Climate change and adaptation — Establishing the National Adaptation Geo-information System (NAGiS)

An effective tool to provide the right answers

HU04 — Programme for adaption to climate change
EEA-C11-1 project

NAGiS

MFGI
Geological and Geophysical Institute of Hungary

Regional Environmental Center

Iceland Liechtenstein Norway eea grants

NAC National Adaptation Center
Geological and Geophysical Institute of Hungary

Climate change and adaptation – Establishing the National Adaptation Geo-information System (NAGiS)

An effective tool to provide the right answers

HU04 – Programme for adaption to climate change
EEA-C11-1 project

Budapest, 2016

The NAGiS Project is supported by a grant from Iceland, Liechtenstein and Norway.
This booklet has been published with the financial support of Iceland, Lichtenstein and Norway through EEA grants and the REC. The Geological and Geophysical Institute of Hungary is responsible for the content of this material.

The preparation of the publication and the results here presented were based on the documentations of the research works carried out in the framework of the NAGiS project.

Publisher in charge: Dr. Tamás Fancsik director, MFGI.

Edited by: Attila Sütő

Scientific revision by: Dr. Tamás Czira and Dr. Tamás Pálvölgyi

More information on the support programme:
www.nagis.hu eea.rec.org eeagrants.org norvegalap.hu

ISBN 978-963-671-306-5

Table of Contents

Welcome note

The Geological and Geophysical Institute of Hungary (MFGI) created by the integration of two well-established institutions (ELGI and MÁFI) in April, 2012 has been performing, besides the previous tasks of the founder institutions, all strategic planning, policy-making and research tasks related to climate change in Hungary since its creation. In this context, since the beginning of its activity, it has been responsible for the establishment and the implementation of the National Adaptation Geo-information System (NAGiS). The launch of NAGiS portal on 1st May 2016 is an important milestone of a development process started nearly four years ago.

The legal basis for the creation of NAGiS was established by the 2010 amendment of the Act LX of 2007 of Hungary. The Concept and feasibility study conducted by MFGI in 2012 upon the request of the Ministry of National Development (NFM) explored in details the motivation and the background behind the creation of NAGiS. They aimed to create a multipurpose data system and information technology tool that provides the flexible policy-making, decision-making and planning procedures with objective information, adapting to the changing circumstances.

Based on this objective, it was possible to start an intense scientific and technical development activity backed by the 95% financial support of Iceland, Lichtenstein and Norway pro-vided from the budget of the Adaptation to Climate Change Programme of the European Economic Area (EEA) Grants. In the project launched on 24th September 2013, the financer was represented by the Regional Environmental Center for Central and Eastern Europe (REC). The development process was also facilitated by the fact that the Decree No. 94 of 2014 (III. 21.) of the Government laying down detailed rules of operation of the NAGiS as well as the Operational Policy of NAGiS have also been outlined from the cooperation of NFM and MFGI.

As part of the NAGiS project, MFGI has created the hardware and software environments necessary for the stable operation of the IT system. We have designed, uploaded the data into the data bases and applied them, and created the meta-database which has played a key role in the research. For creating a map view of the several hundred data layers established at our institute and in partner projects of the Adaptation to Climate Change Programme, we have launched an online map service. Numerous thematic evaluations were created at MFGI as well, amongst others, data layers presenting the risks of flash floods or the assessments of the vulnerability of subsurface waters and drinking water supplies of Hungary to climate change.

Based on our experiences gained during the implementation of the project not only the results collected marked an important milestone in the research work carried out in Hungary investigating and interpreting the expected impacts of climate change, but the inter-institutional network created as a result of scientific cooperation, the establishment of a common platform and the linking of databases and the standardization of the terminology used by the researchers were also a great step forward in strengthening background of the decision-making system in the field of climate policy in Hungary.

We hope that the clearly presented database and the illustrative maps available at NAGiS portal will convince the users that adaptation to climate change is an unavoidable factor. Our goal was to create a geoinformation tool supporting geographical informatics and strategic planning that can be used efficiently in national, regional and local area planning and decision-making as well as in research, education and in everyday life, by a larger public interested in climate change.

I would like to take the opportunity and thank the hard work of all colleagues and institutions participating in the project, the support of the EEA Grant, the helpful approach of REC during the implementation of the project as well as the participation of NFM being responsible for the scientific supervision of the tasks.

You can find more detailed information about the development of NAGiS on the following pages, and please visit the portal at http://nater.mfgi.hu.

Dr. Tamás Fancsik
honorary university professor, director of MFGI

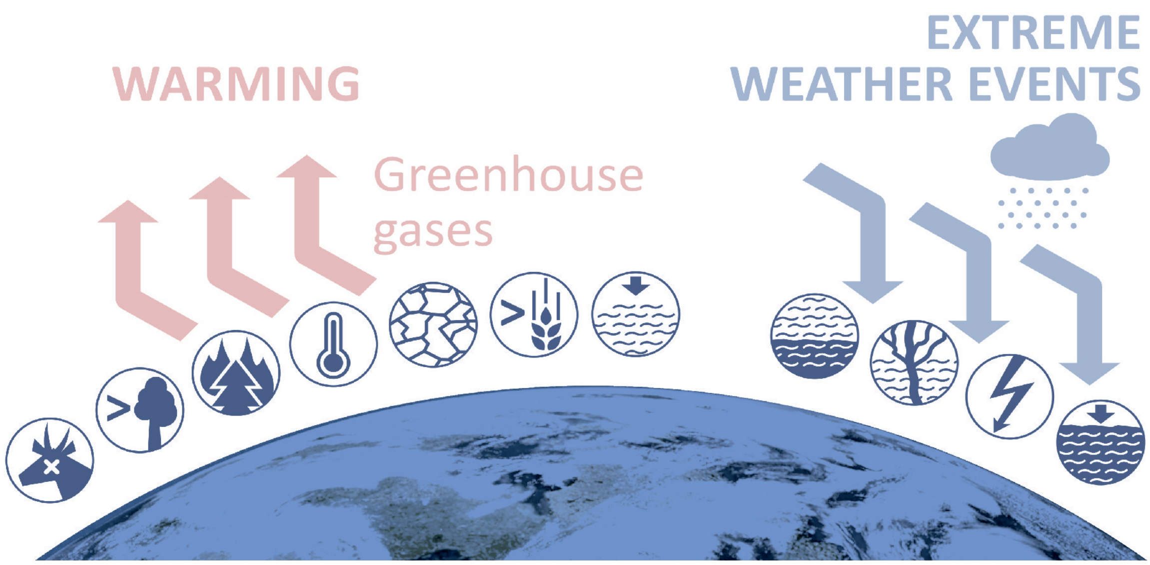
Climate change: the challenge

THE CHALLENGE

Global climate change is one of the most important world-wide challenges, requiring increasingly urging and complex actions from the societies. The scale and frequency of extreme weather conditions are increasing around the globe and the impacts of climate change make numerous branches of the economy and regions vulnerable. The eradication and mitigation of the phenomenon is not possible without developing and applying local adaptation strategies. For this to happen it is necessary to precisely identify and monitor such phenomena, trends and impacts.

The population and economy of certain regions is especially vulnerable even to a minor change in the climate. Nevertheless, the vulnerability of people can be increased already if the climate conditions do not change permanently or only change slightly (e.g. as a result of constructions in floodplains or deforestation on hillsides). The quick change of climate conditions will make this situation even more complicated. Adaptation to climate change is crucial in order to keep these regions attractive and liveable. The combination of the mitigation criteria (reducing GHG emissions) and of the adaptation aspects may be an effective solution to address the risks.

The regional impacts of climate change in Europe may vary and the adaptability of every region also differs from each other. As a consequence, certain regions and branches are more vulnerable to changes. Coastal areas, valleys and plains exposed to the risk of flooding, mountain areas, the arctic, as well cities and urban areas are especially sensitive to the changes of climatic conditions. Differentiated vulnerability is also characteristic of Hungary. Taking into account that it is located in a basin, the risk of flooding is a serious hazard. Although, not to the same extent as in Southern-Europe, but agriculture in Hungary is also menaced by droughts, desertification and heat waves. Densely populated urban areas, due to their high proportion of built-up areas, are exceptionally sensitive to temperature rises and to floods, and due to rising concentrations of the population, to extreme weather events. A large part of the area in the country suffers at the same time from water scarcity and surplus.

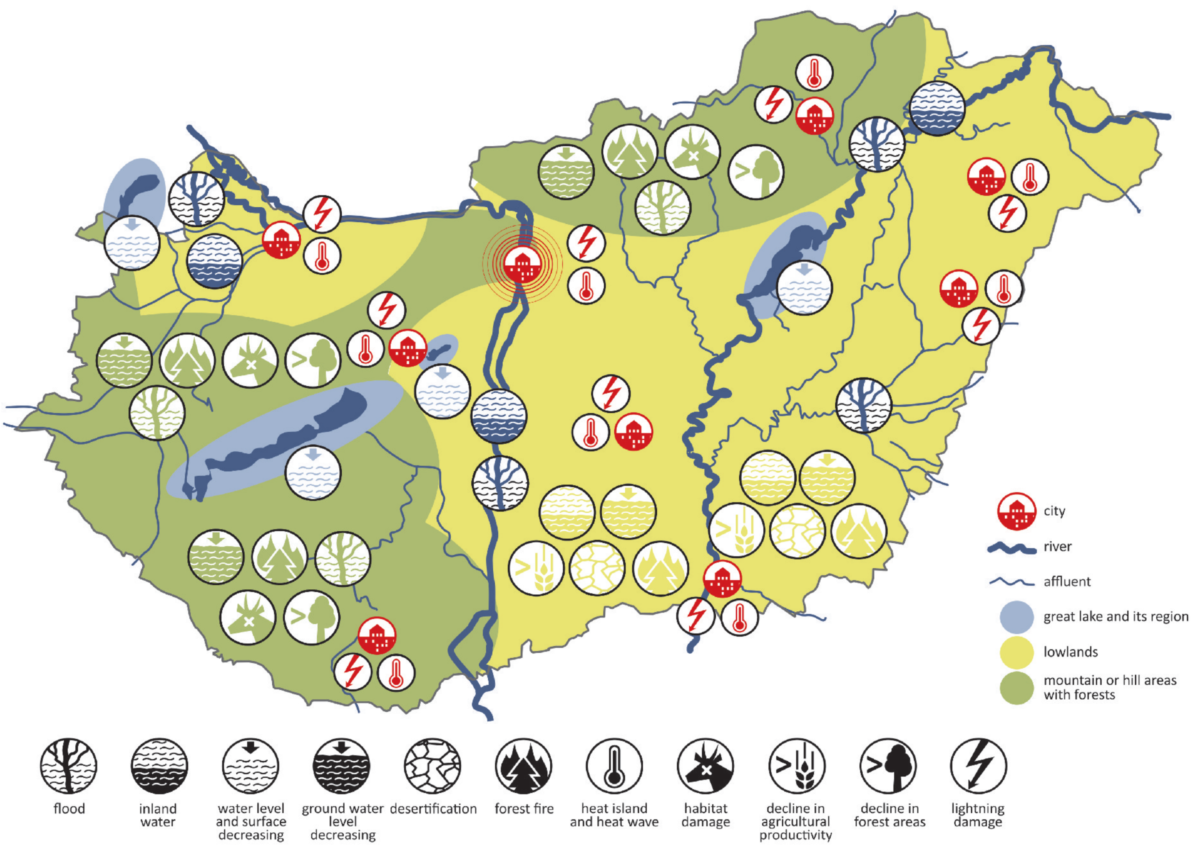


Climate change and its impacts are of primary importance out of the factors determining long term development possibilities of Hungary. For the 21st century in the region of the Carpathian Basin, the different climate models anticipate the unambiguous continuation of the warming that has been witnessed during the previous decades. This means, that even if for the period between 2021–2050, the total annual rainfall will not change significantly, the average summer rainfall may decrease by over 5–10%. The number of consequent dry summer days is expected to increase and longer dry summer periods are forecasted than there are today. Parallel to this, the number of days with higher rainfall figures (20 mm or above) will also increase in each season except for summer periods. Floods and inland water problems however are also frequent. The area at risk of inland flooding in Hungary is 21 088 km^2. Being 23% of the total surface area of the country this is quite a high rate as compared to other European countries. The frequency of torrential rains, gale force storms, blizzards and heat waves is also expected to grow, such as the incidences of extreme water levels and bushfires, the length of drought periods and as a consequence of all the above biological diversity is likely to decrease.

The listed processes have a serious impact on our health, on ecosystems, on the fundamental infrastructure systems and on agricultural productivity. In summary, they affect almost all spheres of life.

The various impacts caused by climate change have a different territorial scope, hence, based on the different vulnerability levels of the various types of space, the mitigation and adaptation capabilities of the regions also differ from each other. Logically, the problems should also be handled in a differentiated way, aiming to find customized solutions based on the area and its capabilities.

Successful adaptation to climate change is inconceivable without having a sound knowledge of the impacts of climate change. In Hungary however, prior to the launch of the NAGiS project there had been no complex and multisectorial data- and knowledge bases



which could have provided information by area on the expected changes, necessary for planning adaptation measures. As a consequence of the insufficiency of data and methodology, analysis had only been prepared to a limited extent and only applicable to certain narrow fields which could have given well-founded information on the territorial vulnerability due to climate change and on the possibilities for adaptation. The whole project and work packages presented in this publication have aimed to outline a comprehensive picture on Hungary regarding above described issues, creating at the same time the bases of future continuous monitoring activities. On the following pages the reader will find a selection of these results.

Today it is already clear that we have the possibility to prepare for the impacts of climate change in numerous spheres of life. This ambition is backed by NAGiS providing well-founded scientific background information. We hope that after reading the recent publication, you will also feel motivated to register online to the developed system.

