológiai körzetek és a területi fejlesztés. Közgazdasági és Jogi Könyvkiadó, Budapest (2) Bartholy J. – Pongrácz R. (2006): Szélsőséges éghajlati tendenciák alakulása a XX. században a Kárpát-medencében, In: Láng I. et al. (szerk): A globális klímaváltozás: hazai hatások és válaszok. Akaprint Kft., Budapest (3) Bartholy J. – Pongrácz R. – Gelybó Gy. (2007): Regional Climate change expected in Hungary for 2071-2100. Applied Ecology and Environmental Research 5(1): 1-17. (4) Erdélyi É. – Ferenczy A. – Boksai D. (2008): A klímaváltozás várható hatása a kukorica és búza fenofázisainak alakulására. „Klíma-21" Füzetek 53: 115-130. (5) IPCC (2001): Climate change 2001: Synthesis Report. Cambridge University Press, Cambridge, UK, http//:www.ipcc.ch (6) Mitchell, T.D. – Carter, T.R. – Jones, P.D. – Hulme, M. – New, M. (2004): A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre Working Paper 55, University of East Anglia, Norwich, UK, http://www.tyndall.ac.uk/publications/working_papers/wp55.pdf (7) Mitchell, T.D. – Jones, P.D. (2005): An improved method of constructing a database of monthly climate observations and associated high-resolutiongrids. Int. Journal of Climatolology 25: 693–712. (8) New, M. – Lister, D. – Hulme, M. – Makin, I. (2002): A high-resolution data set of surface climate over global land areas. Climate Research 21: 1-25 (9) Szenteleki K. (2007): A KKT klímakutatás adatbáziskezelő rendszerei. „Klíma-21" Füzetek 51: 89-115. (10) Varga-Haszonits Z. – Varga Z. (2006): Az éghajlatváltozás hatása a növényfejlődésre és a tenyészidőszak hosszára. In: Láng I. et al. (szerk.): A globális klímaváltozás: hazai hatások és válaszok. Akaprint Kft., Budapest

Table 1

Expected changes in the length of the vegetative period (days)

Periods	Changes in Spring		Changes in Autumn	
	A2	B2	A2	B2
2001–2030	-7 – -4	-9 – -6	+4 – 6	+6 – 8
2016–2045	-8 – -4	-10 – -6	+8 – 10	+10 – 13
2031–2060	-11 – -7	-13 – -8	+10 – 13	+12 – 16
2046–2075	-17 – -13	-17 – -13	+15 – 20	+16 – 21
2061–2090	-24 – -19	-22 – -17	+19 – 23	+18 – 22

Figure 1



Expected changes in the length of the vegetative period (days)

Table 2

Effective heat units and precipitation for maize (Upper-Tisza region)

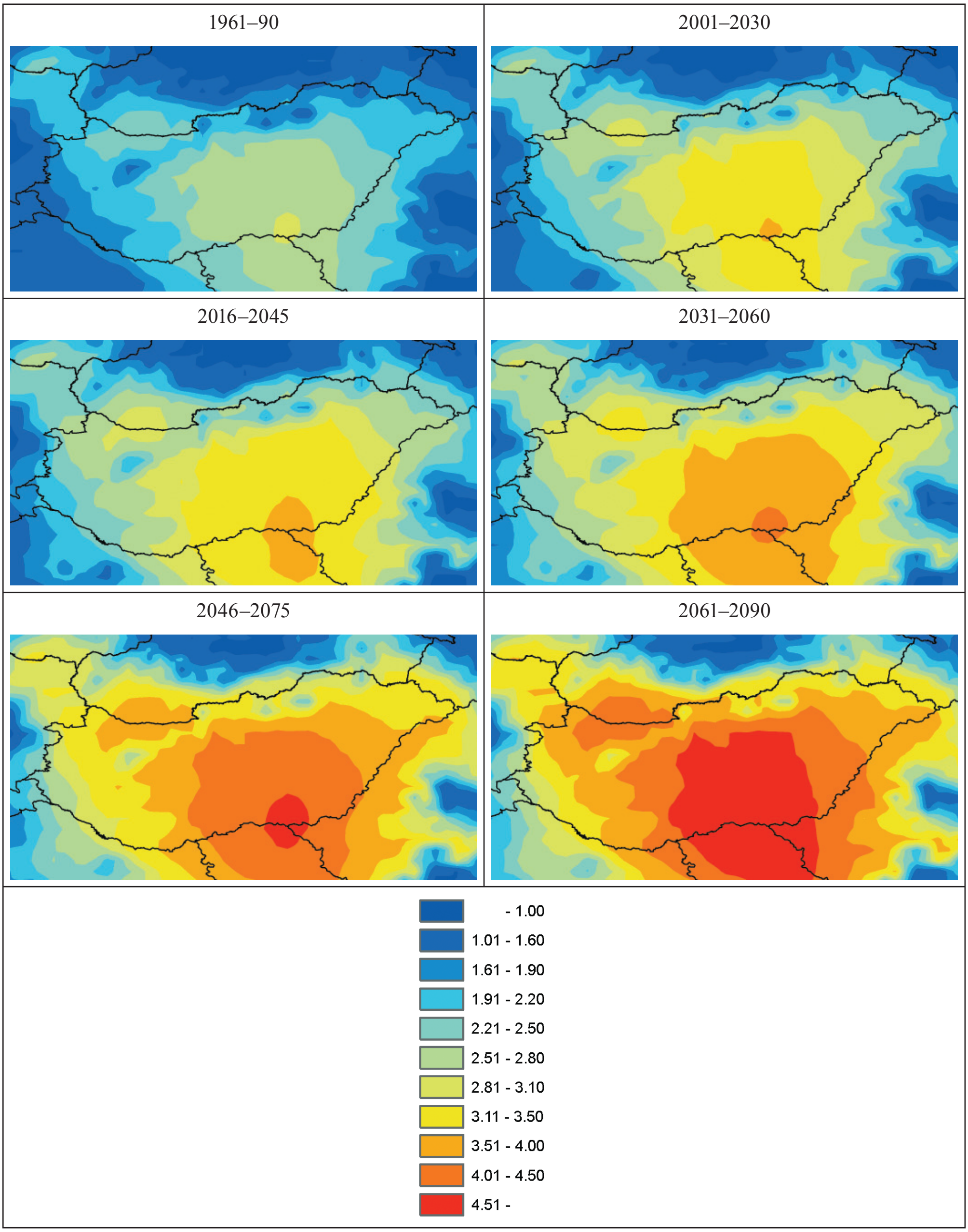
	Heat units in April – September (°C)		**Precipitation in April – September (mm)**	
	A2	**B2**	**A2**	**B2**
1956–1985	1221		378.0	
1971–2000	1238		392.7	
1986–2015	1365	1388	372.4	369.0
2001–2030	1467	1543	363.3	353.1
2016–2045	1606	1716	360.4	345.8
2031–2060	1814	1912	340.1	325.2
2046–2075	1995	2039	302.4	291.1
2061–2090	2114	2074	303.1	297.3

Table 3

Effective heat units and precipitation for wheat (Upper-Tisza region)

	Heat units in May – June (°C)		**Precipitation in April – May (mm)**	
	A2	**B2**	**A2**	**B2**
1956–1985	425		105.3	
1971–2000	431		116.8	
1986–2015	469	474	116.9	115.8
2001–2030	479	496	119.2	116.5
2016–2045	504	529	129.0	125.1
2031–2060	569	590	120.6	114.8
2046–2075	612	620	109.4	101.2
2061–2090	640	626	121.7	110.7

Figure 2



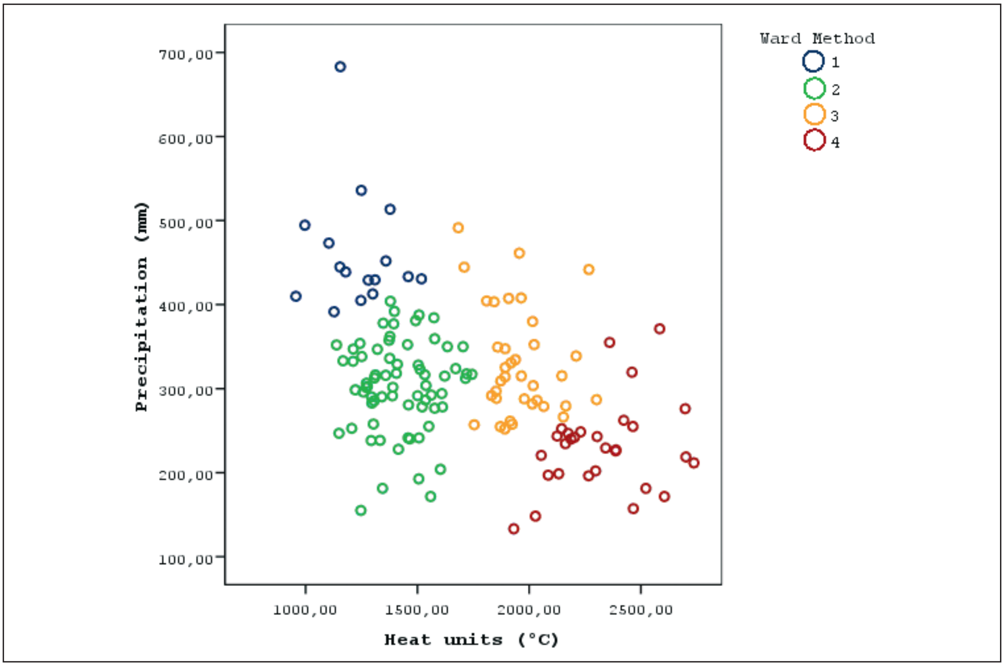
Ángyán's aridity index bases on the A2 scenario

Table 4

Ratios of the areas according to the aridity index (%) – A2 scenario

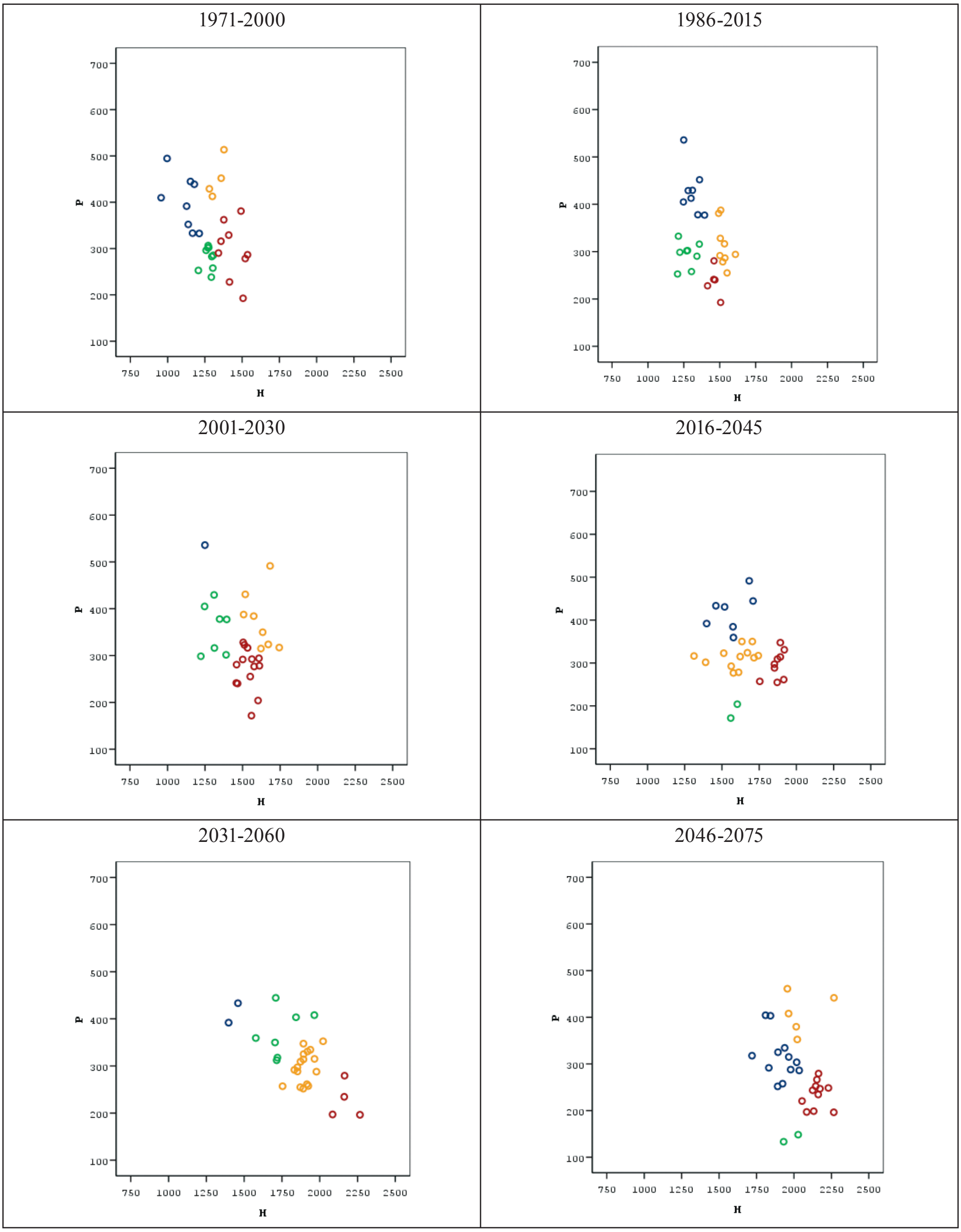
		1961–90	2015	2030	2045	2060	2075
Very poor	1.01–1.60	4					
Medium	1.61–1.90	14	3	1			
Good	1.91–2.20	26	7	3	2		
Very good	2.21–2.50	23	24	15	3	2	
Very good (irrigation recommended)	2.51–2.80	31	19	25	14	4	2
Good (irrigation recommended)	2.81–3.10	2	21	19	26	9	3
Only with irrigation	3.11–3.50		26	34	23	26	13
	3.51–4.00		1	3	30	27	28
	4.01–4.50				2	30	28
	4.51 ≤					2	27

Figure 3



Cluster analysis result of the years 1951-2100

Figure 4



1971-2000

1986-2015

2001-2030

2016-2045

2031-2060

2046-2075

Cluster analysis results for 30-year periods

VITICULTURE CHALLENGES UNDER CHANGING CLIMATE IN HUNGARY

LADÁNYI, MÁRTA

Keywords: risk, viticulture, data management software, stochastic dominance, risk aversion, climate change.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

In this paper first we introduce some methods as the most essential tools of risk assessment and prove that the risk of grapevine production increased in Hungary in the past few decades and discuss the possible reasons. Climate change and its expected impacts on viticulture of Hungary are considered and the reasons and consequences of risk increase are explored. As a result of a synthesized analysis of international and national literature we fix some weather indicators which may significantly define grapevine production. We introduce a data management software which can be used as a tool to reveal how the trends of the examined indicators have been changing with time. Based on RegCM scenarios we introduce the expected change of these weather indicators and formulate some conclusions for Hungary.

INTRODUCTION

Grapevines can only be grown across a fairly narrow range of climates for optimum quality and production. Hungary is now situated at near the north of suitable land for grapevine growing, in a region where climate change can bring for viticulture both positive and negative effects. The area of vineyards is 2% of cultivated area; 5-6% of GDP and 10% of agricultural exports are due to grapevine production. Ripening is quite slow because of moderate radiation; taste and flavour accumulation is good. Both national and international climate change impact studies, however, predict spatial shifts of viticulture suitability (*Webb et al., 2005; Dry, 1988; Gladstones, 1992; Schultz, 2000a,b; Bartholy et al., 2007a,b,c; Szenteleki et al., 2007a*). According to the observations in the last decades as well as to the regional climate change models, Carpathian basin is definitely expecting significant temperature increase and precipitation decrease in the growing season together with several anomalies (drought, frost, storm, wind, flood, hail etc.), in general. It means that this region belongs to the most vulnerable areas in Europe. While the probability of extreme high vine production has increased with climate change, the risk of production quantity and quality has also considerably increased. Dry and hot summers with great among of precipitation in winter and spring as well as frost events after bud initialization force us to research the possible impacts of climate change more extensively because the stakeholders in viticulture might soon need radical and quick adaptation response.

DATA

We used historical weather data with minimum, maximum and average temperature, precipitation and sunshine hours daily data as well as grapevine production data for several Hungarian regions from 1964 and detailed grapevine production data from 2000-2006. For the scenarios approach we applied GCMs of GFDL (*Geophysical Fluid Dynamics Laboratory, USA*) which were downscaled to Hungary and refer to about 2030 and 2060 as well as CRU control data base with reference time series 1901-2000, PRUDENCE monthly data with reference time series 2071-2100 (based on *Hadley Centre*, A2, B2 scenarios), PRUDENCE control data (reference time series 1961-90) and finally monthly data of *Tyndall Centre* with reference period 1901-2000 (CRU) and 2001-2100 (scenario) which was provided by *Mitchell, 2004,* with 10' resolution. The resolution of the downscaled PRUDENCE data is 5 km (*Christensen, 2005; New et al., 1999; Bartholy et al., 2007, a,b,c*).

During our work we usually faced data-problems: the available historical data were often too short, not detailed enough or not relevant. To avoid the problem of data absence or shortage we used some very effective data-management methods which are known in the literature such as:

- Phillips-method for making the data temporary and spatially relevant (*Phillips, 1971*).
- Delphi-method for the synthesis of experts' opinion (*Linstone and Turoff, 2002*).
- Smoothing methods for the distribution determination.
- Triangle-method for the probability assessment (*Hardaker et al., 2004*).
- Rank correlation or *Fackler* stochastic dependency methods to determinate the dependency of the risk variables (*Fackler, 1991*).

WEATHER GENERATOR C2W

There were available historical and control weather data for the baseline periods 1961-90 or 1901-2000. Moreover, there were available RegCM scenarios with reference period 2071-2100. For the period in between, however, we needed a weather generator the weather data of which can somehow connect the two periods. We do not say that the climate changes proceeds in this way, this was just an approximated approach for the time in the near future. We needed it because stakeholders can be persuaded only if we draw a possible scheme of near future as well. To this, we used C2W (*Bürger, 1997*) which is aimed at disaggregating climatological means and anomalies into realistic weather processes. The weather parameters were calculated by a multiple linear fit connecting the baseline and the far future parameters. The parameters were then normalized by the probit normalization method. Then a first order autoregressive model was fitted to the normalized parameters. By way of Monte-Carlo simulations it was assured that the means of the simulated data converge statistically to the given parameters. The practical work of data extraction and generation was made by *Solymosi and Kern* (*Solymosi et al., 2008*). The simulated data, however, are not suitable for extreme weather event approach but they are suitable for trend analysis.

DATA MANAGEMENT SYSTEM VIN-MET

In order to collect, organize, manage and search databases for climate change research in a handsome and friendly way, we used a special data management system named VIN-MET which was developed by *Szenteleki et al. (2007b).* The system has the capacity to filter and aggregate data from different perspectives.

The software contains several basic index examinations, all of which have been formulated and accepted at international level and précised at national level.

There are available climatic profile indicators for daily as well as monthly data by combining temperature (minimum, average, maximum), the distribution of precipitation and radiation. In the case of daily data, the system of conditions can be set up by day, but for making parameters for longer time periods (weeks, for example), linear interpolation can be applied.

VIN-MET is suitable for finding the coexistence or absence of several meteorological profile indicators. Applying the software we can evaluate historical as well as RegCM data while learning temperature and precipitation characteristics.

PRODUCTION RISK INCREASE APPROACH

The historical production data were corrected with the help of Phillips-method. Three efficiency criteria were considered, namely: the E-V-efficiency, the stochastic dominance based on subjective distribution functions (which were calculated based on historical data and experts' opinion), as well as the criterion based on the utility function. The risk increase was in several cases evident, however, in some cases there was no ranking between the time series. The risk increase was finally proved by a simplified variant of the general stochastic dominance criterion (*Hardaker et al., 2004*).

The utility function was calculated depending on the degree of absolute risk aversion r_a as: $U(x,r_a) = \int U(t,r_a) \cdot f(t)dt$. The certainty equivalent CE was defined as: $CE(x,r_a) = U^{-1}(x,r_a)$. Under the assumption of a negative exponential utility function, U can be approximated by:

$$U(x,r_a) = \sum(F_{i+1} - F_i)\left[1 - \frac{(\exp(-r_a x_i) - \exp(-r_a x_{i+1}))}{r_a(x_{i+1} - x_i)}\right]$$

Certainty equivalent CE can be obtained as the inverse of U by the formula:

$$CE = \frac{-\ln[1 - U(x,r_a)]}{r_a}$$

If we represent the graph of certainty equivalent CE depending on the absolute risk aversion r_a, the highest curve indicates the less risky time series.

With the above listed data management techniques and graphic representation we proved that in every examined region the risk of vine production increased between 1964 and 2000, independently to the rate of risk aversion. In some regions the rate of increase became even quicker (Fig. 1). Though some of the examined regions are quite different from each other with respect to their mesoclimates, terrains as well as vine production structures, the fact of risk increase can undoubtedly be proved for all of them (*Ladányi et al., 2007*). In order to see the trends, the time interval 1964-2000 was split into four parts: 1964-76, 1970-82, 1976-88 and 1988-2000 and the risk of vine production was elicited for each interval:

TS1: 1964-76 no symptoms of climate change
TS2: 1970-82 extreme high/low production occurs rarely;
TS3: 1976-88 yield loss occurs frequently;
TS4: 1988-2000 serious extreme events, warming, increased variability of production.

PLANT SPECIFIC WEATHER INDICATOR APPROACH

As Hungary has relatively dry climate, soil plays a relatively smaller role in grapevine production because wine quality is determinated mainly by temperature and precipitation, therefore, in our first survey, we considered temperature and precipitation/humidity effects, only.

Temperature sensitivity of grapevine

Temperature effect on grapevine quality and quantity is not a question (*Jones et al., 2000*), however, it can be very different in different phenological phases and when accompanied by different other circumstances (e.g. high/low precipitation and/or humidity, radiation, wind, etc.). Let us consider the most important ones.

In early bud development relatively high temperature improves fruitfulness (*Gladstones, 1992*). After the initialization of bud development frost can severely damage the potential fruiting load (*Trought et al., 1999*). At budburst the plant is quite sensitive to temperature fluctuation (*Martin and Dunn, 2000*) and the number of flowers increases under cool temperature (*May, 2000*). Near flowering high temperature reduces fruitfulness while low one reduces fruit set (*Ebadi et al., 1996*) which means practically that grapevine is sensitive on temperature during the whole spring.

During veraison extreme heat events, especially associated with hot winds and low humidity can cause serious damages, at most risk are red varieties and berries that are well exposed (*Carbonneau, 1985*). Warm summer, nevertheless, decreases the risk of diseases.

High temperature while ripening results in general poorer quality must concerning with low acid and pH content increase as well as phenolic content of the must (*Herrick and Nagel, 1985*). In very hot environment earlier maturity can happen shortly after the warmest month which is quite unfavourable for plant function. Under cool circumstances, nevertheless, white wines become to be fresher, more acidic and finer in bouquet and aroma (*Jackson and Lombard, 1992*). According to *Coombe (1970)* the optimum daily average temperature is between 17-26 °C in this period or say 23-25 °C after *Buttrose (1969)*. Daytime temperature over 30 °C can be very harmful, especially when accompanied by hot nights (*Kliewer and Torres, 1972*).

Low variation in temperature around the mean in the last month before harvest helps grapevine to pick up great flavour, aroma and pigmentation. The optimum mean temperature is about 15-21 °C (*Johnson and Robinson, 2001*) and 10-15 °C around harvest. High temperature, however results higher soluble sugar content in grape (*Jackson and Lombard, 1992*) and high alcohol content and less fine taste and aroma in wine (*Becker, 1977*). In case the temperature is extremely high in this period (over 33 °C), transpiration and photosynthesis is impeded and sugar assimilation is reduced.

If the daytime mean temperature is high in harvest season, photosynthesis and net assimilation are suppressed and it can result an inflated estimate of grape maturity.

If the autumn temperature is high in post harvest season, re-accumulation of carbohydrates prior to defoliation is improved, thus bud and inflorescence differentiation is improved and spring growth in the following year is supported (*Shaulis and Pratt, 1965*).

All impacts of warming are of concern to Hungary as in our region (Carpathian Basin) A2 and B2 scenarios predict relatively higher warming compared to global rates. Though warming is the lowest in spring, we expect it to be higher than 3 °C (A2) or 2.5 °C (B2). Warming is the highest in summer (over 4 °C) and autumn but it is not lower than 3 °C in winter, either.

Warming nevertheless is expected to come with unequally distribution and with serious extremes in summer (long hot and dry periods) and at nights (Table 1) which has an impeding impact to acidity retention.

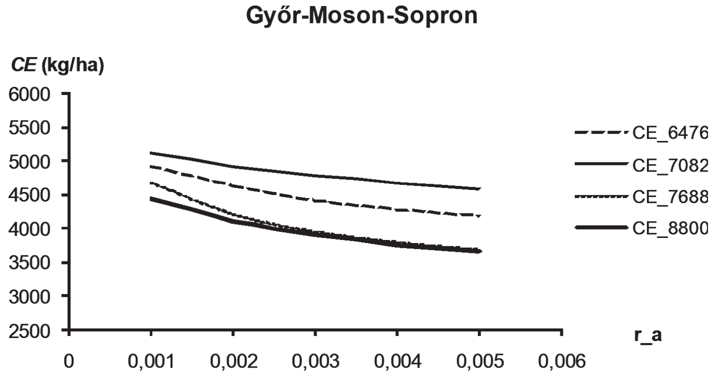
Autumn frost (-15 to -18 °C) directly damages the canes and maturing berries. Damage to canes and leaves leads to premature senescence and a lack of post harvest assimilate storage to support the following season's spring growth (*Shaulis and Pratt, 1965; Trought et al., 1999*). Moreover, temperature below -25 °C kills most cultivars.

Because of the quite high rate of the expected winter warming in Hungary, the risk of winter frost decreases considerably, however, the risk of spring frost increases, mainly because of early frost free days and earlier initialization of bud development and flowering.

Temperature indicators

Based on international literature and Hungarian experts' opinion as well as threatening scenarios' predictions and case studies we have drawn up a list of the most important plant specific weather indicators for grapevine with Hungarian location.

