MULTI-SECTORIAL IMPACTS OF ATMOSPHERIC EXTREME EVENTS AND CLIMATE CHANGE IN NORTH-EAST HUNGARY

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ABSTRACT. The aim of the paper is to comprehend possible impacts of the atmospheric extreme events and of the expected climate change in three different spatial levels. They are first collected at the national level, i.e. all impacts are included in matrices, where the rows are the extremities in the first aspect and the regional climate change in the second aspect. The columns are the impacts on the natural resources, i.e. on hydrology & water management, on natural ecosystems and on agriculture & food supply, as well, as on the human dimensions, i.e. on urban settlements, on energy and transportation and on human health, in both aspects. The impacts most relevant in the two other levels, i.e. North-East Hungary and the Bükk-Miskolc microregion are also unequivocally indicated in the matrices. Importance of the impacts is preliminarily illustrated by quantitative information on the extremes, the changes and some impacts already happened at the selected space scales. The paper is closing by the related adaptation measures in North-East Hungary.

Key words: extreme weather, climate change, impact, adaptation, Hungary

1. Introduction

Both weather extremes and climate change bear serious adaptation challenges. Many of them are similar in a wider climate region or belt, but the importance (urgency) of the specific challenges may be different from one region to the other. Though the changes are global and their regional aspects are inter-dependent, the regional consequences and the adaptation targets and tasks are rather site-specific.

In frame of the LOC-CLIM-ACT project, an international HU-SK-UA team had explored the common responsibilities and opportunities of crossborder areas facing similar climate challenges. In order to minimize the vulnerability and damages of the borderline regions joint adaptation measures have been identified.

The present study intends to contribute to the experience of experts and

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local decision-makers on the impacts and adaptation requests caused by weather and climate in a hilly region. Firstly, Section 2 describes the region, including some records of weather and climate. Section 3 illustrates how strongly the atmospheric, agricultural and hydrological extremes could vary in the recent past. Section 4 provides a list of impacts by the extreme events in six sectors of nature and human activities in Hungary, in North-East Hungary and in the Miskolc micro-region.

These three spatial levels and six targeted sectors are further applied in connection with the impacts by the expected climate change (Section 5). The paper is closed by the corresponding adaptation aspects in Section 6.

2. Characterisation of the applied spatial levels

2.1. The investigated regions

Analyses of the impacts and consequences on adaptation are related to three spatial levels (Fig.1). They (I) are the country-level, i.e. Hungary with its 93 000 sq. km and 19 administrative counties, (II) North-East Hungary, formed by six counties with special emphasis on two hilly regions Borsod-Abaúj-Zemplén and Heves counties. The smallest (III) unit is the Bükk-Miskolc micro-region (sometimes mentioned after its its Hungarian name as Miskolc microregion, only).

The area of North-East Hungary is 31,16 thousand sq. km, its population in 2010 was 2.693 million inhabitants. The six counties count exactly 999 settlements.

The area of the Bükk-Miskolc microregion is 1.06 million sq. km with 0,264 million inhabitants. The number of settlements is 40, including Miskolc, the third most populated town after Budapest and Debrecen (ca 200.000 inhabitants).

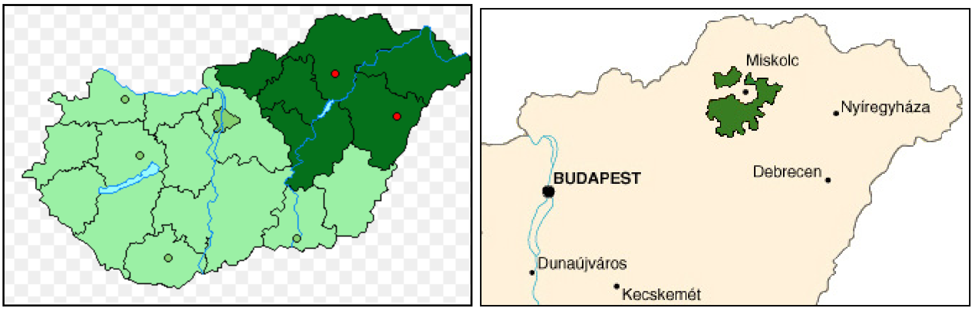


Figure. 1. North-East Hungary and the Bükk-Miskolc microregion as different spatial levels embedded into each other. The administrative counties of North-East Hungary are: Nógrád, Heves, Borsod-Abaúj-Zemplén and Szabolcs-Szatmár-Bereg (upper part, close to the northern border), Jász-Nagykun-Szolnok and Hajdú-Bihar (further lying counties).