The background and the operating framework of the NAGiS project

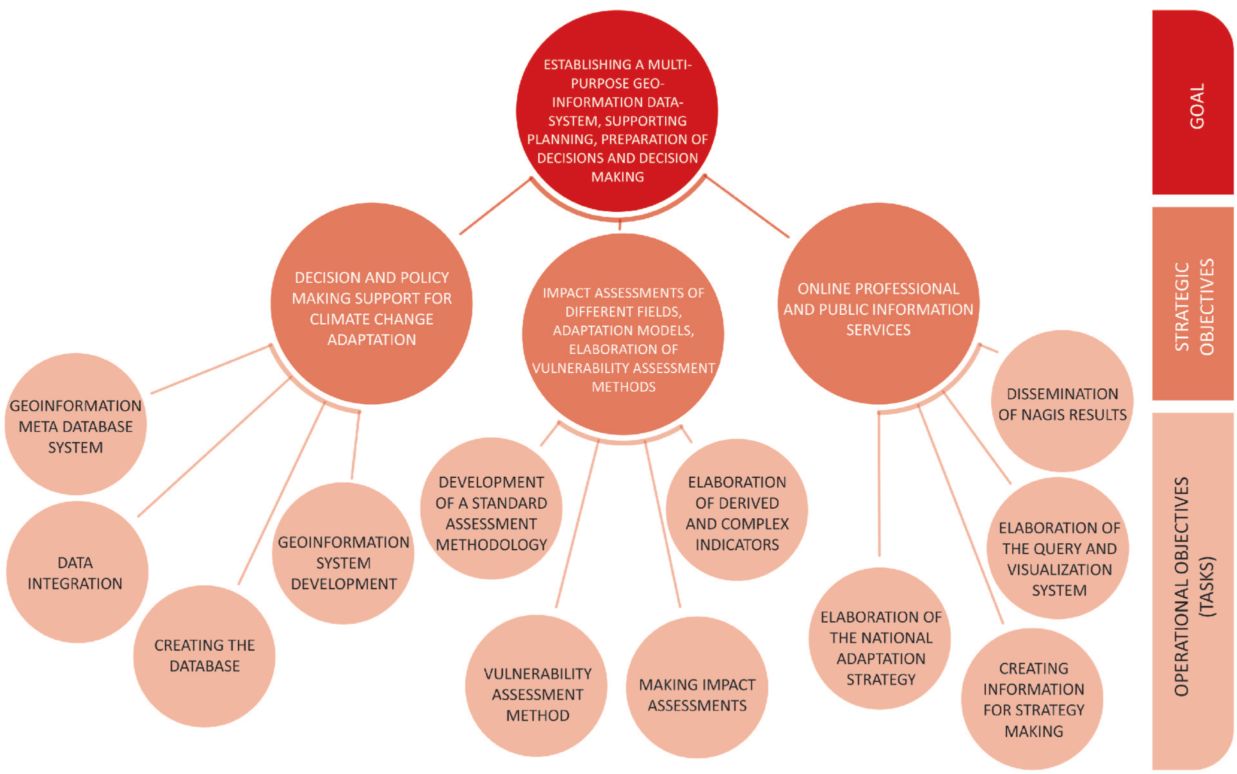
Besides the needs outlined in the introduction, the National Adaptation Geo-information System (NAGiS) was called into existence as a result of recent researches and evaluations carried out in the field of climate change, based to a large extent on the results of the Hungarian VAHAVA and of the European ESPON CLIMATE projects. The system is of pioneering importance in Hungary for the complex monitoring of the impacts of climate change in several sub-topics as well as for providing a basis for mitigation and adaptation solutions.

The legal basis of the creation of NAGiS was provided by §14 of the Act LX of 2007 on the implementation framework of the UN Framework Convention on Climate Change and the Kyoto Protocol thereof. The Decree No. 94 of 2014 (III. 21.) of the Government laying down detailed rules of operation of the National Adaptation Geo-information System was adopted, based on the above legal mandate. NAGiS provides information on the climate status of the country, on the impacts of strategic risks connected to climate change and other long-term natural resource management issues and on the correspondent adaptation possibilities, based on the indicators, analysis and impact studies prepared using the data, and within the limits specified by the Decree. The NAGiS is operated by the Geological and Geophysical Institute of Hungary (MFGI). The MFGI operates under the authority of the Ministry of National Development.

The project aiming the establishment of a knowledge-based system was launched in September 2013 and finishes in April 2016. Its operating principles are in line with international climate protection obligations as well as with EU policies, guiding principles (e.g. INSPIRE directive), strategies (e.g. EU 2020, Territorial Agenda 2020). The project is one of the three fundamental pillars of the Adaptation to Climate Change Programme financed by the European Economic Area (EEA) Grants, and 95% of its financing was provided by the Grants. The Regional Environmental Centre for Central and Eastern Europe (REC) was responsible for managing the funds. The project was implemented by the Geological and Geophysical Institute of Hungary, and the implementation was coordinated by the National Adaptation Centre, a department of MFGI.

THE AIM OF THE NAGiS

The prediction of future climate conditions is made possible by climatological modelling. The continuous developments of the models on different levels (global, regional) requires a strengthened capacity for building long term climate scenarios for Hungary, especially because the models cannot be interpreted without their adaptation to Hungary. However, the mere knowledge of climate change parameters is not sufficient to understand the impacts that climate change has, and the extent to which certain areas of Hungary are vulnerable to it. The National Adaptation Geo-information System helps to determine this.



The policy objective of NAGiS

The comprehensive objective of NAGiS is to establish a geo-information and data system which helps to identify climate change impacts, to determine the extent to which certain areas are vulnerable, thus encourage the adaptation to the impacts. It provides the flexible policy-making, decision-making and planning procedures as well as the connected legislation with objective information, adapting to the changing circumstances. All this is accomplished by ensuring long-term operation of the system, putting it on a completely scientific basis and by a full-scale documentation of the methods used to obtain the results published in NAGiS.

As a result, a system containing comprehensive information was created,

1. which includes a multifunctional, user-friendly geo-information meta-database which is based on processed data originating from other databases;
2. which helps to carry out, in compliance with INSPIRE guidelines, a spatial impact-analysis of climate change as well as the data collection, data processing, climate modelling and analysis and the further development of the methodology of vulnerability-examina-

tions supporting the connected adaptation methods in a way that they could be incorporated into the National Infrastructure for Spatial Information;

3. which establishes a web-based climate policy information hub, ensuring access to factual information for all interested stakeholders on fields related to and affecting adaptation to climate change.

Therefore, besides a rather narrow public of Hungarian professionals of the subject, the main target groups include the population of the areas that are vulnerable to climate change and that are at risk of extreme weather events, the national, regional and local government bodies, local governments, decisions-makers of public bodies, policy makers. The participants of sectoral (climate policy, energy policy, transport development, development policy, agricultural and rural development, woodland management, urban and territorial development and land use planning, public service planning, tourism, disaster management) decision-making and planning can also be included here.

THE TOOL: DATABASES AND SOFTWARE IN SERVICE OF MONITORING CLIMATE CHANGE – THE INFORMATION TECHNOLOGY BACKGROUND

THE TOOL

In the first phase of the project, the most important task was to create an information technology background which, being integrated into the IT environment of MFGI, is capable of planning, establishing and starting the operation of NAGiS. NAGiS has also designed its own database and map servers.

The NAGiS database should not be thought of as a single database, but much more as a (geo-)information system that is built up of several underlying databases in the background. The most important out of these are:

– **Map database:** map layers that are the intermediate and final products of the project. Instead of having only one large database, it is built up of smaller databases or file systems organised in thematic categories. The two main parts of the map system are the dataset stored on the public map server and a larger dataset as compared to the previous one, stored in the internal NAGiS (MFGI) system.

– **GeoDat:** A database-management application designed for NAGiS with a supporting background database, built up in a standardized system. The latter one contains all numerical and alphanumerical data which are considered to be the end products of the project. As for its content, partially it overlaps with the map-based database but it is much more expanded. It also contains data that have not been displayed on the maps.

– **Meta-database:** the database containing and providing meta-data of the map layers of NAGiS.

– **nagis.hu portal:** A web portal in the classic sense of the word, with the above mentioned database laying behind. Beyond the establishment of the portal it also contains the access data of the users.

HARDWARE ENVIRONMENT OF THE NAGIS DATABASE

In order to store the data internally, the system stores the data retrieved from various data management systems in the NAGiS basic database in a standardized way. The core data are stored in separate tables whereas time series data are stored in parameter tables. The system enables to identify any point objects and to store all related core data and parameters.

The unit of external data storage contains the public data of NAGiS. This has been established in an environment and following a structure that are completely identical to that of the internal databases of NAGiS. All data made available for the general public are transmitted here from the internal databases. All actions of public data provision refer to this external data storage system.

As the hardware background of the project needed for the operation of the system, it was necessary to purchase 9 desktop computers and screens for the desktop working environment of employees working on the project; a notebook for external lectures; and a scanner for digitalizing the printed maps that were used. Two servers and four uninterruptable power sources were also purchased to store the map-based and basic data as a database-background. An archiving unit has also been designed for daily-weekly-monthly-yearly archiving of the project files. The purchases were made in the framework of public procurement procedures.

CONTENT UNITS AND SOFTWARE OF THE NAGIS DATABASE

For using the equipment presented in the section on hardware background, a server operation system, a software controlling smart archiving and a database management software have also been purchased. Geo-information work was carried out in an ESRI environment in the project.

For the management of non-map-based basic data, a database-management tool was developed by the project. The application was named GeoDat. The core system provides a table view of the data as well as advanced research options. A separate module of the application has been designed for the display of time-series data. The graphic display enables the users to edit, export and to analyse the data. In connection with the latter, NAGiS makes it possible to define various statistical indicators (e.g. mean values, multiplicity, minimum/maximum, standard deviation).

METADATA: NAVIGATION IN THE DATA SYSTEM

The database of NAGiS stores several hundred maps and several thousand related work files. In order to help navigation amongst these, a background system was also needed, taking into account that the database itself does not store information on the connections of particular data elements, on the method of their production and on their physical location. Information of such kind is described and transmitted to the user by the metadata system. The primary role of the metadata is to enable users to find the information they need in the quickest possible way.

NAGiS metadata can be categorized into four main groups:

Map metadata: containing the address, the description, the type and other basic features of the maps. They help the free text search ensuring quick access.

Metadata of map figures: They contain the basic characteristics of single figures displayed on the maps. They help experts to explore the objects (e.g. drillings, measurement points) used to create the thematic categories of the maps.

Research metadata: They provide a precise description to the measurement and processing procedures necessary for establishing the thematic categories of the maps. They help experts in making a more detailed evaluation of the results.

Registry metadata: The background data created during the measurement and processing procedures which help the users accessing data sources which have already been arising before and can be reused.

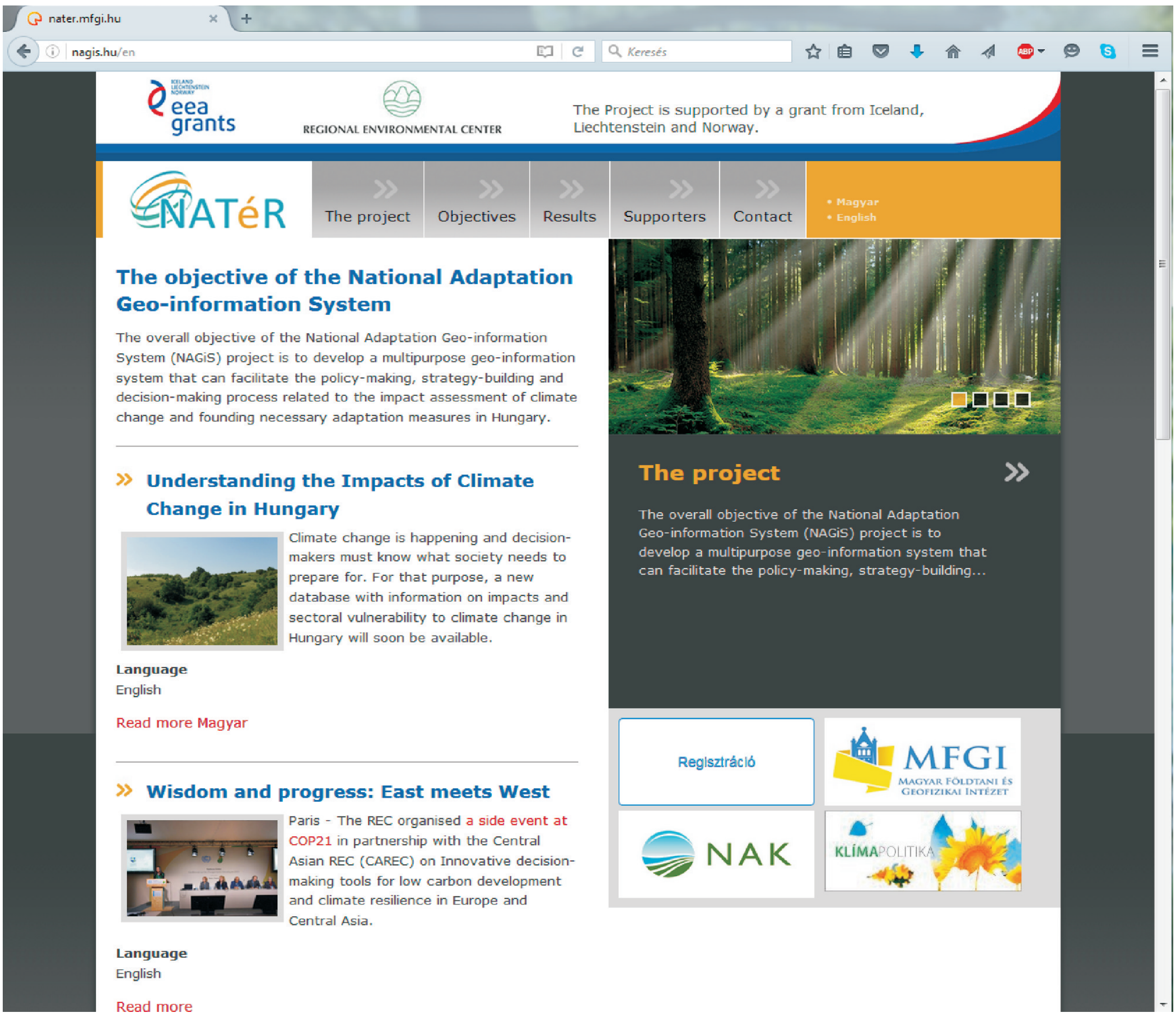
Metadata can be used through a user-friendly search module. By typing several keywords of the given category, enabling quick navigation, the user is provided a clearly presented list of search results containing further labels to find more detailed information.

NAGIS USER INTERFACE

NAGiS has three different user interfaces: the basic portal, a map view and a database interface. The **basic portal** is a traditional web portal available at the www.nagis.hu or the www.mfgi.hu/nater addresses, enabling the users to search metadata or to register and login to the NAGiS system. It performs the identification of users as an engine portal and transmits the user data to the other two interfaces.

The **map-based portal** displays the map layers of the project at the map.mfgi.hu/nater address. It is a classic online map-based interface with a special layer management feature, considering that it can make 600 map layers available to the users in an easily understandable form and way. The content that can be accessed depends on the rights given during NAGiS registration.

The **database interface** is available only for registered users at the www.nagis.hu/geodat address. With the help of the GeoDat application users can access the data loaded into the NAGiS system in a table format. The interface enables the users to view, export and even to edit the data.