Figure 1



Stochastic efficiency for vine production in Győr-Moson-Sopron county with respect to 1964-76, 1970-82, 1976-88, 1988-2000. If we represent the graph of certainty equivalent depending on the absolute risk aversion, the highest curve indicates the less risky time series

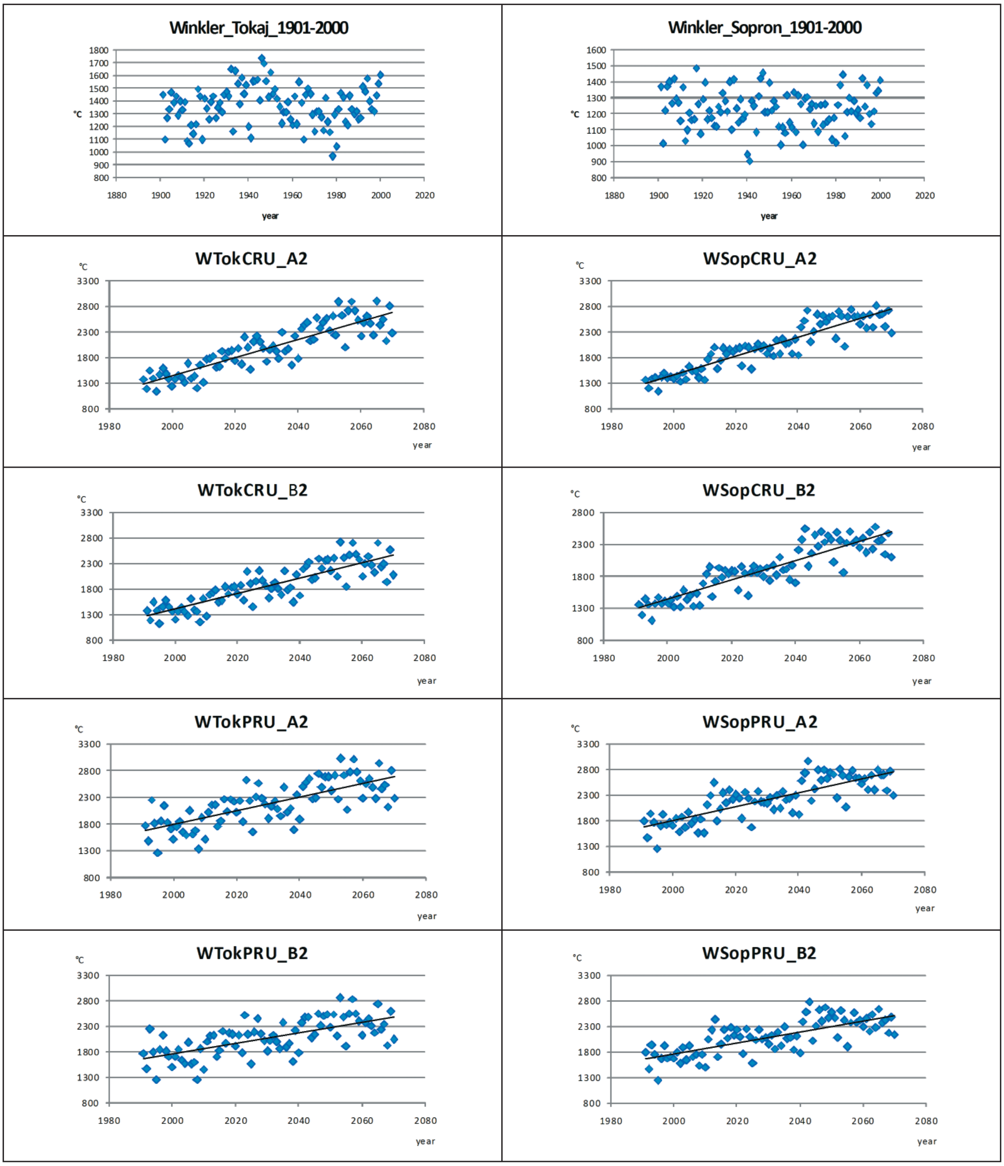
Table 1

Expected changes of extreme temperature indices after 2071 in Hungary

Extreme indices	The rate of change
Number of days when the daily maximum temperature is above 25 °C	+39%
Number of days when the daily maximum temperature is above 30 °C	+91%
Number of days when the daily maximum temperature is above 35 °C	+250%
Number of days when the daily maximum temperature is under 0 °C	–75%
Number of days when the daily minimum temperature is under –10 °C	–83%
Number of days when the daily minimum temperature is under 0 °C	–65%
Number of days when the daily minimum temperature is above 20 °C	+625%

Source: Pongrácz and Bartholy, 2007

Figure 2



Winkler index (Tokaj and Sopron regions) calculated for
1. 1901-2000 as well as for 1991- 2070 (scenarios).
The weather data were interpolated by C2W weather generator between
2. CRU and Prudence Hadley Center (HC) A2,
3. CRU and HC B2,
4. Prudence Controll and HC A2,
5. Prudence Controll and HC B2

We do not state that production (quality and quantity) is exactly determined by these factors and there can not be other important indicators. We just think that grapevine production depends on these factors very much and there has been detected a very strong, mainly very obvious connection between years with high/low amount and/or quality of production and the values of the weather indicators in the historical data. Therefore, if we learn the indicators more or less, we can conclude the production as well as the expected risk in the future, too (*Ladányi et al., 2007; Szenteleki et al., 2007b*).

With the help of VIN-MET data management software we investigated the trends of the outlined indicators. Corresponding to the conducted literature and Hungarian case studies we identified climate indicators' effects that are likely associated with grapevine growth and/or grape quality.

One of the most commonly used indices is *Heat Degree Days* (°C) known also as *Winkler Index – WI –* (*Amerine and Winkler, 1944; Winkler et al., 1974*). The basis of this index is that growth of grapevines is limited to above 10 °C; the amount of average temperature experienced above this baseline is summed for the entire growing season (April to October). *Gladstones (1992)* advocates the adoption of an index known as *Biologically Effective Day Degrees* (°C) – *BEDD*. This index similarly sums the heat experienced over ten degrees like *WI*. However, *Gladstones* suggests that there is no further advance in phenological development with temperatures above 19 °C. He therefore suggests this index with a cut-off at 19 °C. *Salonius (2002)* proposes that for a more detailed survey *Degree Days* are worthy to record for each month as well.

According to *Riou's (1994) Winkler Index* classification of the viticultural climatic regions, Sopron and Tokaj grapevine production regions of Hungary are belonging to the first (below 1390 °C) and the second (1391-1670 °C) coolest classes based on temperature data of 1901-2000. Both regions, however, are expected to be belonging to the fifth (warmest) regions (over 2220 °C) up to 2070 based on A2 and B2 scenarios' data of Prudence Hadley Center (Fig. 2). Compare this with the fact that the fifth class corresponds to the current *Winkler Index* values of e.g. *Split* (South-Croatia), *Palermo* (Italy) or *Algiers* (Algeria).

We can see that *Biologically Effective Day Degrees (°C)* of *Tokaj* and *Sopron* are also both expected to increase if we compare the values based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios). Moreover, not only variances but also coefficients of variances (%) increase significantly, too (Fig. 3, Table 2).

The most widely accepted indicator of the suitability of a site to produce quality grapevines is the so-called *Huglin Index* (°C) – *HI* – (*Huglin, 1978, 1986*). Huglin Index is defined by

$$HI = \sum_{1.\,April}^{30\,Sept.} \frac{[\max(0,(T_{\max} - 10\,°C)) + \max(0,(T_{aver} - 10\,°C))]}{2} * K$$

where $T_{\max}$ and T_{aver} denote the daily maximum and average temperature while K denotes a coefficient for the day length. (K is ranging from 1.02 to 1.06 between 40° and 50° of latitude.) *Huglin Index* provides us some more information than *Winkler Index* does as daily maximum is considered, too. Moreover, these two indices are highly correlated to each other, meanwhile, *Huglin Index* is higher correlated to quality than *Winkler Index* (*Tonietto and Carbonneau, 2004*). Compare the graphs of *Huglin Index* values based on temperature data of 1901-2000 and the ones of A2 and B2 scenarios' predictions of *Prudence Hadley Center* (Fig. 4)! According to the classification due to *Tonietto and Carbonneau (2004)*, we can conclude that up to 2070 Hungarian grapevine growing regions may shift from temperate class (over 1800 °C and under 2100 °C) to warm class (over 2400 °C and under 3000 °C). It means that, supposed that humidity, radiation and wind circumstances allow it, regions producing now *Riesling, Pinot*

Noir, Chardonnay, Merlot or Cabernet franc may become to be suitable for *Cabernet Sauvignon*, *Grenache* or even all cultivated varieties as there is no more constraint to ripen them. Till the end of the century, however, the values of *Huglin Index* may exceed the needs of even the late varieties resulting high risk of production.

The grapevine ripening capacity of a region has also been related to the mean temperature of the warmest month (*MTWM*) or, on the north hemisphere, shortly to *Mean July Temperature* (°C) – *MJT* – (*Dry and Smart, 1988*).

Note that *Latitude Temperature Index* (°C) – *LTI* – is more general than *Mean July Temperature* as it considers the latitude as well: *LTI* = *MJT**(60 – latitude) (*Jackson and Cherry, 1988*). However, since latitude does not change with time, we have not considered this index.

Mean July Temperature (°C) indices calculated for the scenario data are significantly higher than the ones calculated for time series 1901-2000 in both *Tokaj* and *Sopron* regions. Note that not only variances but also coefficients of variances (%) are much higher for scenario data which means us significantly hotter and more variable July temperatures in the next few decades (Table 3).

Harvest Maximum Temperature (°C) and *Winter Minimum Temperature* (°C) (*Happ, 1999*) are indices with which we can filter years with extreme high and low temperature events that can result serious damages. *Winter Minimum Temperature*, moreover, can be applied to the risk analysis of pests and diseases the lifecycle, spread and/or the rate of invasion of which are expected to change in Hungary with high winter minimums (*Suthurst et al., 2000*).

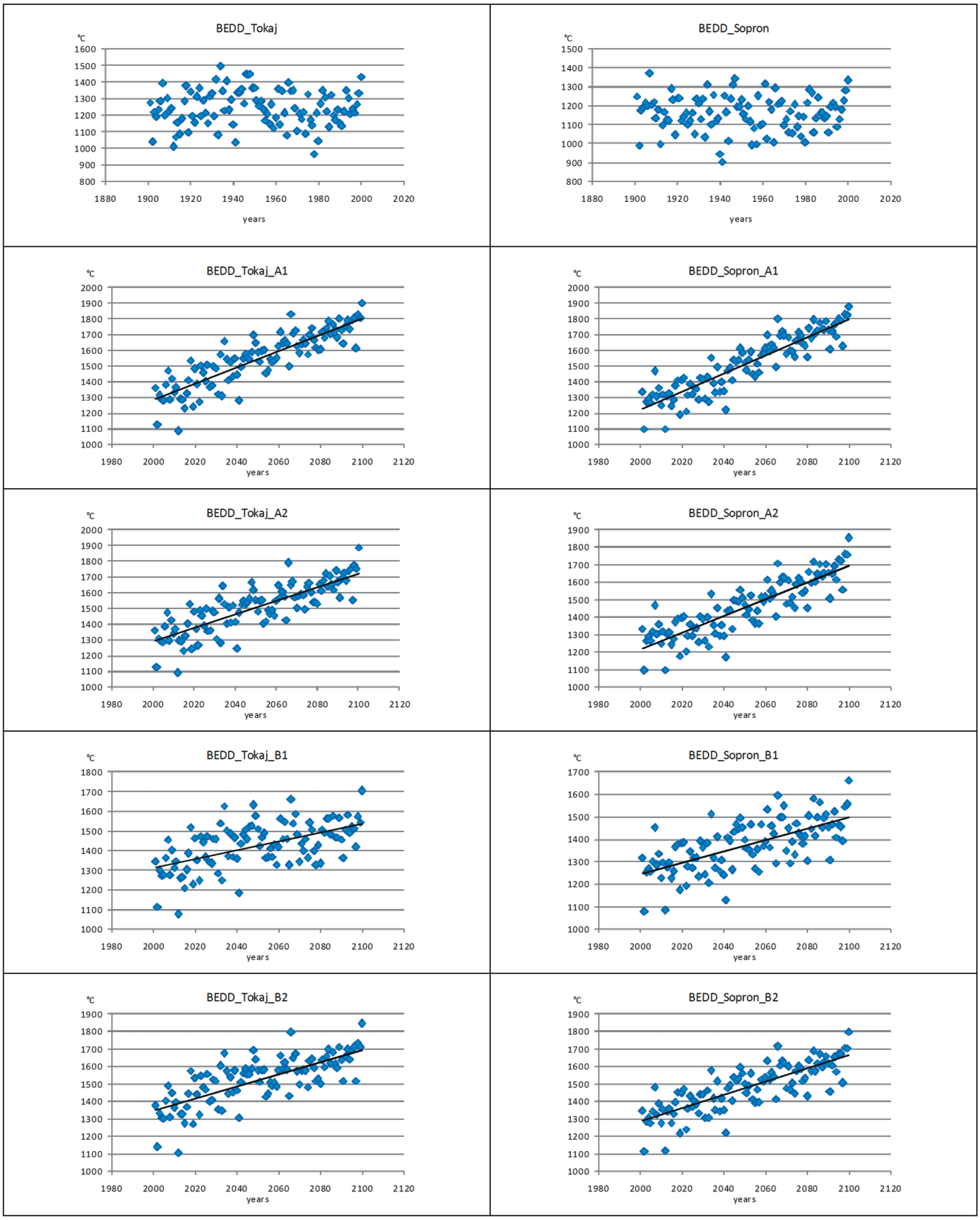
Continentality (*Gladstones, 1992*) is an index which can successfully indicate one of the most hardly detected changes, namely, how Hungarian climate is becoming "less and less continental" and "more and more Mediterranean" (with extremes that are not characterizing any current climate).

Spring Frost Index (°C) (*Gladstones, 2000; Trought et al., 1999*) is a tool to measure spring frost risk. *Spring Frost Index* practically measures the tendency to have large fluctuations in temperature over a short period of time as the index is based on the average mean temperature for a given month (say, April) and the average minimum temperatures of the same month. According to *Kurtural (2007) Spring Frost Index* classification, based on time interval 1901-2000, Tokaj is belonging to the regions with moderate (11.5-13) frost risk with 9 years of high values (above 13.5); Sopron is belonging to the one with low (9-11) frost risk with 11 years of moderate and 4 years of high values and with quite high variance. If we calculate *Spring Frost Index* from scenario data, the averages of both regions increase. Moreover, both regions reach in some years their *Spring Frost Index* value of 15 which is extremely high and happened never before 2000 (Table 4). Note that the coefficients of variances (%) do not change meaningfully.

Applying *Growing Season Length* (*Jordan et al., 1980; Jorgensen et al., 1996*) we can show how present site classification is changing with climate change since because of warmer springs and thus earlier bud break and flowering, the growing season length increases in Hungary.

The Growing Season Maximum Temperature Average (°C)) index (*Jones et al., 2005*) is created from the average monthly maximum temperature of the pre-harvest months (June-September). The index is particularly important from the aspect of both quality and quantity of production. The increase of the averages, the variances and the coefficients of variances for both regions is almost threatening (Table 5). Compare with the fact that while *Jones et al. (2005)* were considering the same index for nine European locations yet in the past 50 years, they calculated an increase of 1.8 °C, only, as an average.

Figure 3



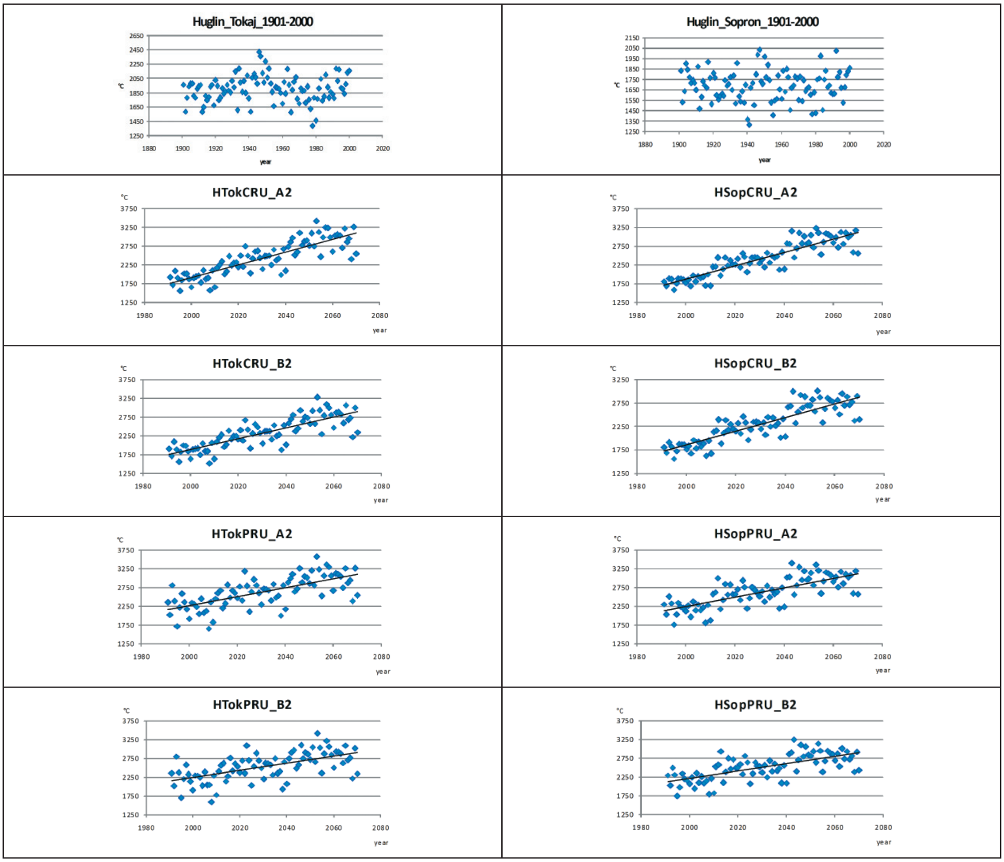
Biologically Effective Day Degrees (Tokaj and Sopron regions) calculated for 1901-2000 (top) as well as for 2001- 2100 (scenarios A1, A2, B1, B2), Tyndall database

Table 2

Averages, variances and coefficients of variances (%)
of the Biologically Effective Day Degrees (°C) indices for Tokaj and Sopron
based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios)

Tokaj	Average	Variance	CV	Sopron	Average	Variance	CV
1901-2000	1242.87	11759.71	8.73	1901-2000	1158.98	8537.70	7.97
A2	1509.55	23549.24	10.17	A2	1459.77	26125.13	11.07
B2	1523.79	18381.68	8.90	B2	1475.21	18609.44	9.25

Figure 4



Huglin_Tokaj_1901-2000

Huglin_Sopron_1901-2000

HTokCRU_A2

HSopCRU_A2

HTokCRU_B2

HSopCRU_B2

HTokPRU_A2

HSopPRU_A2

HTokPRU_B2

HSopPRU_B2

Huglin index (Tokaj and Sopron regions) calculated for
1. 1901-2000 as well as for 1991-2070 (scenarios).
The weather data were interpolated by C2W weather generator between
2. CRU and Prudence Hadley Center (HC) A2,
3. CRU and HC B2,
4. Prudence Controll and HC A2,
5. Prudence Controll and HC B2

Precipitation and humidity sensitivity of grapevine

Gladstones (1992) states that the best environment for grapes is with even rainfall distribution, moderate temperatures and sufficient sunshine with sufficient soil moisture stores or irrigation. Hungary, however, is not belonging to the regions with optimal circumstances. In general, in the last 10-20 years vineyards in Hungary have been suffering from relatively arid, hot and low humidity summer climate. Therefore, transpiration demands outstrip root water uptake, thus even with adequate soil moisture; grapevines close stomata and cease photosynthesis to conserve moisture (*Freeman et al., 1980*). As the saturation deficit increases, the moisture:carbon dioxide ratio increases, thus growth (yield) per unit of water transpired is decreased (*Barber, 1985*).

Grapevine is quite sensitive to both precipitation and humidity. The minimum level of rainfall or irrigation is of 500 mm or higher, especially if the growing season is characterised by high evapotranspiration rates (*Johnson and Robinson, 2001*). The ideal relative humidity is 50-65% for the ripening of grapes for table wine and 40-50% for fortified wines (*Gladstones, 1992*). More than sufficient relative humidity may result fungal infections (*Jackson and Lombard, 1992*). In spring grapevine is very susceptible to moisture stress. Heavy rain may promote vigorous growth which suppresses bud differentiation and fruit setting by causing overshading (*Johnson and Robinson, 2001*).

In case there is adequate moisture available till veraison, yield is higher and final sugar content is lower (*Alleweldt and Ruehl, 1982*). If there is severe moisture stress in the few weeks up until and after veraison, both berry and flavour development are endangered (*Carbonneau and Huglin, 1982*). Nevertheless, some moderate water stress can be favourable for colour and flavour by limiting berry size easing vegetative growth (*Ludvigsen, 1987; Mathews and Anderson, 1988*).

After veraison and before harvest moisture stress may reduce photosynthesis and thus the movement of sugar to the berry but may also increase the movement of potassium from the leaves to the fruit. The higher potassium:sugar ratio tends to increase must pH and results lower must and wine quality (*Freeman et al., 1982; Iland, 1988*). Excess rain in this period, however, may cause berry splitting, especially in hotter, drier climates (*Galdstones, 1992*) with delayed ripening even in hot climates (*Jackson and Cherry, 1987*). In this case, as a risk management strategy grape growers usually harvest the immaturate grapes (*Jackson and Lombard, 1993*) to avoid even greater loss.

If there is insufficient moisture available after harvest and prior to leaf fall, root growth, photosynthetic activity and assimilation for the following vintage are reduced which endanger a vigorous, even budburst and early growth in the following spring (*Gladstones, 1992*).

The risk of drought would be considerably higher in Hungary even if precipitation were not predicted to decrease over the growing period. Thus, if we add that summer precipitation deficit is expected to be up to 30% (A2) or 15% (B2), we expect that the increase of evapotranspiration rates leads to the reduction in available soil moisture in our region where water is already short, therefore the risk of drought is expected to be extremely high.

Precipitation indicators

Though there is no agreement if *Annual Rainfall* (mm) (*Bruggen and Semenov, 1999*) in Hungary is going to decrease at all, the yearly distribution and variety of it are expected to change considerably (*Bartholy et al., 2007a,b,c*). *Summer Rainfall* (mm) (*Nicholas et al., 1994*) is very important as besides warming, precipitation in expected to decrease in summer significantly, during the growing period of grapevine. Considering Table 6 we can see that there is significant provable change neither in averages, nor in variances or coefficients of variances (%) of the *Annual Rainfall* (mm) indices of Tokaj and Sopron. However, the case of *Summer Rainfall* (mm) indices is quite different. We can detect significant decrease in the averages and, meantime, an increase in variances and coefficients of variances (%). It means that climate change brings us not only much hotter but also much drier summers to Hungary.

The *Number of Growing Season Rain Days* (*Salinary et al., 2006*) gives some information about the (unbalanced) distribution of future precipitation. *Ripening Month Rainfall* (mm) (*Allen CG, 2005*) is the base of berry splitting and emergency early harvest events' risk assessment.

SUMMARY OF THE TRENDS IN HUNGARIAN CLIMATE AND THEIR IMPACTS ON GRAPEVINE PRODUCTION

According to the downscaled Prudence A2/B2 as well as Tyndall A1/A2/B1/B2 scenarios we can expect the following changes in Hungary up to and after 2070:

- Increasing mean temperature. The rate of increase is the greatest in summer (A2: 4.5-5.1 °C or B2: 3.7-4.2 °C), nevertheless, A2 and B2 scenarios predict more than 2.5-3 °C warming in each season and in all regions. Consequently, winter dormancy will be reduced. We can expect warmer and longer growing seasons and season's shift of 6-25 days earlier over numerous varieties and locations. Ripening will begin earlier during the hotter summer months. Higher temperatures at ripening may depress quality and will shorten the harvest window for premium quality wines. Because of more rapid phenological development, suitable locations of varieties with long time growers' experience are expected to be shifted northward, while current grape growing regions may shift into another maturity type.
- Increasing winter-spring (A2: 0-37%, B2: 3-27%) while decreasing summer-autumn precipitation (A2: 3-33%, B2: 0-20%). Less water is likely to be available, due to either or both increased evapotranspiration and lower precipitation, and yield/quality variability is likely to increase creating a higher economic risk for the producer.
- Increased atmospheric CO_2 concentration. It can be beneficial to plant growth but some studies of the combined effect of higher CO_2 concentrations, temperatures and solar radiation indicate that yield may actually be depressed (*Schultz, 2000a*). In warmer climates it is possible to ripen larger crops as there is more photosynthetic potential (*Howell, 2001*). Anyway, modelling researches do not still agree on the effect of CO_2 on assimilate (sugar and starch) accumulation in the fruit, the timing of bud initialization and flowering and the final composition of the fruit which enlarges the uncertainty and risk of production in the future (*Tate, 2001; Taylor, 2004*).
- More frequent and serious anomalies (heat wave, storm, wind, flood, hail). More complex management is needed against catastrophes and for already scarce water resources. Formerly, grapevines were mostly not irrigated in Hungary, thus there may be a substantial risk in terms of more frequent and more severe droughts with negative effects on yield and quality (*Schultz and Lebon, 2005*).
- Warming during also the dormant periods. Thus the number of winter/frost days decreases at more than 60% (Table 1), nevertheless, late frost risk increases because of early vegetation period start.
- Longer extreme periods as well as increased seasonal variability. The number of days with maximum daily temperature above 25 °C will increase at 39%, it will be nearly as high as 140-150 days in some regions and it is not less than 120 days a year anywhere (according to A2). This factor of changes may result risk increase in most widely distributed sectors in connection with grapevine production (*Kenny et al., 1993*).
- Changes in the presence or intensity of pests and diseases. Current integrated

Table 3

Averages, variances and coefficients of variances (%) of the Mean July Temperature (°C) indices for Tokaj and Sopron based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios)

Tokaj	Average	Variance	CV	Sopron	Average	Variance	CV
1901-2000	20.89	1.69	6.23	1901-2000	20.04	1.55	6.22
A2	24.32	5.71	9.83	A2	23.56	5.80	10.23
B2	24.27	3.88	8.11	B2	23.49	3.67	8.15

Table 4

Averages and variances of the Spring Frost Indices for Tokaj and Sopron based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios)

Tokaj	Average	Variance	Sopron	Average	Variance
1901-2000	12	0.67	1901-2000	10.7	1.32
A2	12.03	0.56	A2	11.08	1.43
B2	12.13	0.39	B2	11.17	1.60

Table 5

Averages, variances and coefficients of variances (%) of the Growing Season Maximum Temperature Average (°C) indices for Tokaj and Sopron based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios)

Tokaj	Average	Variance	CV	Sopron	Average	Variance	CV
1901-2000	25.28	1.38	4.64	1901-2000	23.80	0.85	3.87
A2	29.75	7.38	9.13	A2	27.97	6.53	9.14
B2	29.90	5.42	7.79	B2	27.91	3.80	6.98

Table 6

Averages, variances and coefficients of variances (%) of the Annual and Summer Rainfall (mm) indices for Tokaj and Sopron based on time series 1901-2000 and 1991-2070 (A2 and B2 scenarios)

Annual Rainfall (mm)							
Tokaj	Average	Variance	CV	Sopron	Average	Variance	CV
1901-2000	608.07	12812.57	18.62	1901-2000	627.19	10500.66	16.34
A2	593.28	12396.20	18.77	A2	616.52	10424.90	16.56
B2	594.39	12237.33	18.61	B2	629.13	10514.54	16.30
Summer Rainfall (mm)							
Tokaj	Average	Variance	CV	Sopron	Average	Variance	CV
1901-2000	214.31	5230.54	33.75	1901-2000	222.98	4195.58	29.05
A2	163.50	5701.26	46.18	A2	179.12	4590.85	37.83
B2	166.09	5257.32	43.66	B2	180.94	4321.15	36.33

pest management strategies may not be useful any more (*Emmett et al., 2000*) e.g. because of warmer dormant periods. Thus new technologies and management practices are needed to be put into action in order to mitigate the risk caused by pests and diseases.