2.2 The nature and the economy in brief

North-East Hungary has got a good geographical location (Eastern gate of the EU, bordered by Slovakia, Ukraine and Romania) and an environment rich in natural resources and heritage sites. The region holds an essential ecological potential and diversity; it embraces mountainous areas and one of the world largest plain areas (Hungarian Great Plain) abundant in spas. In spite of the economic transition and structural changes, this part of Hungary has preserved its industrial character as a result of Foreign Direct Investments, available qualified labour force at reasonable costs as compared to Western European cities and strong higher education background with great potential for R&D&I.

The economy is dominated by the SMEs employing most of the local labour force, though multinationals are also present. The strengths of the region lie in its potential for medicinal and wine-tourism, its cultural heritage and the centres for education and research. The most dominant industries are vehicle industry, chemicals and plastic material production, mechanical engineering, metal processing, electricity, food- and environmental industry and also creative industry.

2.3 Weather and climate extremes

Hungary is situated between the 45°45'N and 48°35'N latitudes, in the temperate climatic zone. Its climate is rather variable. The main reasons of it is that Hungary is situated in between three climatic zones: the oceanic climate with less varying temperature and more evenly dispersed precipitation; the continental climate with more extreme temperature and relatively moderate precipitation; also, a Mediterranean effect with dry weather in summer, and wet one in winter.

The records of Hungary are seen at the homepage of the Hungarian Meteorological Service (*http://owww.met.hu/eghajlat/Magyarorszag/rekordok/*). From this site you may find that the lowest diurnal minimum temperature -35.0^{o}C occurred at Miskolc, Görömbölytapolca on February 16, 1940. The absolute maximum temperature, 31.4^{o}C, occurred at Kékestető (985 m) on July 20, 2007.

The absolute maximum annual precipitation total was observed at Miskolc-Lillafüred-Jávorkút with 1554.9 mm in 2010. The annual climate mean of days with precipitation (0.1 mm or more) is at Kékestető with 147 such days from the 365 ones in 1971-2000. The last maximum registered in North-East Hungary is the absolute maximum of 60 minutes rainfall at Heves with 120 mm/1 hour.

Kékestető holds four further absolute records: In 1943-1944 there was 157 days with snow cover, absolute maximum snow depth, 146 cm, only 3 % (!) of relative humidity was measured in December 2, 1994 and the number of foggy days was 221 in 1970.

3. Observed tendencies and extremes

This Section illustrates the extremes and changes that took place in the recent past, and how they differed from each other in different regions of the country. At the same time, the three examples represent our three spatial scales, as well.

3.1 Weather and climate

As concerns climate change tendencies, only a few stations exhibit fairly high quality (homogeneity) data from the beginning of the 20th century. Therefore, experts of the Hungarian Meteorological Service (HMS) publish mainly country-wide averages, derived from data of a few complete stations, only.

For shorter periods, one may find maps of changes, too. Experts of the HMS perform homogenisation (MASH, Szentimrey, 1999) and statistically optimum interpolation (MISH, Szentimrey and Bihari, 2006) of the data. The latter uses not only the spatial correlation of the elements, but also the temporal ones which is not known in any other spatial interpolation methodology.

Fig. 2 and *3* represent trends of country-mean temperature and spatial distribution of annual mean temperature trend values during the 30 years between 1980 and 2009, respectively. This latter period is characterised by monotonous warming in the Northern Hemisphere, so it is a natural experiment, reminding the future global warming. The map demonstrates that the annual warming tendencies exhibit strong west-east gradient, i.e. the more continental areas warm faster jam those for which the oceanic effect is more active.

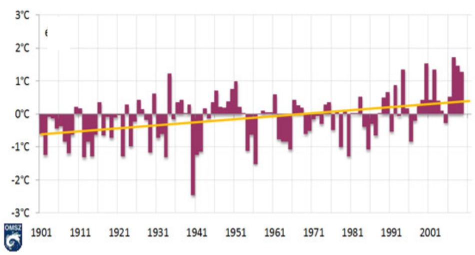


Figure. 2. Long-term anomalies and linear trend of mean temperature in Hungary for 1901-2009 (°C) compared to 1971-2000.