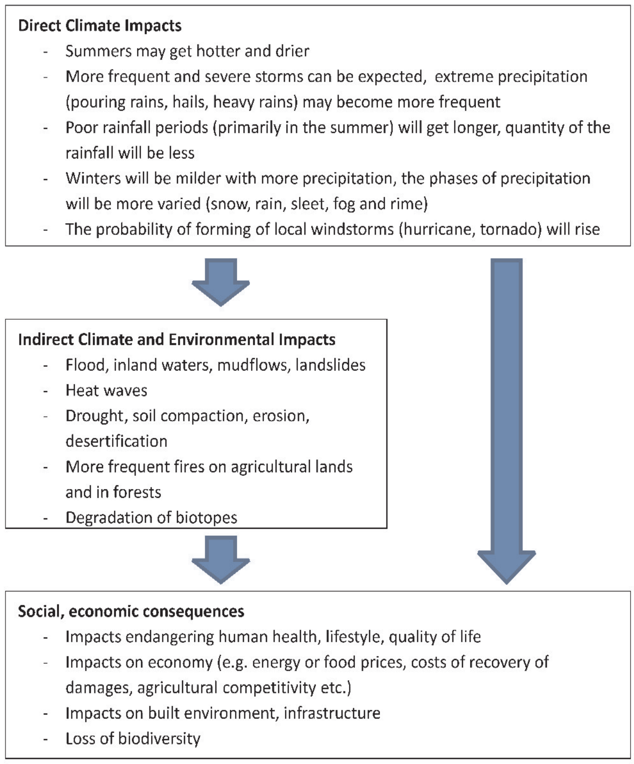
The methodology: climate change vulnerability assessment framework

METHODOLOGY

The unambiguous identification of particular impacts present at different environmental, social and economic levels is the starting point of the evaluation of climate change on a regional level. Not only the direct consequences of climate change can be problematic, but on a local scale, climatic impacts may also put at risk the state of economic organisations, community values, infrastructural elements (buildings, transport networks) and supply systems. It is important to investigate to what extent the built environment, that is to say the physical environment of everyday life is "climate safe" and how far its current developments will be adapted to the impacts of changing climate. Therefore, a specific evaluation method and model is needed which can handle the process in its complexity, taking also into account the whole chain of climatic impacts, including their social consequences as well.

The climatic impacts to be examined form a complex chain. The direct climatic impacts appear under the form of changes that can be described using regional climate indicators. Complex local natural phenomena generated by climate change, interacting with each other and having repercussions on the climate indicators as well, may be identified as indirect climatic and complex natural impacts. The impacted systems are primarily affected by these. Natural, social and economic consequences are the unfavourable socio-economic consequences produced jointly by the direct climatic impacts and the indirect impacts that natural systems and ecosystems are exposed to.

In connection with the assessment of the impacts of climate change, the aim of the CIVAS (Climate Impact and Vulnerability Assessment Scheme) model used is to provide a standardized methodological background to quantitative climate impact assessments.



Direct and indirect climatic impacts and complex socio-economical consequences on local and regional levels. (Source: Pálvölgyi, 2010; referred by: NÉS 2015)

The model is based on the approach published in 2007 in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, but numerous experiences of application can be found in scientific literature. CIVAS has been developed in the framework of the CLAVIER international climate research project[1], amongst others to examine the impacts of climate change on ecology and on the built environment.

The definitions introduced in the regional adaptation of the CIVAS model are as follows:

[1] CLAVIER project: Climate Change and Variability: Impact in Central and Eastern Europe EU 6th Framework Programme, GOCE Contract Number: 037013

Complex climate problems and impacted systems: Identification of complex climatic problems arising all in a social, economic and environmental space, and the systems that can be described as impacted by these.

Exposure: The factors of climate change on a regional (local) level. Differently to sensitivity (which characterizes the impacted system), exposure is only characteristic of the geographical location.

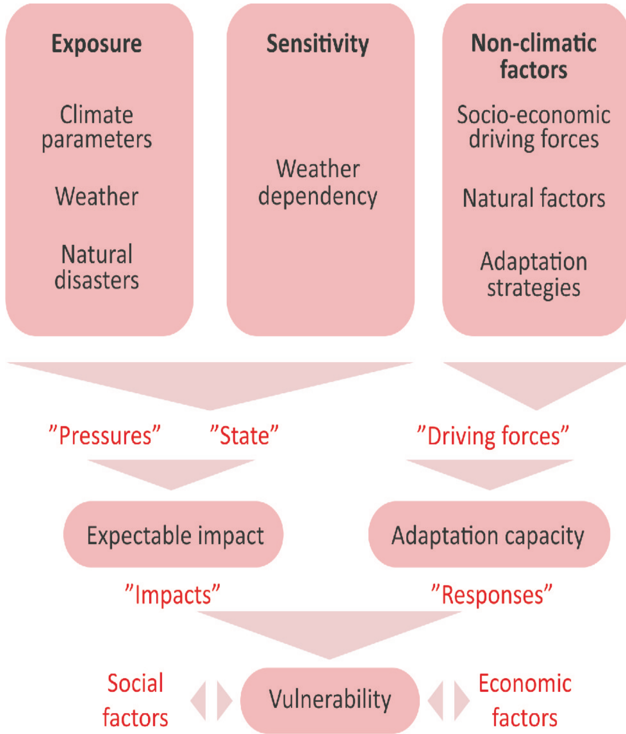
Sensitivity: Weather-dependent behaviour (e.g. susceptibility to droughts, risk of surface ponding) of the impacted systems (e.g. agriculture, human health, state of engineered structures). It is independent of climate change and is primarily characteristic of the impacted system.

Potential impact: The combination of sensitivity and exposure which are both characteristic of the geographical location and of the impacted system being examined (e.g. urban heat-island effect weighted by mortality).

Adaptability and other non-climatic factors: The nature and strength of local socio-economic answer to climate change (e.g. a form of agricultural adaptation is irrigation which depends amongst others on agricultural profitability; mobility, being a possible solution to urban heat waves is dependent on the income).

Vulnerability: a complex indicator combining the expected results with adaptability, taking into account that a given expected impact may lead to much more serious consequences in an area having lower adaptability.

In line with the theoretical structure, the first step of the application of the CIVAS model is the definition of the impacted systems, the sensitivity, exposure and adaptation indicators and of the calculation proce-



The structure of the CIVAS model (Source: Second National Strategy for Climate Change, 2015)

dures on impact and vulnerability. Vulnerability is calculated in the second phase of the assessment, followed by the analysis and evaluation of vulnerability based on the results.

During the evaluation, the systems that are only exposed to a slighter climate impact and that are also characterized by a strong adaptability are called “robust systems”; their vulnerability is the lowest. The systems affected by an important impact and that can be adapted to a moderate extent can be considered as the most vulnerable systems. The intermediary systems are less likely to adapt, even if they are only affected by a minor impact: these are the cases that are at risk. Finally, the systems with a larger expected impact and a strong adaptation can be considered vulnerable.

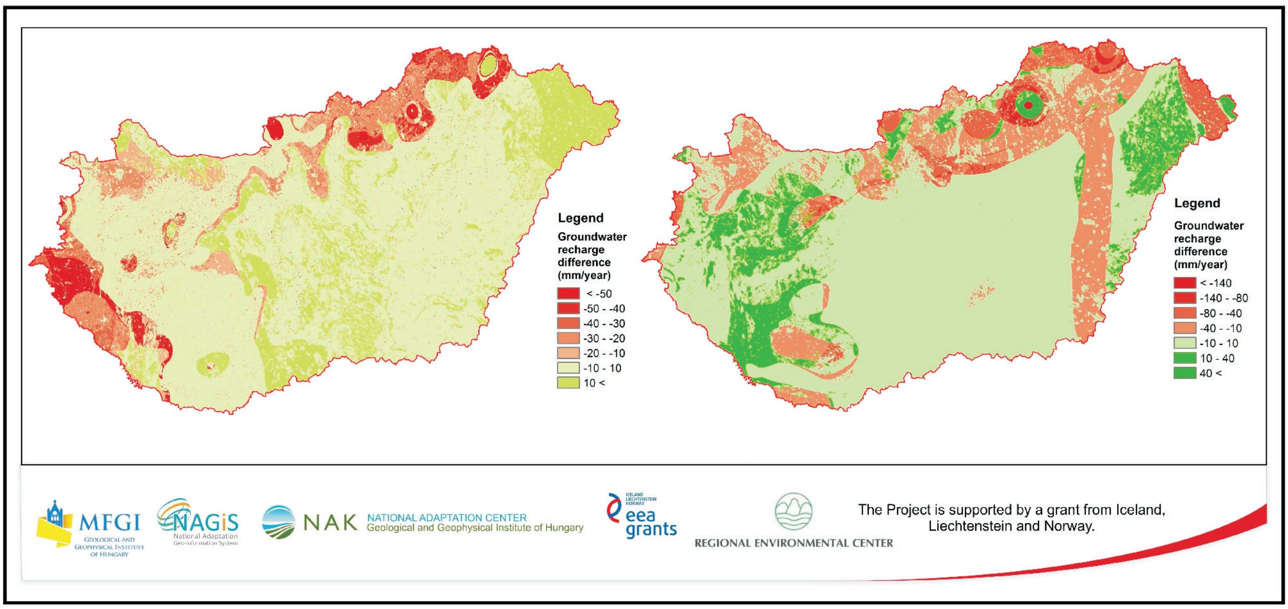
THE RESPONSES: NAGiS RESULTS CONNECTED TO CLIMATIC ADAPTATION

THE RESPONSES

Based on the databases and climatic models available in the framework of NAGiS project, research has been carried out in several thematic fields, examining the vulnerability, the exposure and the adaptation potential of particular geographical areas to given impact factors of climate change. The sensitivity of subsurface waters, especially of drinking water supplies, the waterflow schemes of larger lakes, especially of Lake Balaton, the exposure of residential areas to flash floods, the impacts of climate change on agriculture, woodland management and natural habitats, the changes taking place in land use have all been subject of partial research activities of the project. In the following sections our publication outlines the main methodological approaches and results.

THE IMPACT OF CLIMATE CHANGE ON SHALLOW GROUNDWATER

By the modification of rainfall and evaporation conditions, the impacts of climate change also affect groundwater stocks. Based on the forecasts of climate models, the annual average temperature of Hungary is expected to grow by 3–5 °C until the end of the 21st century. In parallel to that, the annual rainfall will decrease. Due to the decreasing amount of rainfall, a decreasing quantity of infiltrating water and due to the increasing temperature, an increase of quantity of evaporating water can be forecasted, expectedly leading to the increase of water abstraction for agricultural use, and hence, putting further stress on groundwater stocks. All the above may result in the decrease of groundwater-levels and in the shrinking of the stocks of groundwater. The forecast of the intensity and territorial distribution of these processes is possible by modelling assessments.



Recharge difference, based on the CarpatClim-Hu database for the periods between 1961–1965 and 2005–2009

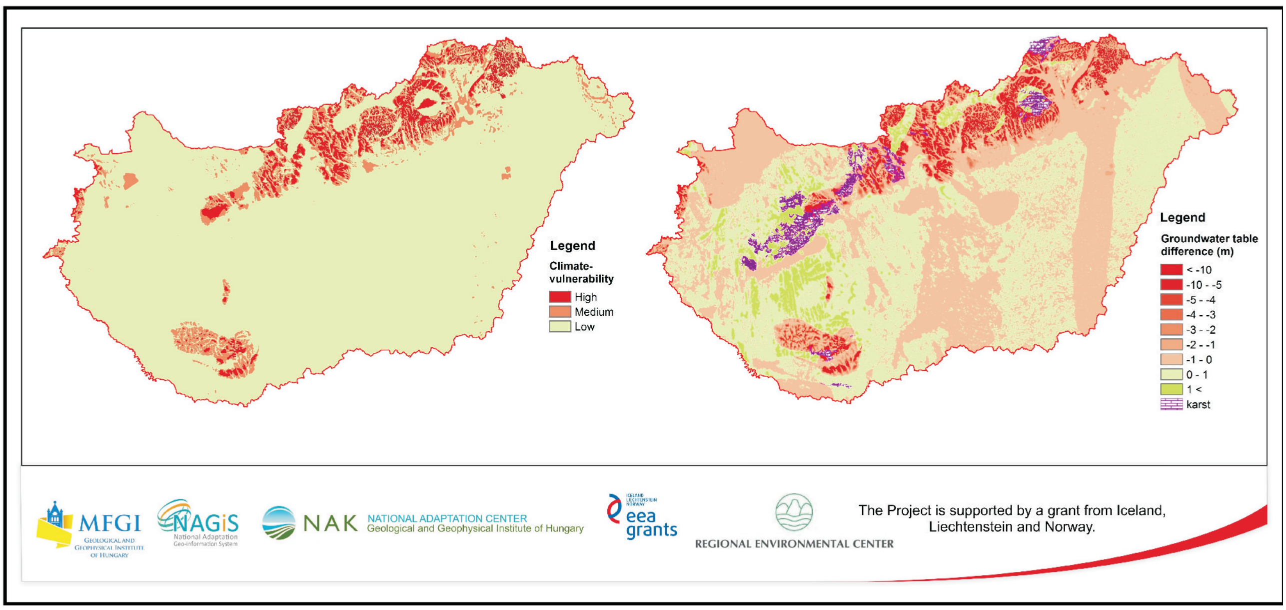
Recharge difference, based on the results of the climate model ALADIN for the periods between 1961–1990 and 2071–2100

Methodology: During the monitoring of the impacts on groundwater, the inspection of water levels is of key importance. The time-series on water levels created as a result of continuous monitoring provide basic data for the evaluation of the changes and for the calibration and verification of the models established for the forecasts. MFGI has been operating its Hungary-wide hydrogeological observation network since the 1970s. For a more precise evaluation of the possible impacts of climate change, the network of measurement stations already in service has been complemented with 6 new water-level observation wells in the framework of the NAGiS project. The data of the measurements keep being incorporated into the database of MFGI. In the 1960s–80s, in Hungary shallow, mostly 10 m deep drillings were installed on the territory of the Great Plain, of the Little Plain and in the Southern Transdanubia region. Regarding the data on drillings that had been missing from the data records of these shallow-drilled wells, recording and integration to the database was completed in the framework of the NAGiS project, providing a stable and faultless query option for this volume of data.

The aim of the groundwater-level monitoring workflow was to elaborate a methodology by the shallow groundwater table can be modelled under different climate conditions, investigating the impact of climate change on groundwater and characterizing climate sensitivity of shallow groundwater flows. The research elaborated a multi-stage method by determining climatic and infiltration zones; the level of infiltration; and finally the distribution of groundwater using numerical models. During the examinations carried out, the CarpatClim-Hu database established from the weather and rainfall observation stations of the Carpathian Basin was used, whereas for determining future groundwater conditions, the results of the regional climate models of ALADIN (developed by the Hungarian Meteorological Service [OMSZ]) were applied.

Results: Following the examinations carried out, the infiltration distribution data calculated for the reference period between 1961–1965; the change of infiltration between the sixties and the two thousands; and the forecasted change of infiltration for between the period 1961–1990 and 2071–2100 were displayed on a map.