- Increasing uncertainty due to delayed ecological and economical feedback.
- Extreme positive and negative production, nevertheless, in both cases with great economical risk.

Now it is obvious that Hungarian grapevine production depends highly on the magnitude, rate and distribution of future warming, precipitation and extreme events. The issue is likely mostly about adaptation. We can recognize that for grapevine production we need the assessment of the expected impacts and it is necessary adapt to them accordingly by altering varieties and management practices or mitigate production quantity and/or quality risk by developing new technologies in time such that our grandchildren can benefit from them.

OUTLOOK

In our near future plans intend to start a modelling work (parameterisation and validation) with DISAT (Bindi), the data management of which has been started yet. We analyse how productivity (quantity, quality), phenology, pest-disease occurrence etc. change under different environmental and climate circumstances.

Meanwhile we are going to create a questionnaire and an initiative of intensive dialog with growers in order to get and provide information, persuading them about necessary responses, support them in decision and organize warning system.

Moreover, we aim to create and analyse combined (temperature – precipitation) indicators as well a generalized-time indicators as well in order to handle the seasons more flexible. We plan to approach varieties-specific impact and adaptation strategies.

We go on with collecting historical data (soil, hydrological, meteorological, productivity, etc.), further monitoring as well as downscaling.

ACKNOWLEDGEMENTS

Our work was supported by NKFP-B3-2006-0014, by ADAM GOCE 018476 EU6 project.

REFERENCES

(1) Allen Consulting Group: (2005): Climate Change, Risk and Vulnerability. Promoting an efficient adaptation response in Australia. Final Report, March 2005. (2) Alleweldt, G. – Ruehl, E. (1982): Utersuchungen zum Gaswechsel der Rebe. I. Einfluss von Temperatur, Blattalter und Tageszeit auf Nettophotosynthese und Transpiration. Vitis, 21, 93-100. pp. (3) Amerine, M. A. – Winkler, A. J. (1944): Composition and quality of musts and wines of Californian grapes. Hilgardia 15, 493-675. pp. (4) Barber, S. A. (1985) Potassium availability at the soil-root interface and factors influencing potassium uptake. In: R. D. Munson (ed) ‘Potassium in Agriculture’, Madison. 309-324. pp. (5) Bartholy, J. – Pongrácz, R. (2007a): Regional analysis of extreme temperature and precipitation indices for the Carpathian Basin from 1946 to 2001.Global and Planetary Change 57: 83–95. pp. (6) Bartholy, J. – Pongrácz, R. – Torma, Cs. – Hunyady, A. (2007c): Regional climate change expected in Eastern/Central Europe. 87th AMS Annual Meeting (AMS Forum: Climate Variations and Change Manifested by Changes in Weather). San Antonio, TX, 14-18 January 2007 (7) Bartholy, J. – Pongrácz, R. – Gelybó, Gy. – Szintai, B. – Szabó, P. – Torma, Cs. – Hunyady, A. – Kardos, P. (2007b):

Expected regional climate change in the Carpathian Basin using different climate model outputs. Geophysical Research Abstracts, Vol. 9, CD-ROM. EGU General Assembly 2007. EGU2007-A-04602. Vienna, Austria, 15-20 April 2007. (8) Becker, N. J. (1977): Experimental research on the influence of microclimate on grape constituents and on the quality of the crop. IN: Proceedings, OIV Symposium on Quality of the Vintage. Oenological and Viticulture Research Institute, Capetown. 181-188. pp. (9) Bruggen, van A. H. C. – Semenov, A. M. (1999): A new approach to the search for indicators of root disease suppression. Australasian Plant Pathology. 28, 4-10. pp. (10) Buttrose, M. S. (1969): Vegetative growth of grapevine varieties under controlled temperature and light intensity. Vitis, 8, 280-285. pp. (11) Bürger, G. (1997): On the disaggregation of climatological means and anomalies. Climate Research, Vol. 8. 183-194. pp. (12) Carbonneau, A. (1985): Trellising and canopy management for cool climate viticulture. In: D. A. Heatherbell, P. B. Lombard, F. W. Bodyfelt and S. F. Price (eds) Proceedings of the International Symposium on Cool Climate Viticulture and Enology, Oregan. 158-174. pp. (13) Carbonneau, A. P. – Huglin, P. (1982): Adaptation of training systems to French regions. In: Proceedings of the Grape and Wine Centennial Symposium, University of California, Davis, 1980, 376-385. pp. (14) Coombe, B. G. (1970): Fruit set in grapevines: the mechanism of the CC effect. Journal of Horticultural Science, 45, 415-424. pp. (15) Christensen, J. H. (2005): Prediction of Regional scenarios and Uncertainties for Defining European Climate change risks and Effects – Final Report. DMI. 269 p. (16) Dry, P. R. – Smart, R. E. (1988): Vineyard site selection. In: B. G. Coombe and P. R. Dry (eds) 'Viticulture', Vol. 1: Resources in Australia. Australian Industrial Publishers: Adelaide 190-204. pp. (17) Ebadi, A. – May, P. – Coombe, B. G. (1996): Effect of short-term temperature and shading on fruit-set, seed and berry development in model vines of V. vinifera, cvs Chardonnay and Shiraz. Australian Journal of Grape and Wine Research. 2(1), 2-9. pp. (18) Emmett, R. W. – Magaey, P. A. – Chakraborty, S. (2000): Shifts in pest and disease dynamics of vineyards – implications for integrated pest management. In: Proceedings of 5th International Symposium on Cool Climate Viticulture and Oenology, Melbourne, January, 2000. (19) Fackler, P. L. (1991): Modeling Interdepencies: an Approach to Simulation and Elicitation. American Journal of Agricultural Economics 73, 1091-1098. pp. (20) Freeman, B. M. – Kliewer, W. M. – Stern, P. (1982): Influence of wind breaks and climatic region on diurnal fluctuation of leaf water potential, stomatal conductance, and leaf temperature of grapevines. American Journal of Enology and Viticulture, 33, 233-236. pp. (21) Freeman, B. M. – Lee, T. H. – Turkington, C. R. (1980): Interaction of irrigation and pruning level on grape and wine quality of Shiraz vines. American Journal of Enology and Viticulture, 31, 124-135. pp. (22) Gladstones, J. S. (1992): Viticulture and Environment. Winetitles, South Australia (23) Gladstones, J. S. (2000): Past and Future Climatic Indices for Viticulture. 5th International Symposium for Cool Climate Viticulture and Oenology, 2000, Melbourne, Australia (24) Happ, E. (1999): Indices for exploring the relationship between temperature and grape and wine flavour. The Australian and New Zealand Wine Industry Journal. 1999, 14(4): 68-75. pp. (25) Hardaker, J. B. – Huirne, R. B. M. – Anderson, J. R. – Lien, G. (2004): Coping with Risk in Agriculture. 2nd edn. CABI Publishing, Wallingford-Cambridge, 2004 (26) Herrick, I. W. – Nagel, C. W. (1985): The caffeoyl tartrate content of white Riesling wines from California, Washington and Alsace. American Journal of Enology and Viticulture, 36, 95-97. pp. (27) Howell, G. S. (2001): Sustainable grape productivity and the growth yield relationship: a review Am. Journal of Enology and Viticulture 52(3). (28) Huglin, P. (1978): Nouveau mode d'evaluation des possibilities heliothermiques d'un milieu viticole, C. R. Academy of Agriculture in France (111726) (29) Huglin, P. (1986): Biologie et ecologie de la vigne. Payot Lausanne, Paris (30) Jackson, D. I. – Cherry, N. J. (1988): Prediction of a district's grape-ripening capacity using a latitude temperature index (LTI). American Journal of Enology and Viticulture, 39, 19-28. pp. (31) Jackson, D. I. – Lombard, P. B. (1992): Environmental and management practices affecting grape composition and wine quality – A review. American Journal of Enology and Viticulture, 44(4), 409-430. pp. (32) Johnson, H. – Robinson, J. (2001): The World Atlas of Wine. 5th edition. Mitchell Beazley: London (33) Jones, G. V. – Davis, R. E. (2000): Using a synoptic climatological approach to understand climate-viticulture relationships. International Journal of Climatology, 20, 813-837. pp. (34) Jones, G. V. – Duchene, E. – Tomasi, D. – Yuste, J. – Braslavska, O. – Schultz, H. – Martinez, C. – Boso, S. – Langellier, F. – Perruchot, C. – Guimberteau, G. (2005): Changes in European winegrape phenology and relationships with climate. http://www.sou.edu/geography/jones/Publications/ (35) Jordan, T. D. – Pool, R. M. – Zabadal, T. J. – Tompkins, J. P. (1980) Cultural practices for commercial vineyards. New York State College of Agriculture and Life Sciences. Misc. Bulletin 111. (36) Jorgensen, G. – Escalera, B. M. – Wineman, D. R. – Striegler, R. K. – Zoldoske, D. – Krauter (1996): Microsprayer Frost Protection in Vineyards. VERC. CATI Publication #960803. (37) Kenny, G. J. – Harrison, P. A. (1993): The effects of climate variability and change on grape suitability in Europe. Journal of Wine Research, 3(3), 163-184. pp. (38) Kliewer, W. M. – Torres, R. E. (1972): Effect of controlled day and night temperatures on coloration of grapes. American Journal of Viticulture and Enology, 23, 71-77. pp. (39) Kurtural, S. K. (2006): Growing Regions and Site Selection for Grapes. University of Kentucky. http://www.uky.edu/Ag/Horticulture/siteselection.pdf. (40) Ladányi, M. – Erdélyi, É. – Szenteleki, K. (2007): The increase of the risk in Hungarian vine production due to climate change. Efita Conference, Glasgow, Scotland, 2007 (41) Linstone, H. A. – Turoff, M. (eds) (2002): The Delphi Method: Techniques and Applications. New Jersey Institute of Technology, Newark, New Jersey (42) Ludvigsen, R. K. (1987): Wise use of irrigation could improve yield without harming wine quality. Australian Grapegrower and Winemaker, 280, 102-108. pp. (43) Martin, S. R – Dunn, G. M. (2000): Effect of pruning time and hydrogen cyanamide on budburst and subsequent phenology of Vitis vinifera L. variety Cabernet Sauvignon in central Victoria. Australian Journal of Grape and Wine Research, 6(1), 31-39. pp. (44) Mathews, M. A. – Anderson, M. M. (1988): Fruit ripening in Vitis vinifera L.: responses to seasonal water deficits. American Journal of Enology and Viticulture, 39, 313-320. pp. (45) May, P. (2000): From bud to berry, with special reference to inflorescence and bunch morphology in Vitis vinifera L. Australian Journal of Grape and Wine Research, 6(2) 82-98. pp. (46) Mitchell, T. D. – Carter, T. R. – Jones, P. D. – Hulme, M. – New, M. (2004): A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: the observed record (1901-2000) and 16 scenarios (2001-2100). Tyndall Centre Working Paper 55, University of East Anglia, Norwich, UK, http://www.tyndall.ac.uk/publications/working_papers/wp55.pdf (47) New, M. – Hulme, M. – Jones P. (1999): Representing twentieth-century space-time climate variability. Part I: Development of a 1961-90 mean monthly terrestrial climatology. – Journal of Climate 12: 829–856. pp. (48) Nicholas, P. – P. Magarey, – M. Wachtel. (1994): Diseases and Pests. Grape Production Series, Winetitles, Adelaide, 106. (49) Phillips, J. B. (1971): Statistical Methods in Systems Analysis In: Dent, J. B. – Anderson, j. R. (eds) Systems Analysis in Agricultural Management. Wiley, Sydney, 34-52. pp. (50) Pongrácz R. – Bartholy J. (2007): Detected trends in extreme temperature and precipitation indices in the Central/Eastern European region. 87th AMS Annual Meeting (AMS Forum: Climate Variations and Change Manifested by Changes in Weather). San Antonio, TX, 14-18 January 2007. (51) Riou, C. (1994): The Effect of Climate on Grape Ripening: Application to the Zoning of Sugar Content in the European Community, European Commission, Brussels, Luxembourg (52) Salinari, F. – Giosuè, S. – Tubiello, F. N. – Rettori,

A. – Rossi, V. – Spanna, F. – Rosenzweig, C. – Gullino, M. L. (2006): Downy mildew (Plasmopara viticola) epidemics on grapevine under climate change. Global Change Biology 12 (7), 1299–1307. pp. (53) Salonius, P. (2002): A New Climate Index for Grape Growing in Short Season Areas, Minnesota Grape Growers Association Annual Report, 2002 (54) Schultz, H. R. (2000a): Climate change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. Australian Journal of Grape and Wine Research, 6, 2-12. pp. (55) Schultz, H. R. (2000b): Impact of climate change in Europe, and climatology and physiology of UV-B radiation. In: Proceedings of the Fifth International Symposium on Cool Climate Viticulture and Oenology, January, 2000, Melbourne, Australia (56) Schultz, H. R. – Lebon, E. (2005): Modelling the effect of climate change on grapevine water relations. ISHS Acta Horticulturae 689: VII International Symposium on Grapevine Physiology and Biotechnology (57) Shaulis, N. – Pratt, C. (1965): Grapes: Their growth and development. Farm Research, Cornell University, No. 401 (58) Solymosi, N. – Kern, A. – Maróti-Agócs, Á. – Horváth, L. – Erdélyi, K. (2008): An easy to use tool for extracting climatic parameters from Tyndall datasets. Environmental Modelling & Software. (in press) (58) Suthurst, R. W. – Russell, B. – Maywald, G. F. (2000): Predicting the effects of climate change on pests of grapes using the CLIMEX model. In: Proceedings of 5th International Symposium on Cool Climate Viticulture and Oenology, January, 2000, Melbourne, Australia (59) Szenteleki, K. – Botos, E. P. – Szabó, A. – Horvath, Cs. – Martinovich, L. – Katona, Z. (2007a): Definition of the ecological facilities, ecological indicators and quality of products in the Hungarian vine and wine sector using updated GIS. 2007, EFITA Conference, Glasgow (60) Szenteleki, K. – Ladányi, M. – Szabó É. – Horváth, L. – Hufnagel, L. – Solymosi, N. – Révész, A. (2007b): Introducing the KKT climate research database management software. 2007, EFITA Conference, Glasgow (61) Tate, A. B. (2001): Global Warming's Impact on Wine. Journal of Wine Research, 12:2, 95-109. pp. (62) Taylor, J. A. (2004): Precision Viticulture and Digital Terroir. PhD Thesis. The Univ. of Sydney (63) Tonietto, J. – Carbonneau, A. (2004): A multicriteria climatic classification dydtem for grape-growing regions worldwide. Agricultural and Forest Meteorology, 124, 81-97. pp. (64) Trought, M. C. T. – Howell, G. S. – Cherry, N. (1999): Practical Considerations for Reducing Frost Damage in Vineyard. Report to New Zealand Winegrowers: 1999. Lincoln University. http://www.nzwine. com/assets/frost_review. pdf (65) Webb, L. B. – Whetton, P. H. – Barlow, E. W. R. (2005): Impact on Australian Viticulture from Greenhouse Induced Temperature Change. International Congress on Modelling and Simulation, Melbourne, 1504-1510. pp. (66) Winkler, A. J. – Cook, J. A. – Kliewer, W. M. – Lider, L. A. (1974): General Viticulture. University of California Press, Berkeley, 143-144. pp.

THE POTENTIAL IMPACTS OF CLIMATE CHANGE ON MAIN FIELD CROPS AND THEIR YIELDS, CASE STUDIES

ERDÉLYI, ÉVA

Keywords: climate needs, maize, modelling, phenology, risk, winter wheat.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

We examined the effects of climate change on main field crops, maize and winter wheat. We have traced the possible changes of their production risk, expected yield and phenology. With a new stochastic dominance criterion, we have proved that the risk of winter wheat and maize production has increased independently to the risk aversion of the decision maker. In search of the reasons, we analyzed the temperature and precipitation needs of winter wheat in each phenological phase. We examined the frequencies of extreme temperature values during the growing season, as well. For the comparison we used six of the most accepted climate scenarios (BASE, GFDL2535, GFDL5564, UKHI, UKLO, UKTR) and the historical meteorological data of their reference period 1960-1990. The location of our case studies was Debrecen, which is of big importance in Hungarian agricultural production. Our aim was to analyze the climate demands of the plants from both quantity and quality aspects. We have shown that the quality of winter wheat might be better in the near future and that with appropriate adaptation strategy we can benefit from climate change. Next we analysed how the yield and the length of the phenological phases of the plants are expected to change. As producing energy from biomass is one of the best ways to reduce GHG emissions, we give an idea of using agricultural byprodacts as renewable energy sources. We have simulated the future secondary biomass quantities and the proportion of the parts of the plant corn, as well. Modelling is a useful tool for investigation of the future circumstances without having expensive and long experiments. The simulations were run by 4M model. It can be stated that – as a result of temperature increase – the starting points of the phenological phases are expected to shift to earlier dates for both corn and winter wheat. Harvesting is predicted to be a day per ten years earlier in the future. We used the model for finding an adaptive strategy for increasing the yield with changing the sowing date. For both biomass and grain mass quantity the simulation results are very promising in case of the two weeks earlier sowing date. There is a wide scientific consensus that in analysing climate change impacts further interdisciplinary, collaborative research projects are very much needed all over the world.

INTRODUCTION

It is evident that global climate change is one of the serious problems facing humans in the 21st century. Climate and climate change basically determine agricultural production. Climate change affects agriculture in many direct and indirect ways. The tendency of a potential global climate change is still not obvious, but the most accepted models predict warming and increasing frequency of extreme weather events. Climate change is not only characterized by changes in temperature, but also by changes in other variables, like precipitation, global radiation, etc. Increasing atmospheric CO_2 and rising temperatures may allow earlier sowing dates, shorter phenological phases, longer vegetation period, enhance crop growth and increase potential crop yield. On the other hand, rising temperatures increase the crops' water demand. In combination with changing precipitation patterns, rising temperatures are expected to lead to increasing crop yields in areas with sufficient water supply, and decreasing yields in areas with hot and dry conditions. It is never more urgent to understand climate change impacts on risk in agriculture as the observed trends have undoubtedly great influence on production and quality. Anomalies are going to be increasingly frequent. Risk caused by climate change should be managed with coordinated adaptive strategies. In Hungary the risk of production is especially meaningful as it has considerably been increased in the last few decades. It gives us many questions, as well. Seeing the big increase in risk of field crop production, we decided to use a crop model for analyzing the biomass changes. We can say that moderate warming can increase the yield, but more increase of the temperature can cause big losses. Considering possible future changes we have to answer many questions about plant protection, safe food supply, economical factors, etc. Climate change has already various and considerable impacts on the environment, human health and society, which are expected to become more severe in future. In addition, the frequencies of extreme weather events such as droughts, heat-waves and floods have increased, so the future is very unpredictable. Preventive adaptation strategies are required for dealing with consequences, reducing the damages and the effects of uncertainty factors.

Living under changing climate conditions, one of our most urgent tasks is to create well-designed descriptive-forecasting systems, as well as to define the optimal preparing and response strategies to the conditions in change. While testing the efficacy of three dripping irrigation systems we found that biomass and grain levels of corn increased significantly in all used climate scenarios.

As maize is an energy crop, we analyzed the impacts of climate change on its growing periods using modelling method, a crop model with different climate scenarios as weather inputs. Analysing the observed and the future weather by using climate scenarios we see a big increase of the sum of the daily average temperature in the observed region, for the vegetation period (April-October) (Fig. 1).

We examined the effects of changing temperature on the proportion of the parts of the plant in biomass, as well.

This means that the starting date (sowing), ending date (ripening) and the length of the phenophases of growing plants will change, too. In summary it can be said that phenological phases of maize shortened and happened earlier as a result of temperature increase (Fig. 2).

The effects of climate change through changing temperature and precipitation conditions can be very different in different phenological phases of the plant. Thus during the research the temperature and the precipitation needs of wheat were defined for its phenological phases. We also examined the predicted changes for the vegetation period and the yearly accumulated heat and precipitation amount. During our research we used some of the most commonly accepted climate scenarios. The object of our investigations is an important centre of Hungarian agricultural production in Northern Great Plain, in the region nearby Tisza.

In this work our aim was to study the effects of climate change described by six of the most acceptable, different weather scenarios. Climate scenarios can be defined as relevant and adequate pictures of how the climate may look like in the future. During our research, we applied the principles defined by IPCC (*Intergovernmental Panel on Climate Change*) and we used some of the most widely accepted scenarios presented in international reports. For scenario generation, the so-called GCM-s (*General Circulation*

Model or Global Climate Model) are used. This work is based on GCMs downscaled to Debrecen, which is in the observed region

- scenario BASE which is the base of all other scenarios with the parameters of our days;
- scenarios GFDL2535 and GFDL5564 have been created by *Geophysical Fluid Dynamics Laboratory* (USA) with consideration of CO_2 increase in atmosphere. The only difference between the two scenarios is, that the latest has a finer resolution;
- and UKHI (high-resolution equilibrium climate change experiment), UKLO (low-resolution equilibrium climate change experiment) and UKTR (high-resolution transient climate change experiment) are three very different scenarios worked out by *United Kingdom Meteorological Office* (UKMO). Scenarios UKHI and UKLO show the most drastic change very similar the newest scenarios developed for studies about the end of century.

In our crop model research we used the 4M model, which has been developed by the *Hungarian Agricultural Model Designer Group* from the various institutes in the country and adapted to Hungarian circumstances. It contains several models to describe the physiological interactions of soil – plant systems and offers a possibility of building up different system models in it for the specific purposes of the users need. The CERES model was chosen to be a starting point, as for several other crop models in the world. The simulations were run for the daily average temperature, precipitation amount and radiation forecasted by climate scenarios. The location of our experiment was the same, observed region an important centre of agricultural production in Hungary.

The other calculations were made using the KLÍMA KKT Program designed for this project at the Department of Mathematics and Informatics at *Corvinus University of Budapest* and in MS Excel using the daily precipitation, minimum and maximum temperature forecasted by climate scenarios.

For the comparison we applied daily precipitation and average temperature data are from the monitoring database of OMSZ (*Hungarian Meteorological Service*) for the same region.

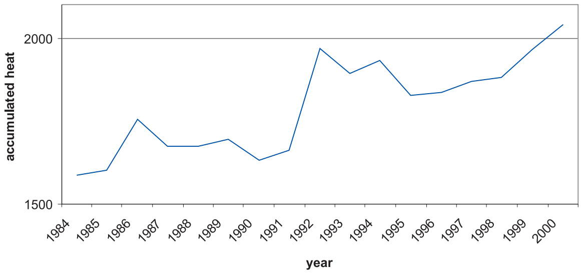
For the risk analyses the data of the Hungarian regional yearly crop results of corn and wheat were applied. The data were gained from the database *Agro-ecological Integrated Informatics System* (AIIR) and the KSH (*Hungarian Central Statistical Office*).

RISK ASSESEMENT OF CEREAL CROPS GROWING IN HUNGARY

The observed data of maize yield / winter wheat yield were fitted by nonlinear (logistic) regression. Then they were corrected by MS Excel® with the help of Phyllips-method (Fig. 3 / Fig. 4) in order to make them comparable. The subjective expectation, as well as the subjective standard deviation (E_s, D_s) were calculated based on experts' estimations. The corrected data were defined by $y_i^{corr} = f(x_{act}) + \varepsilon_i$ where ε_i denotes the residuals of the logistic regression, while $f(x_{act})$ denotes the value of the regression function at the right endpoint of the regression domain. The type of logistic regression was chosen not only because of its excellent fitting properties (R^2, ANOVA, t values for the coefficients), but also because of the changed producing technologies between 1970 and 1973.

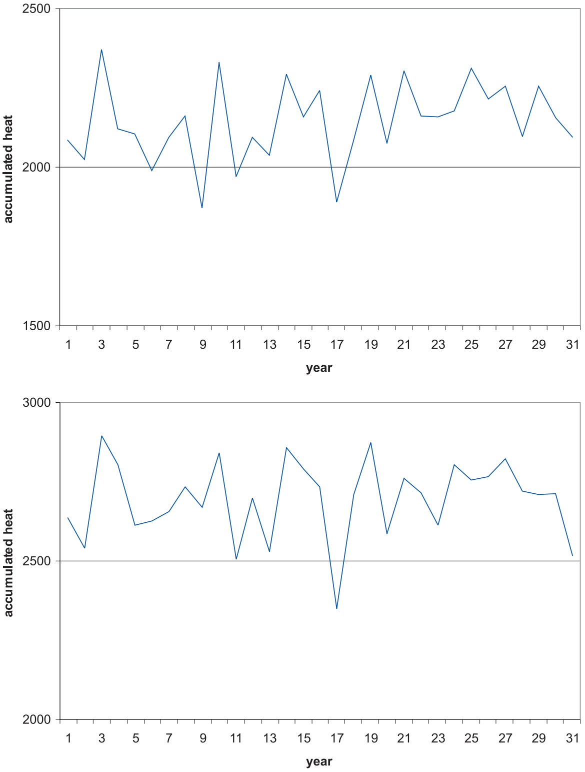
Observing the graphs of corn and winter wheat yield we can recognize that beside the yield loss caused by the Hungarian political situation at the end of the eighties, the deviation of the yield started to become greater yet at the beginning of the eighties. Using the current data calculated on the basis of experts' estimations we defined the subjective distribution functions for the four counties and for the time intervals 1951-70, 1961-80, 1971-90. They were calculated based on experts' estimations and used for comparison of the yields for the given time intervals. Denote by E_t and D_t the

Figure 1



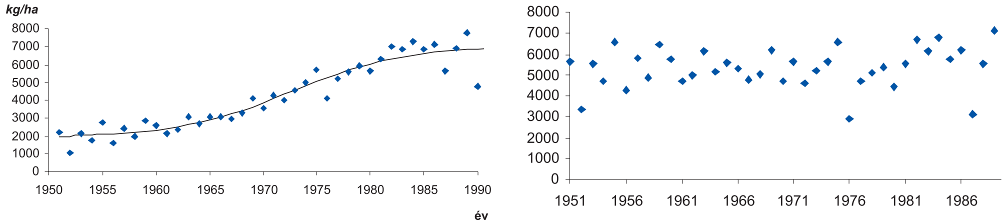
The accumulated heat for the vegetation period in the observed region, 1984-2000

Figure 2



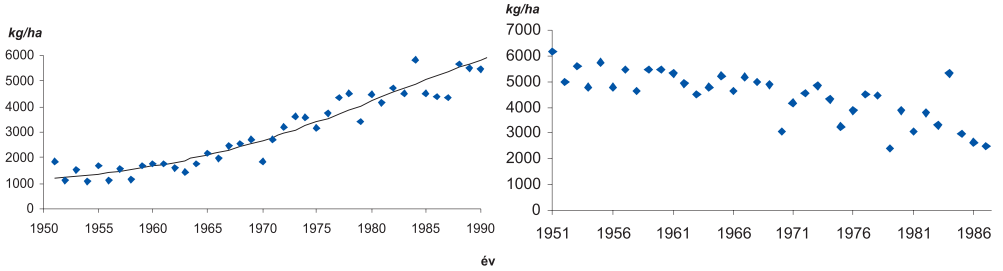
The accumulated heat for the vegetation period in the observed region in future 30 years, estimation using GFDL5564 (upper) and UKHI (lower) climate scenario

Figure 3



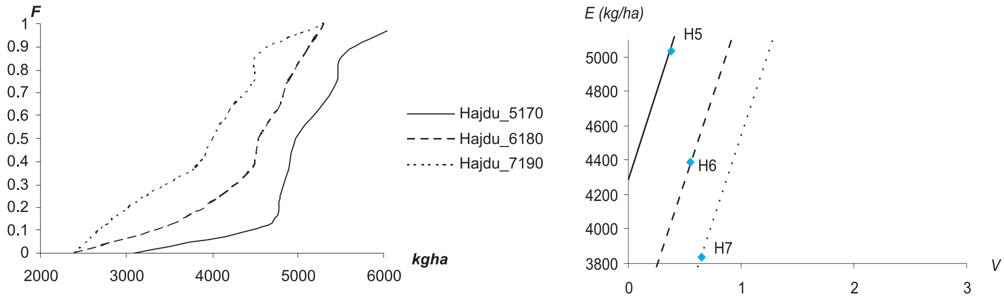
Data and the corrected data of the maize yield in the observed region

Figure 4



Data and the corrected data of the winter wheat yield in the observed region

Figure 5



Comparison of the time intervals 1950-70, 1961-80, 1971-90 by E, V- efficiency and the utility function criterion for Hajdú-Bihar (the observed region) county, maize

expectation and the standard deviation of y_i^{corr}, respectively. The current data can be gained as follows:

$$\mathrm{Yi} + \frac{y_i^{corr} - E_t}{D_t} \cdot D_s$$

It is evident that $E(Y_i) = E_s$ and $D(Y_i) = D_s$. As the exact personal risk aversion was not known, we used the widely applied negative exponential utility function $U : w \rightarrow U(w) = 1 - \exp(-cw)$. The most important property of this function is that its absolute risk aversion r_a is constant while its relative risk aversion r_r is linearly dependent of wealth w. $r_a(w) = c$ and $r_r(w) = cw$. Three efficiency criteria were considered, namely: the stochastic dominance based on the subjective distribution functions, the E,V-efficiency as well as the criterion based on the utility function.