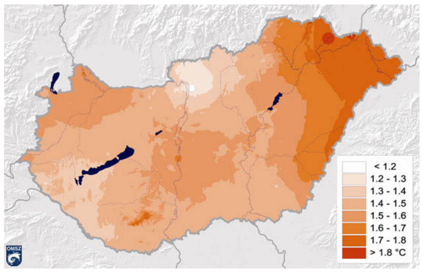


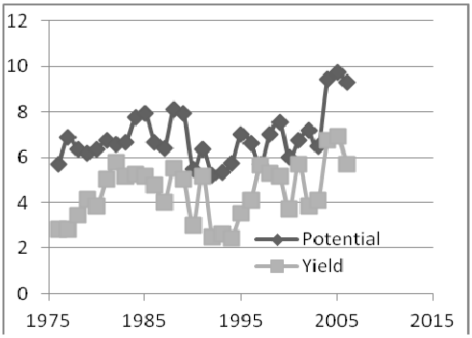
Figure. 3. Spatial distribution of annual mean temperature trend values during the 30 years between 1980 and 2009.

3.2 Maize yield data in North-East Hungary

In this point illustration of variability is performed on maize yield and also in its potential yield, governed by climate variations, according to the methodology by (Péter et al., 2007). In the followings we draw the actual yield and the potential yield, computed by this methodology. For our purposes it might be enough to establish that the real maize yield exhibited large inter-annual variations in the two counties of our focus area, including long-term tendencies, though none of them took place along the whole 31 years period.

In Borsod-Abaúj-Zemplén county the yield trend is positive with a significant 0.34 correlation coefficient exactly at 95 % level, whereas the potential yield exhibits similar 0.38 correlation coefficient with time. The correlation coefficient between the real and potential yields is 0.74. In Heves county, overall correlation of the real yield with time is almost zero, and the potential exhibit a non-significant positive trend. So here practically no long-term trend can be established in any of the real or potential yields. Despite the lack of long-term trends in the real and potential yields, their correlation is 0.75 (left part of *Fig 4*).

The lack and existence of trends in the neighbouring counties, together with the same difference in the climate potential would need further investigation, though a preliminary explanation might be the different treatment of land use. It is possible that in Borsod-Abaúj-Zemplén county the climate is so critical that land selection, i.e. using proper climatic sectors, was more careful than in Heves county.



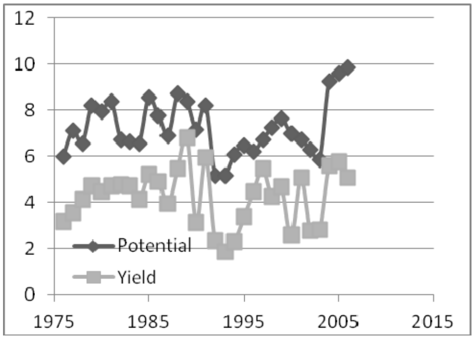
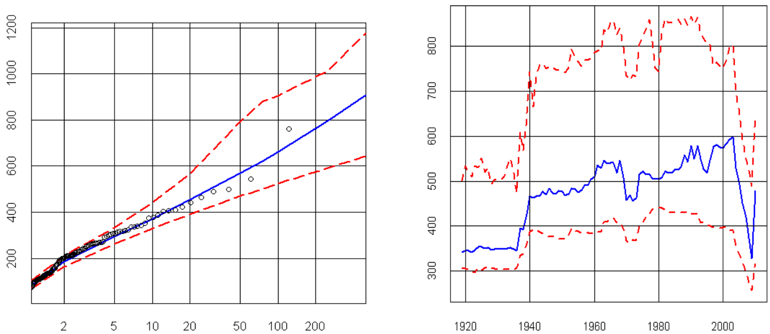


Figure. 4. Maize yield in Borsod-Abaúj-Zemplén county (left) and Heves county (right) in the 1976-2006, together with the multi-variate climate estimation based on annual values of precipitation, temperature, sunshine duration as well as the July-August xerothermal index, which is the proportion between temperature and precipitation of the two months.