Based on the change of calculated infiltrations, an approximately 50 mm/year decrease of the infiltration can be detected for mountain areas between the periods 1961–1965 and 2005–2009. Based on the model outputs of ALADIN, the change of simulated infiltrations also forecasts a decrease of 50 mm/year for the



Climate sensitivity map of groundwater in Hungary, defined on the basis of climate modelling outputs

The map of groundwater-level differences calculated for the periods 1961–1990 and 2071–2100 remaining decades of the century in the area of the mountain range of Mecsek, the North-Hungarian Mountains and the Transdanubian Mountains.

Besides calculating the groundwater-distribution for the initial reference period (1961–1965), the graphical display of the hypothetical change of groundwater calculated for the period between the sixties and the two thousands based on the observed climatic parameters was also prepared. Based on the modelled climatic parameters, the expected change of groundwater is illustrated on a separate map.

The differential maps calculated on the basis of the climate model outputs predict a similar decrease of the water level for the coming decades. The most significant decreases are expected for the area of the North-Hungarian Mountains, of the Transdanubian Mountains and of the mountain range of Mecsek. The same models indicate a decrease of 1–2 meters for the Danube–Tisza Interfluve and for certain areas of the Transtisza geographical regions.

The groundwater reservoirs of the country were classified into sensitivity categories based on the extent to which the modelled groundwater levels react to climate change. The sensitivity map was prepared based both on measurement data and on the simulations performed on the basis of climate model outputs. Both sensitivity maps indicate that the mountain areas (the North-Hungarian Mountains and the Transdanubian Mountains) are highly climate-sensitive, while the foothill areas thereof are considered to be moderately sensitive.

Conclusions: It is important to note that the results of the examinations also contain the faults and uncertainties of the databases used. The modelled distributions were prepared with a national level of certainty, therefore, they cannot be used for the purposes of local examinations.

The modelling methodology established can be used both for updated and enlarged input databases and for producing results of higher precision if higher resolution is provided, being this way a universal tool for determining the distribution and the climate sensitivity of shallow subsurface waters.

THE IMPACT OF CLIMATE CHANGE ON DRINKING WATER SUPPLIES

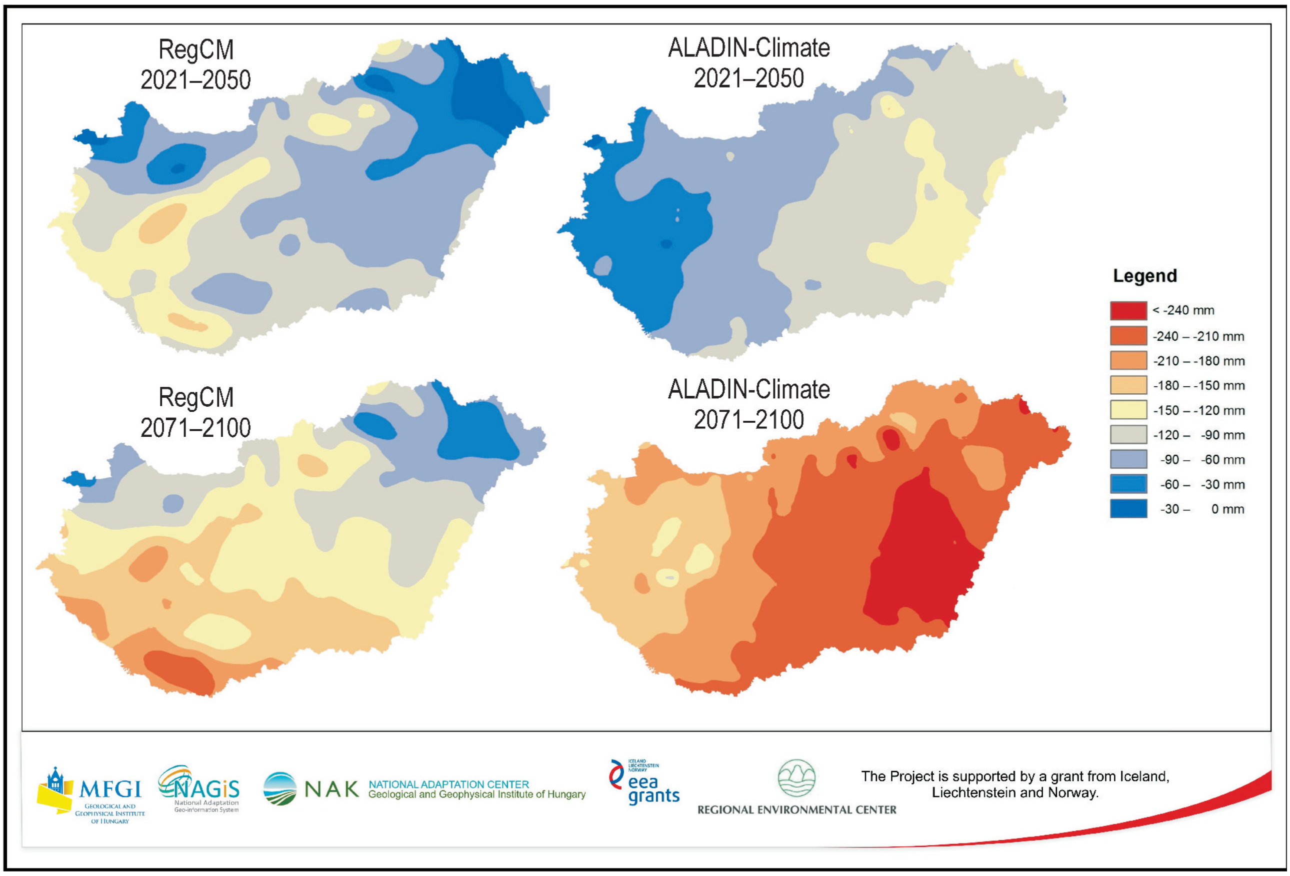
The importance of subsurface water stocks is apparent already based on the previous section on groundwater, the future of drinking waters however draws even more attention to this resource and to the necessity of gaining precise knowledge on the connected impacts of climate change. 95% of the drinking water stocks of Hungary originate from subsurface waters. The largest drinking water stock of the country comes from the deep groundwater layers of sedimentary deep basins laying under the plains, whereas in certain regions, the main source of drinking water comes from karst waters of the mountain ranges. The bank filtered water systems using both surface and subsurface waters play a crucial role in drinking water supply. Generally, the permanent alteration of climatic conditions on subsurface waters is not as direct and excessive as in the case of surface waters, and often only the results of several years of continuous influence can be observed. These changes, however need a longer period to be applied, and their initial situation can only be restored via very slow processes.

In view of the more and more frequent occurrence of extreme weather conditions a detailed assessment of the impacts of climate change exerted on drinking water supplies has become necessary. Within the framework of NAGiS the climate elements alongside with the geological formation being particularly characteristic of the vulnerability of drinking water supplies have been performed, characterizing also the possibilities of adaptation. Beyond the establishment of a methodology for analysis of climate vulnerability of drinking water supplies a data system containing geo-information elements has also been created, helping to strengthen adaptability and to decrease unfavourable impacts.

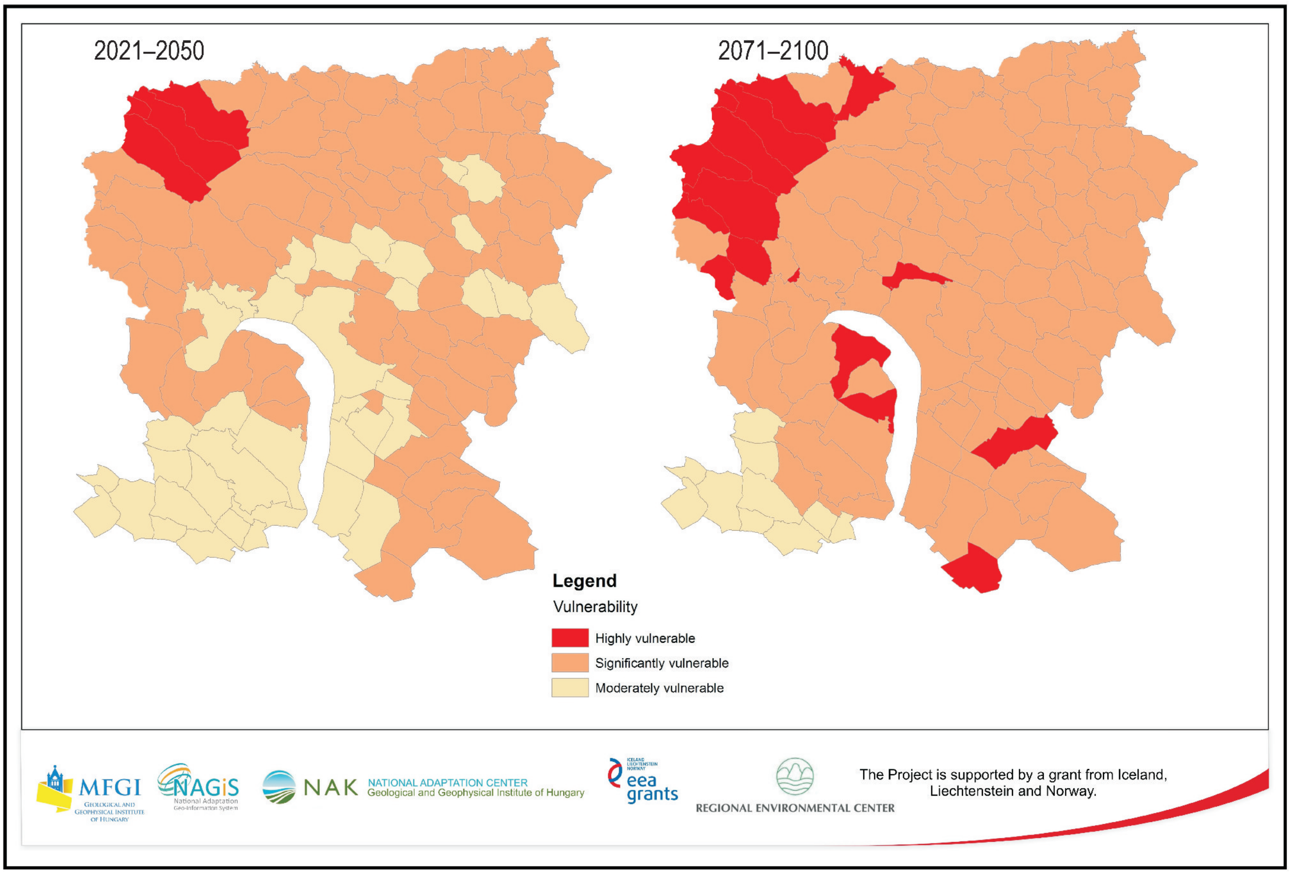
Methodology: The research was based on the CIVAS model: the impacts of climate change on drinking water supplies were examined in the project as part of the frame of reference of exposure, sensitivity, expected impact, adaptability and vulnerability. In order to take anthropogenic impacts into account, the model was complemented by the examination of the exploitation of subsurface water bodies by water production. Exposure, climate sensitivity and stress inflicted by water extractions were examined for the whole territory of the country; the assessment of adaptability and the determination of the adaptation indicators were carried out based on the information obtained directly from the operator of the drinking water supplies on a selected sample area.

Results: The research examined exposure through climate conditions (rainfall, and the temperature determining evaporation and vaporization) affecting the reemergence of infiltrations and of the subsurface waters at the end of their flow way, and their future evolutions. To describe exposure, the data series of the ALADIN-Climate and RegCM climate models as well as CarpatClim-Hu were available. Based on the above, for the period between 1961–1990, at lower areas an increasing exposure can be observed, and the most significant water scarcity was present at the central areas of the Great Plain, witnessing however a rainfall surplus in the mountainous regions and the South-Western Transdanubia region. The two climate models both prognosticate an increasingly significant drying of the climate in Hungary, painting however different pictures on the scale and territorial distribution of the changes.

The climate-sensitivity of subsurface drinking water supplies is defined based on the geological and hydrogeological parameters of the water table and its recharge area. Based on this, climate-sensitivity can be categorized into different sensitivity groups. In the framework of the cooperation of OVF-MFGI, 2018 water tables were classified into four categories, and further complementary examination was carried out in the sampling area at the Danube Bend region.



The expected evolution of the climatic water balance



The climate vulnerability of drinking water sources in the operation area of the DMRV Waterworks, based on the data provided by the ALADIN-Climate model

The exploitation of the subsurface spaces by water production was defined by the research after analysing the time-series of 844 water-level observation wells and establishing a numerical model on the flow systems of subsurface waters. In Hungary, the scale of extraction of subsurface waters for drinking purposes is significantly increased since the 1950s, inducing long term decreases of the water-level in numerous aquifer layers. The depression impact is most common in the middle areas of the Great Plain, the scale of which continues to grow in proportion with the depth. By the mid-1990s, further decreases of water-levels stopped in several areas, and since then no significant changes can be observed.

The adaptability represents the local socio-economical solutions to the impacts of climate change. Its main determining factors are the state and the development opportunities of the supply infrastructure for drinking-water, the water-needs of the population and the income conditions. From the point of view of adaptability, it can be considered a positive change that if a local area is supplied by several drinking water supplies, there is a possibility to expand the current drinking water supply and to develop its production capacity and also that water needs of the population are low and its income conditions are favourable. In the research, different category values were allocated to each indicator, then by summing up the category values, the extent of adaptability of every local area were classified into four categories: highly, increasingly, moderately and poorly adaptable. The region with the lowest rate of adaptability in the sample area was the Lower Ipoly Valley region, but the right side municipalities of the Danube Bend are also in an unfavourable situation, where infrastructural deficiencies and the high water consumption of the population are the main sources of the problem.

Vulnerability integrates exposure, climate sensitivity and adaptability. Taking into account that the adaptation indicators were only available for the area of the Danube Bend, examination of vulnerability was also carried out here. In the research, categories were defined, where the factors of exposure, sensitivity, stress and adaptability were taken into consideration with equal importance, with the complex indicators derived from certain indices. The climate-vulnerability of water tables was examined by both climate models and for both climate windows in the research. Differences in the vulnerability of different areas arise as early as during the period between 2021–2050. As the time passes, the extent of vulnerability increases for the period between 2071–2100.

Conclusions: The climate exposure of water tables is not identical throughout the entire territory of Hungary, but it changes in a relatively narrow range as compared to other European countries. The recharge rate of subsurface waters is expected to decrease as a result of climate change. The currently available climate models may be characterised by a rather significant amount of uncertainty, therefore during further researches it is important to reduce the extent of such uncertainty; and it is also advised to extend vulnerability examinations to the whole country and to fine-tune the weight of particular elements.