Stochastic dominance involves comparing points on more entire distributions. Its disadvantage that the assumption of risk aversion may not hold and often happens that after a tiresome computation we cannot rank the distribution functions, and so, the set of alternatives remains too large. With the E, V-efficiency criterion the most preferable interval is the most left and most upper one (Fig. 5 and Fig. 6).The disadvantage of the method based on utility criterion is, that it can make an order for fixed absolute risk aversion, only. In almost every case we got that the situations become more risky with time. However, the results have not fulfilled all of our expectations. For more information we should call for the more general stochastic efficiency criterion. We finally proved that the risk of winter wheat production increased between 1951 and 1990 in all examined Hungarian counties, independently to the rate of risk aversion. In some regions the rate of increase became even quicker. In every case we got that the situations become worse with time. If we represent the graph of certainty equivalent *CE* depending on the absolute risk aversion r_a, the highest curve indicates the less risky time series (Fig. 7).

If we continue analysing the production risk by adding the newest yield data until 2005, splitting the new time intervals into shifted 1980-2000 and 1986-2005, we see that the risk is incresing very rapidly (Fig. 8) which can be seen from the results of the added intervals very clearly.

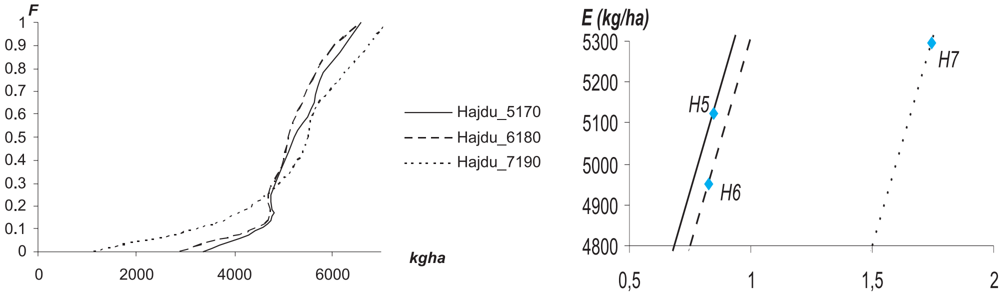
The most evident risk increase, so the most uncertainty production of wheat was observed in this region. The subjective distribution functions are ordered here pointwise. The same can be proved with the E,V-efficiency method, the criterion based on the utility function gives the same ordering. This proves the risk increase obviously, though, only for a fixed r_a value. Comparing the used time intervals and applying the stochastic efficiency criterion we proved that the risk of wheat production has increased independently from the rate of absolute risk aversion r_a.

IS CLIMATE CHANGE LIMITING THE NEEDS OF WINTER WHEAT GROWING IN HUNGARY

Using geographical analogues *Horváth* showed that the possible future climate – predicted by the scenarios – would be similar to the present climate of South-Southeast Europe. Increased mean annual temperatures in our region, if limited to two or three degrees, could generally be expected to extend growing season. In case of crops, where phenological phases depend on the accumulated heat unit, the phenophases could become shorter. Whether crops respond to higher temperatures with an increase or decrease in yield, depends on whether their yield is currently strongly limited by insufficient warmth or it is near or little above the optimum. In *Central Europe* where temperature are near the optimum under current climatic conditions, increases in temperature would probably lead to decreased yields of several crops.

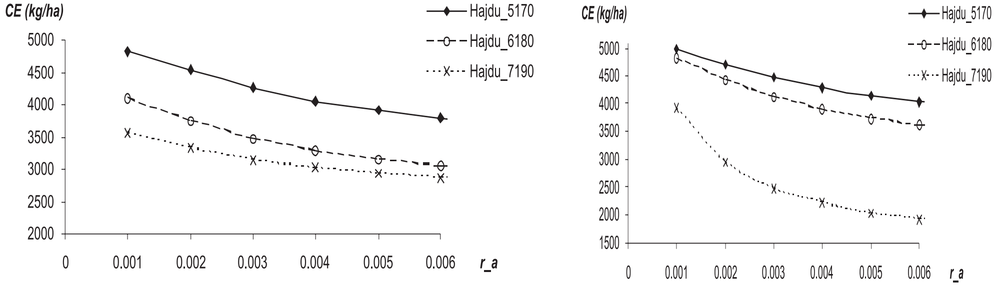
In Hungary the risk of production is especially meaningful as it has considerably

Figure 6



Comparison of the time intervals 1950-70, 1961-80, 1971-90 by E, V- efficiency and the utility function criterion for Hajdú-Bihar (the observed region) county, winter wheat

Figure 7



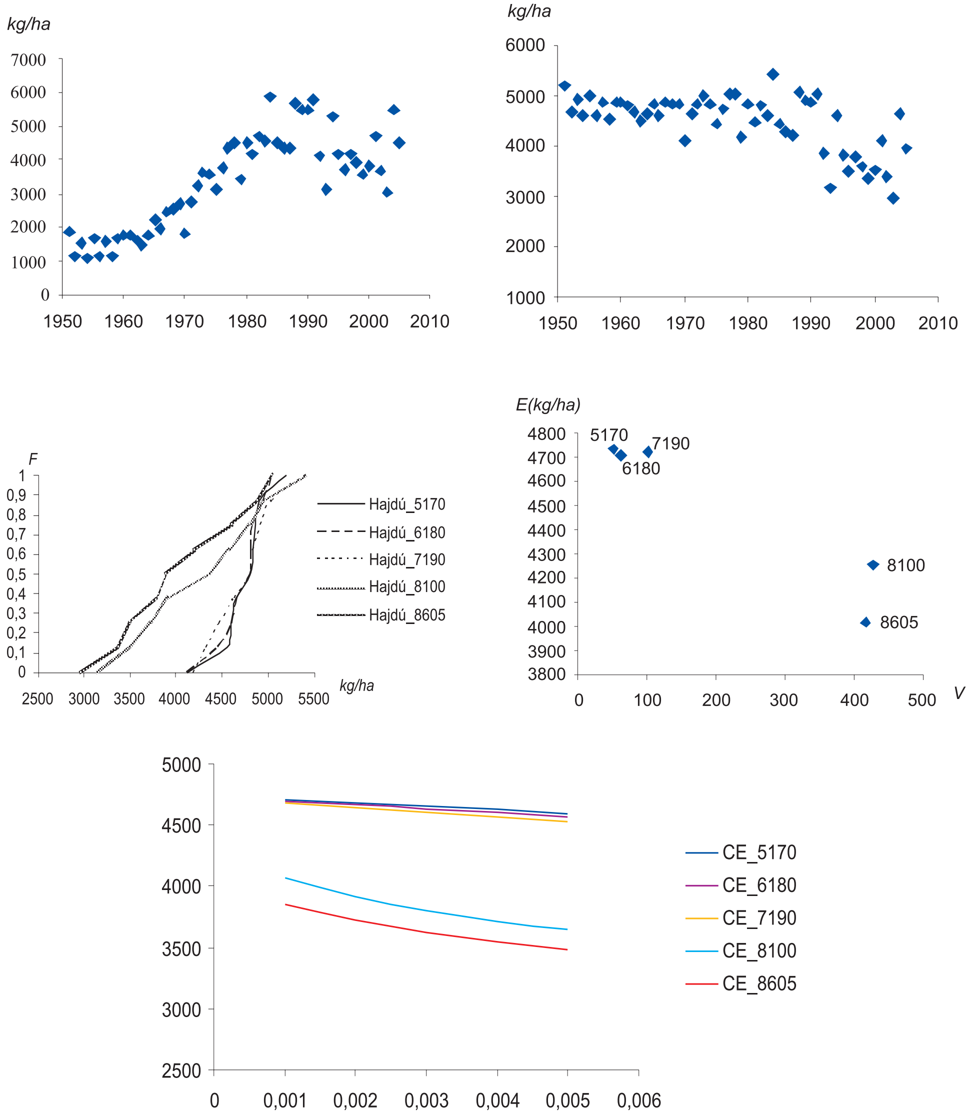
General stochastic efficiency curves (CE – kg/ha) for the time intervals 1950-70, 1961-80, 1971-90, Hajdú-Bihar (the observed) county, maize and winter wheat

been increased in the last few decades, in the observed region, moreover, the increase is quite high and became even quicker.

Climate change is not only characterized by changes in temperature (there are lots of climate change indices defined by temperature), but also by changes in other variables, for instance precipitation. The importance of the precipitation can be seen from the list of the Climate Change Indices, where 11 of 27 definitions are about it. The variability of the amount and frequency of the precipitation is very high, but the decrease of it could be a great limiting factor in agriculture. We decided to find out what can we expect in field crop production in the future by analyzing both temperature and precipitation needs of winter wheat. The calculations were made in KLÍMA KKT Program designed by *Szenteleki* and in MS Excel using the daily precipitation, minimum and maximum temperature forecasted by climate scenarios.

In the following we want to present some results. First we wanted to see, if there is any difference in the accumulated heat for the vegetation period measured in the past in Debrecen and those estimated by the climate scenarios in the future for the same region. We observed that the accumulated heat increased by time in the past, scenarios predict even more drastic increase (Fig. 9). This means that the starting date (sowing), ending date

Figure 8



Investigating the risk increase until the closer past for the same region, winter wheat (ripening) and the length of the phenophases of growing plants will change, too.

We compared the sums of the precipitations for the growing season of winter wheat, as well. We can see a slow decrease of the accumulated precipitation for this period (October-July) in the city of *Debrecen*, for years 1984-1995 (Fig. 10), and that the scenarios predict smaller values in the future (Fig. 11). This might be good for winter wheat, because its yield grows with less precipitation in some periods of growing. But analyzing the observed and the future weather using climate scenarios we see a big variability in the amount of the precipitation. This means, that the frequency of extreme weather events such as droughts and floods have increased, are more probable.

Next we wanted to see, what climate scenarios predict for the periods of importance in wheat production. In this work we demonstrate the results we got using precipitation data. We also compared the precipitation needs and the forecasted amounts for different phenophases.

Though wheat production is determined mostly by the temperature, and the precipitation itself doesn't give us too much information, there are periods of the year, when the precipitation is of big importance in winter wheat growing. Winter wheat can easily stand dry conditions (it comes from regions with drought) and in some phenological phases the precipitation might be even harmful for it. We analyzed the precipitation needs of the plant in three main phenological phases: the perods of sowing – emergence, stem elongation – spikelet initiation, and anthesis – grain filling.

It's good to know what we can expect in different phenological phases of the plant. After sowing, the grains need to be in wet soil, so it's very important to have precipitation in November. According to the results of the used climate scenarios (Fig. 12) it can be said that the precipitation requirement (10-45 mm) in sowing-emergence phenological phase will not be fulfilled. When winter wheat starts growing in spring, it needs wet soil again.

Winter wheat is very sensitive on meteorological circumstances when it's producing the most of its organic substances, in the stem elongation – spikelet initiation period. The shortage of precipitation can be seen in leaf development. The other problem is that too wet soil and high evapotranspiration produce lower yield. In this phase the need of the plant is between 70 and 80 mm. The precipitation pattern for this period of growing is not changing much, according to most of the used climate scenarios (Fig. 13). In this period precipitation is of higher importance than temperature.

The third period we made calculations for is the anthesis-grain filling phenological phase. In this period the plant develops its generative organs, the precipitation need is 75-160 mm. With lower amounts the plant may produces infertile florets or the florets may not develop as required, so the winter wheat production becomes smaller. In this period we cannot be satisfied with the forecasted values we got (Fig. 14).

We calculated the predicted average values with their variability measures and compared them with the needed amounts of precipitation (Table 1). The averages show us the same conclusions as above, but the measures of variability are unfortunately too high. This means that the standard deviations are big and the future is very unpredictable.

Using the KLÍMA KKT Program we can get the number of the years when the needs of the plant are not satisfied, but it can give us information about climate change indices, too. One is (two are) R95 (and R99), the percent of days in a given year, when the daily precipitation amount on a wet day is out of the 95th (and the 99th) percentile calculated for the reference period 1961-1990. These indices show that the precipitation has significant variability. This result can give us information for predicting extreme conditions, too. With this program we can calculate other climate indices, like the monthly maximum 1 (or more)-day precipitation, precipitation intensity index, the annual count of days when the precipitation amount is bigger than a given value, maximum length of dry and wet spell and other indices also for the temperature.

Next, we present the results we obtained for the periods of importance in wheat production using temperature data. We compare the temperature needs of the plant with the amounts forecasted by the used climate scenarios.

Wheat production is determined mostly by temperature, because it is of great importance in its growing. Winter wheat can easily stand dry conditions, because it comes from regions that typically experience drought. It is good to know what we can expect in the different phenological phases of the plant. The experienced temperature requirement in the sowing-emergence period is 9-12.5 °C. According to the results of almost all of the climate scenarios (Fig. 15) predict warmer circumstances.

The sowing-emergence phenological phase lasts usually 12-15 days, but can be shorter than a week when its warmer than 14 °C. Our results show, that this will happen quite often in this period. This period can last longer than 20 days with temperatures lower than 7 °C, which might occur fewer times in the future.

Winter wheat is very sensitive to meteorological circumstances when it is producing the most of its organic substances, in the stem elongation – spikelet initiation period. The average temperature in this phenological phase used to be 13-17 °C in the past (the optimal is 20-25 °C), this period usually lasts 20-49 days. It is longer than 40 days with temperatures lower than 14 °C and shorter with temperatures higher than 20 °C.

The climate scenarios show big variability in the frequency of the extreme values, but future doesn’t show big change in the average, except two, the more drastic climate scenarios (Fig. 16). Climate scenarios show a little higher temperature in May, which is good for the plant and also in June, which is harmful for it.

The third period we made calculations for is the anthesis-grain filling phenological phase. In this period, the plant develops its generative organs, and the temperature need is 18-20 °C. With temperatures lower than 16 °C this period lasts longer than 45 days, with temperatures higher than 20 °C this phenological phase is shorter than 40 days. The scenarios don’t show big variability and extreme temperatures too many times (except the two more drastic ones), so this period is in favor of the plant (Fig. 17).

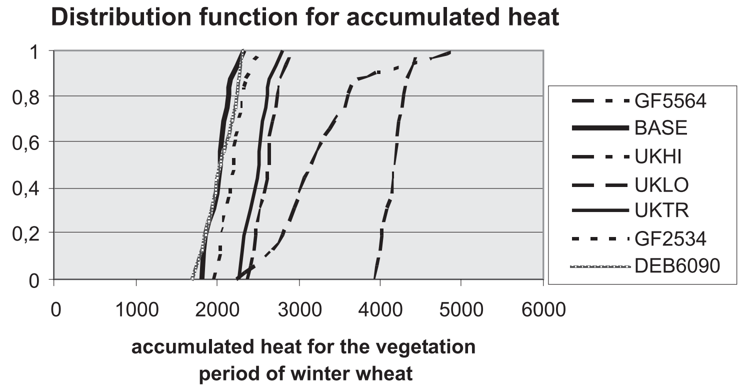
It is very important to know as much as possible about factors which influence the wheat yield, but it is also very important to examine the quality factors as well. The quality of the grain depends on its gluten and starch content. The gluten content of wheat grain is a determinative quality factor especially in baking industry. It depends on the enzyme activity of the plant which is influenced by the temperature. The optimal temperature for it is 17-23 °C. Results show that climate change might be good for winter wheat in this sense. We have counted the number of days with optimal temperature for the enzyme activity (Table 2 and Fig. 18).

Seeing these results we decided to analyze the future winter wheat growing periods and production using crop models and the same climate scenarios. We used the model 4M, which has been developed by the *Hungarian Agricultural Model Designer Group* from the various institutes in the country, adopted to the given circumstances.

MODELLING THE PROSPECTIVE LENGTHS OF THE PHENOLOGICAL PHASES OF CORN AND WINTER WHEAT

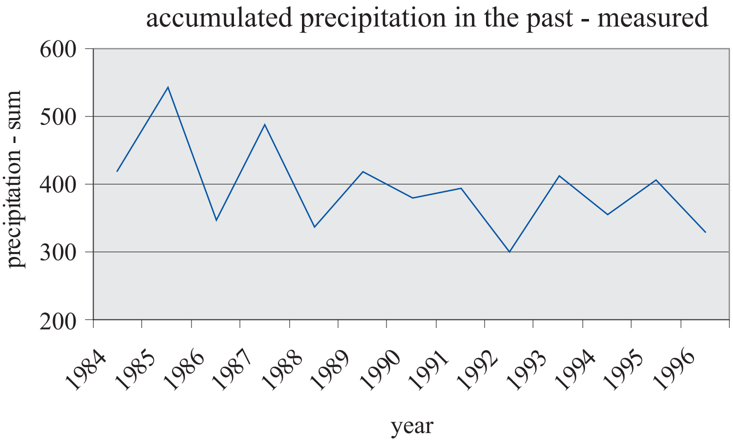
After analysing if the needs of the plant will be fulfilled or not according to the prediction of the applied climate scenarios, we wanted to see how the length and the starting dates of phenological phases of the two most important field crops in Hungary – maize and winter wheat – change in the case of different scenarios. Models are very

Figure 9



The accumulated heat for the vegetation period in the observed region, historical data for 1984-2000 and estimations for future 30 years using climate scenarios

Figure 10

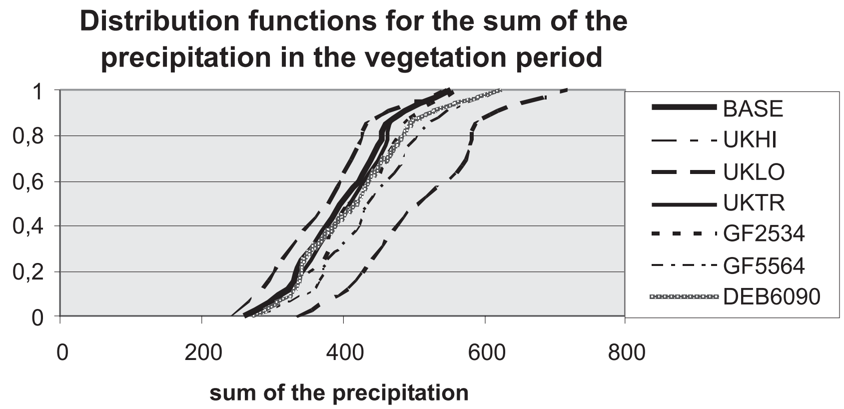


The accumulated precipitation for the growing season of wheat

applicable for the description of changes in the future, for giving hints in improving new plant varieties, which are resistant to probable changes. The simulations were run by the 4M model which is based on the CERES model, developed by the Hungarian Agricultural Model Designer Group and adopted to Hungarian circumstances. In summary, it can be said that for both, maize and winter wheat the phenological phases might shorten and happen earlier in the future as a result of temperature increase.

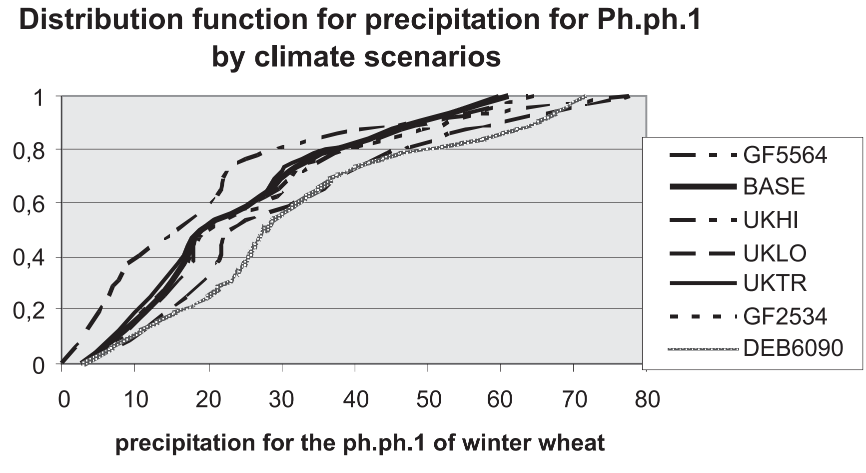
First we present the results of the simulations for the phenophases of corn: 1 – sowing,

Figure 11



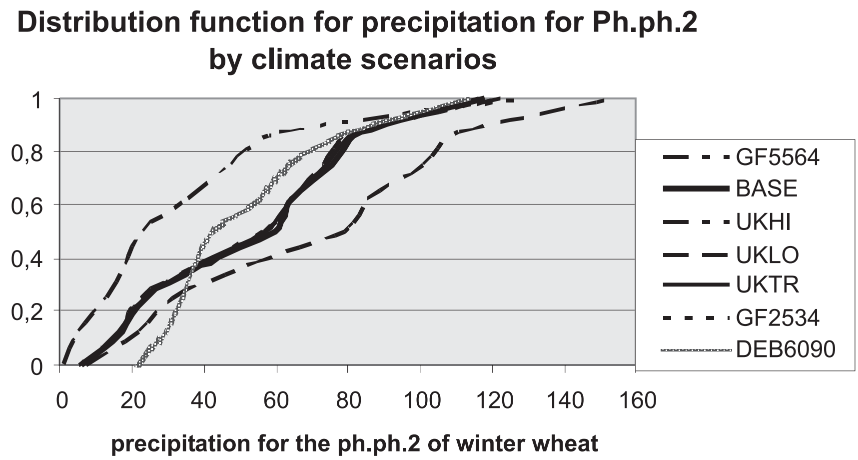
Distribution functions for the accumulated precipitation in the growing season of wheat, comparison of the estimated future data and the historical data for reference period of the used scenarios

Figure 12



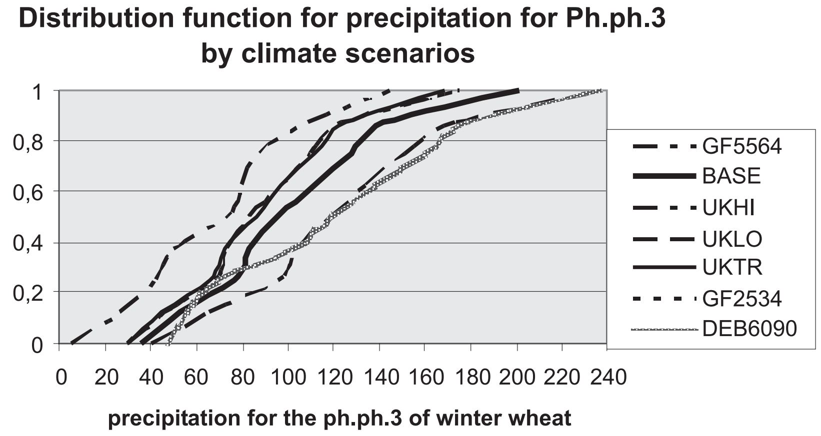
The amount of the precipitation for the sowing – emergence phenological phase of winter wheat, comparison of the estimated future data and the historical data for reference period of the used climate scenarios

Figure 13



The amount of the precipitation for the stem elongation – spikelet initiation phenological phase of winter wheat, comparison of the estimated future data and the historical data for reference period of the used climate scenarios

Figure 14



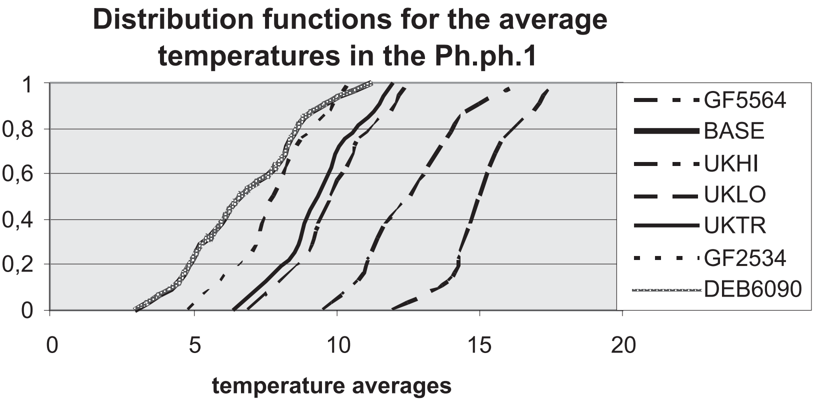
The amount of the precipitation for the anthesis – grain filling phenological phase, comparison of the estimated future data and the historical data for reference period of the used scenarios

Table 1

Winter wheat precipitation needs and the forecasted average amounts with measures of variability (CV): yearly, sowing-end of growing, sowing-emergence (ph.ph1), stem elongation – spikelet initiation (ph.ph2) and anthesis – grain filling (ph.ph3)

precipitation sums	yearly	growing period	ph.ph.1	ph.ph.2	ph.ph3
Need	500-600	390-480	10-45	70-80	75-160
BASE average	520.04	392.43	23.65	51.71	98.58
CV	0.18	0.2	0.69	0.61	0.43
UKHI average	433.62	367.4	19.68	32.56	65.43
CV	0.2	0.23	1.02	0.95	0.56
UKLO average	635.71	505.08	30.15	68.65	120.2
CV	0.18	0.2	0.7	0.61	0.41
UKTR average	499.02	399.9	22.7	50.65	85.64
CV	0.17	0.19	0.69	0.62	0.43
GF2534 average	525.76	413.21	24.3	50.32	86.14
CV	0.17	0.19	0.69	0.62	0.42
GF5564 average	575.44	438.28	25.12	57.77	118.86
CV	0.18	0.2	0.7	0.66	0.43

Figure 15



The average temperature for the sowing – emergence phenological phase, comparison of the estimated future data and the historical data for reference period of the used climate scenarios

2 – emergence, 3 – tillering, 4 – flowering (silking, tassering), 5 – measuring, 6 – black layer formation, 7-8 – phases of ripening. In this analysis we used the same periods of growing as the used model.