3.3 Flood frequency series

In this example, extreme high water cases are provided, courtesy to Gábor Bálint who provided the results by GEV analysis (Bálint and Lipták, 2011 and Bálint et al., 2011). Time series of maximum runoff provided for Felsőzsolca and Gesztely is seen in *Fig. 5*. The left side modules represent GEV analysis of the maximum value within n years of observation, in other words the level at a given return period.

Sajó – Felsőzsolca (1890-2010)
Maximum: 486 cm ~ 760-780 m^3/s



Hernád – Gesztely (1946-2010)
Maximum: 506 cm ~ 864,1 m^3/s

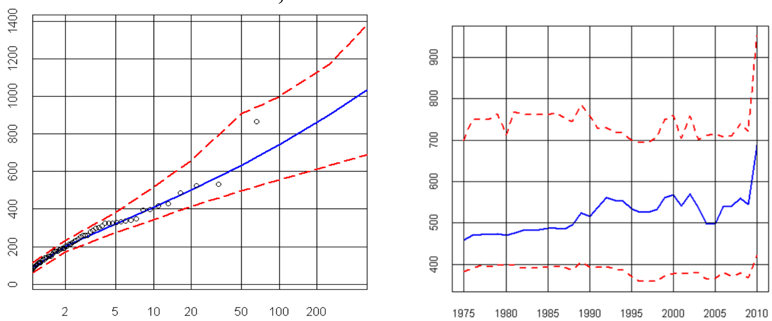


Figure. 5. Return periods of maximum runoff (m^3/sec) based on 121 years of data for Felsőzsolca (river Sajó, upper) and for Gesztely (river Hernád, lower). The left modules indicate the mean values and confidence intervals of threshold concerning the given return period, if deriving it from maxima of the 121 years. The right modules are the results of averaging the previous 30 years, concerning the maximum runoff (m^3/sec) and forming a time series both from the point-wise estimates and the 95 % confidence borders.

These maxima can be estimated not only from the 121 years, but from any part of the sample. Right side modules of the figures show the thresholds for the 30 years return periods, computed from the previous 30 years. These values exhibit long-term components, although single extremes may cause strong fluctuation.

4. Matrices of extreme weather effects and impacts

This Section summarizes the relevant impacts by atmospheric extremes taken from the weather observation codes by the World Meteorological Organisation *(http://www.srh.noaa.gov/jetstream/synoptic/ww_symbols.htm)* at the three spatial levels, considering climate of the country. These effects are listed in *Table 1-2.*

Table 1. Impacts of weather extremes on the natural resources. ***Bold italic***: important in Miskolc sub-region, *italic*: important in N-E Hungary, normal set: country-wide. Proportion of the three sets is equal in the columns and rows for the full matrix, joined with Tab 2, too.

Priority effects	**Sectors / Areas relevant to the target region**		
	Hydrology, water management	**Natural ecosystems**	**Agriculture, food supply**
Extreme cold day and night	unexpected freezing of lakes	*likely damages (animals)*	damages possible (e.g. winter wheat)
Extreme hot day and night	*increased peak water demand*	damages possible	*risk of damage, overheat of plant*
Long heat wave	*water quality degradation*	*damages possible*	***crop reduction, food safety risks***
Severe drought	***less sources, more demand, water quality***	*green-mass reduction*	***strong crop reduction***
Heavy rainfall, long rain period	***flash flood, water surplus, inundation***	***soil degradation, mudslide, pests***	*soil degradation, crop quality risks*
Heavy snowfall, accumulation	*flood risk possible after melting*	inundation risk, after melting	***inundation risk, after melting***
Evenly bright day	strong evaporation, water quality risk	some plants sensitive to UV	*some plants sensitive to UV*
Thunderstorm, lightning, hail	***danger for devices and workers***	*lightning and hail damage on plants*	***lightning, hail damage: fruit, grape***
Stormy wind, inc. tornado	***tilted slope of lakes, danger for devices***	***wind break of trees possible***	*wind damage possible*
Long lasting lack of wind	water quality problems possible	***enhanced ozone near the roads***	enhanced ozone near the roads
Haze, fog	*lake and river shipping limited*	more plant diseases possible	more plant diseases possible
Freezing rain surface icing	mechanical load on devices	***mechanical damages***	mechanical damages

The considered sectors, technically separated into two parts (natural resources and human activities) are Hydrology and water management; Natural ecosystems; Agriculture and food supply; Urban settlements; Energy and transportation; Human health. These sectors have been selected by collecting the individual effects listed in land-based chapters of the former IPCC WG II (2007) Report, and joined to avoid too minor sectors with possibly missing windows, and too many columns of the matrix. The impacts are supplemented by experiences of operational climate service, personally gained by one of the authors (JM).