During water supply more attention should be paid to water tables that are less sensitive to climate. The role of bank filtered water resources may rise due to their large storing capacity and their continuously renewing stock. It is helpful to gradually substitute the karst and shallow porous water tables, highly vulnerable to climate by new water supplies.

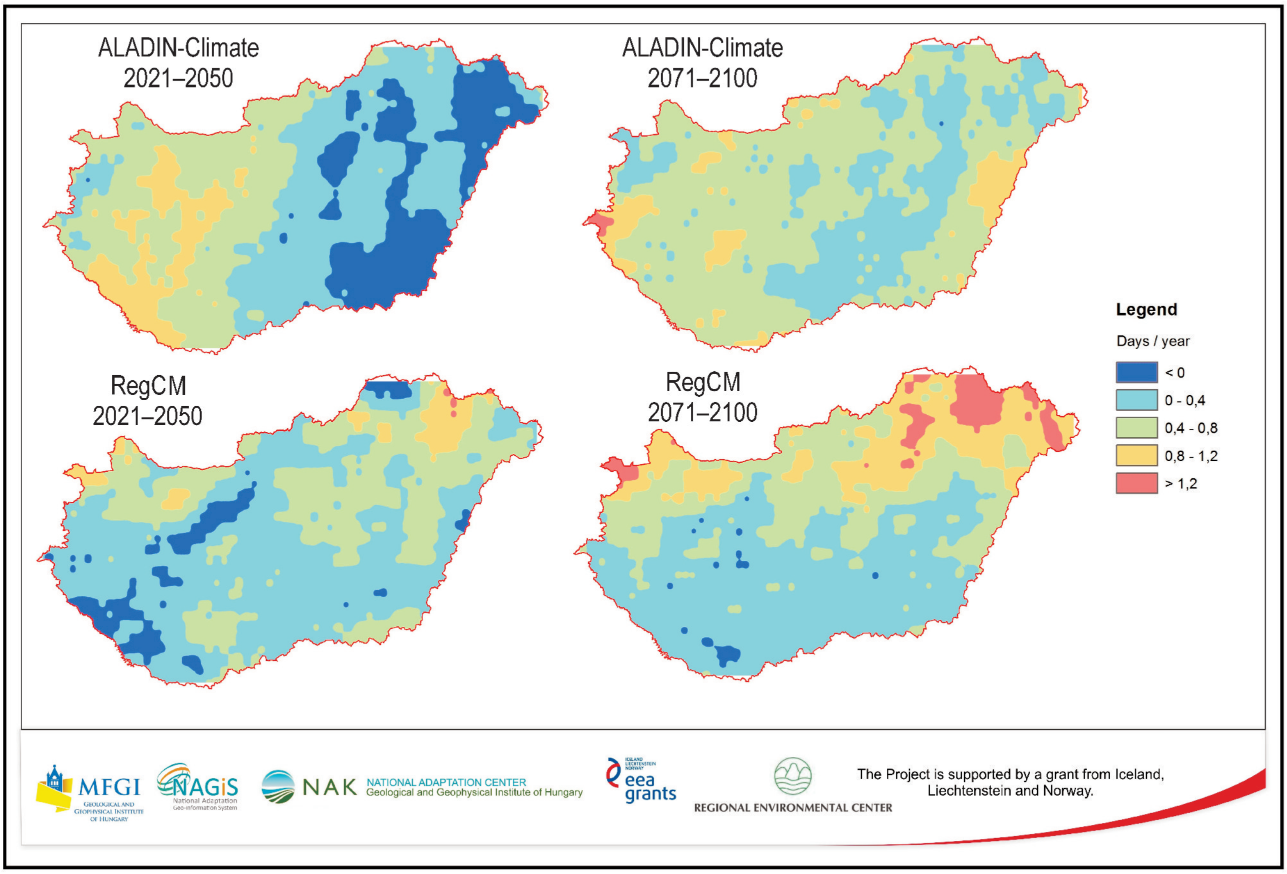
The condition of subsurface waters, the impacts of climate change, and the extent of stress should be followed up as part of a regular monitoring activity. Possible mitigation and adaptation measures may be taken based on the regular, periodic evaluation of the observations and the identification of changes. Much more attention should be paid to adaptation: e.g. regional supply systems, the application of solutions for water management and for the diversion of water between different areas, encouragement of conscious and economical water consumption habits by the separation of the supplies of water used for different purposes. In terms of regional development (e.g. infrastructure of drinking water supplies) the climate vulnerability of water tables and the improvement of adaptability shall be taken into consideration.

THE IMPACT OF CLIMATE CHANGE ON THE RISK OF FLASH FLOODS

Nowadays, climate change can also be witnessed in connection with weather events arising in the short term, and in increasingly frequent extreme weather situations. Intense precipitation concentrated in small areas can be mentioned here, together with a possibly accompanying flash floods causing significant damage. The water drops emerging onto the surface will be accumulated within a short time on the sole and the such abruptly accumulated quantities cannot be transported at once by the water flows in the area. Flash floods can develop in mountainous and hilly areas, putting mostly at risk the local areas and districts situated in valleys.

Methodology: The exposure of a local area to flash floods depends on the characteristics of the water catchment area including the local area, and the actual development of the phenomenon depends on rainfall. The aim of this research was to determine this exposure of local areas, based on the surface specificities helping or blocking the development of flash floods. The project defines these specificities for the whole water catchment area that can be allocated to the local area in a way, that it classifies the parameters (size of the water catchment, gradient conditions of the topography, level difference within the water catchment area, plant coverage, the shape of the water catchment) into five ranges and then it calculated a mean value characteristic of the water catchment by each type of feature. The weighted average of these also expresses the final classification in five groups.

Water catchments are the basic units of decisive importance of the model, therefore this way, a flash flood exposure classification can



The changes of the average number of days with precipitation exceeding the threshold (30 mm)

even be established on a national level which can be fine-tuned even almost real-time. The NAGiS project provides an automatic evaluation in a resolution that can be used for overview (1:500000 – 1:100000), however, the answers can be fine-tuned in case of a particular local area. CarpatClim-Hu based on climatological measurements, serving as the basis of the examinations, and the databases of the ALADIN-Climate and RegCM climate models cover three so-called climate windows: one is used normally as a reference for the period between 1961–1990, and two as forecasts for the periods 2021–2050 and 2071–2100.

Future developments are directed towards the possibility of determining the amount of rainfall reaching the surface (water catchment area) which surpasses the water diversion capabilities of the given local area. For this to happen, it is important to evaluate the probability of the incidence of extreme precipitation. The joint evaluation of these two information will be needed for decision-making and preparation.

Results: From the perspective of flash floods it is of primary importance that the impact of topography can be well identified regarding the spatial arrangement of the average number of days with rainfall above the threshold value of 30 mm. The lowest value of frequency can be found on the Great Plain, whereas the phenomenon is typically more frequent on slopes, or hilly and mountainous areas. Carrying out the same examination, the data of climate models for all three climate windows clearly indicate a consistent increase of days with extreme rainfall. The exposure of particular areas to situations characterised by extreme quantities of daily precipitation becoming increasingly frequent due to climate change was specified by the researchers based on a 5-category classification system allocated to the results, where category 1 marks the areas that are the least affected by extreme precipitation whereas 5 stands for extreme rainfall. The figures above recapitulate the future developments and spatial distribution of the cases when the threshold value for precipitation is expected to be exceeded, where the two maps on the left represent the period between 2021–2050 and two maps on the right represent the 2071–2100 period, based on the data of ALADIN-Climate model on the top and of RegCM on the bottom.

Based on the results of the climate models, by the 2021–2050 period, the days with rainfall exceeding the critical value is expected to grow in a significant part of the territory of Hungary, nevertheless in certain regions the frequency is not expected to change or it may even decrease. Typically, the pace of decrease does not exceed one case every two years, the two models however have different expectations regarding the areas concerned.

Conclusions: Although there are some differences regarding the pace of the change, the results coincide regarding the fact that by the end of the century, practically, the number of days with precipitation levels exceeding the critical value can be expected on the whole territory of the country. This increase will be least characteristic of the Great Plain area where the change of frequency will not reach the level of one day per year according to any of the models. ALADIN shows a more equal distribution of the increases of frequency for the territory of the country, whereas RegCM estimates a higher level change for Northern regions, amounting to even three days every two years. All this draws our attention to the importance of getting prepared to protection against flash floods, regarding infrastructure development as much as forecasting.

THE CHANGE OF WATERFLOW SCHEME OF LAKE BALATON TO THE IMPACT OF CLIMATE CHANGE

The larger lakes of Hungary (Lake Balaton, Lake Velence, Lake Fertő and Lake Tisza) with no exception, are typical shallow lakes and one of their important characteristics is to be highly sensitive to the spatial and periodical changes of environmental factors (including climate) in terms of quantity (changes impacting water level, water surface and water stock) and quality as well.

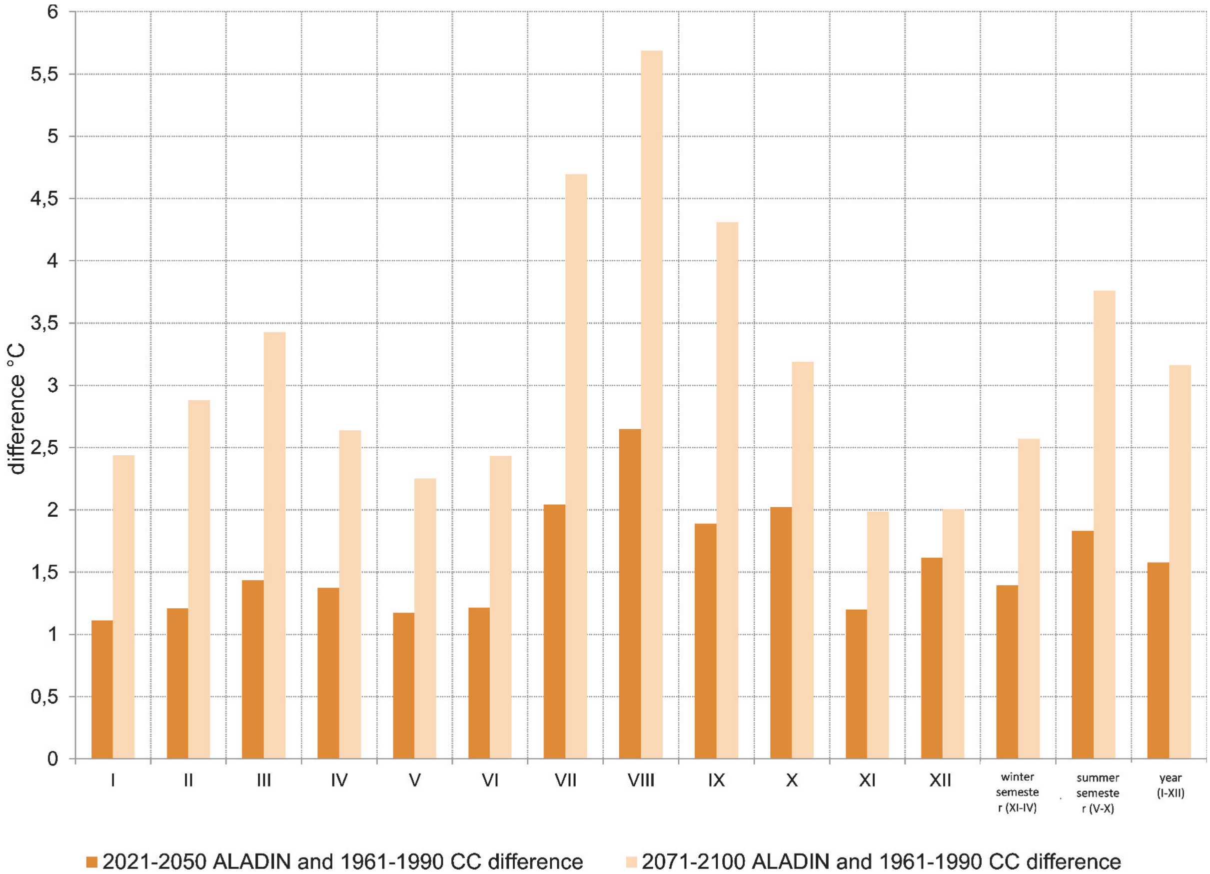
Methodology: The related research of NAGiS concerns the expected direction and extent of the change of water movements in Lake Balaton, the largest lake of the country, as a result of climate change. The research builds the estimation of changes in the natural water stock, interpreted as the algebraic sum of the precipitation, or water inflow and evaporation built on the results of hydrological calculations carried out by the Hungarian Meteorological Service and based on the ALADIN-Climate model running results for the 1961–1990 reference period and for the 30-year long climate windows between 2021–2050 and 2071–2100.

Results: In the estimated evolutions of the precipitation in the water catchment area of the lake for the 2021–2050 climate window, an increase exceeding 10% can be expected as compared to the average values of the reference period for April and September–November, whereas a 32% can be expected for January. For the 2071–2100 climate window, a decrease of over 10% can be estimated for the summer, whereas a 10% increase is expected for winter. The peak of the decrease in rainfall is expected for July–August, whereas that of the increase in precipitation is concentrated to November–December.

For the 2021–2050 climate window, a significant change (of over 1 °C) can be expected in the evolution of the mean temperature of the water catchment area of Lake Balaton on a six-months and one-year time frame as compared to the mean values of the reference period. A larger degree of the warming (1.8 °C) is expected for the summer season.

A change exceeding already 2 °C can be expected for the 2071–2100 climate window. A larger degree of warming (3.8 °C) is expected again for the summer season.

It can be observed that the estimated growth of actual evaporation is essentially not caused by



Absolute deviations of one-month, six-months and one-year average temperature of the water catchment area of Lake Balaton as compared to the mean value of the reference period for future climate windows (2021–2050 and 2071–2100) in °C

the change of precipitation but by the severe warming of the climate that is expected. Therefore, in the periods of future climate windows, parallel to an almost unchanged average annual precipitation a significant increase of evaporation can be expected which may result in a significant decrease of water-inflow from the perspective of the water balance of Lake Balaton.

For the 2021–2050 climate window, a significant change (of over 10%) can be expected in the evolution of the evaporation of Lake Balaton on a six-months and one-year time frame as compared to the mean values of the reference period. For the 2071–2100 climate window an even more important change (an increase exceeding 40%) can be expected. On a monthly basis, the greatest deviations (57–73%) as compared to the reference period can be observed for the July–September period.