Our results are the following: the length of phenophase 2 decreased in case of GFDL5, UKHI, UKLO, UKTR scenario. The length of phenophases 3-7 decreased in the case of all scenarios (Table 3 and Fig. 19). The first day of phenophase 3 remained the same in case of GFDL2 and shifted to an earlier date in case of GFDL5, UKHI, UKLO and UKTR scenario. The first day of phenophases 5-7 shifted to an earlier date in case of all scenarios (Table 4). Significant difference (95%) compared to the BASE scenario is marked by *. In summary it can be said that phenological phases of maize shortened and happened earlier as a result of temperature increase.

We analysed the effects of changing climate on the growing periods of winter wheat, as well. We used the historic data of Debrecen for the reference period of the climate scenarios (1960-1990) and the estimations of the same downscaled climate scenarios. Each meteorological data contains daily temperature, precipitation and radiation values for 31 years. We know that we can expect the increasness of the accumulated heat in the vegetation period in the future, so we were interested in how the lengths and the starting points of the growing periods of the plants change. We used the simulation method based on the 4M model again. We show the results by comparing the historical data and the UKTR scenario for the starting dates of the phenological phases of winter wheat on Fig. 20. The starting points of the phenological phases shifted to an earlier date, especially in the first period of growing. Harvesting is predicted to be eight days earlier (in average) in the future.

Climate change affects agriculture in many direct and indirect ways. Information about weather and predicting the potential climate change impacts are of great importance all over the world. Considering the possible changes we have to answer many questions in order to prepare for the future. We intend to point out, that studies about different circumstances in agriculture and interdisciplinary, collaborative research projects are very much needed in order to help us prepare for the future. Modelling is a great tool for investigating the future circumstances without having expensive and long experiments. It helps us finding a good strategy in preparing for the future.

USING DIFFERENT SOWING DATES AS A PART OF THE ADAPTATION STRATEGY

Living under changing climate conditions, one of our most urgent tasks is to define the optimal preparation and response strategies to the conditions in change. Since we have proved that the risk of winter wheat production in several counties of Hungary has been even until the late eighties increased and the probability of the shortening of the periods of growing, we were interested whether changing the sowing date can decrease the production risk or increase the yield or not in the future.

In the case of corn the simulations were run for the 25th of April and four other dates: one and two weeks earlier and one and two weeks later. The 4M model was run for the same weather data as before, for the same location, but with these input sowing dates We examined by comparing the results, how the lengths and the starting points of the growing periods of the plant change and whether the changing conditions decreases the yield or not. Results show, that the ripening day of the plant is shifted with the shifting of the sowing date, for the one week earlier case by 4 days, for the two week earlier case by almost two weeks, in the one and two weeks later case for 5-6 days in average. For the earlier sowing dates the variability has increased, especially for the two weeks case, but for the later sowing dates not (Table 5).

The probability of increasing biomass and grain mass quantity of maize is high for the two weeks earlier sowing date, which could mean that the for decreasing the production risk and the uncertainty the two weeks earlier sowing might be a good adaptation strategy. This strategy is good for the plant because its growing period could avoid the most unfavourable drought condition, enhance its ripening is more probable. The coefficients of variation for the grain mass and biomass give even smaller values (Table 6 and Table 7).

In case of winter wheat he used sowing date was the 20th of October and the one and two weeks earlier and later dates. The results are very promising for the two weeks earlier sowing date for both biomass and grain mass quantity (Table 9 and Table 10), even with the almost same variability as for the others. For this plant however, the shifting in sowing dates can be hardly seen at the end of the vegetation period (Table 8). The more significant influence on the ripening date has the two weeks earlier sowing, which has the highest variability, as well.

We present the results we got by the simulation for the biomass and grain mass amounts at the end of the growing period with the estimated average, minimum and maximum values (Fig. 21 and Fig. 22). While running the model it can be seen that the duration of the grain ripening is significantly the same for each sowing date in case of maize and shifting with it in case of winter wheat, especially for the two weeks earlier sowing where the simulation shows the shortest grain development duration.

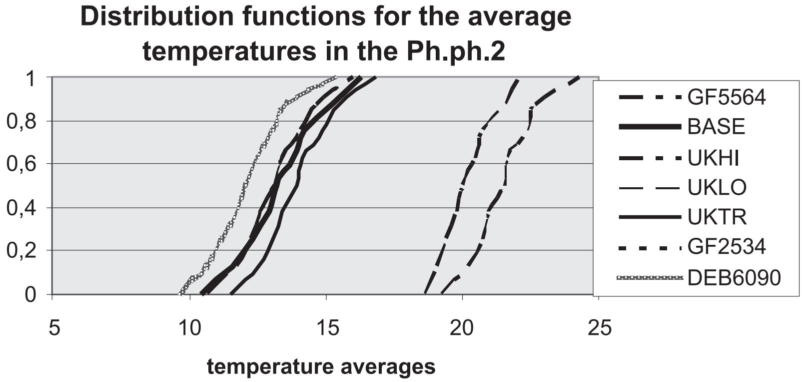
Beside analyzing the average values for the used scenarios we studied the effect of each of them separately on the biomass changes of maize. Using the 4M model for these climate scenarios as weather inputs and saw that moderate warming can increase the yield, but any further increase in temperatures can cause big losses. We also saw that the variability of the temperature does not change much for the used climate scenarios, but the estimated mean yield does (Table 11).

Even being aware of the shortage of the available water for irrigation, we tested the efficacy of three dripping irrigation systems. The location of our experiment was the same region, which is of big importance in Hungary’s maize production. Our standard was BASE, which represents the current weather conditions. When comparing runs without treatment and runs with irrigation, we found that in case of no irrigation biomass and grain levels decreased in the case of GFDL2534 and UKHI compared to BASE. In the case studies for different irrigation treatments biomass and grain levels increased significantly in all scenarios, 3*80 mm before sowing and 5*80 mm in July, and 5*30 mm in July treatment had the largest effect on them. Our results have shown that climate change itself does not increase biomass or grain levels, while significant increase in yield can be reached by irrigation. This probably means that economic aspects about not using watering are worth reconsidering.

CORN BIOMASS PRODUCTION AS A PART OF THE MITIGATION STRATEGY

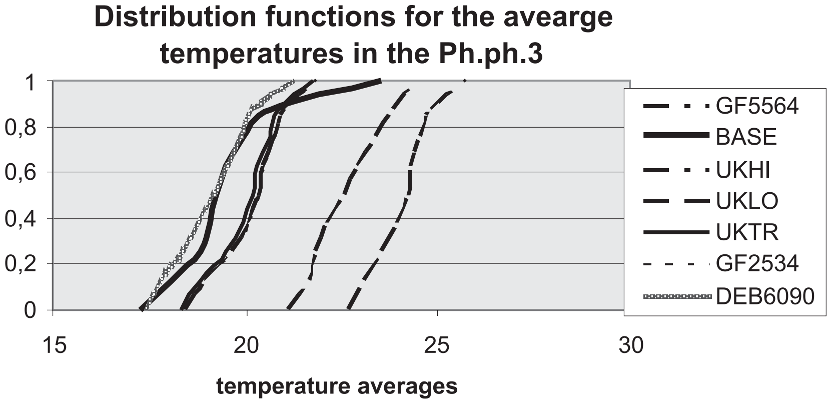
There is dramatic evidence that various Greenhouse Gases are responsible for global warming and climate change. Agriculture can play a role both for reducing GHG emissions and to sequester carbon. Producing energy from biomass is one of the best ways to reduce GHG emissions. “Biofuels” is a term that commonly denotes liquid or gaseous fuels made from biomass. The biomass can have different sources: starches from cereals, grains and sugar crops, waste products from agriculture and forestry, etc. Agricultural residues include a wide range of plant material produced along with the main product of the crop. Example of biomass for energy production could be corn stems, as well. Ethanol obtained from biomass is one of the most promising sustainable transportation fuels. Producing biogas is also

Figure 16



The average temperature for the stem elongation – spikelet initiation phenological phase, comparison of the estimated future data and the historical data for reference period of the used climate scenarios

Figure 17



The average temperature for the anthesis – grain filling phenological phase, comparison of the estimated future data and the historical data for the reference period of the used climate scenarios

a sustainable technology. Europe is facing increased efforts for bioenergy production support, both based on existing resources and energy crops implementation. There are biomass-power projects in Hungary as well, we have an example of using it even in the observed region, local buses are operated by biofuel in *Debrecen*.

Energy potential of Hungary is approximately half-half of products and by-products. Maize is an energy crop with significant by-production and only about 30% of it has to be ploughed back into the soil. We analyze the possibilities agriculture can provide for bioenergy production. In this work we give an example for maize biomass production in the future. We were interested in the available secondary biomass quantities and the proportion of the parts of the plant in biomass, too. In our research we used the method of simulation modeling. The 4M model was run with climate change scenarios as weather inputs. Our idea was that using by-products for biogas production and as green dung can be a step in prevention of global warming.

Using biomass as a substitute for fossil fuel is highly prioritized, but the primary aim of agricultural production is food and feed supply. Converting secondary biomass, plant residues to valuable energy products might be a solution. That's why we discuss the secondary biomass quantities. Since scenarios are given for 31 years, we could analyse them statistically. We got the result that the UKTR scenario doesn't show significant difference comparing to the BASE scenario, the result for UKLO was very similar to the result of the GFDL5 scenario, which shows significant increase in the predicted quantities of secondary maize biomass comparing to the scenario BASE, but GFDL2 and UKHI show much lower values. We present the results on Fig. 23.

We examined the effects of changing temperature on the proportion of corn-stalk and leaf mass in biomass, as well. The result for the UKTR scenario doesn't show significant difference comparing to the BASE scenario, the result for GFDL5 scenario shows significant increase in the predicted quantities of corn biomass available for biogas production (secondary biomass) comparing to the scenario BASE, UKHI shows much lower values. In averages UKHI shows the smallest values, GFDL2 and UKTR predict a little lower quantity, GFDL5 and UKLO higher values compared to the results of the BASE scenario (Table 12).

The next step in our research was analyzing the effects of changing temperature on the proportion of grain, leaf, corn-stalk and root in corn biomass by using the 4M model for different climate scenarios as weather inputs.

The results for the proportion of the parts of the plant of the scenario GFDL2 were very similar to the results for the GFDL5, and the results for the UKTR doesn't show significant difference comparing to the BASE scenario. Next we present the two most different results, the Figures for the scenario BASE and for GFDL5 (Fig. 24 and Fig. 25).

Winter wheat is one of the most cultivated plant in Hungary and half of its yield is exported, so we analysed the effects of changing temperature on its biomass and grain mass, as well. In our research we used again the method of simulation modelling. The 4M model was run with climate change scenarios as weather inputs. We give an example in Table 13. Comparing the results for the period 1960-90 and simulated values for the UKTR climate scenarios we can say again, that climate change might be good in cereal production of Hungary. Even on the basis of small standard deviation and coefficient of variation values (CV) we can conclude that the results are very promising.

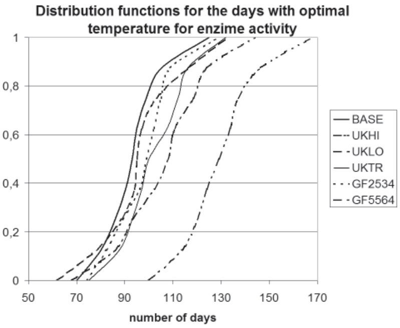
The recently released IPCC WGI fourth assessment report is illustrating human influence in warming effect on the global climate. Nowadays, world energy supply is dominated by fossil fuels. Biomass resource sectors such as agriculture are playing a very significant contributing role. In order to accomplish the Kyoto greenhouse gas (GHG)

Table 2

The average number of days in a year with optimal temperatures (17-23 °C) for enzyme activity and its variability in the observed region predicted by the climate scenarios

	BASE	UKHI	UKLO	UKTR	GF2534	GF5564
Average	88,576	120,139	88,05	97,158	92,567	101,753
Coeff. of Variation	0,285	0,287	0,3	0,285	0,284	0,292

Figure 18



Number of days in a year with 17-23 °C temperatures in the observed region predicted by the climate scenarios

Table 3

The starting dates of phenological phases of maize for the scenarios

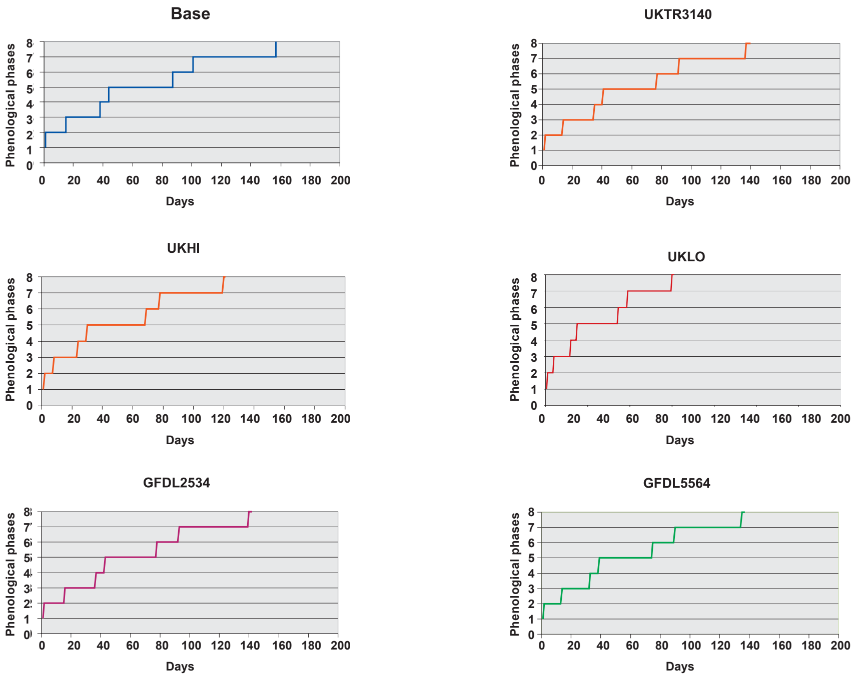
First day of phenophases	BASE	GFDL25	GFDL55*	UKHI*	UKLO*	UKTR
2	122	122	119	113	112	120
3	147	146	141	129	127	144
4	154	153	148	135	133	151
5	197	192	187	172	168	191
6	211	205	199	183	179	204
7	267	247	241	215	212	256

Table 4

The length of the phenological phases of maize for climate scenarios

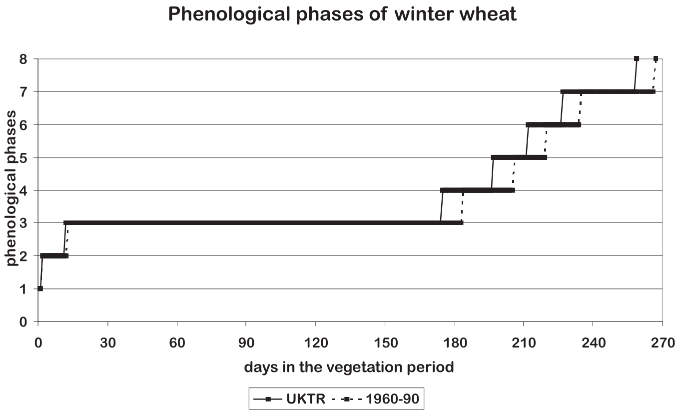
Length of phenophases	BASE	GFDL25	GFDL55*	UKHI*	UKLO*	UKTR
2	16	16	13	7	6	14
3	25	24	22	16	15	24
4	7	7	6	6	6	6
5	43	40	40	37	35	40
6	14	12	12	11	11	13
7	56	42	42	32	33	52

Figure 19



The length of the phonological phases of corn for different scenarios

Figure 20



Comparing the starting dates of the phenological phases of winter wheat for the reference period and the UKTR climate scenario

Table 5

The estimated ripening date of maize for different sowing dates, average, standard deviation and the coefficient of variation (CV)

The estimated end of the growing period of maize					
sowing date	25th April	-1 week	-2 week	+1 week	+2 week
average	250.23	246.1	237.33	255.22	256.58
st.dev.	6.97	8.148	17.567	4.348	4.219
CV	0.0285	0.033	0.074	0.017	0.016

Table 6

Biomass quantity of maize estimated by climate scenarios, average, standard deviation and the coefficient of variation (CV)

The estimated biomass quantity of maize					
sowing date	25th April	-1 week	-2 week	+1 week	+2 week
average	11185.08	11218.93	11432.47	11327.43	11203.75
st.dev.	1596.541	1453.91	1077.694	1592.39	1795.532
CV	0.143	0.129	0.094	0.14	0.16

Table 7

Grain mass quantity of maize estimated by climate scenarios, average, standard deviation and the coefficient of variation (CV)

The estimated grain mass quantity of maize					
sowing date	25th April	-1 week	-2 week	+1 week	+2 week
average	6788.96	6963.07	6978.73	6858.74	6810.92
st.dev.	1475.9	1255.67	1301.75	1444.52	1651.73
CV	0.217	0.18	0.186	0.21	0.24

Table 8

The estimated ripening date of winter wheat for different sowing dates, average, standard deviation and the coefficient of variation (CV)

The estimated ripening day of winter wheat					
sowing date	20th October	-1 week	-2 week	+1 week	+2 week
average	182.2	181.9	186.16	182.5	182.57
st.dev.	4.51	4.54	16.76	4.6	4.58
CV	0.0247	0.024	0.09	0.025	0.025

Table 9

Biomass quantity of winter wheat estimated by climate scenarios, average, standard deviation and the coefficient of variation (CV)

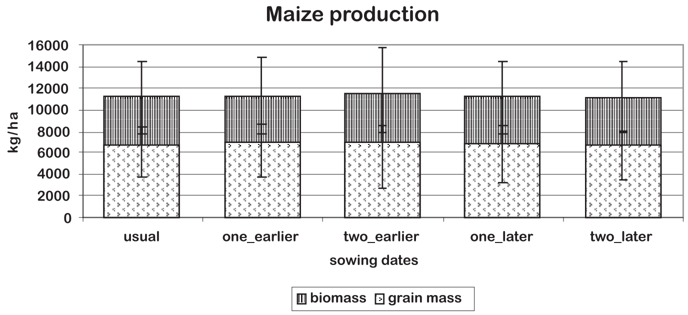
The estimated biomass quantity of winter wheat					
sowing date	20th October	-1 week	-2 week	+1 week	+2 week
average	11216.5	11220.5	11449.867	11231.87	11118.47
st.dev.	1759.83	1770.94	1885.075	1681.4	1634.55
CV	0.157	0.158	0.165	0.15	0.147

Table 10

Grain mass quantity of winter wheat estimated by climate scenarios, average, standard deviation and the coefficient of variation (CV)

The estimated grain mass quantity of winter wheat					
sowing date	20th October	-1 week	-2 week	+1 week	+2 week
average	3864.73	3865.33	4086.87	3880.9	3844.9
st.dev.	825.71	823.41	1137.78	828.20	844.38
CV	0.214	0.2135	0.2784	0.213	0.212

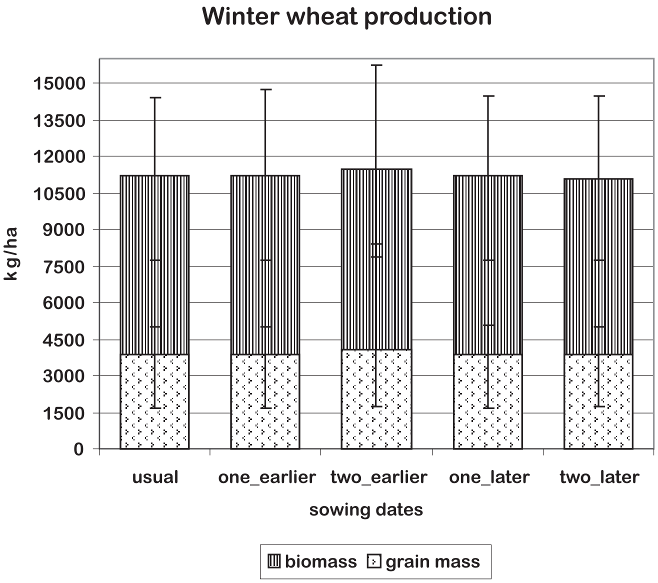
Figure 21



Biomass and grain mass quantity of maize estimated by climate scenarios, minimum, maximum, and average values

reduction targets, the modern utilisation of biomass has to increase rapidly. Bioenergy gives Europe the best opportunity to reduce GHG emission and secure its energy supply. However, the biomass production should not create additional pressure on the environment. Diversity in energy supply would bring greater economic security and stability for the environment and the society. Moreover socio-economic considerations of renewable energy production have become a trendy new standard, particularly in the field of biomass utilisation. No other renewable energy than biomass is so closely linked with mankind, nature and therefore with the climate and offers a wide playfield for socio-

Figure 22



Biomass and grain mass quantity of winter wheat estimated by climate scenarios, minimum, maximum, and average values

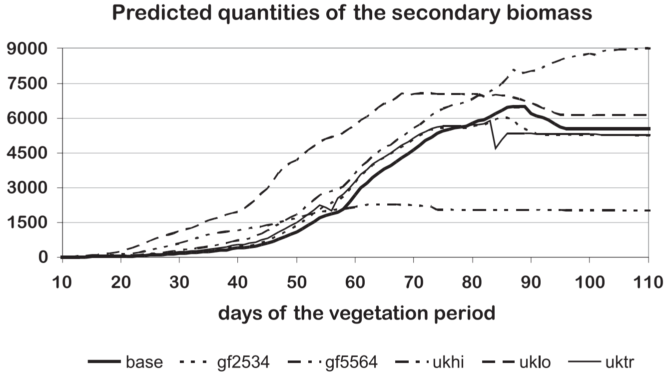
Table 11

Maize production (average with the measures of variability: CV) estimated by the used climate scenarios

SCENARIO	BASE	UKHI	UKLO	UKTR3140	GFDL2534	GFDL5564
average	9429.65	5831.87	9806.97	7101.35	7941.55	10600.19
st.deviation	2877.95	2048.57	2497.38	2372.81	2557.62	2887.04
CV	0.31	0.35	0.25	0.33	0.32	0.27

economic discussions. Energy crop has at the same time a high potential to create new jobs and introduces high-tech applications into rural areas thus offering options to keep trained people in rural villages. Biofuels nowadays are less competitive than fossil fuels. But the largest increase in renewable energy use, in the coming years, will take place in the EU countries driven by strong governmental support. Most promising crops for certain agro-climatic conditions have been selected already in some countries. We investigate the potentials of agriculture residues in Hungary. Simulations give us a great opportunity. We would like to call the attention to the importance of creating well-designed descriptive-forecasting systems, as well as defining the optimal preparing and response strategies to the conditions in change. The secondary biomass of plants are valuable byproducts, which can be used as sources of renewable energy. Analysing

Figure 23



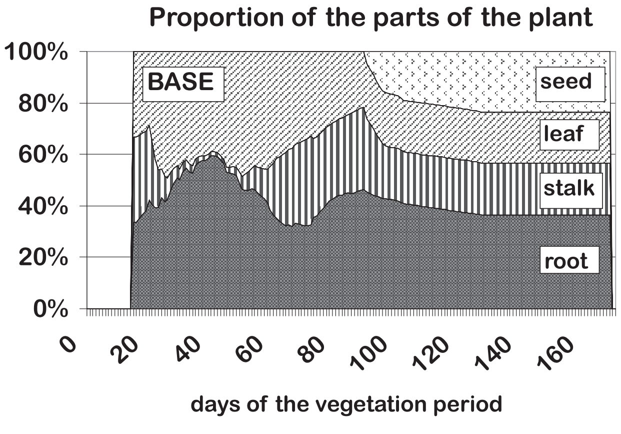
Predicted quantities of the maize secondary biomass, comparing six different climate scenarios

Table 12

Predicted average secondary biomass quantities

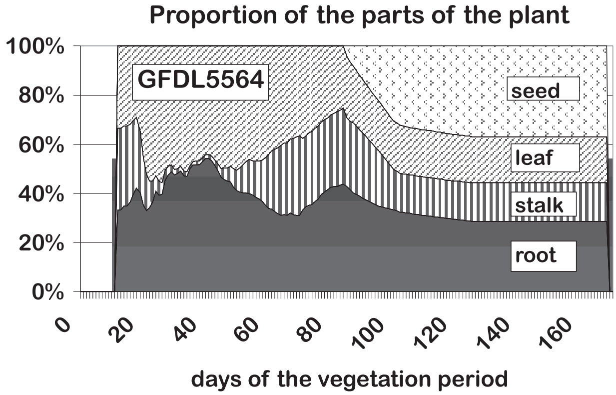
SCENARIOS	BASE	GFDL2	GFDL5	UKHI	UKLO	UKTR
Biomass (kg/ha)	4977	4254	5538	3842	5727	4665

Figure 24



Biomass proportions of the parts of the corn plant simulated by climate scenario BASE

Figure 25



Biomass proportions of the parts of the corn plant simulated by climate scenario GFDL5564

Table 13

Grain-mass and biomass of winter wheat simulated by 4M model for meteorological data of 1960-90 and the UKTR climate scenario (average, standard deviation and CV)

	1960-90			UKTR		
	average	st.dev.	CV	average	st.dev.	CV
grain mass	2695.21	510.62	0.19	512.86	688.62	0.20
biomass	7420.07	1656.15	0.22	10038.71	1281.49	0.13

further possibilities of using renewable energy and finding other resources as well, is our important task in adopting to possible changes and saving our environment in the future. Agriculture can help reducing global warming by increasing the absorption (land use, irrigation, plant improvement) and decreasing the emission of (biomass as energy resource), too. There is a wide scientific consensus that if these changes continue, significant damage to global ecosystems, food production and economies will ensue.

ACKNOWLEDGEMENTS

This work was supported by the NKFP 6-00079/2005 and ADAM projects.