In this way, the nationwide matrices (Table 1 and 2) containing impacts of 12 atmospheric extremes on 6 sectors, i.e. 72 boxes, filled with often 2-3 individual impacts on the same sector. The 3 spatial scales are indicated by different setting.

Table 2. Impacts of weather extremes on various human activities. ***Bold italic***: important in Miskolc sub-region, *italic*: important in N-E Hungary, normal set: country-wide. Proportion of the three sets is equal in the columns and rows for the full matrix, joined with Tab 1, too.

Priority effects	**Sectors / Areas relevant to the target region**		
	Urban settlements	**Energy and transportation**	**Human health**
Extreme cold day and night	*unexpected energy request*	***enhanced heating, technical problems***	***lives in danger***
Extreme hot day and night	heat alarm, water supply problems	***enhanced cooling, melted roads, traces***	***lives in danger***
Long heat wave	***heat alarm, water supply problems***	enhanced cooling, workers in danger	lives in danger
Severe drought	water supply problems possible	water energy, water traffic limitations	*drinking water*
Heavy rainfall, long rain period	canalisation problems	*low class road damages possible*	rheuma, open air activity risk
Heavy snowfall, accumulation	*too heavy load possible*	***road and train transport in danger***	risk of food availability
Evenly bright day	***photochemical smog possible***	*unexpected melting, car limitation possible*	***more UV- and ozone***
Thunderstorm, lightning, hail	mechanical and lightning damage	mechanical and lightning damage	*lightning, heart risks*
Stormy wind, inc. tornado	*mechanical damage possible*	mechanical damage possible	mechanical danger
Long lasting lack of wind	***increased air pollution possible***	*engine use reduction possible*	*risk of air pollution*
Haze, fog	***London-type smog possible***	*reduced speed, engine-use limitation*	***risk of air pollution***
Freezing rain surface icing	*bus and car transport at risk*	***electric wires at risk, road transport at risk***	*leg and arm breaks risk*

Of course, threat by the different impacts depends on the climate of the site, but also on the non-climatic conditions. These conditions can be distinguished as *exposure* and *vulnerability* (IPCC, 2012). The *exposure is* “presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social, or cultural assets in places that could be adversely affected.” *Vulnerability* is defined as “The propensity or predisposition to be adversely affected.”

One may argue the equal number of boxes chosen in each line and column. However, firstly, there is no simple way how distinguish them and according to what metrics. Another reason is that the retained proportion (24, 48 and 72 boxes at the corresponding levels) may still be managed in adaptation preparation, especially as they are equally distributed among the extremes and the targeted sectors, too. One sector should cope with impacts of 4, 8 and 12 extreme events.

Approaching to the end of this Section, we emphasise that the extreme events are by no means direct consequences of the ongoing global warming. They are parts of our climate, although their frequency and severity may change in the future, as they were changing in recent decades of moderate global warming, too.

4. Matrices of climate change impacts

This Section summarizes impacts by the expected future climate changes at the three spatial levels. The changes are collected according to the regional scenarios firstly presented below. Nine 9 changes, selected from it and combined with more recent results (HREX, 2012), are further listed afterwards.

Some earlier results, based on empirical regression from the past (Mika, 1988, 2005) are compared to global model approaches of the IPCC (2007) and the mesoscale modelling by the PRUDENCE project (Christensen et al., 2007). In *Table 3,* there are the expected changes for 2030 in the three above approaches.

Table 3. Changes of annual and seasonal means of temperature and precipitation for Hungary in 2030 compared to 1961-1990. The average changes represent 25, 21 and 5 approaches. The global mean change is 1.0 K according to the IPCC (2007) A2 projections.