Conclusions: Based on the estimations of the ALADIN-Climate model, a significant climate change may occur in the water catchment area of Lake Balaton in the 2021–2050 and 2071–2100 periods. The most remarkable change will be the estimated increase in temperature, which shall result in the acceleration of evaporation both in the water catchment area and on the free water surface of the lake. Because of that, the water balance of the water catchment area is expected to change, which will result in a significant decrease of outflow, leading to a deficit on the input side of the water balance of Lake Balaton. This will significantly change the hydrological picture of the lake, especially in the period of the 2071–2100 climate window. The water exchange activity of the lake will significantly deteriorate and endorheic periods will occur more frequently and more permanently, and moreover, in the last decades of the 21st century, Lake Balaton may practically become an endorheic lake. Because of the water balance permanently presenting a deficit, the lake will shift towards a new hydrological state of balance. Besides the decrease of the water level this will also mean a decrease in the water surface. As a result of these changes, the extreme conditions of water balance elements may be mitigated, however it will not be possible to continue to sustainably satisfy the requirements related to the utilization of the lake with the same content and form as it is known today.

In the evolution of all water movements, the series of anthropogenic effects cannot be neglected either [future modifications of the principles and practice of outflow control through Channel Sió, the impact of water usage directly concerning the lake (water outtakes, introducing water into the water system), changes of land use in the water catchment area]. The long-term evolution to 6-8 decades of the above mentioned factors is practically impossible to predict.

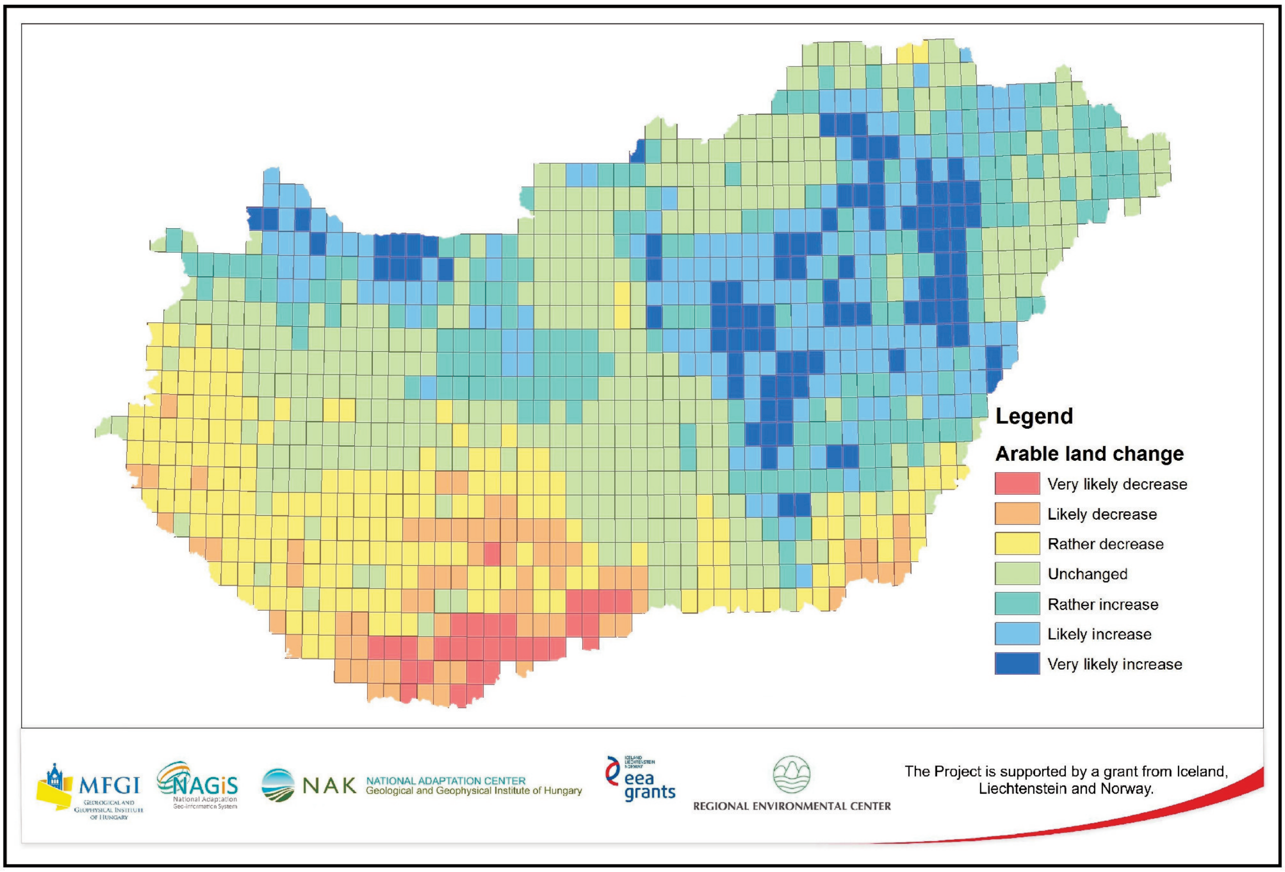
THE IMPACT OF CLIMATE CHANGE ON LAND USE

It is possible to talk about anthropogenic land use since humanity started to manipulate the natural landscape in order to satisfy its own needs. During history, this influence on the landscape has been continuing to grow, whereas the area of green environment and its carrying capacity keep decreasing. An ever-growing population must be supplied from an increasingly smaller area, the productivity of which is influenced by different factors of the agricultural area: this is where the impact of climate change also starts to play a role. Parallel to the development of technological systems, it is still to find out, how to define arable lands on a longer time-frame, to ensure that the little land available could be used in the most efficient way, and with making the least possible environmental impact for the sake of present and future generations.

Methodology: The analysis of expected impacts of climate change on land use was carried out using the data of the Hungarian Central Statistical Office (KSH), Hungarian and international literature, remote-sensing and woodland management data and the most recent research results of NAGiS. Climate factors have a crucial role in this situation, regarding that they have a fundamental impact on the productivity figures of basic crops at the land use types with the highest share (arable lands, lawns, grasslands, pasture lands, forests). Therefore, the examination targeted the yield changes caused by climate change when defining the estimated land change index of particular categories of land use; using standardized yield change indicators weighted with land take for predicting the changes between the categories of land use. It was possible to make predictions regarding three branches of cultivation marking their order of priority as well: arable land, woodland, grassland.

Results: The given categories of land use, the distribution of territories in service of agricultural plant production is mainly in accordance with social and economic needs and possibilities. The population and the level of technological development influence together the size of agricultural areas (for food production purposes). 86% of the territory of Hungary is cultivable and the proportion of agricultural lands is 57% based on 2015 data of the Hungarian Central Statistical Office (KSH). Based on research results and on statistical data, the changes of population will have a rather decreasing or, at the best, stagnating tendency on the medium and long run as well, therefore for this primary reason neither the size of residential areas nor that of agricultural areas are expected to grow. It is much more likely that land use will be optimized instead of a change of land use category for social purposes.

The investigations of the 30-year tendencies of the categories of land use in Hungary have also shown that recent changes of land use have taken place mainly for socio-economic reasons, and for purposes of use optimization. Taking into account that the climatic conditions neither in the past 30 years nor before did not restrict the developments of



Estimation on the changes of arable areas in Hungary 2071–2100

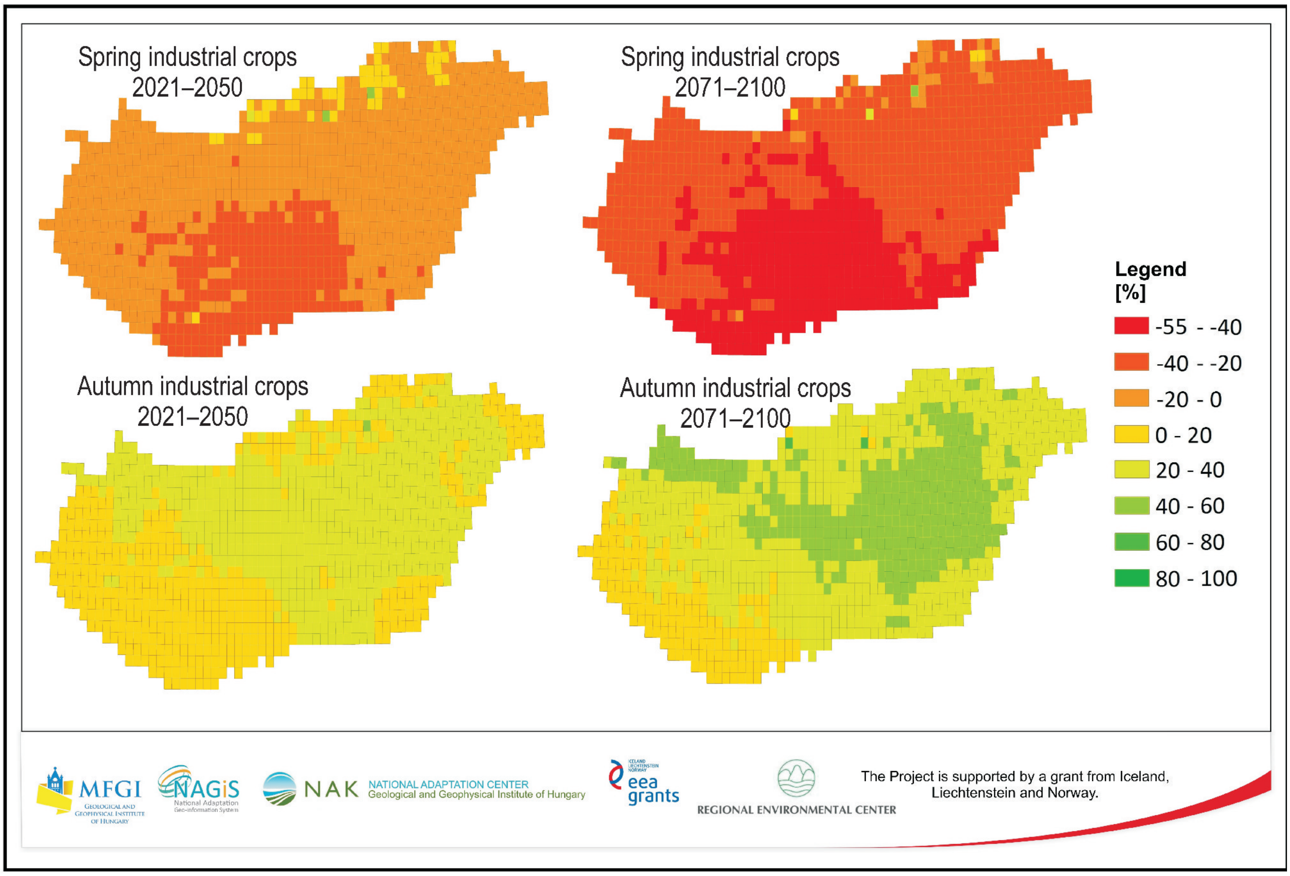
the forms of land use, and according to the examinations, it is not expected within a reasonable timeframe that forms of land use will be made impossible for climatic reasons, changes of land use will be governed in the field of agriculture mainly by the better possibilities of yields or use.

Conclusions: The modelled climate change will have a clearly negative impact from an agricultural and woodland management perspective on the regions of Western Transdanubia and Southern Hungary. In these areas, the conditions for plant production both on arable lands and woodlands will deteriorate. Besides these, an unfavourable change can be expected in forest associations in hilly and mountainous areas. Furthermore, the woodland management branch of the sandy areas in Nyírség region will also be disadvantageous. In case of arable lands, a drop can be expected mainly in the already mentioned Transdanubia and Southern regions, whereas in the regions of Northern Hungary the conditions of plant production may become more favourable. The grassland and pasture lands of Eastern and Central Hungary are expected to decrease whereas in Southern and Western Hungary the size of these types of land is forecasted to grow.

THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL BIOMASS PRODUCTION

The population of the world is expected to reach nine billion people by 2050, and at the same time the demand for food and forage plants may grow by 70% as compared to today. The challenge is even greater if we take it into account the probability of extreme weather phenomena (droughts, floods) will grow. Further crop losses and decreasing crop safety are anticipated and new pests, weeds and plant diseases may also appear.

Methodology: Crop simulation models are often used to estimate the expected results of climate change both on local or global levels.



Relative changes of crop yields as compared to the reference period (1961–1990), in case of spring (corn, sunflower) and autumn (wheat, barley, rapeseed) industrial crops

During the research, a so-called 4M crop simulation model (mapping the main processes of the soil-plant system) was calibrated, then it was connected with two of the most up-to-date climate change projections and with the high resolution, national geo-information database. The objective of the work was to make forecasts for the biomass-production of the five most important arable crops. The model was calibrated with the CarpatClim-Hu database with a spatial resolution of 10×10 km covering the territory of Hungary with 1104 cells, the DoSoReMi soil database with a resolution of 0.1×0.1 km and the data of 294 representative agricultural enterprises obtained from the FADN (Farm Accountancy Data Network). The aim of this was to find the parameter-combination having the least important difference between the calculated and the observed crop yields. The impact of climate change on biomass-production was defined on this basis, as the differences of the model outputs which were obtained using future (estimated) and present (observed) data on climate. Data on future weather conditions were available for the 2021-2050 and 2071-2100 periods.

Results: When estimating the impacts of climate change, the model took into consideration in the calculations the increase of CO_2 concentration; the shortening growing seasons; the accelerating leaf decomposition due to the increased temperature; slowed down photosynthesis due to higher water stresses and the deficient pollination occurring due to extreme high temperatures during the time of pollen spreading. Based on the results, the following maps illustrate the relative changes of crop yields as compared to the reference period (1961–1990), in case of spring (corn, sunflower) and autumn (wheat, barley, rapeseed) industrial crops.

Conclusions: A serious yield loss has to be dealt with in the distant future (2071–2100) concerning spring crops (e.g. corn); crop safety of these crops will decrease on the whole territory of Hungary. Autumn crops (e.g. wheat) may produce increasingly higher yields as the end of the 21st century approaches; in certain areas, results may exceed those harvested nowadays even by 50%. During the 2071–2100 period wheat, barley and rapeseed may have significantly higher crop yields (exceeding 30%).

The carbon-dioxide concentration of the atmosphere may double during the investigated period, which has a significant fertilization impact on primary biomass-production, and to a certain extent it even compensates for the negative effects of water shortage.

In certain areas, irrigation may result in an increase of crop yields by even 50% for the 2071–2100 period; in case of corn, the national average may even reach an increase by over 75%. In numerous areas, the irrigation of spring and autumn crops may be significantly or moderately profitable. It seems that it is worth investing in irrigation development, taking also into account that irrigation is impossible/unadvisable to implement in certain regions.

Agricultural professionals may decrease the negative impacts of climate change by adapting agricultural technologies to the changing environmental conditions, hence e.g. they increase the number of autumn crops in the rotation of crops; they sow earlier; they use varieties with shorter growing seasons or that are more resistant to droughts; or they involve other, alternative plants into crop production.