REFERENCES

(1) Barrow, E.M. – Hulme, M. (1996): Constructions of scenarios of climate change and climatic variability: Development of climate change scenarios at a range of scales. In: Harrison P.A.- Butterfeild R.E. –Dowing T.E.(eds): Climate change, Climatic Variability and Agriculture in Europa. An Integratid Assessment.Annual Report 1996. Oxford: Environmental Changa Institute, University of Oxford. 13-18. pp (2) Boksai, D. (2006): Klímaváltozási szcenáriók értékelése a kukorica egyedfejlődésének szimulációs modellezése alapján. Student Conference, Budapest (3) Botos, L. – Varga-Haszonits, Z. (eds.) (1974): Agroklimatológia és növénytermesztés. Budapest (4) Climate Change Indices, Definitions of the 27 core indices, Available at: http://cccma.seos.uvic.ca/ETCCDMI/list_27_indices.html (5) Erdélyi, É. (2006): Climate Change and Temperature Needs of Winter Wheat. Ecological problems of our days – from global to local scale, 2006, Keszthely, 274-279. pp. (6) Erdélyi, É. – Horváth, L. (2006): Climate change and precipitation needs of winter wheat. Summer University on IT in Agriculture and Rural development, Debrecen (7) Erdélyi, É. – Ferenczy, A. – Boksai, D. (2007): Climate Change and Cereal Crops Growing in Hungary. EFITA Conference, Glasgow, 2007 (8) Erdélyi, É. – Horváth, L. – Boksai, D. – Ferenczy, A. (2006): How climate change influences the field crop production I. Yield variability of maize, IV. Međunarodna eko-konferencija – Zdrastveno bezbedna hrana, Novi Sad, 7-12. pp. (9) Erdélyi, É. – Horváth, L. – Boksai, D. – Ferenczy, A. (2006): How climate change influences the field crop production I. and II. Use of Spatial Analogy and Yield variability of maize, 4th International Eco-conference – Safe Food, 2006, Novi Sad, 1-12. pp. (10) Fodor, N. – Máthéné-Gáspár, G. – Pokovai, K. – Kovács, G. J. (2002): 4M – software package for modeling cropping systems. European J. of Agr. Vol 18/3-4 389-393. pp. (11) Gaál, M. – Horváth, L. (2006): Geographical analogies in climate change research. HAICTA, Greece, 840-846. pp. (12) Hardaker, J. B. – Huirne, R. B. M. – Anderson, J. R. – Lien, G. (2004): Coping with Risk in Agriculture. 2nd edn. CABI Publishing, Wallingford-Cambridge (13) Harnos, N. (2003): A klímaváltozás hatásának szimulációs vizsgálata őszi búza produkciójára. “Agro-21” Füzetek 31. 56-72. pp. (14) Holm-Nielsen, J.B. – Madsen, M. – Popiel, P.O. (2006): Predicted energy crop potentials for bioenergy, worldwide and for EU-25. In: World Bioenergy 2006, Conference and Exhibition on Biomass for Energy, Jonkoping (15) Hoogwijk, M. – Faaij, A. – Eickhout, B. – de Vries, B. – Turkenburg, W. (2005): Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. Biomass and Bioenergy, Vol.29, 225-257. pp. (16) Horváth, L. – Erdélyi, É. (2006): How climate change influences the field crop production. ECO-Conference 2006. (Novi Sad), 1-6. pp. (17) Horváth, L. – Gaál, M. – Erdélyi, É. (2006): The use of spatial analogy in climate change research. Summer University on IT in Agriculture and Rural development, Debrecen (18) Hungary’s Report on Demonstrable Progressunder Article 3.2 of the Kyoto Protocol, in line with Decisions 22/CP.7 and 25/CP.8 of the UNFCCC Republic of Hungary 2005. http://www.kvvm.hu/szakmai/klima/ (19) IPCC Report on Climate Change 2001. Working Group II: Impacts, Adaptation and Vulnerability (20) IPCC, Climate Change, The Physical Science Basis; Summary for Policymakers. The IPCC 4th Assessment Report, 2007 (21) IPCC, Climate Change: The IPCC Scientific Assessment, (Eds. Houghton, J.T., Jenkins, G. & Ephraums, J.J.), Cambridge University Press, Cambridge, 1990 (22) IPCC, Climate Change: The Science of Climate Change, (Eds. Houghton, J.T., Meira Filho, L.G., Callander, B., Harris, N., Kattenberg, A. & Maskell, K.), Cambridge University Press, Cambridge, 1996 (23) IPCC: Climate Change 1995: “The Science of Climate Change”, (Eds. Houghton, J.T., Meira Filho, L.G., Callander, B., Harris, N., Kattenberg, A. & Maskell, K.), 1996. Cambridge University Press, Cambridge

(24) KIM, S. – DALE, B.E. (2004): Global potential bioethanol production from wasted crops and crop residues. Biomass and Bioenergy, Vol.26, 361-375. pp. (25) KOVÁCS, G. J. (1998): Estimation of the Effect of Global Warming on Yields and Environment of Arable Crops in Hungary. Agrokémia és Talajtan 47. (1-4.) 133-144. pp. (26) KOVÁCS, G. J. – RITCHIE, J. T. – NÉMETH, T. (1998): CERES models in Multiple Objective Decision Making Process. El-Swaify and Yakowitz D. S. (eds) 1st Internat. Conf on MODSS for Land, Water and Envir. Man.: Concepts, Approaches and Appl. Honolulu. Lewis Publ. 281-290. pp. (27) LADÁNYI, M. (2006): Alternatives of process approaches in agro-ecosystem modeling. PhD theses, Corvinus University of Budapest, Dpt. of Mathematics and Informatics (28) LADÁNYI, M. – ERDÉLYI, É. (2005): A kukoricatermesztés kockázatának vizsgálata egy új sztochasztikus hatásossági módszerrel. (The increase of risk in maize production detected by a new stochastic efficiency method), Agrárinformatika 2005 1-6., Debrecen (29) PARRY, M.L. – CARTER, T.R. (1998): Climate impact and adaptation assessment. Earthscan (30) RAJKAI, K. – SZÁSZ, G. – HUZSVAI, L. (2004): Agroökológiai modellek. Debrecen university, ISBN 9634-7285-6 Debrecen (31) RICHARDSON, J. W. – SCHUMANN, K. – FELDMAN, P. (2001): Simetar: Simulate Excel to Analyse Risk. pt. of Agricultural Economics, Texas A&M University, College Station (32) SEMENOV, M. A. – JAMIESON, P. D. – PORTER, J. R. – ECKERSTEN, H. (1996): Modelling the effects of climate change and climatic variability on crops at the site scale. Wheat. In: Harrison P. A., Butterfield R. E., Downing T. E., (eds): Climate Change, Climatic Variability and Agriculture in Europe. An Integrated Assessment. Annual Report 1996. Oxford: Environmental Change Institute, University of Oxford. 85-92. pp. (33) SEPASKHAH, A.R. – BAZRAFSHAN-JAHROMI, A.R. – SHIRMOHAMMADI-ALIAKBARKHANI (2006): Development and evaluation of a model for yield production of wheat, maize and sugarbeet under water and salt stresses. Biosystems-Engineering. 93(2): 139-152. pp. (34) SZENTELEKI, K. – LADÁNYI, M. – ERDÉLYI, É. – HORVÁTH, L. – HUFNAGEL, L. – RÉVÉSZ, A. (2007): A climate research database management software. Efita Conference 2007, Glasgow (35) VARGA-HASZONITS, Z. (1972): Agroklimatológiai model az őszi búza fenofázisainak meteorológiai jellemzésére. Kandidátusi értekezés (36) VARGA-HASZONITS, Z. (1987): Agrometeorológiai információk és hasznosításuk. Mezőgazdasági Kiadó, Budapest (37) VEISZ, O. – HARNOS, N. – TISCHNER, T. (1996): The effects of CO_2 levels on the development and yield of cereals. Aspects of Applied Biology 45, Implications of "Global Environmental Change" for crops in Europe, 107-111. pp.

ENERGY CROPPING CONSIDERATIONS

JOLÁNKAI, MÁRTON

Keywords: energy cropping, GHG emission, renewable energy sources.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

Renewable energy prodution is one of the main issues for mankind in the 21st century. There are three major factors that may influence renewable energy production: one of them is the availability and economic conditions of regular energy sources, the other is the emission reduction of GHG gases – in first place CO_2 – in relation with climate change mitigation efforts, and last but not least challenges of agriculture and rural development. Nowadays there are many initiations underway to find new, renewable energy sources. Fuels derived from agricultural biomass cover a wide range. The most important ones are bio-diesel, bio-ethanol and bio-gas. There are high expectations regarding novel energy sources: they have to be economically viable, and at the same time they have to be environmentally acceptable.

Primenergy consumtion structure in Hungary has been changed profoundly during the past decades. In the seventies of the last century two thirds of energy consumption was based on the use of coal and oil. Recently the two most important energy sources are the gas and the nuclear power. There is only one field of energy sources that seems to be rather stable during the period examined: alternative energy – namely water, wind, solar and renewable energy sources – including the various uses of biomass. Since the use of these alternative energy sources have been expanded recently, they represent only a minor slice within the energy structure. The use of oil based motor fuels represent a most peculiar field of energy budget. Hungary uses an annual amount of 1.5 million tons of petrol and 2.8 million tons of diesel.

Agriculture in general and energy cropping in particular is a most important field of renewable energy sources. There are three major fields within agricultural renewable energy resources: one is the biomass production for direct combustion and for indirect uses and further processing. The other is the bio-diesel and the third is the bio-ethanol production. The two latter belong to the target area of energy cropping. There are two reasons that are supporting the development of these fields. Hungary is a land of very limited natural resources. The only natural resource regarding energy is the ability for agricultural production, namely that 1500 MJ/m^2 photosynthetically active energy that may convert atmospheric carbon dioxide into various biological matters. The other reason is the highly variable global food market that is often resulting food surpluses in this part of the world combined with the rather strict EU regulations regarding regional and national food production contingents. Energy cropping may also be a considerable tool in mitigation of GHGs, especially CO_2 emissions. Fuels derived from agricultural energy crops may replace fossil energy sources. Photosynthetic carbon sequestration may be utilized in three possible fields (Fig. 2).

The problems of any of these fields are manyfold:

- Low energy conversion efficiency (1:1 to 1:6 maximum).
- Economic losses in comparison with conventional energy sources (fossil fuels, nuclear power etc).
- Deterioration of environment by abusing organic matter cycles. Exploitation of natural resources.
- Lack of sustainable long term vertical and horizontal technology structures.
- Uncertainities in industrial byproduct outputs and technology side effects.
- Counteracting of food security while producing energy crops on areas dedicated to food supply or when alimentary crops or edible grain yields are converted into bio fuels.

The three main fields of photosynthetic carbon sequestration are all affected by the problems listed above, however in different ways and to various extent respectively. Any of them may have positive and negative effects. There are two characteristics that should be evaluated in all cases whatever is the energy source of that: once the energy input, namely the energy conversion efficiency (NEB – net energy balance), and on the other hand the economic viability in comparison with the cost of regular commercial energy. Fig. 3 and 4 provide information on these characteristics.

It can be seen, that there are considerable differences regarding the use of various agricultural crops. The highest efficiency was found in cases of direct and indirect uses of biomass, like burning or fermentation of that. Biomass energy conversion may have a 1:6 energy input-output ratio. Biofuels – bio-diesel and bio-ethanol – have much poorer energy return figures. Bio-diesel production has a 50-60 per cent efficiency in comparison with that of biomass derived energy. Bio-ethanol versions have the lowest NEB ratios. According to the crop species used, that is in a range between 1 to 2 NEB ratio. Regardless to this low energy conversion rate, ethanol production seems to be a most promising field of renewable fuel production. It has two reasons. One is the relative low cost of production, while the other is the safe and simple technology. Commercial large scale production of ethanol, based on almost any of agricultural crops and byproducts like grain crops, root and tuber crops, fruits, and various farm and processing byproducts has been quite general in Hungary since the mid nineteenth century. Whatever is the case – today neither bio-ethanol, or bio-diesel production can be economically efficient in comparison with fossil fuels, however the continuously rising oil prices may be promising for the future.

According to the present economic situation net production prices of petrol free of any taxes added, vary between 0.56 to 0.70 USD/l. Today – 2008 Spring – in Hungary the net production price of bio-ethanol is approximately 1 USD/l and that of bio-diesel is about 1.2 USD/l calculated on petrol energy equivalent base. It means, that these renewable fuels can be sold only by sever tax reductions or other means of government subsidies. The situation is economically not viable yet, however that may be improved. The price of fossil fuels can not be properly predicted, but one fact should be taken into consideration: global oil resources are finite, consequently the prices of this raw material will hardly decrease int he future. There is an other factor, that may influence the improvement in energy cropping: EU legal obligations regardig GHG, and within that CO_2 emissions that require strict measures in Hungary to meet these requirements. EU recommendations suggest 5.75% alternative motor fuel use proportion for 2010. The only question is, what shall be the source and the means to produce renewable fuel in this country, and what level of economic efficiency can be handled by the government, and accepted by the society.

Crop production is one of the promising fields that may provide renewable energy for mankind. Maize (*Zea mays* L.) crop with an average 65% starch content is highly suitable for bioethanol production. Starch content of some cultivars have been slightly increased by recent plant breeding projects. Both starch componets of maize crop; amylose and amylopectin can be fermented to sugars and then to ethyl alcohol. The result of this chemical process is a solution containing 18-20 (V/V)% ethanol. Further distillation may produce 96 (V/V)% ethyl alcohol. Bioethanol can be used for energetic purposes in two main forms. It can be used as motor fuel mixed to petrol in 5-15 per cent volume. Also pure bioethanol is suitable for direct use, however provides less energy, since 1 l ethanol equals to 0.65 l petrol. The other significant form is the use of ethyl-tertiary-butyl-ether (ETBE). From among agricultural plant species grain crops like maize and wheat seem to be the most suitable sources for ethanol production, since strorability and portability of grain provides a chance for permanent industrial processing all along the year (*Márton, 2006*). Maize, due to its higher yielding ability and energy density can be a best source for deriving ethanol from (*Berzsenyi and Lap, 2004; Jolánkai et al., 2005*).

The *Szent István University Crop Production Institute* has recently started a new research on exploring the most characteristic agronomic impacts (biological bases, production sites, plant nutrition and crop year effects) influencing the efficiency of maize starch based bioethananol and so ETBE production. The aim of the research is to observe, identify and quantify agronomic impacts and their interactions that may have an influence on production efficiency and stability. The main purpose of the research is, that agronomic influences, site characteristics, and varietal genotypic differences may result in huge alterations regarding ethanol yield performance. According to our preliminary trials varietal differences in ethanol production have outranged 10% on identical starch bases. Also, experimental conditions provided a chance for increasing carbohydrate content of maize hybrids, as well as to optimise ethanol output. Ethyl-tertiary-butyl-ether conversions have suggested, that the conversion rate from alcohol to ETBE may be variety specific. Fig. 5 demonstrates starch yield of maize hybrids produced on various nutrient levels. Fig. 6 presents results on variety specific differences regarding ethanol output.

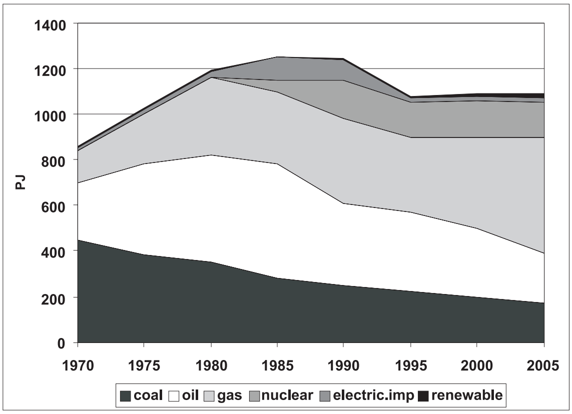
The results obtained give a chance to form some conclusions, however there is a wide range of open questions that request further investigations. There is an evidence, that contribution of plant breeding to energy cropping is highly significant. The maize hybrids studied had an average starch content of 70.5-74.2%, what is 8.4-14.1% higher than that of conventional genotypes. The yielding ability of maize hybrids was influenced by the maturity group they belonged to; early hybrids had some 40% less grain yield compared to the late ones in average.Higher N fertilizer rates resulted in higher grain yield in all hybrids.

Starch content of grain samples have shown a slight, but definite decline in accordance with higher N fertilizer rates applied. All maize hybrids studied, especially in higher N treatments have produced sufficient amount of starch for exceeding 400 l t^{-1} ethanol:grain production ratio.

There are some open questions that have not been studied yet. Impacts of production site and crop year are to be studied later. Grain starch alcohol as well as ETBE processing should be tested in industrial technological laboratories. Amount of byproduct carbohydrates in form of fibres and other plant tissues as cob, stalk, leaves and ways of alcohol conversion from that are to be observed. Economic and energy budget analysis has to be done to verify the utility of agronomic impacts.

In the ADAM climate change research according to the work plan schedule of Tisza River basin case study P3di the main tasks were described in the following: "Land Use and Agriculture for adaptation & mitigation". One of the research fields was – "Energy crops & their cost effectiveness in relation to adaptation & mitigation".

Figure 1



Primary energy consumption in Hungary
Source: FST, 2006.

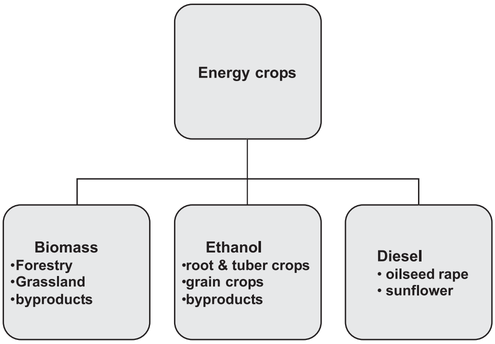


Figure 2

Main fields of photosynthetic carbon sequestration in Hungary
Source: Jolánkai, 2007

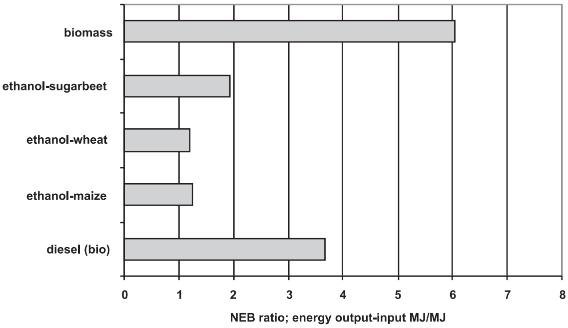
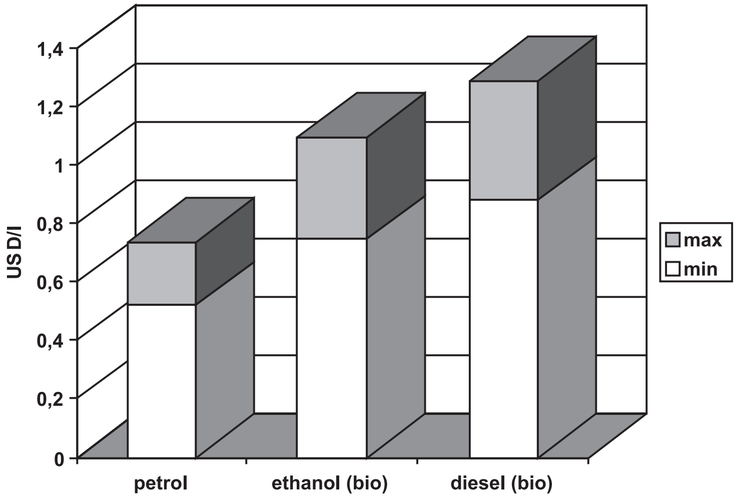


Figure 3

Energy conversion efficiency of some agricultural crops
Source: Hill et al., 2006

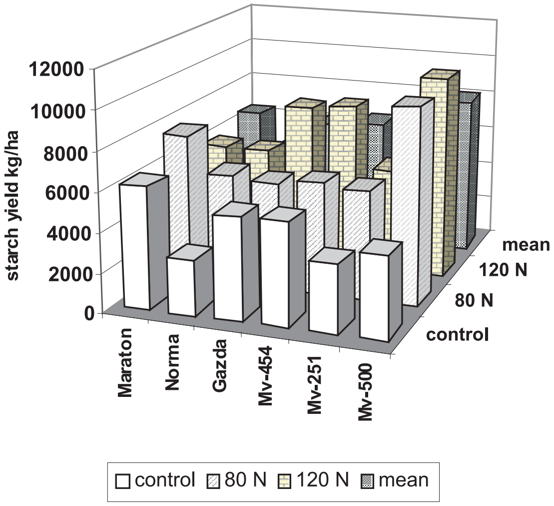
Figure 4



* 100-110 USD/barrelprice; energyequivalent = 0,66 ethanol , 0,91 diesel

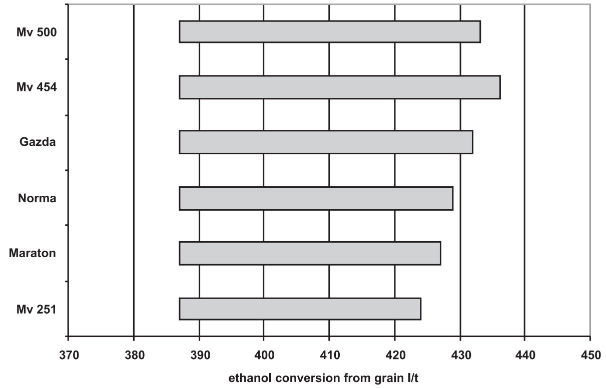
Net production costs of some renewable fuels, 2008*

Figure 5



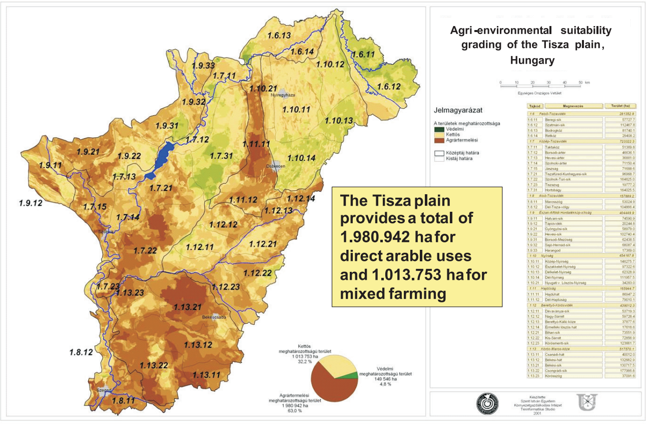
Starch yield of maize hybrids at different nutrient levels
Source: Jolánkai et al., 2007

Figure 6



Varietal differences in grain ethanol conversion
Source: Jolánkai et al., 2007

Figure 7



Agri-environmental suitability grading of the Tisza plan, Hungary

The Tisza plain in Hungary covers some 3 million hectares area from what some 2 million hectares can be used for direct arable farming, whereas 1 million hectares for reduced agricultural and improved environmental activities according to ecological aspects (Fig. 7).

In the CUB coordinated research agronomic use of 24 potential energy crops have been studied (grain crops, legumes, oil seed crops, root and tuber crops and energy grasses). The possible production area and the regional distribution has been identified. According to the recent energy and food shortages int he world ramarkable changes can be observed int he cropping structure of the region. In 2008 year the area of oil seed crops, eg. oil seed rape and sunflower has been expanded with 24-32% in comparison with the previous year's figures, respectively. There are considerable attempts for producing other energy crops as well. Major grain crops have a renaissance as well. Some other cash crops, like sugar bee tor potato, as well as fodder crops have lost areas.

Altogether it can be stated, that the agro-ecological conditions of Hungary and within that the Tisza region is suitable for efficient energy cropping that may contribute to the national energy supply. There are some doubts as well. There are too high expectations regarding energy cropping, and on the other hand there are also improving markets for food and food products as well.

ACKNOWLEDGEMENTS

This research was supported by the Hungarian Government by the research funds OTKA, NKFP and NKTH-GAK. Also, the research is related to the ADAM EU-FW6 project.

REFERENCES

(1) Berzsenyi, Z. – Lap, D.Q. (2005): Responses of maize (Zea mays L.) hybrids to sowing date, N fertiliser and plant density in different years. Acta Agronomica Hungarica. 53. 2. 113-119. pp. (2) Hill, J. – Nelson, E. – Tilman, D. – Polasky, S. – Tiffany, D. (2006): Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. PNAS, Vol 103. 30. 206-210. pp. (3) Jolánkai, M. – Máté, A. – Nyárai, H.F. (2005): The carbon cycle: a sink-source role of crop plants. Cereal Research Communications, 33.1. 13-17. pp. (4) Jolánkai, M. – Nyárai, H.F. – Farkas, I. – Szentpétery, Zs. (2007): Agronomic impacts on energy crop performance. Cereal Research Communications, 35.2. 537-541. pp. (5) Jolánkai M. – Nyárai H.F. – Farkas I. – Szentpétery Zs. (2007): Kukorica (*Zea mays* L.) hibridek energetikai célú termesztése. Acta Agronomica Óváriensis 49. 2. 489-494. pp. (6) Lawlor, D.W. (2002): Carbon and nitrogen assimilation in relation to yield: mechanisms are the key to understanding production systems. Journal of Experimental Botany, 53. 773-787. pp. (7) Márton L. (2005): A műtrágyázás és a csapadék változékonyságának hatása a kukorica (Zea mays L) termésére. Agrokémia és Talajtan. 54. 3-4. 309-324. pp. (8) Sárvári, M. (2005): Impact of nutrient supply, sowing time and plant density on maize yields. Acta Agronomica Hungarica. 53. 1. 59-70. pp.

INSTITUTIONS FOR ADAPTING TO CLIMATE CHANGE IN THE TISZA RIVER BASIN

MATCZAK, PIOTR – FLACHNER, ZSUZSANNA – E. WERNERS, SASKIA

Keywords: formal and informal institutions, Tisza river region, local actors, New Vásárhelyi Plan.

SUMMARY FINDINGS, CONCLUSIONS, RECOMMENDATIONS

Adaptation is increasingly seen as an inevitable answer to the challenges posed by climate change. Recent predictions of an increased incidence of extreme events have been the driving force behind the quest for adaptation strategies to maintain safety and reduce climate related problems in managed river basins. Current initiatives focus on the mainstreaming of adaptation, the appraisal of specific adaptation options and the role of institutions in adaptation. This paper looks at adapting to climate change as a collective action in the new institutional economics context. Climate change is an additional source of risks for organisations. To cope with these risks, organisations use both formal legal institutions (such as laws and binding agreements) and informal social institutions (such as norms, conventions, self-imposed codes of conduct). Trust towards the government, and mediating organizations (NGOs, business, etc.) is widely considered as an important factor in decreasing the enforcement costs of institutions and opportunistic behaviour.

This paper aims to identify what formal and informal institutions allow organisations to manage the risks associated with climate change. The paper firstly presents a literature overview of formal and informal institutions for adapting to climate change. Secondly it compares formal and informal institutions in the Hungarian Tisza river basin. It appraises how these institutions are perceived to facilitate adapting to climate change. Evidence from the Tisza region so far supports that successful adaptation requires both informal and formal institutions. Formal institutions can mainstream adaptation and are required to include adaptation in longer term planning, investment and large-scale infrastructure. Informal institutions are crucial in strengthening adaptive capacity and implementing non-structural measures. In implementing adaptation the role of informal institutions seems to have been neglected.