A2 scenario	**Global change = 1.0 K for 2030**					
Approach	**Temperature change (K)**	**Annual**	**DJF**	**MAM**	**JJA**	**SON**
IPCC 2007	Mean	**0.9**	**1.0**	**--**	**1.3**	**--**
PRUDENCE	Mean	**1.4**	**1.3**	**1.1**	**1.7**	**1.5**
EMPIRICAL	Mean	**1.6**	**2.0**	**--**	**1.1**	**--**
Approach	**Precipitation change (%)**	**Annual**	**DJF**	**MAM**	**JJA**	**SON**
IPCC 2007	Total	**-0.7**	**1.9**	**--**	**-3.7**	**--**
PRUDENCE	Total	**-0.3**	**9.0**	**0.9**	**-8.2**	**-1.9**
EMPIRICAL	Total	**-2.2**	**7.6**	**--**	**-19.7**	**--**

One may note that the signs and the magnitudes of the changes, projected by different approaches are similar. According to the results, temperature indicates higher changes in Hungary, than the global averages. Annual total of precipitation will not change substantially, but the summer decrease and the winter increase are clear in all approaches. This involves increased frequency of droughts in the future.

Based on the above scenarios, nationwide matrices of impacts attributed to the expected climate changes are included into *Table 4* and *5*. They contain 9 impacts on 6 sectors, i.e. altogether 54 boxes, often containing 2-3 impacts on the same sector. Of course, content of each box considers those compiled in Chapter 3.

Table 4. Impacts of climate change on various human activities. ***Bold italic***: important in Miskolc sub-region, *italic*: important in N-E Hungary, normal set: country-wide. Proportion of the three sets is equal in the columns and rows for the full matrix joined with Tab. 5, too.

Priority effects	**Sectors / Areas relevant to the target region**		
	Hydrology, water management	**Natural ecosystems**	**Agriculture, food supply**
Increased temperature in all seasons	worse water balance, intensified chemical, biological processes	***phenologic shifts more yield and invasive species***	*phenologic shifts more yield, where enough rainfall*
Less extreme cold days and nights	less unexpected freezing of lakes,	*more productive yield, where enough rainfall*	***better and more evenly crop yield and quality***
More extreme warm day and nights	*more water quality and peak water supply problems*	***reduced biomass possible, some plants in stress***	reduced crop yield, problems in food treatment
Longer heat waves in summer	*stronger water quality and supply problems,*	more tourist load, reduced biomass possible	***reduction in crop yield, problems in food treatment***
Less rainfall in the warm half of the year	***more low level cases in rivers, less water energy and supply***	*phenological shifts, loss of yield and biomass possible*	***reduction in crop yield, but better quality of e.g. wine***
Longer dry periods, more drought	***stronger water quality and supply problems, enhanced demand***	loss of biomass production and carbon store	*reduction in crop yield and livestock*
More heavy, even torrential rain	***wider spread of water level in rivers, lakes, more flash floods***	*faster soil erosion and more lightning may cause losses*	the faster soil degradation may lead to crop loss
Less snowy days, shorter snow cover	*possibly less frequent spring flooding in average*	***longer vegetation period, less soil moisture in spring***	longer vegetation period, less soil moisture in spring
More sunshine (less clouds) in summer	enhanced areal, lake evapotranspiration and water chemistry	more productive yield, where enough rainfall	*better fruit, grape quality, enhanced photosynthesis*

Table 5. Impacts of climate change on various human activities. ***Bold italic***: important in Miskolc sub-region, *italic*: important in N-E Hungary, normal set: country-wide. Proportion of the three sets is equal in the columns and rows for the full matrix joined with Tab. 4, too.

Priority effects	**Sectors / Areas relevant to the target region**		
	Urban settlements	**Energy and transportation**	**Human health**
Increased temperature in all seasons	heat island surplus starts from higher temperature	***less energy needs for heating, but more for cooling***	*new pests, vector-born diseases*
Less extreme cold days and nights	less insulation is enough in walls and windows	*less energy supply and transport challenges*	***good for ill people, more pests survive***
More extreme warm days and nights	***more heat alarms, water supply and quality problems***	*more energy for cooling, pavement and trace melting*	risks for ill people and for healthy ones
Longer heat waves in summer	*stronger insulation is needed, water supply at risk*	overheated energy and transport infrastructure risk	***risks for ill people, shift in pollen peak***
Less rainfall in the warm half of the year	less water supply and wet deposition, high concentration	less water energy available, more dry days on roads	*shift in pollen peak, less epidemics*
Longer dry periods, more drought	*water supply and quality problems, more air pollution*	less water energy and shipping is possible	***air- and water quality risks***
More heavy, even torrential rain	***canalisation needs and lightning safety requests increase***	*more temporal and persistent road traffic problems*	cardiovascular ill people at risk in electric field
Less snowy days, shorter snow cover	*advantage for urban transport and hygiene*	***good for road traffic, more heating due to less roof insulation***	less polluted, black snow
More sunshine (less clouds) in summer	***more summer smog and solar energy***	***more solar energy, but more pavement and trace melting***	*UV radiation risk increase, additional heat*