THE IMPACT OF CLIMATE CHANGE ON WOODLAND MANAGEMENT

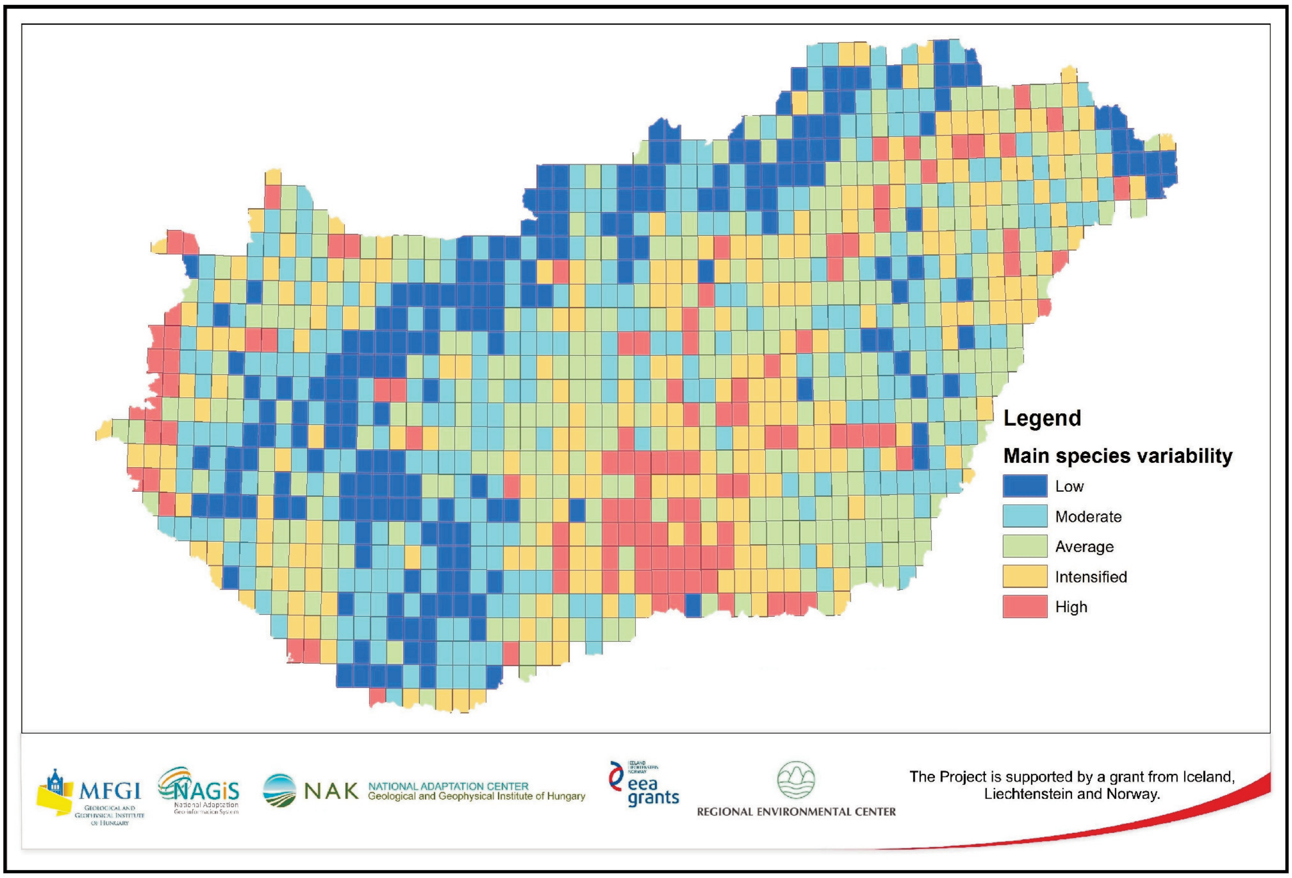
Sustainable woodland use in Hungary is only possible by the continuous increase of woodland resources. The woodland assets of the country amount to more than 2 million ha, therefore the rate of forestation reaches the value of 21.5%. Hungarian woodlands can be classified into two main categories, namely economic forests, amounting for almost two third of the total, whereas the largest part of the remaining forests have a protective function. Most of our woodlands are mixed deciduous forests.

Regarding land take, oak is significantly represented in the altogether 21.5% of woodlands: 20.5%. Beech, as a species having a significant economic value occupies 6%. Hornbeam is an important mixing species of mesic woodlands, taking a 5.5% share. Black locust deserves special mention which despite being an alien species in Hungary is the tree species occupying the largest territory with 23% of all woodlands. The proportion of indigenous and exotic pines is 13.3%.

The backbone of woodland management in Hungary is based on the management of forests with cutting, and differentiating between age groups, however, nature-friendly woodland management techniques become increasingly important as well. The ratio of semi-natural woodlands is roughly 50%. The other half of woodlands are cultivated forests composed of black locust, pine and poplar.

Methodology: The exposure of woodlands to climate change can be estimated mostly by estimating the changes of climate classification of woodlands. Based on the available climate models, the research examined the ways in which the territories belonging to different climate classification categories in the 1960–90 reference period are expected to change in case of the two climate windows of 2021–2050 and 2071–2100. Out of the two climate models that can be used for the examinations, the ALADIN model showed more deviations than RegCM, therefore hereinafter this less favourable estimation was used.

Results: The changes of the investigated climate conditions made a significant impact on the spatial distribution of woodlands based on climate classification. All this is expected to make a significant impact on the exploitation of current woodland areas. The impacts may be witnessed under different forms: as the change of structure of forests with a main species of great yields but sensitive to climate, as a significant decrease of yields, as a change from economic woodland to protected woodland or as the decrease of the woodland area because of



Diversity of the main species of the age groups of trees

becoming unsuitable for woodland coverage.

The oldest forests of the country are in the most natural state as well, providing at the same time a diverse habitat, since diversity in sizes and ages usually means a higher level of biodiversity as well, which is one of the main sources of adaptability. In case of a significant proportion of these woodlands, it is practically now to decide what renewing strategy to follow and what composition of species to choose for the next 100-150 years, therefore their evaluation from the perspective of climate change should be carried out as soon as possible. In parts of the country covered by larger woodlands, the measures in service of the adaptation of woodland management will play a crucial role.

The main species of the given age groups having the greatest land take show to the best extent the ways in which the stock structure of future woodlands is expected to change and in which different policies of species played a determining role in the past (the latter is witnessed by remaining forests). On the territory of the semi-natural woodlands of the country the beech, sessile oak, Austrian oak and pedunculate oak are still predominant which suggests, that in the semi-natural woodlands there are no perceptible signs of preparation to climate change in the establishment of the woodland stocks of the future. This is not necessarily a fault, but it is definitely important to pay attention to this in the future. In case of young woodlands, black locust is dominant and its widespread presence shows that it is a highly preferred species for creating new forests. In the future, the land take of black locust and prime poplar is expected to increase.

The main species of particular age group show the highest degree of diversity in sandy areas of the Great Plain, of river valleys and plain areas and in the areas near the Western border. In contrast to that, in most of our hilly and mountainous areas the territory-base diversity of main species calculated between age groups has a lower value. This can be deduced from the conservative tree species policy of semi-natural woodlands: the semi-natural woodlands of the country therefore have a lower degree of diversity than cultivated forests. This is one of the reasons behind the fact that the researches warn of a clearly negative impact originating from climate change in the areas covered by semi-natural woodlands, whereas they forecast a variable, and sometimes even improving tendency in case of cultivated forests. It is definitely justified therefore to diversify woodland stocks implemented on the level of main species as well as of age groups.

Conclusions: Regarding the future, one of the most important issues is the subject of forest renewing. This activity will require a sufficient quality and quantity of propagules, for which the supply bases should be established and the existing supply bases should be preserved. All these factors must be taken into account not only in case of cultivated forests relying on propagules, but also in connection with propagule-stocks of semi-natural woodlands. For the latter, the increasingly hectic crops of seed and the growing frequency of drought periods unfavourable for the regrowth increase the risks of natural renewing. The supply system of vegetative and generative propagules and the genetic preservation networks in forestry should be developed and it will be necessary to get prepared for starting experiences of origin with propagules originating from propagule-sources of the Carpathian Basin.

THE IMPACT OF CLIMATE CHANGE ON NATURAL HABITATS

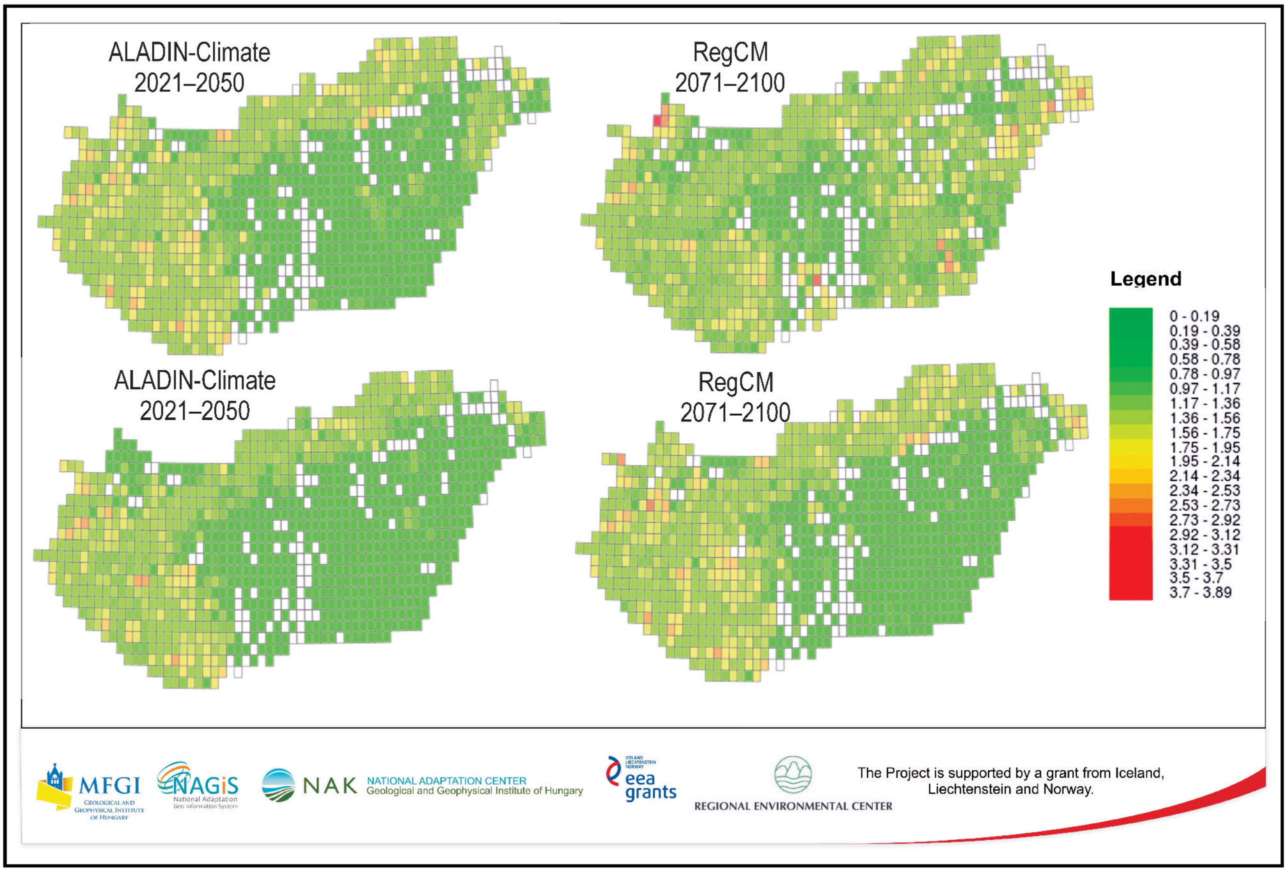
The natural and semi-natural ecosystems are self-organizing systems. Their physical and biological characteristics determine their sensitivity to climate and their adaptation capability. These dependencies can also be described with models. The examination here presented aims to make an estimate of the elements of the CIVAS framework system to the most climate sensitive natural habitats (CSH) of Hungary.

Methodology: As a first step, the climate sensitivity of Hungarian habitats has been explored and the CSH-s have been selected using bioclimatic models, which was followed by the determination of the possible impact (PI) to these habitats, applying the models for the present and future conditions. The calculations of adaptation capability (AC) for CSH-s were made in accordance with the conceptual framework of Czúcz et al., created in 2011, then the researchers gave a detailed example of the vulnerability-analysis carried out, based on impact and on adaptation capability.

Climate sensitivity was determined based on the observed occurrences of the observed habitats and on the environmental conditions experienced at these places. The habitat observations were built on the Map-based Database of the Habitats of Hungary. The variable describing the environment (climate, soil- and hydrological conditions, relief) were taken from NAGiS. In case of adaptation capability, naturalness of the landscape at the habitats, the diversity of the habitat (how heterogeneous the landscape is) and the connectivity of the landscape were taken into account in the research. The expected impact was characterized by the difference of the possibilities of occurrence of the given habitat in the present and in the future for two periods (2021–2050; 2071–2100), using two different climate models, estimating PI this way in four different variations. Vulnerability (V) is dependent on the impacts and on adaptability. The greater the expected impact is, the more the habitat will be vulnerable, although the impact may be attenuated by the adaptation capability.

Results: In Hungary, the 12 types of habitats that qualified as the most sensitive to climate based on the examinations were: the acidofrequent mixed coniferous forests; the forests of slopes and screes; the annual salt pioneer swards of steppes and lakes; the beech woodlands; the floating fens, oligotrophic reed and Typha beds of fens; the closed lowland steppic oak woodlands; the closed steppes on loess; the closed mixed steppic oak woodlands on loess; the Quercus cerris-oak woodlands; the semi-dry grasslands; the willow carrs; and the oak-hornbeam woodlands.

The possible impact (PI) of climate change will



The vulnerability of natural habitats based on the vulnerability of the 12 most climate sensitive habitats, referring to NAGiS squares. Vulnerability is increasing from green to red

be unfavourable in general to climate sensitive woodlands. The other climate sensitive habitats (without trees) seem to be benefitting from climate change, or at least partially. In wetland habitats this could be the result of an increased level of winter precipitation. For loess steppes and annual halophytic habitats, a favourable impact can be forecasted, regarding that saline soils are generally formed under predominantly dry and warm climate conditions, which is in the same direction as Hungarian climate is moving towards.

Most of the CSH-s in Hungary are widespread habitats, dependent on the climatic zone, therefore, they have a high adaptation capability, which compensates the expected impact to a great extent.

For demonstration purposes, the researchers have prepared themselves a vulnerability analysis base on landscape criteria, in which they calculated vulnerability first by habitats. The estimation of these has also been prepared in four layers, in accordance with future periods and climate models. The titles of partial figures refer to future periods, and to the climate model used. The colour scale indicates vulnerability increasing from green to red. Climate models are quite unambiguous regarding long term vulnerability (2071–2100). The natural vegetation will be more vulnerable in Western Hungary and in the mountain ranges as well as in the Eastern areas of Nyírség region. This is most likely due to the fact the vegetation of forests is the most vulnerable from the perspective of climate change.

