Water in Hungary

Status overview for the National Water Programme of the Hungarian Academy of Sciences

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The preparatory process was managed by the Water Research Coordination Group, Centre for Ecology, Hungarian Academy of Sciences.

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Introduction

Water is one of the essential resources of life. Its fundamental importance is receiving growing impetus in international processes. The Sustainable Development Goals include Goal 6 dedicated to water and covering all aspects of the water cycle: safe drinking water and sanitation, water quality, sustainable use of water resources, integrated water management and aquatic ecosystems. Intersectorial and international cooperations are highlighted as key elements in meeting the water targets. Other goals, such as nutrition, healthy life, safe and sustainable human settlements, climate change adaptation or ecosystem protection are also interwoven with linkages to water.

The protection and sustainable use of water resources are core provisions of the European Union legislation as well. The Water Framework Directive – setting the background for all other water related directives – requires member states to assess the qualitative and quantitative status of all water bodies and to ensure the protection or restoration of their good chemical and ecological state.

Hungary is rich in freshwater resources; both surface waters and groundwaters are abundant in most parts of the country, but unfortunately the distribute on is uneven both in space and time. Its thermal waters and special water habitats are unique in Europe. This heritage is not only a benefit and a potential for the country but also a responsibility: to manage these precious resources sustainably and safeguard them for future generations.

Emerging global challenges, such as climate change or urbanization and their consequences, the increase in water demand and chemical pollution of the environment pose a growing risk to the quality and quantity of our waters. Tackling these challenges requires cooperation between all participants within the water sector and beyond, from legislation and science through engineering and operation to the end users and the general public.

The recently adopted National Water Strategy defines four cornerstones for future actions: avoiding the global water crisis, preserving our water resources, using their potential efficiently and safeguarding ourselves from water hazards. The key instrument towards these goals is integrated water resources management. However, effective actions require a sound basis of knowledge and information.

The Hungarian Academy of Sciences launched the National Water Research Programme to provide the scientific evidence base for implementing the strategic targets of the National Water Strategy. This baseline document provides a concise overview of the situation, based predominantly on the extensive documentation developed as part of the revision process of the Hungarian River Basin Management Plan by the National Water Directorate under the Ministry of Interior.

Imre Hoffmann

Deputy State Secretary for Public Employment and Water

Acknowledgement

The current document was prepared on the initiative of the President of the Hungarian Academy of Sciences with the aim of highlighting selected elements on the status and challenges of water in Hungary.

The presented data is predominantly based on the revised River Basin Management Plan (RBMP) of Hungary, compiled with the coordination of the General Directorate of Water Management. The full text and all attachments (charts, tables, maps and supporting materials) of the RBMP are available online (in Hungarian) at http://www.vizugy.hu/index.php?module=vizstrat&programelemid=149. Further sources are listed under References.

The present document was proofread by experts of the General Directorate of Water Management; their invaluable contribution is highly appreciated.

Contents

1. The geographic context of Hungary

Hungary is a lowland country, situated in the Carpathian Basin in the heart of Europe. Its terrain is relatively unvaried, 68 % of its area is below 200 m altitude, 30 % is covered by hills (200-400 m), and only 2 % exceeds 400 m. The highest peak of Hungary is the Kékes (1014 m).

The entire area of the country (93000 km^2) belongs to the Danube catchment. The Danube catchment is the second largest in Europe, covering over 800000 km^2. The basin extends to 19 countries, 14 of which (Austria, Bosnia-Hercegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Montenegro, Republic of Moldova, Romania, Serbia, Slovakia, Slovenia and Ukraine), have a share over 2000 km^2 of the catchment. More than 81 million people live in the Danube basin. The two largest tributaries of the Danube are the Tisza and the Sava. The Tisza sub-catchment is the largest (157000 km^2), shared between 5 countries. The Sava, though its basin is only two-third of the Tisza's, has almost twice higher flow (1564 m^3/s).