The 18, 36 and 54 boxes at the corresponding levels may hopefully be managed in adaptation preparation to climate change. One sector should cope with impacts of 3, 6 and 9 projected features of the global warming, only.

At the end of this Section, one may establish that (i) there are fairly certain changes of climate averages that are expected in Hungary and in the smaller regions in connection with the global warming; (ii.) on the other hand, especially the tendencies of several extreme events are quite uncertain in the light of the various empirical and model-based approaches; (iii.) for the common set of likely changes in the means and in the extremes there are serious impacts to cope with.

6. Adaptation aspects

Climate change adaptation strategies are key instruments to minimize vulnerability. In response to the above detailed impact matrices, strategies are to be designed on the bases of individual measures. The above introduced LOC-CLIM-ACT cross-border cooperation project is a good example for such measures (*Table 6*).

Table 6. Adaptive measures based on the above impact matrices (to be continued)

1. More frequent occurrence of intense heat waves
1.1. Measures implemented within public spaces
Increasing of vegetation ratio, especially in built-up centres of cities Planting urban tree vegetation associations (pools, fountains, artificial lakes)
1.2. Measures implemented in and on buildings
Sufficient thermal insulation of buildings Utilisation of green roofs New standards for construction of environmental buildings, to collect and use rain water
1.3. Measures implemented in the field of transportation
Using of transportation technologies and materials adapted to the changing temperatures Creation of suitable micro-climate for pedestrians and cyclists in cities, public transport users
1.4. Measures implemented in the field of power engineering
Priority to technologies of higher efficiency and reliability in energy production in heat waves Suitable inclusion of new sources operating in high temperatures and decreased water availability
2. Average Annual Temperatures Increase
2.1. Measures related to vegetation in urban units
Adjustment of trees and shrubs selection to be planted in urban units Creation of more green zones, providing shadow, especially in places, where heat is the highest
2.2. Measures implemented in the field of agriculture
Switching to new varieties or utilisation of new varieties of crops Creation of water infrastructure of agriculture, water reservoirs and water supply systems
2.3. Further measures related to the average temperatures increase
Use of public spaces for cooling down Preparing the hospitals and medical workers for heat waves, defining spare beds in the hospitals
3. Stronger and more frequent storms – strong winds and gales occurring more frequently
3. 1. Measures related to vegetation
Planting forests or woody plant associations in rural zones, green planting in cities Maintaining good sanitary state and ecological stability of trees and green plants in the settlements
3.2. Measures implemented in the field of power industry
Priority to energy production of higher efficiency, reliability and no affect environmental stability Ensuring sufficient distances around electricity lines
3.3. Measures implemented in the field of transportation
Early warning system Traffic norms updating, which assist pedestrians and cyclists and public transport
3.4. Measures aimed against wind erosion
Planting of wind-belts, hedges, afforestation, aerial tree plants, grassing over and portable barriers Agrotechnical and organisation rules application