Conclusions: Climate sensitive habitats overlap with most of the vegetations in Hungary that are dependent on the climatic zone, therefore, the conclusions drawn based on these are most likely to be representative regarding the reactions given to climate change. An important direction of future research would be to expand the pool of climate models used and the future periods to examine. The estimations made on impact and adaptation capability were incorporated into the NAGiS online database which helps to carry out a large variety of scientific analysis and practical examinations, e.g. vulnerability analysis in the future, and to channel these results into the definition of nature protection and restoration priorities, to landscape analysis and to landscape planning tasks.

Since the launch of NAGiS in 2013, the increasingly developing results of the project have been shared regularly by MFGI and its experts both with scientific stakeholders and with the larger public interested in the topic. The following section outlines the main elements of knowledge sharing going through the main dissemination categories (events that have been organized, participations at scientific/professional forums, publications, other promotional tools).

SHARING THE KNOWLEDGE – DISSEMINATION OF PROJECT RESULTS

DISSEMINATION OF KNOWLEDGE

EVENTS

Project (Kick-off Meeting), 14th October 2013, Budapest.

Soil – Climate – Adaptation workshop with the participation of NAGiS project (MFGI) and the researchers of the Research Institute for Soil Science and Agricultural Chemistry of the Centre for Agricultural Research, Hungarian Academy of Sciences (MTA ATK TAKI) (26 participants). 2nd December 2014, Budapest.

Bilateral workshop to discuss the interim results of the NAGiS project with the participation of Norwegian and Hungarian professionals. The event was organized by MFGI and REC and funded by the EEA/REC Bilateral Grants. 19–20th October 2015, Budapest.

Workshop and scientific debate on the interim results of the C–11, C–12, C–13 projects and on the possibilities of their use. 3rd November 2015, Budapest.

LECTURES, POSTERS

The NAGiS project. Lecture at the "Changing climate – changing communities. The opportunities and good practices of sustainable energy supply" conference. Research Institute for National Strategy, 6th February 2014, Budapest.

The NAGiS project. Poster at the event of RENEXPO® (Central Europe International Exhibition on renewable energies and energy-efficiency). 12–13th March 2014.

Presentation of the NAGiS project. Lecture, Euro Geosurvey 36th General Meeting, 24–27th March 2014, Brussels.

Presentation of the NAGiS project. Lecture at the 21st Conference on subsurface waters, 2–3rd April 2014, Siófok.

The NAGiS project. Poster. Öko City exhibition, 2–6th April 2014, Budapest.

Presentation of the NAGiS project. Lecture, 29th Annual Meeting of Geoscience Information Consortium (GIC), 26–30th May 2014, Slovakia.

The NAGiS project. Lecture, Study visit on the Adaptation to Climate Change Programme, 24–27th June 2014, Bergen, Norway.

Presentation of the NAGiS project. Lecture, Climate Change Adaptation Forum, 26th June 2014, Budapest.

Presentation of the NAGiS project. Lecture at the 12th Meeting of Hungarian Geoscientists (HUNGEO), 20–24th August 2014, Debrecen.

Presentation of the NAGiS project. Lecture, 41st IAH International Congress on Groundwater: Challenges and Strategies. 15–19th September 2014, Marrakesh, Morocco.

Presentation of the NAGiS project. Lecture, Study tour of a Latvian delegation in the framework of complementary activities of EEA Grants at REC. 6–7th October 2014, Szentendre.

Presentation of the NAGiS project. Lecture, ESRI Hungary User Conference. 9th October 2014, Budapest.

The NAGiS project. Material prepared on NAGiS for the presentation given by an associate of REC. Lecture.

Showing What's Possible: Computer Simulation and GIS Mapping for Decision Makers: side-event of the Climate Change World Conference (COP20), 12th December 2014, Lima, Peru.

Presentation of the NAGiS project. Lecture, EWA Spring Days 2015 Budapest Water Conference, 4–6th March 2015, Budapest.

Rotár-Szalkai, Á., Gál, N., Szőcs, T., Tolmács D.: Characterization of climate change sensitivity of Drinking Water Protection Areas. Poster. EWA Spring Days 2015 Budapest Water Conference, 4–6th March 2015, Budapest.

Presentation of the NAGiS project. Lecture, 20th meeting of the IG CCA of the Network of European EPAs'. 5–6th March 2015, Rome, Italy

Presentation of the NAGiS project. Lecture. 22nd Conference on subsurface waters, 24th April 2015, Siófok.

Presentation of the NAGiS Project. Lecture. Kick-off Meeting of the "EEA-C13-10, New climate change scenarios for the Carpathian Basin region based on changes of radiation balance (RCMGiS)" project. 27th April 2015, Budapest.

Presentation of the NAGiS project. Lecture, The GIC's 30th Anniversary Conference at BGR, 4–8th May 2015, Hannover, Germany

Presentation of the NAGiS project. Lecture, 6th Hungarian Conference on Landscape Ecology, 21–23rd May 2015, Budapest.

Presentation of the NAGiS project. Lecture, 6th Geoinformation Conference and Forum, 28–29th May 2015, Debrecen

Presentation of the NAGiS project. Lecture. Kick-off Meeting of the "EEA-C12-13, Vulnerability and Impact Studies on Tourism and Critical Infrastructure (CRIGiS)" project, 1st June 2015, Budapest.

Presentation of the NAGiS project. Lecture. Natural resources, geological risks, climate change: where does the geological path of sustainability lead? 4th June 2015, Budapest.

Presentation of the NAGiS project. Lecture, at the joint impact assessment consultation workshop of the "RCMGiS and CRIGiS projects, 22nd June 2015, Budapest.

Presentation of the NAGiS project. Lecture. The opening event of the project EEA-C12-11, titled "Long-term Socio-economic Forecasting for Hungary". 23rd June 2015, Budapest.

Presentation of the NAGiS project. Lecture, 58th Annual Symposium of the International Association for Vegetation Science (IAVS), 18–26th July 2015, Brno, Czech Republic.

Bede-Fazekas, Á., Czúcz, B., Somodi, I.: Development of fine-scale ecological database for the National Adaptation Geoinformatic System (NAGIS), Hungary. Poster. 58th Annual Symposium of the International Association for Vegetation Science: Understanding broad-scale vegetation patterns. Data sources for broad-scale vegetation studies section. 19–24th July 2015, Brno, Czech Republic.

Lepesi, N., Botta-Dukát, Z., Somodi, I.: Binarization options of probabilistic predictions of Predictive Vegetation Models (PVMs) for NAGIS. Poster. 58th Annual Symposium of the International Association for Vegetation Science: Understanding broad-scale vegetation patterns. Vegetation in macroecological modelling section. 19–24th July 2015, Brno, Czech Republic.

Presentation of the NAGiS project. Lecture, The 13th International Symposium on Geo-Disaster Reduction, 9–12 August 2015, Prague, Czech Republic.

Presentation of the NAGiS project. Lecture, 10th Congress of Hungarian Ecologists, University of Pannonia, 12–14th August 2015, Veszprém.

Presentation of the NAGiS project. Lecture, Session No. 21 of the European Environment Agency Interest Group Climate Change and Adaptation (EPA IG CCA), 11th September 2015, Budapest.

Presentation of the NAGiS project. Lecture, The 42nd Annual Conference of the International Association of Hydro-geologists (IAH), 14th September 2015, Rome, Italy.

Presentation of the NAGiS project. Lecture, ESRI Hungary User Conference, 8th October 2015, Budapest.

Presentation of the NAGiS project. Lecture at the International Association of Hydro-geologists – 2nd Conference on the Subsurface Waters in Central Europe, 15th October 2015, Constanca, Romania.

Presentation of the NAGiS project. Lecture at the training on Climate-KIC: Spatial planning in municipal water management. 26th November 2015, Budapest.

Presentation of the NAGiS project. Material prepared on NAGiS for the presentation given by an associate of REC. 6th Sustainable Innovation Forum, the side-event of the 21st Climate Change Conference of the UN (COP21), 4th December 2015, Paris, France.

Presentation of the NAGiS project. Lecture at the closing event of the project titled "Long-term Socio-economic Forecasting for Hungary", 7th December 2015, Budapest

Presentation of the NAGiS project. Lecture at the closing event of "AGRAGiS – Extension of the

National Adaptation Geo-information System to the field of agri-sector" project, 21st December 2015, Budapest

The experiences of the NAGiS project and possibilities for next steps. Lecture given in the framework of the workshop on the implementation tasks of the NAGiS project to be completed in 2016. 18th March 2016, MFGI, Budapest.

Possible uses of the National Adaptation Geo-information System in planning and decision-making. Lecture at the connected presentation and profes-sional forum. 21st March 2016, MFGI, Budapest.

The creation of the National Adaptation Geo-information System. Lecture at the closing conference of the project. 13th April 2016, MFGI, Budapest.

Kovács, A. Marton, A., Szőcs, T., Tóth, Gy.: Climate change impact on shallow groundwater conditions in Hungary: Conclusions from a regional modelling study. Lecture. EGU General Assembly, 17–22nd April 2016, Vienna.

Szalkai, Á.: Climate vulnerability of drinking water supplies. Lecture. EGU General Assembly, 17–22nd April 2016, Vienna.

Selmeczi, P.: Application of geographic information systems in the field of strategic planning in climate politics via the example of drinking water service. Lecture. EGU General Assembly, 17–22nd April 2016, Vienna.

PUBLICATIONS

Short article on the NAGiS project in the "Adaptation to climate change" newsletter of REC.

Lepesi, N., Botta-Dukát, Z., Somodi, I.: Prediktív modellek valószínűségi becsléseinek binarizálási lehetőségei a NATéR elemzések megalapozására. Conference abstract. 6th Hungarian Conference on Landscape Ecology, 2015. Landscape use and landscape protection – challenges and opportunities. 21–23rd May 2015, Budapest.
http://tajokologiai konferencia. hu/program

Bede-Fazekas, Á., Czúcz, B., Somodi, I.: Development of a fine-scale ecological database for the National Adaptation Geo-information System (NAGIS). Conference abstract 6th Hungarian Conference on Landscape Ecology, 2015. Landscape use and landscape protection – challenges and opportunities. 21–23rd May 2015, Budapest.
http://tajokologiaikonferencia. hu/program

Orosz, L. Mattányi, Zs., Turczi, G., Kajner , P., Simó, B., Vikor, Zs.: A NATéR (Nemzeti Alkalmazkodási Térinformatikai Rendszer) fejlesztés. In: Az elmélet és a gyakorlat találkozása a térinformatikában. 6th Geo-information Conference and Forum, Debrecen Conference papers. Ed.: Boda, J. Debrecen, Egyetemi Kiadó, 2015. http://geogis.detek.unideb.hu/Tkonferencia/2013/Kotet.phpunideb.hu/Tkonferencia/2013/Kotet.php

Lepesi, N., Botta-Dukát, Z., Somodi, I.:Prediktív ökológiai modellek valószínűségi becsléseinek binarizációs stratégiái a Nemzeti Alkalmazkodási Térinformatikai Rendszer (NATéR) számára. In: 10th Hungarian Ecological Congress. University of Pannonia, Veszprém, 12–14th August 2015. Conference papers. http://limnologia.hu/mok2015/bin/book_of_abstracts. pdf

Bede-Fazekas, Á., Somodi, I.: Statistical scaling of climate data for the ecological model set up within the framework of the National Adaptation Geo-information System (NAGiS) In: 10th Hungarian Ecological Congress. University of Pannonia, Veszprém, 12–14th August 2015. Conference papers. http://limnologia.hu/mok2015/bin/book_of_abstracts.pdf

Kovács, A. Marton, A., Tóth, Gy., Szőcs, T.: A sekély felszín alatti vizek klímaérzékenységének országos léptékű kvantitatív vizsgálata. Hidrológiai Közlöny (Journal of the Hungarian Hydrological Society), year 2015, issue no. 4.

Rotárné Szalkai, Á., Homolya, E., Selmeczi, P.: The climate vulnerability of drinking water supplies. To be published in Hidrológiai Közlöny (Journal of the Hungarian Hydrological Society), in 2016.

PR ACTIVITIES

In the first phase of the project, a logo and a website-design plan was created, the general information website was available at the www.nagis.hu or nater.mfgi.hu addresses.

During the first quarter of 2014 a flyer was made on NAGiS in English and in Hungarian. The English and the Hungarian versions of the website were cre-ated.

In summer 2015, the first issue of the NAGiS newsletter and its translation were made. The Hungarian and English versions of the newsletter were sent to 730 recipients via e-mail and the two versions were also uploaded onto the website.

In autumn 2015, the second issue of the NAGiS newsletter were sent to 760 recipients via e-mail in Hungarian and in English and uploaded onto the website.

The NAGiS project was referred to in the press release of the AGRATéR project (titled "Planning the future taking climate change into account").

In autumn 2015 the website of REC published an article on the event organized at COP21 in Paris where NAGiS was also presented (titled "Wisdom and progress: East meets West").

The NAGiS was also presented in the article published on the official website of the EEA Grants (titled "Understanding the impacts of climate change in Hungary").

Register to the NAGiS System!

Are you interested in what you have read? Would you like to know more on the impacts of climate change and on the vulnerability of different areas? It can be seen clearly that certain issues have also become unavoidable in Hungary as well, influencing everyday life on the short and medium run already. Getting prepared to these impacts, mitigating them or adapting to them required the appropriate knowledge and information. This requirement is addressed by NAGiS. The data and analysis contained in the system help climate strategic planning, and provide a scientific basis for taking local adaptation measures. The analysis of interactions of the territorial differences are enabled in the system by the derived data referring to the direction and to the extent of the changes based on the data on the three climate windows (1961–1990: Reference years; 2021–2050; 2071–2100) originating from the climate models.

NAGiS can be accessed at several levels. One of its components does not require registration and it consists of interfaces that can be used by the general public, which makes it an awareness-raising tool, supporting climate awareness of citizens. The other component of the system requires registration, providing access to a large pool of information on a given topic (e.g. territorial climate projections, modification of subsurface water tables, etc.) or field (e.g. agriculture or woodland management) for examinations, making it also possible for researchers, education institutions or local governments to analyse their interactions.

The results collected so far helps to make comparative analysis of local climate vulnerability, it provides filterable information that can be limited to the exposed areas, and it is also possible to display data on exposure and to examine adaptation capabilities. The information can be viewed in databases and on map displays, illustrating this way the expected impacts of the changes, assisting policy-making and research by displaying local and regional differences.

Register to the system at the http://nagis.hu/regisztracio website, and get to know the latest news in the topic!