INTRODUCTION

Climate change is likely to cause more frequent and less predictable floods, heat waves, droughts etc. (*IPCC, 2007*). Significant uncertainties associated with climate impacts make the application of mitigation and adaptation measures difficult. Thus, notwithstanding the importance of mitigation measures, adaptation is gaining attention since climate impacts are unavoidable (or combination of both).

Since 1980 weather related disasters are treated not only as physical happenings. Efficient adaptation involves not only structural (technical) measures, but also has to take into account socio-economic aspect (*Helmer and Hilhorst, 2006*).

Difficulty lies however in the necessity to combine the global scale measures (since climate change is a phenomenon of supranational scale) with the regional and local ones (*Schipper and Pelling, 2006*). Implementation of large, top-down policies, based on international agreements, and national regulations brings the problem of accountability[1]. The multi-scale approach has been discussed in the area of natural resources management (*Roth, 2004*) and social sciences (*Biermann, 2007*).

Institutions offer trustworthy ways of weighting the needs of local communities and global commons and are of crucial importance. Moreover, *Adger (2001)* poses the question, whether the state is able to deliver adaptive capacity, and how far national policies must be coherent with local norms and based on local social capital.

It is argued that a source of adaptation capacity can be found at the level of local communities (*Allen, 2006; Adger, 2001*). The idea of Community Based Disaster Preparedness searches for adaptation at the local level. However, drawbacks of reliance on local capacities are pointed out too (*Bollin, 2003; Allen, 2006*). *Adger (2001)* advocates focus on collective action, social capital, and co-management (*Plummer and FitzGibbon, 2006; Adger et al., 2005*) as a basis for adaptation capabilities.

Adaptation to climate change requires both planned, top-down action and autonomous, locally rooted efforts. Uncertainties connected with climate change make it difficult to devise generally applicable adaptation measures. Adaptive capacity is more importance instead. There is little knowledge how to facilitate adaptation, however.

This paper explores planned and autonomous adaptation in the Hungarian part of the Tisza river basin Strength and weaknesses of formal and informal institutions in supporting adaptation are investigated. The paper presents the basic assumptions and methodological approaches as well as the first results of a study on the role of institutions in adaptation.

INSTITUTIONS

Coping with climate related risk requires coordination and regulation, i.e. establishing institutions. The importance of institutional aspects is often mentioned in the context of climate change (*Feldman and Mann, 1991; Bulkeley, 2001; WHO, 2002; Adger et al., 2003; WHO, 2004; Kunreuther et al., 2004; Lorenzoni et al., 2005; Schipper and Pelling, 2006; O'Brien et al., 2006; IPCC, 2001*). Institutions are understood in a wide meaning, comprising of organisations like administration bodies, agencies, laws and regulations. A more precise notion of institutions worked out within the conceptual framework of the new institutional economics (*Ostrom, 1990; 2005; North, 1990*), offers useful insights in the study of adaptation. Institutions are understood, as: „sets of working rules that are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregations rules will be used, what procedures must be followed, what information must be or must not be provided, and what payoffs will be assigned to individuals dependent on their actions" (*Ostrom, 1990, p. 51*). Institutions are built in order to deal with production and sustaining of any kind of public goods. The function of institution lies in the ability to deal with spill over effect, in terms of externalities, and with free rider problems in terms of decision-making and collective action. Moreover, it is emphasised that institutions reduce uncertainties of human actions *(North, 1990)* and decrease risks *(Root, 2005).*

---

[1] Accountability is understood as proactive process by which public officials inform about and justify their plans of action, their behaviour and results and are sanctioned accordingly (*IBRD, 2005*).

Formal and informal institutions

The global scale of climate change involves large-scale policies. Costs of information and enforcement are increasing when a top-down policy is applied (*Williamson, 1985*). Often local knowledge and capabilities are disregarded. In this respect, a distinction between formal and informal institutions offers insight. The former institutions are legally introduced and enforced by state institutions. They are embedded in state operations, based on laws and policies.

Informal institutions rely on enforcement methods not supported by state. The examples of them are: customs, traditions, rules of conduct, etc. Rising awareness campaigns, public information actions are largely focused on the informal institutions, trying to establish them, strengthen, or – change. Also informal network relations between actors, based on ties of sympathy, interest, corruption[2], family relations etc. are based on informal institutions. Although formal, legal institutions play much bigger role in modern societies, but the importance of informal institutions should not be disregarded (*Ingram and Nee, 1998; World Bank, 2002*). They often regulate behaviour in private mode and it is especially important when the collision between informal norms and formal regulation appears. *Ellickson's (1998)* study on farmers disputes in California show unexpectedly high reliance on informal rules. Moreover, in countries of low GDP per capita, informal institutions can play a role, which in the developed societies is attributed to formal ones (*Platteau, 2000*)[3].

Both formal and informal institutions have a role in adaptation to climate change. The former offer rigid enforcement (helping to deal with the collective action problems, spill-over effects, externalities), while the latter use locally rooted compliance based on tradition. Additionally, the relation between the levels is important. Below, institution on the community level, on the state level and the relations between these are discussed.

Adaptation institutions at the community level

Centralisation of adaptation policies can be flawed. Measures can fail at the local level, where formal rules meet informal practices (*Nee and Ingram, 1998; Hurrelmann, 2005*). In this respect informal institutions operation on local level can hinder implementation of policies. At the same time, global scale of climate change challenge give little space for local communities to adapt, taking into account the scale of impacts, basing on their own resources (*Marsh, 2005*). Nevertheless, there is adaptation potential on the local level. Local government plays a fundamental role in land – use, urban density, etc. Climate change impacts will be felt and differentiated mainly at the local level. If climate change policies are to be effective at the individual and household level, local government will have to play a key role to foster informal networks of expertise and cooperation among local businesses, local schools, colleges, universities, libraries, NGOs, churches, and other social groups, that is policy networks (*Crabbé and Robin, 2006; O'Riordan et al., 1998*).

The background paper for this conference affirms that adaptive and inclusive earth system governance requires the consent and involvement of agencies beyond the state (*Biermann, 2007*). The role of informal institutions has been recognized for climate change policies. *Adger (2001)* argues that adaptation to the risks posed by the climate change is rooted in local culture and traditions. It can involve certain, although not easily measurable, adaptation capacity. In terms of internal features of a community, *Adger* points out the role of the collective

---

[2] In post communist countries many aspects of government collapsed and were replaced by a new network economy *(Grabher and Stark, 1998).*

[3] Property rights can serve as an example.

Table 1

Styles of policy implementation depending on the quality of state and type of social capital

	State promotes security and sustainability	*State works through coercion*	*Ineffective state, lack of legitimacy*
Bridging social capital	Social and policy learning; participatory planning; co management	Conflicts	Migrations; network economy (Rose, 1999); criminal and corruption networks.
Bonding social capital	State substitutes external linkages	Local conflicts (hidden)	Communities take over the functions of the state

Source: Adger, 2001

action[4], and social capital[5] in adaptation. Social capital can be treated as a specific institution establishing a basis for collective action (*Nostrum, 1994*). Badger investigates two types of social capital: bonding (concerning ties within a group) and bridging (related to trust relations reaching outside the group), and notices a role in adaptation for both. *Bonding type* of social capital, based basically on kinship, provides help in case of disaster and recovery but does not help much in adaptation in advance. *Bridging type* social capital, based on reciprocity – not on family ties, helps to keep wider social relations and can offer help in establishing different type of social services, systems eg. health care systems, community flood protection networks (Table 1).

The importance of local institutions for adaptation is a core assumption in Community Based Disaster Preparedness (CBDP). CBDP approach focuses the attention on the adaptive abilities of a community, emphasizing the role of self-reliance of a community, awareness of its members and their practical skills. The idea is to empower local people in adaptive capacities[6]. There are several measures[7] possible to employ in order to achieve this (*Allen, 2006: Bollin, 2003*): a) technical information dissemination; b) raising awareness of risk; c) assessing local knowledge and resources; d) mobilizing local people.

Allen (2006) notices the importance of informal institutions in promoting partnerships of local and government actors in preparedness to disasters. Communities have ability to choose options taking into account also their members of low impact.

There are, however, several difficulties in application of CBDP. Firstly, although there are capabilities to cope with a disaster within a community, a community itself can hardly be treated as homogeneous.

Hence, several features should be considered when CBDP is to be design: a) presence of minorities (e.g. ethnic minorities); b) vested local interests; c) instability of a community caused by e.g. migration opportunities, large external investments; d) concentration of ties densities (e.g. in Philippines case family relations are stronger than civil society and state in providing the security – *Allen, 2006*); e) increase of national political influence (polarization). Also turnover of personnel influences the results (*Bollin, 2003*). CBDP implementation can strengthen tensions existing within a community. If officials select participants without recognition

---

[4] Collective action results rely on mutual interdependence of performance of actors.

[5] Social capital is understood as „…features of social organisation, such as trust, norms, that can improve the efficiency of society by facilitating co-ordinated actions" *(Putnam et al., 1993).*

[6] *Allen* observes the shift from independent role of civil society (1980-90s) to partnership relations between government and civil sectors.

[7] CBDP is an approach distant from interventionist, focused on the technology.

of local circumstances it can result in disempowerment of local knowledge and local community. Allen notices a dangerous tendency to search for short term design and effects of isolated small scale projects, and concentration on physical hazards rather then people's experience of vulnerability.

The role of state in building local adaptation

The role of local, informal institutions in adaptation to climate change is important but since many climate change impacts are of supra local scale a substantial contribution to adaptation has to come from state (eg. flood protection programmes, energy sector strategy).

Concerning the relation between state and community, *Collier (1998)* distinguishes two forms of social capital. The first one appears at civil level and provides common values, traditions, norms, informal networks etc. It is located within a community. The second one can be found at government level, and helps to enforce societal contracts, and provides rule of law and. The second type of social capital offers institutional environment for operations of local actors.

Adger (2001) exploring the role of state in relations to social capital differentiates between three types of governmental conduct concerning policies' designing and implementation: a) state promoting security and sustainability; b) state enforcing policies by coercion; c) ineffective or weak state (Table 1).

Adger emphasizes that a state can be of a different „quality" and it influences the conduct. When the state is weak or absent then social capital can replace its duties. *Adger* offers an example of coastal management in Vietnam. Similar case can be found in other post-socialist countries: irrigation systems in Bulgaria (*Theesfeld, 2003*), economic life in Russia (*Rose, 1999*). At the same time, properly working state can substitute weak social ties (*Juetting, 2003*).

Dynamic aspect of adaptation capacity

Introduction adaptation policies is a dynamic process. The existing institutions (both formal and informal) and resources comprise the background of policy implementation. The policy design and performance of the state can empower local institutions and use them, can disregard them, and also the new institutions can contradict the existing ones.

Adaptation measures can be introduced relying on existing informal institutions. *Adger (2001)* mentions, for Asian examples, informal networks of credits; networks helping in maintaining religious buildings, funerals, and marriage ceremonies, as resources of social capital offering the basis for adaptation policies. *Molnár (2004)* emphasises the importance of community responsibility and joined management of local water networks both for individual and community benefits. *Jalali (2002)* emphasizes the role of media in managing a disaster. Also well-developed vertical relations based on synergy between the state and civil sector are helpful for establishing novel adaptive arrangements.

In many cases, attempts to increase adaptive capacity require establishing new institutions. The very idea of CBDP aims to build institutions regulating the area within civil society and the area between state and civil sector, in order to reduce vulnerability. The state has initiative power in this respect. Building a good information exchange and cooperation between regulatory agencies and civil sector working closely together, establishing a platform for discussion or – action groups can produce good results (*Bollin, 2003; Adger, 2001*).

However successful conduct is not easy. Experience from Bangladesh cases shows that when flood management were prepared without proper funding delivery, it resulted in the state control over the engaged civil sector (*Allen, 2006*). The vulnerability can be politicised and become a part of an argument on scope of responsibility of the state, land use planning etc. Building bridge and cooperation between the different sectors (policy, research, civic and local administration, farmers), which supports establishment of new combined institutions are also not easy, need careful planning, time and trust (*Flachner, 2005*).

More generally, to establish an institution is difficult in itself. It requires a common engagement that is problematic. Households are reluctant to invest in communal projects. Collective action without special enforcement or incentives reaches suboptimal level or cannot start at all (*Olson, 1965; Ostrom, 1990*). Free riders (not participating in costs of institution preparation, maintenance and sanctioning but counting on the benefits from it) have to be avoided and made to comply. Otherwise the institutions fail (or – it does not emerge).

For these reasons, the actors operating in the formal sphere are more effective than the informal ones. They are able to gain power and resources to work in a scale wide enough to deal with externalities (for example in a scale allowing for integrated management of resources). They also have capabilities to avoid free rider problem – e.g. they are able to exert taxes or force into action all the stakeholders. Taxation is a basis for dealing with risks (*Root, 2005*).

Nowadays, not only the essential state is responsible for establishment and enforcement of institutions. *Majone (1996)* argues that relatively independent semi-governmental agencies have bigger role in many cases.

However, state involvement is not without deficiencies neither. Its conduct is biased because of their own, internal dynamics: bureaucratic slippage (ability of the bureaucracy to implement a policy which is not preferred by the principal – *Majone, 2004*), budget maximisation syndrome etc. Moreover, formal, state institutions are costly in operation. As a result, a government's bodies are sometimes reluctant in implementation of policies if they bring no value-added incentives for administration. Thus, neither formal nor informal institutions can be regarded as a definite solution in building adaptation concerning climate change.

DATA

Below, the role of formal and informal institutions in relation to adaptation to climate change in the Tisza river basin (Hungary) is presented and discussed. The *New Vásárhelyi Plan* is taken as a main object of investigation. The data were collected through interviews with stakeholders representing national (ministries, water authorities, physical planning) and local organisations (environmental NGOs, academic institutions) in Hungary; a workshop with local stakeholders of the Tisza basin, and analysis of documents on the *New Vásárhelyi Program* and other projects prepared for the region.

RESULTS

Tisza river region

The Tisza river is the largest tributary of the Danube, with the total watershed area of 157 186 km^2. Tisza's tributaries originate in the Carpathian Mountains in the territories of Romania, Slovakia and Ukraine. It flows through the Pannonian flood plain of eastern Hungary and then south into Serbia and Montenegro. Almost 50 per cent of the Hungarian territory is covered by the Middle and Lower Tisza. Tisza is the second biggest river of Hungary. It has special geographical and historical features. It is unique in terms of wetlands and conservation areas, very regulated riverbed and frequent floods.

The Tisza floodplain area was utilized in a very complex way till the 18th century providing sufficient income for the communities along the river. These activities were mainly organized around the operation of „fok" – channel between the main riverbed and the floodplain, cutting through the natural levee. The fok (Fokgazdálkodás), i.e. hook-management was a traditionally developed through hundreds years management system of diverting, and temporarily retaining water in the floodplain for agriculture and fisheries, and growing fruit. This sustainable system included small pits and hand-made water steering canals, and vegetation. It secured income for local communities (*Andrásfaly, 1975; Molnár, 2003*). Habsburg nobilities started improving the shipping transportation on the Tisza, which initiated weakening the \`fok\` system. The main change of the Tisza River was a Vásárhelyi Plan initiated in the nineteenth century, when 32 percent of the river length was regulated. The former huge floodplain was drained, decreasing it by 84 percent. Also system of dikes was constructed. The changes brought degradation of traditional way of management and finally decline of the whole region. The communist era increased the level of pollution due to industrialisation. Privatisation started at the beginning of 1990s, brought dramatic drop of efficiency of the irrigation systems (large drainage, irrigation channels). Large areas have unclear property status (non divided land) resulting in imprecise responsibility for water system maintenance and taxes (*State of the art, KIOP, 2006*).

After the collapse of communism the idea of the New Vásárhelyi Plan (VTT) appeared, strengthened by severe floods combined with drought last years, despite long development and improvement of dikes system.

The risks caused by climate related extremes in Middle Tisza have to be seen as a result of long-term process (*Balogh, 2005*). Climate change enlarges problems of long and local origins. There are several areas where the impact of former human interventions can be seen against new challenges by climate change: nature, landscape, food production security, water, safety, and socio-economic sustainability.

The role of formal and informal institutions within the last water and land use regimes

Four main regimes can be differentiated over the last two hundred years in the Tisza river basin: a) the operation of the fok system (up to mid nineteenth century); b) the period between the first Vásárhelyi Plan implementation and beginning of preparation of the new Vásárhelyi Plan (from end of nineteenth century to the end of 1990s); c) development of the new Vásárhelyi Plan and the beginning of implementation (end of 1990s-); d) implementation and redefinition of new VTT.

Fok system. „The Fok" system was strongly based on informal, evolutionary grown institutions.

Communities and larger individual landowners (nobilities) owned the smaller water steering systems on their property. They operated the smaller water steering systems for their own benefit. Local authorities managed the larger water schemes. The management evolved as result of adaptation to natural processes (seasonal floods) in the way to use the processes for agriculture, fishing etc. The community work and informal exchange of help was also strong. The informal obligations of the basin communities' members were the main driving force sustaining the system.

The formal institutions played relatively small role. These were connected with monarch power and involved property rights and obligations to the crown.

It was intervention of the formal power that initiated undermining (indirectly) the system. In the XVIII century the monarch searched for land to be given to nobles and the Tisza river area was used for this purpose. Consequently, nobles started to drain and use it more intensively for agriculture production. Farmers living there were against the changes but the system the traditional management started slowly to disintegrate.

The first Vásárhelyi plan. The first Vásárhelyi Plan was an ambitious program of land and water management in the whole region. It profoundly changed the landscape in the river basin, through implementation of the system of dikes and channel structure. The shallow water flooding in the area disappeared. It decreased the benefits from fishing and in a longer run it resulted in soil degradation and grain production decline after 20-30 years of cultivation. At the beginning of the twentieth century the region faced crisis and stagnation. The implementation of the Vásárhelyi Plan was based on the strong role of state regulatory institutions. It was strengthened during the communist era, when national government played a dominant role in the water steering system. Also anti-flood measures were introduced in a formal centralized mode. Water boards, a formal bodies attached to the state, were responsible for the second level water steering system. Individual landowners and farmers were subjected to imposed regulations.

The period was characterized by weakening of informal institutions, e.g. degradation of community work and the informal exchange of help. The formalization of the whole economic and social life induced the second economy, parallel to the official one (*Hankiss, 1990; Rona-Tas, 1990*). Within the sphere informal institutions were established, in most respects opposite to formal norms. E.g. illegal wells were common, and people treated water as their private property.

New Vásárhelyi Plan development and implementation. Informal adaptation to the „rules of the game" in the communism system, in the form of the second economy was interrupted by two factors: change of the political and economic system, and change of the natural system. Concerning the latter, local communities members observed decline of floods destroying the possibility of fishing. The important event was the water contamination in 2000. Moreover, in terms of climate change, until 1998 floods in the area were less frequent, while after there were many, and some of them severe. Moreover they appear in unpredictable manner (in terms of seasonality). Climate change projections suggest more erratic rainfall and temperature rise, resulting in more frequent, intense and irregular floods and droughts (*Láng, 2006*). The floods raised the flood protection issue but also the inefficiency of last 150 years management started to be discussed. As a result several initiatives and projects and also the large scale policy – New Vásárhelyi Plan (VTT) were prepared. The first version appeared in 2002. Initially flood protection was the main context of the Plan. However, it was also meant as a stimulus for regional development for the remote part of the country. The main characteristic of the projects, important for adaptation is the attempt to restore the multifunctional land use structure. Reintroduction of natural flood plains can bring progress in terms of flood protection, and nature conservation. It is also believed to contribute to sustainable economic development of the region (which experience economic and social crisis) (*www.bokartisz.hu*).

It was designed within the formal and centralised structures of water management bodies and ministries. The plan promised funding for large-scale infrastructure investments together with subsidies for land use change. The work on the plan design motivated NGOs and activists from academic institutions to participate in the development of the plan. Also local governments started to be active in the plan preparation. The national government invited other actors to participate in plan development and funded participatory planning. Although the development of the plan started within the formal state structures, non-state actors gained influence and advocated solutions, which included informal institutions, e.g. „reintroduction" fok-type management (Table 2).

Notwithstanding that the plan has several measures directed to empower local, informal institutions, the implementation so far has focused on large scale infrastructural investments. The support of informal institutions and regional development measures [e.g. support for land use change]

Table 2

Approaches of main actors in the Tisza river towards cooperation concerning VTT

	Initial approach	**Conduct in development VTT**
Local governments	Demanding help from central government.	They have problems with budget, but they see their role as more important in lobbying for Tisza valley. They also see the benefits of the suggested measures (risk reduction combined with economic and social development; biomass, water issues, eco-tourism).
Central government ministries	Difficulties in cooperation between ministries because of money distribution (separated budgets – source: government reports); necessity to establish a coordination unit was recognized.	Sectoral approach because of lack of financial coordination.
Authorities (water, forest, agriculture, nature)	Worked separately, but they were forced to debate and to cooperate in order to achieve solutions.	Strengthening cooperation; reorganization last years (less staff and resources) it forces them to be partners in projects, they have to cooperate also with local governments to reach common understanding, and integrated solutions.
NGOs	Opposition to central government, trying to put issues and solutions in complex manner (Bodrogkoz, Bokartisz). Started cooperation, and demonstration projects.	Satisfaction with the fact that VTT included their ideas. Climate change is a new argument to better implementation of VTT. Limited role in implementation of VTT.
Local communities	Hoping that government offers solutions.	Awareness for solutions worked out by themselves. Farmers are willing to reshape their land (water utilisation project); they are supportive to new ideas. Social capacity still exists (the memory of the tradition is still present, inherited from parents).
Private sector (agribusiness)	Short term profits orientation.	Slight change: environmental sensitive category of business is prone to change (if there is a subsidy provided).
Academic institutions	Research of Tisza based on scientific interest.	After 2002: more integration (multidisciplinary approach and participation in policy discussions and development). There are attempts to establish the Tisza research group; there is the competition among the institutions however.

are delayed. For example in the Bodrogköz area a retention area is under preparation without planning the operation of the reservoir with local authorities or the appropriate land use change. Although the implemented measures are not the cheapest, they all follow the tradition of engineering infrastructure solutions. For example, to strengthen tourism potential, the technical measure was selected to include the basis for bicycle roads in the top of dykes that were renewed (fifty km) or newly build (another fifty km). Very few non-infrastructural measures were implemented: trainings were offered for water authority on flood prevention.

Central authorities and water boards have decisive power. NGOs' and research communities' status is not clear, and despite their efforts (lobbying, consultations, pilot projects) they are marginalized.

Information dissemination on the implementation is poor. Local people (e.g. the mayors) are involved in the design of the implementation plans only when they are active and want to. There is no formal consultation process. Though generally the planners inform local communities about the project, it is unclear whether feedback gets integrated into the planning process.

Challenges of the VTT implementation

The plan is delayed due to budgetary problem of the national government and shift of interest caused by the political swing (VTT law and governmental order modifications took place 3 times during the last 1.5 years, and one is in pipeline). Also tensions among lobbies within the administration produced deadlocks to establish the central program office to coordinate the efforts of different sectors (environmental, agricultural, social etc.). Moreover, information about the implementation and future directions is very limited.

Difficulties with implementation of the plan come also from not clear property rights (FAO-Bereg project internal report). After nationalisation in the communist times the privatisation in the Tisza region was relatively slow, because the land in this remote part of the country was less valuable for quick privatisation. As a result of privatisation there is extremely mosaic land ownership in the region. Property rights are often not completely clear. There are lands that are not divided joint properties. Also the canal and drainage systems were destroyed or unmanaged because of changes of property rights (*Láng, 2006*).

Blurred property rights constitute an important factor in terms of water management, for any change agreement has to be reached by all the owners which is sometimes difficult and time consuming. Additionally, since re-privatisation tickets (a measure of re-privatisation in Hungary) could be sold, land is many cases in hands of people living outside the region. It also creates difficulty for policies because owners do not always have interest in any action. At the same time, abandoned land is not a huge problem in the area.

Property rights issue are with adaptation. Water use is partially informally privatised, e.g. wells are used according to informal rules. Those who cannot effort buying it, take timber from the forests. Also creeks are informally treated as common land but, at the same time, by farmers as arable land. The status is unresolved, for community it is common, but farmers include them in their land as their own. These informal property right attributions pose a problem for water and land use management. Adaptation measures to climate change have to be combined with wider socio-economic development measures (as within multi functional land and water management). Separated measures dealing with flood protection (or drought) can face difficulties when meeting with informal practices. Community management of land and water systems could also integrate minorities and strengthen the integration process.

Social capital

There is little data on the type of social capital in the region (in terms of bridging-bonding types). Migration however is a sign of bridging social capital. The region faces depopulation and aging (*VÁTI, 2004*). Due to economic crisis inhabitants move outside, using social links helping them to find a new location.

Concerning trust towards the national government and local government, a study of *Albert et al. (2006)* show that in terms of preparedness to floods, water authorities, water associations and local government are ranked higher than central government.

Certain lack of trust towards central government is observed in all post-communist countries, and it is legacy of post war era.

The policies concerning the Tisza region, realized after 1990s were characterised by sudden shifts, giving the impression that a new governments builds it own policies disregarding previous ones (*UNDP, 2004*).

The awareness of the risk exists in the area, especially concerning floods. It is however locally perceived. Wider awareness of the impacts of floods, droughts (also in terms of climate change) is brought by outsiders – environmental NGOs and by scholars. Local governments could have played important role in building the social capital. They are however, small (it is a result of rather radical decentralisation at the beginning of 1990s) and weak in terms of resources. Larger cities have lower awareness since their problems are solved by authorities and municipal companies, rural communities threats and adaptation services are not recognized.

An ethnic factor can be of certain role in terms of social capital, since there is significant Roma minority in the area. An ethnographic study by *Fel (2001)* shows that Roma community was treated with a distance, although at the same time, there was a tradition of collective action and help within a village community in case of necessity (like fire).

Vision of the future

Local actors (NGOs, local governments), and activists from academic institutions are concerned about the deep social, economic crisis of the Tisza basin region. As a result the radical change of the type of development is proposed by many of the local actors. The „fok system" is an important reference point, as local management style, which provided local sustainability, in social, economic and environmental sense. The proposed change assumes empowerment of local communities, and informal institutions. Climate change in this vision constitutes a supportive argument for the necessity to restore locally based sustainability. The recognition of these ecological services – not just climate adaptation and flood risk reduction, but preserving biodiversity, landscape values – are crucial for substituting the development of these complex environmental, socio-economic structures (eg. in water prizing, insurance schemes, agri-environmental payments).

RESULTS AND DISCUSSION

Within last two hundred years water and land management in the Tisza river basin evolved from an adaptive system based on the informally driven „fok system" towards a formal and centralised system of water and land management. The shift entailed economic and social decline in a longer run. Moreover structural flood protection measures resulted in an inflexibly system that is increasingly challenged by climate change.

Restoration of a water and land management regime based on local sustainability, and similar to the idea of 'fok', is a driving idea of the activists' movement in the Tisza region. The ideas involve building local capabilities, and in this respect it is in line with establishing community based adaptation capabilities. Also multifunctional development and land management can be a measure strengthening adaptation.