Table 6. (continued) Adaptive measures based on the above impact matrices

4. Precipitation decrease – higher frequency of droughts
4.1. Measures implemented in the field of water management – natural landscapes
Stricter water resources protection measures Increased utilisation of local water resources
4.2. Measures implemented in the field of water management – urban landscapes
Construction of household sewage treatment facilities in smaller municipalities Utilisation of wastewater (*greywater*) and rainwater
4.3. Measures related to vegetation in urban units
Inclusion of woody plants species with high level of droughts tolerance River bank vegetation protection in urban and rural areas
4.4. Measures implemented in the field of forest management
Forest area increase Change of species, which dry out and creation of forests with adjusted species
4.5. Forest fire prevention measures
Curbing of public usage of forests at high types of fire danger Fire protection measures (fire breaks, mineralized lines, information on boards and in mass media)
4.6. Measures implemented in the field of agriculture
Irrigation systems utilisation, maintenance of irrigation systems Water and energy regime of cover regulation by mulching
5. Intense torrential rains frequency increase
5.1. Measures implemented in rural areas and natural landscapes
Landscape cover structure diversification Rivers, streams and wetlands renaturation and protection
5.2. Measures implemented in the field of forest management
Securing, maintaining and extending of areas and formation of nature-like forests or natural forests Decrease to the minimum of areas of clear cutting (use of clear cuts only for damaged forst stands)
5.3. Hydro-technical measures
Increasing retention capacity by new constructions (waterfalls, reservoirs, accumulating objects) Directing or increasing of discharge/outflow via minor hydro-technical measures
5.4. Measures implemented in urban units in the field of green and blue infrastructure
Increasing green areas, i.e. rainwater retention and infiltration, especially in built up city centres Modification of watercourses in urban zones
5.5. Measures implemented in urban areas in the field of power industry
Building of decentralised reserve energy sources Smart grid introduction
5.6. Measures implemented in urban areas in the field of transportation
Improving of traffic infrastructure draining Modification of parking lots surfaces
5.7. Measures aimed against water erosion
Growing forests of natural structure, ecological stability to optimally fulfil all forest functions Sustainable securing of swift creeks blocking (i.e. riverbank enforcements, walls and waterfalls)

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REFERENCES

1. Bálint, G. and Lipták, G. (2011), *Analyses of flood maxima in the Sajó (Slana) and Hernád (Hornád) sub-basins in view of recent extremes*. (Internal report - Manuscript) VITUKI, NHFS, Budapest, 2011extremes.
2. Bálint, G. Gauzer, B., Gnandt, B., Lipták, G. & Mattányi, Zs (2011), *Projected effects of climate change for the low water periods of river Danube* (project ecconet). Proceedings of XXVth Conference of the Danubian Countries, ISBN 978-963-511-151-0, Budapest, 16-17 June, 2011.
3. Christensen, J.H. and Christensen, O.B. (2007), *A summary of the PRUDENCE model projections of changes in European climate by the end of this century*. Climatic Change 81: 7-30.
4. HREX, (2012), *Hungarian addition to SREX. Hungarian Meteorological Service*. http://www.met.hu/eghajlat/eghajlatvaltozas/IPCC_jelentes/index.php?id=113&hir=Az_IPCC_Tematikus_Jelentesehez_kapcsolodo_magyarorszagi_eredmenyek
5. IPCC, WG I (2007), *Climate Change 2007: The Physical Science Basis. Contribution of WG-I to the Fourth Assessment Report of the IPCC*, Cambridge Univ. Press, 996 pp.
6. IPCC WG II (2007), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds.) Cambridge Univ. Press, 976 pp.
7. IPCC (2012), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge Univ. Press, 582 pp.
8. Mika J. (1988), *Regional features of global warming in Hungary*. Időjárás 92, 178-189 (in Hungarian).
9. Mika J. (2000), *Spatial and temporal variations of the Palmer Drought Severity Index*. In: 3rd Inter-Regional Conf. on Environment-Water: Water Resources Management in the 21th Century with Particular reference to Europe. Budapest, 1-3 June, 2000, 151-160.
10. Mika J. (2005), *Chapter 3. Global warming, regional features in Hungary*. In: „Magyarország tájainak növényzete és állatvilága" (Fekete G., Varga Z., ed.) HAS Society Centre. 397-408 (in Hungarian).
11. Péter B., Bella Sz. and Mika J. (2007), *New system to assess spatial and temporal variability of plant productivity based on agroclimatic characteristics*. Klíma 21, vol. 50, 44-53 (in Hungarian).
12. Szentimrey, T. (1999), *Multiple Analysis of Series for Homogenization* (MASH), Proceedings of the Second Seminar for Homogenization of Surface Climatological Data, Budapest, Hungary; WMO, WCDMP-No. 41, pp. 27-46.
13. Szentimrey, T., Bihari, Z. (2006), *MISH (Meteorological Interpolation based on Surface Homogenized Data Basis)*, COST Action 719 Final Report, The use of GIS in climatology and meteorology, Edited by O. E. Tveito, M. Wegehenkel, F. van der Weland, H. Dobesch, 2006, pp. 54-56