The VTT is an ambitious attempt to solve several problems of the Tisza river basin within the complex policy. Primarily, water management and flood protection concern initiated the project. However, in the last 15 years the emphasis evolved to cover also nature protection, local socio-economic development and climate change issues.

Mobilisation of NGOs and local actors promoting locally based water and land use measures was successful at the preparation phase of VTT. Ideas about multifunctional land management were included to the body of the plan. In the course of implementation however, facing the budget constraints, non-structural measures have been marginalized.

This shows the peculiar position of the central government. Although the solutions based on multifunctional land use, and on local adaptation capabilities are recognized as desirable, they require informal as well as formal institutions. The process is not simply devolution of power but must be combined with strengthening the capabilities of local communities. The „muddling through” conduct of the plan implementation is dominated by a sectoral approach and makes the advocacies of the multifunctional solutions seem powerless. Dominant position of the central government is evident in the information on VTT. Very little is known about the implementation of VTT and the future plans about it. Despite the necessity of information and education, there is very limited access to the information of the plan conduct.

It is a matter of further investigation how far local adaptive capacity can be rebuilt with or without support. It entails another question: how can external support be organized and what can be the role of state institutions and NGOs? Evidence from the Tisza region so far suggests that the role of informal institutions is marginalized in the current conduct. The local capacity in this respect is limited, and despite the declarative recognition of its importance, there is no platform to strengthen the role of local actors. As a result, it leads to disappointment of local activists who counted on being involved in the process. Establishment of the Tisza alliance in June 2006 (*elotisza.hu*) has been motivated by the dissatisfaction of the local actors and NGO regarding the conduct of the VTT.

Evidence from the Tisza region so far supports the conclusion that successful adaptation requires both informal and formal institutions. Whereas informal institutions are crucial in strengthening autonomous adaptation and adaptive capacity, formal institutions can mainstream adaptation and are required to include adaptation in longer term planning, investment and large scale infrastructure.

ACKNOWLEDGEMENTS

The work has been supported by a grant from the European Commission through the EU research project ADAM (Project no. 018476-GOCE). The authors would like to thank research partners István Láng, Zsolt Harnos, Márton Jolánkai, Péter Balogh and Géza Molnár for their support in the Tisza region. We thank all interviewees and participants of the Tisza region workshop for sharing their experience on institutions and adaptation in the Tisza region.

REFERENCES

(1) Adger, W.N. (2001): Social capital and climate change. Norwich: Tyndall Centre Working Paper No. 8 (2) Adger, W. N. – Brown, K. – Tompkins, E.L. (2005): The political economy of cross-scale networks in resource co-management. Ecology & Society 10(2): 9. www.ecologyandsociety.org/vol10/iss2/art9 (3) Adger, W.N. – Huq, S. – Brown, K. – Conwaya, D. – Hulme, M. (2003): Adaptation to climate change in the developing world. Progress in Development Studies 3,3, 179–195. pp. (4) Albert, F. – Dávid, B. – Ferencz, Z. – Flachner, Zs. – Tamás, P. – Vári, A. (2006): Indicators of vulnerability to floods. Questionnaire survey in the Bodrogköz Area. unpublished report (5) Allen, K.M. (2006): Community-based disaster preparedness and climate adaptation: local capacity building in the Philippines. Disasters, 30(1): 81-101. pp. (6) Biermann, F. (2007): ‘Earth system governance’ as a crosscutting theme of global change research. Global Environmental Change doi:10.1016/j.gloenvcha.2006.11.010 (7) Bollin, Ch. (2003): Community-based disaster risk management approach. Experience

gained in Central America, Eschborn: GTZ (8) Bulkeley, H. (2001): Governing climate change: the politics of risk society? Transactions – Institute of British Geographers, n 26: 430-47. pp. (9) Collier, P. (1998): *Social Capital and Poverty.* Social Capital Initiative. WP No 4, The World Bank, Washington DC. (10) Crabbé, P. – Robin, M. (2006): Institutional adaptation of water resource infrastructures to climate change in Eastern Ontario. Climatic Change 78: 103–133. pp. (11) Ellickson, R. (1998): On Coase and cattle. In: M.C. Brinton and V. Nee red.: The new institutionalism in sociology, Stanford: Stanford Univ. Press (12) Fel, E. (2001): Fejezetek Tiszaigar társadalmának megismeréséhez. In: Régi falusi társadalmak, Fel E., Hofer T., Pozsony: Kalligram: 199-236. pp. (13) Feldman, D.L. – Mann, D. (1991): Policy Analysis and the Management of Climate Change: Institutional Adaptability in the Face of Scientific Uncertainty. Policy Studies Journal, Vol. 19, No. 2: 43-49. pp. (14) UNDP (2004): Rapid environmental assessment of the Tisza river basin. Geneva: UNEP/Regional Office for Europe (15) Hankiss, E. (1990): East European Alternatives. Oxford: Clarendon Press (16) Helmer, M. – Hilhorst, D. (2006): Natural disasters and climate change, Disasters, 30(1): 1-4. pp. (17) Hurrelmann, A. (2005): Agricultural land markets. Organizations, institutions costs and contracts in Poland, Aachen: Shaker Verlag (18) IPCC (2001): Climate change 2001, Synthesis report. Cambridge: Cambridge University Press (19) IPCC (2007): *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Summary for Policymakers*, IPCC Secretariat, Geneva, CH (20) Jalali, R. (2002): Civil Society and the State: Turkey after the Earthquake. Disasters vol. 26 2: 120-139. pp. (21) Juetting, J. (2003): Institutions and development: a critical review. OECD working paper no 210. (22) Kunreuther, H. – Meyer, R. – Van den Bulte, Ch. (2004): Risk Analysis for Extreme Events: Economic Incentives for Reducing Future Losses. Gaithersburg: National Institute of Standards and Technology (23) Lorenzoni, I. – Pidgeon, N.F. – O'Connor, R.E. (2005): Dangerous Climate Change: The Role for Risk Research. Risk Analysis, Vol. 25, No. 6: 1387-1398. pp. (24) Majone, G. (1996): Regulating Europe, London: Routledge (25) Majone, G. (2004): Dowody, argumenty i perswazja w procesie politycznym. [Evidence, argument and persuasion in the policy process], Warszawa: Scholar (26) Marsh, G. (2005): The concept of 'community': inclusion and empowerment in relation to vulnerability, resilience and disaster management. 7th Conference of European Sociological Association paper, Torun 7-9 September 2005 (27) Nee, V. – Ingram, P. (1998): Embeddedness and beyond: institutions, exchange, and social structure. In: M.C. Brinton and V. Nee red., The new institutionalism in sociology, Stanford: Stanford Univ. Press (28) North, D.C. (1990): Institutions, institutional change and economic performance. Cambridge: Cambridge Univ. Press. (29) O'Brien, G. – O'Keefe, P. – Rose, J. – Wisner, B. (2006): Climate change and disaster management. Disasters, 30(1): 64-80. pp. (30) Olson, M. (1965): The logic of collective action. Cambridge, Mass.: Harvard University Press. (31) O'Riordan, T. – Cooper, C. L. – Jordan, A. – Rayner, S. – Richards, K. R. – Runci, P. – Yoffe, S. (1998): 'Institutional Framework for Political Action'. In Rayner, S. and Malone, E. L. (eds) Human Choice & Climate Change, vol. 1, Battelle Press, Columbus (OH), 345–439. pp. (32) Ostrom, E. (1990): Governing the commons. Cambridge: Cambridge University Press (33) Ostrom, E. (2005): Understanding institutional diversity. Princeton: Princeton University Press. (34) Ostrom, O. (1994): Constituting Social Capital and Collective Action. Journal of Theoretical Politics 6 (4) (35) Platteau, J.-P. (2000): Institutions, social norms, and economic development. Amsterdam: Harwood Academic Publishers (36) Plummer, R. – FitzGibbon, J. (2006): People matter: The importance of social capital in the co-management of natural resources. Natural Resources Forum 30 51–62. pp. (37) Putnam, R. – Leonardi, R. – Nanetti, R. (1993): Making Democracy Work: Civic Traditions in Modern Italy. Princeton

University Press, Princeton, USA (38) Róna-Tas, Á. (1990): The Social Origins of the End of Socialism: The Second Economy in Hungary. Kézirat. (39) Root, H.L. (2005): Capital and collusion. The Politics of Risk and Uncertainty in Economic Development. Princeton: Princeton University Press (40) Rose, R. (1999): Getting Things Done in an Anti-modern Society: Social Capital Networks in Russia. In: Dasgupta and Seregeldin eds., Social Capital: A Multifaceted Perspective, World Bank, Washington DC, USA (41) Roth, R. (2004): Spatial organization of environmental knowledge: conservation conflicts in the inhabited forest of northern Thailand. Ecology and Society 9(3):5. www.ecologyandsociety.org/vol9/iss3/art5 (42) Schipper, L. – Pelling, M. (2006): Disaster risk, climate change and international development: scope for, and challenges to, integration, Disasters, 2006, 30(1): 19-38. pp. (43) KIOP (2006): State of the art, Report (44) Láng, I. (2006): The project „VAHAVA". Executive summary, Ministry for the Environment and Water Management (KvVM) and the Hungarian Academy of Sciences (MTA), Budapest, May 2006 (45) Theesfeld, I. (2003): Constraints on collective action in a transitional economy: the case of Bulgaria's irrigation sector. World Development 32 2. (46) WHO (2002): Floods: climate change and adaptation strategies for human health. Copenhagen (47) WHO (2004): Heat waves: risks and responses. Copenhagen (48) Williamson, O. (1985): The economic institutions of capitalism. Firms, markets, relational contracting, New York: Free Press (49) World Bank (2002): World development report 2002: building institutions for markets, Oxford: Oxford University Press.

KLÍMAVÁLTOZÁS ÉS NÉHÁNY HATÁSA A KÖRNYEZETRE, VALAMINT EGY MEZŐGAZDASÁGI MODELLSTRUKTÚRA

HARNOS ZSOLT

Kulcsszavak: klímaváltozás, hatás, környezet, mezőgazdaság, modellezés.

A klímaváltozással kapcsolatos kutatások alapvetően modellezésen alapulnak. Ez nem csak magára a klímaváltozás folyamatára vonatkozik, amit úgynevezett **G**lobális **C**irkulációs **M**odellek írnak le, hanem a hatásmechanizmusra, a következményekre is. A modellek használhatósága sokszor megkérdőjelezhető, mert ami működik a jelen körülmények között, az nem biztos, hogy a jövőben is, más paramétertartományban is elfogadható eredményre vezet. A jelen dolgozatban néhány a mezőgazdasággal, azon belül a növénytermesztéssel összefüggő kérdést vizsgálunk.

A klímaváltozással összefüggő néhány átfogó kép után a növénytermesztés egy modellstruktúráját mutatjuk be, illetve hívjuk fel a figyelmet néhány problémára. A klímaváltozás következményeként a fenofázisok eltolódnak, egyes paramétertartományok a ma elfogadottakon kívülre nyúlnak, a kockázati tényezők eloszlása ismeretlen stb. Ez természetesen nem jelenti azt, hogy fel kell hagyni a modellezési munkával, hanem inkább azt, hogy bővíteni kell az eszköztárat, új adekvát rendszereket kell fejleszteni, s az eredményeket, amennyire lehet, az adott körülmények között validálni kell.

FÖLDRAJZI ANALÓGIA ALKALMAZÁSA A LEHETSÉGES FÖLDHASZNÁLAT-VÁLTOZÁSRA MAGYARORSZÁGON

HORVÁTH LEVENTE

Kulcsszavak: klímaváltozás, analógia, földhasználat.

Kidolgoztuk a földrajzi analógia módszertanát, mellyel Európában olyan területeket keresünk, melyek mostani klímája (1961-1990 időszakra nézve) olyan, mint a célterületünké a jövőben. A számunkra elérhető szcenáriók alapján az évszázad végéig tudunk analóg területeket keresni. Eddig két időszakot vizsgáltunk: a 2011-2040 és a 2041-2070 intervallumot, az ezekhez tartozó analóg területek a Vajdaságban, Dél-Romániában és Észak-Bulgáriában találhatók. Az eddigi tapasztalatok alapján az évszázad végére nem találtunk analóg területet Európában. Az analóg területek vizsgálatához adatbázisba rendeztük az EUROSTAT régiók földhasználati jellemzőit és mezőgazdasági adatait (termesztett növények területe és termésátlagai). A lehetséges földhasználati (landuse) változásokat ezen adatbázis alapján vizsgáltuk. A természetes vegetációt jellemző adatokat a CORINE 2007 adatbázisból vettük. Az analóg területek földhasználati típusainak diverzitását a magyarországi területtel összehasonlítva, az analóg területek mindegyikében a jelenlegi hazainál sokkal magasabb a földhasználati diverzitás. A földhasználati eloszlást tekintve az analóg területeken a hazainál sokkal jelentősebb a rét-legelő és az erdőgazdálkodás.

Az analóg területek termesztett növényeit a magyarországival összehasonlítva megfigyelhető, hogy az analóg területek termesztett növényeinek diverzitása kisebb. A következő évtizedekben a búza- és kukoricatermesztés emelkedő, majd 2040-től csökkenő területarányt mutat, az analógia csökkenő mértéke szerint.

A Debrecennel analóg területek természetes vegetációs viszonyait elemezve, az északi analóg területek a tűlevelű erdők és a lombos erdők övébe esnek, addig a magyar terület, valamint analógjai az erdős-sztyepp zóna részei, s csupán a nagyon extrém klímaváltozást jelentő görög terület tartozik a mediterrán kemény és babérlombú erdők övébe. A tényleges vegetáció szempontjából analóg területek a természetközeli erdők nagyobb arányával tűnnek ki hazánkhoz képest, ami csak Görögország esetében nem mondható el.

A NÖVÉNYTERMESZTÉS KLIMATIKUS FELTÉTELEINEK VALÓSZÍNŰSÍTHETŐ VÁLTOZÁSAI

GAÁL MÁRTA

Kulcsszavak: kukorica, búza, klímaszcenáriók, klimatikus évtípusok.

Közismert tény, hogy a klíma alapvetően meghatározza a mezőgazdasági termesztés lehetőségeit, ezért fontos vizsgálni a várható változásait. A jövőben várható klimatikus feltételeket a Hadley Centre HadCM3 modellje alapján vizsgáltuk, az A2 és B2 szcenáriók esetén, különböző időszakokban. Az adatbázis csak havi adatokat tartalmaz, ami a munka korlátozó tényezője volt – nem teszi lehetővé pl. a tavaszi fagy kockázatának, a nyári hőségnapoknak és az extrém csapadékértékeknek a vizsgálatát.

A klímaszcenáriók jelentős növekedést jeleznek a hőmérsékletileg lehetséges vegetációs periódus hosszára vonatkozóan és a hőösszegek tekintetében, valamint jelentős csökkenést a nyári félév csapadékában. A növekvő hőmérséklet és csökkenő csapadék kedvezőtlen hatása jól jellemezhető az ariditási indexekkel.

1951 és 2100 közötti időszak adatai alapján megpróbáltunk a kukoricatermesztéshez kapcsolódó klimatikus évtípusokat elkülöníteni. Az eredmények egy folyamatos eltolódást mutatnak, és kb. 2030-tól a „hideg" évtípusok hőösszege egyenlő lesz a korábbi „meleg" évtípusokéval. Az eredmények felhívják a figyelmet arra a problémára, hogy a század második felében a hőösszegek az eddigi értelmezési tartományon kívülre kerülnek. Ez a drasztikus változás megkérdőjelezheti néhány növény, többek közt a kukorica termeszthetőségét is.

A MAGYARORSZÁGI SZŐLŐTERMESZTÉS KIHÍVÁSAI A KLÍMAVÁLTOZÁS TÜKRÉBEN

LADÁNYI, MÁRTA

Kulcsszavak: kockázat, szőlőtermelés, adatkezelő és értékelő szoftver, sztochasztikus dominancia, kockázati averzió, klímaváltozás.

Dolgozatunkban bemutatunk néhány kockázatelemzési módszert, majd ezek alkalmazásával bizonyítjuk, hogy a magyarországi szőlőtermesztés terméskockázata az elmúlt évtizedekben jelentősen növekedett. A lehetséges okok és következmények feltárásának céljából egyrészt elemezzük a klímaváltozás már tapasztalható, illetve a későbbiekben várható hatásait a magyarországi szőlőtermesztésre vonatkozóan. Másrészt a nemzetközi és hazai szakirodalom, illetve szakértői vélemények szintézisének eredményeképpen bevezetünk néhány specifikus időjárási indikátort, melyek múltbeli, illetve regionális klímaszcenáriók által becsült jövőbeli értékeit vizsgálva a szőlő termésmennyiségére gyakorolt, várhatóan meghatározó hatásait elemezzük. Bemutatunk egy adatkezelő és -értékelő szoftvert, mely célirányosan a kutatás igényeihez igazodva, és annak megkönnyítésére készült.

A KLÍMAVÁLTOZÁS LEHETSÉGES HATÁSAI A SZÁNTÓFÖLDI NÖVÉNYTERMESZTÉSRE, ESETTANULMÁNYOK

ERDÉLYI ÉVA

Kulcsszavak: klimatikus igények, kukorica, modellezés, fenofázis, kockázat, őszi búza.

Növénytermesztésünknek elsősorban felmelegedésre és csapadékhiányra kell felkészülni, a változásokat még a szélsőségek gyakoriságának növekedése is kísérni fogja. Vizsgálatainkat kukoricára és őszi búzára végeztük. Az elmúlt időszak termésadatai alapján egy új, általánosított sztochasztikus dominancia-módszert alkalmazva az őszi búza és a kukorica esetében is azt tapasztaltuk, hogy a változékonyság és ezzel együtt a kockázat növekedése a döntéshozó kockázatvállalási hajlandóságától függetlenül az utóbbi évtizedben jelentősen megnövekedett. Ezután – az okokat keresve – a búza klimatikus igényeit foglaltuk össze, fejlődési szakaszonként. Összehasonlítottuk néhány klímaváltozási forgatókönyv (BASE, UKHI, UKLO, UKTR, GFDL2534, GFDL5564) és referencia időszakuk (1960-90) historikus meteorológiai adatait. A vizsgálat helyszíne Debrecen, hazánk egyik legjelentősebb mezőgazdasági központja volt. Megmutattuk, hogy a közeljövőben a hőmérsékleti értékek további növekedése valószínűsíthető a növény minden fejlődési szakaszában; a csapadékellátottság általában megfelelhet, bár rendkívül nagymértékű változékonyságával nagyon nagy bizonytalanságot hozhat magával. Megmutattuk, hogy a fenofázisok hosszát meghatározó alsó hőmérsékleti határt mindig, a felsőt majdnem mindig meghaladják a forgatókönyvek által előre jelzett napi átlaghőmérséklet-értékek. A búza minőségét a klímaváltozás kedvezően befolyásolhatja. A további vizsgálatokban szimulációs modellezést használtunk. A 4M, a CERES modellen alapuló és hazai viszonyokra fejlesztett modellrendszert alkalmazva kimutattuk, hogy a hőmérséklet-növekedés következtében mindkét növény fenológiai fázisai vár-

hatóan előbbre tolódnak. Az érés időpontja korábban várható, átlagosan tízévente egy nappal. Ezután arra kerestük a választ, hogy a vetés időpontjának megváltoztatásával tompítható-e a klímaváltozás kedvezőtlen hatása a hozamra vonatkozóan. Eredményeink azt mutatták, hogy a vetési időpontok eltolása a szemfejlődés hosszára és az érés időpontjára is hatással van, a két héttel korábbi vetés kedvezőbb átlagot eredményez, csökkentve a terméskockázatot. Mivel a biomassza megújuló energiaforrásként való alkalmazása komoly szerepet játszhat az üvegházhatás csökkentésében, modelleztük a kukorica biomassza és másodlagos biomassza mennyiségét is, valamint a növényi részek arányát a biomasszában a növény fejlődését követve. A számítógépes növénynövekedési és produkciós szimulációs modellek jól használhatók a megváltozó körülmények lehetséges hatásainak feltérképezésére és az alkalmazkodási lehetőségek vizsgálatára. Ezáltal a klímaváltozáshoz való alkalmazkodásban, a felkészülésben a változások hasznosításában, sőt a károk enyhítésében is segítségünkre lehetnek.

AZ ENERGIANÖVÉNY-TERMELÉS KÉRDÉSEI

JOLÁNKAI MÁRTON

Kulcsszavak: alternatív energiatermelés, üvegházgáz-kibocsátás, megújuló energiaforrások.

A megújuló energiatermelés az emberiség egyik legfontosabb témája a 21. században. Három fő tényező van, amely meghatározólag hat az alternatív energiatermelésre: a hagyományos energiahordozókhoz való hozzájutás körülményei, illetve annak gazdaságossága, a klímavédelem, főként az üvegházhatású gázok – elsősorban a szén-dioxid – emissziója és végül, de nem utolsósorban a mezőgazdaság és a vidékfejlesztés kihívásai. Az utóbbi évtizedekben az energiaválság központi kérdéssé vált. Az alternatív energiatermelés egyik legfontosabb területe a mezőgazdaság, azon belül is a legkülönfélébb energianövények termesztése. Általánosságban az energianövények termesztésének három fő területe különböztethető meg: biomassza-előállítás további feldolgozás, illetve közvetlen tüzelés céljára, valamint biodízel és bioetanol termelése.

Az ADAM project magyarországi kutatásai során számos energianövény termesztési lehetőségeinek vizsgálatára került sor. Részletesen vizsgáltuk a bioetanol-előállítás gazdaságosságát és hatékonyságát. A vizsgálat eredményei szerint Magyarország általában, a Tisza régió pedig különösen alkalmas lehet energianövények termesztésére. A mezőgazdasági eredetű energia képes hozzájárulni az ország energiafogyasztásához. Ugyanakkor számos probléma is felmerül e területen: elsődlegesen az energiahatékonyság kérdése, valamint a gazdaságossági és nem utolsósorban az élelmiszer-ellátási szempontok.

A KLÍMAVÁLTOZÁSHOZ VALÓ ALKALMAZKODÁS A TISZA VÍZGYŰJTŐ TERÜLETÉN

PIOTR MATCZAK – FLACHNER ZSUZSANNA – SASKIA E. WERNERS

Kulcsszavak: formális és informális intézmények, szereplők,
Tisza Régió, Új Vásárhelyi Terv.

A klímaváltozás kihívásaira egyre inkább az alkalmazkodás az elkerülhetetlen válasz. A szélsőséges események gyakoriságnövekedési előrejelzése az a hajtóerő, amely az alkalmazkodási stratégiák megfogalmazását sürgette a vízgyűjtők biztonságának és klímaváltozási problémáinak kezelésére. Az újabb kezdeményezések az alkalmazkodás integrálásával, speciális alkalmazkodási változatok értékelésével és az intézményrendszerek szerepével foglalkoznak. A tanulmányban a klímaváltozáshoz való alkalmazkodást mint kollektív tevékenységet elemzik újszerű gazdasági-intézményi környezetben. A klímaváltozás a szervezetek számára újabb kockázatot jelent. A szervezetek a kockázatkezelésben építenek a formális jogi intézményekre (jogszabályok, kötelezettségek) és az informális társadalmi intézményekre (pl. normák, konvenciók, belső szabályozók).

A tanulmányban vizsgálják, hogy mi a szerepe a formális és informális intézményeknek a klímaváltozás kockázatainak kezelésében. Irodalmi áttekintésben a formális és informális intézmények klímaadaptációs szerepét mutatják be, majd a Tisza vízgyűjtőjén a két intézményrendszert hasonlították össze. Kifejtik az egyes intézmények elvárt hatását a klímaadaptáció folyamatában. A Tisza vízgyűjtőn történő kutatás eddigi tanulsága alátámasztja a formális és informális intézmények együttes alkalmazásának fontosságát az alkalmazkodásban. Formális intézmények elősegítik az alkalmazkodási javaslatok beépülését és elengedhetetlenek az alkalmazkodóbb hosszú távú tervezési folyamatok, beruházások és a nagyléptékű infrastruktúra-fejlesztésben. Az informális intézmények feltétlenül támogatják a nem szerkezeti javaslatok megvalósítását és az alkalmazkodási kapacitásokat erősítik. Az alkalmazkodásban úgy tűnik, hogy az informális intézményeket elutasították, szerepét nem ismerték fel.

TARTALOM

AUTHORS

E. Werners, Saskia, Wageningen University and Research Centre, Team ESS-CC
(Earth System Science-Climate Change) (PO Box 47, 6700 AA Wageningen, Netherlands,
Ph.: +31/317-486-442, Fax: +31/317-426-101, E-mail: werners@mungo.nl)

Erdélyi, Éva, Corvinus University of Budapest, Faculty of Horticultural Science, Department
of Mathematics and Informatics, assistant professor (1118 Budapest, Villányi út 29–33.,
Hungary, Ph.: +36/1482-6179, Fax: +36/1466-9273, E-mail: eva.erdelyi@uni-corvinus.hu)

Flachner, Zsuzsanna, Hungarian Academy of Sciences, RISSAC
(1022 Budapest, Herman Ottó út 15., Hungary, Ph.: +36/1225-3201,
E-mail: flachner@rissac.hu)

Gaál, Márta, Corvinus University of Budapest, Faculty of Horticultural Science, Department
of Mathematics and Informatics, associate professor (1118 Budapest, Villányi út 29–33.,
Hungary, Ph.: +36/1482-6192, Fax: +36/1466-9273, E-mail: marta.gaal@uni-corvinus.hu)

Harnos, Zsolt, Corvinus University of Budapest, Faculty of Horticultural Science,
Department of Mathematics and Informatics, professor, head of department
(1118 Budapest, Villányi út 29-43., Hungary, Ph.: +36/1482-6261, Fax: +36/1466-9273,
E-mail: zsolt.harnos@uni-corvinus.hu)

Horváth, Levente, MTA–BCE Adaptation to Climate Change Research Group
(Hungary, 1118 Budapest, Villányi út 29-35., Hungary, Ph.: +36/1482-6181,
Fax: +36/1466-9273, E-mail: levente.horvath@uni-corvinus.hu)

Jolánkai, Márton, Szent István University, Faculty of Agricultural and Environmental
Sciences, Institute of Crop Production, professor, head of institute
(2103 Gödöllő, Páter K. u. 1., Hungary, Ph.: +36/28/522-000/1671,
Fax: +36/28/410-804, E-mail: Jolankai.Marton@mkk.szie.hu)

Ladányi, Márta, Corvinus University of Budapest, Faculty of Horticultural Science,
Department of Mathematics and Informatics, associate professor
(1118 Budapest, Villányi út 29-33., Hungary, Ph.: +36/1482-6183,
Fax: +36/1466-9273, E-mail: marta.ladanyi@uni-corvinus.hu)

Matczak, Piotr, Polish Academy of Sciences, ul. (H. Wieniawskiego 17/19, 61-713 Poznań, Poland, Ph.: +48/61/852-8503, 852-9410, Fax: +48/61/852-0671, E-mail: matczak@amu.edu.pl)