The climate of Hungary – determined mainly by its geographic location – is continental, with Atlantic and Mediterranean influences. The mean temperature is 8-11 °C, with large yearly variation (20-25 °C). January is the coldest and July is the hottest month. Within the country, the Western regions have the lowest number of sunny hours (1800 h), while the Southern-Central parts the highest (2100 h). The wind is usually from North-West, the average wind speed is 2-4 m/s. The yearly precipitation is 500-900 mm, the lowest values are measured in the Great Plains, while the highest in Western Hungary. Primary wet periods are in early summer (May-June) and in the autumn (October-November). Snowfall is observed on 20-30 days in the lowlands and 50-60 days in the higher hills. Snow coverage is 30-80 days, depending on the altitude. The natural water balance of Hungary is positive, the total precipitation is 55707 million m^3, while the evapotranspiration is 48 174 million m^3. As a result of climate change, yearly mean temperature is expected to rise, the yearly precipitation pattern to change (and the total yearly amount to decrease) and the frequency of extreme weather events is likely to increase. This might lead to increased frequency of floods and inland water accumulation. The trend of a more variable precipitation pattern is already visible, 2010 was the most humid and 2011 the driest year since 1901, and 2011, 2012 and 2013 were all significantly hotter than average. Climate change is likely to affect the availability and quality of water in Hungary, and the climate is expected to shift towards a Mediterranean climate. Droughts are already prevalent, especially in the Great Plains area.

Soil fertility parameters (physical, chemical and biological) in Hungary are good, 83 % of the country is suitable for agriculture and forestry. The best quality soil is in Bácska, Mezőföld, Hajdúság and in the Körös-Maros intertributary region. Almost 40 % of the country's area is vulnerable for soil erosion, emphasizing the need for soil retention interventions. In addition to water- and wind erosion, urbanization and other infrastructural developments also increase the loss of arable land.

Hungary – due to its location and unique geology – is exceptionally rich in groundwater. The average depth of shallow groundwater is 2-5 m (extremes 0-16 m) depending on the precipitation. Shallow groundwater is vulnerable to surface contamination and usually not suitable for consumption. Bank filtration, on the other hand, is one of the main sources of drinking water (among others, Budapest relies solely on bank filtration). Deep groundwater is less vulnerable to contamination, but its recharge is much slower. The number of deep groundwater wells is close to 70000 nationally. Abstraction is mainly used as drinking water, though in several areas naturally occurring chemicals (e.g. arsenic, iron or manganese) hinder the use without treatment. Karstic waters also contribute significantly to drinking water production.

Overall, approximately 95 % of drinking water in Hungary is from groundwater source (including bank filtration). However, almost 2/3 of the sources is vulnerable. The geothermic gradient in Hungary is higher than average, resulting in the abundance of thermal (often 70-90 °C) waters. Thermal waters are used for recreational and therapeutic purposes.

There are 9800 registered surface water flows in Hungary. 90 % of the water flow is from large or medium transboundary rivers. Danube is the main axis of surface water, its Hungarian segment is 417 km (140 of which is shared with Slovakia). Average water flow in Budapest is 600, 2300 and 8000-10000 m^3/s in low, medium and high flow conditions, respectively. Main tributaries are Lajta, Rábca, Rába, Ipoly, Sió and Dráva. The Tisza is the second largest river of Hungary. Its formerly 950 km segment was reduced to 595 km during the 19th-20th century flood management interventions (straightening by cross-cutting meanders). The flow of the Tisza is 170, 800 and 3400 m^3/s in low, medium and high flow conditions, respectively. Tisza is very turbid due to the high particulate matter concentration. Main tributaries are the Túr, Szamos, Kraszna, Bodrog, Sajó, Zagyva, Körös, Maros. Hungarian rivers usually flood twice a year, in early spring due to snowmelt ("icy flood") and in early summer, due to the precipitation peak of the period ("green flood"). Per capita surface water resource (11000 m^3/year) is one of the highest in Europe, but the contribution of the flows within the boundaries is low (600 m^3/year/person), resulting in unequal geographic and temporal distribution of surface water resources. Regional water management systems are designed to overcome the disparities. Flood and inland water management practices significantly decreased the previously predominant wetland area in the Great Plains, and increased its drought vulnerability. Watercourses at higher elevations were also regulated and reservoirs were created, significantly affecting the status of the water systems.

Water quality of large rivers in Hungary is mainly determined by the quality of the received water from upstream countries. Small and medium watercourses under low flow conditions are vulnerable to contamination, which may lead to severe ecological impact.

Majority (75 %) of the 4000 stagnant water bodies in Hungary are artificial lakes. Total surface is 1685 km^2, 2 % of the area of the country. Lake Balaton is the largest lake in Central-Europe (594 km^2). Both the lake and the adjacent Kis-Balaton wetland are nature preserve areas. Balaton has also high touristic relevance. Its water quality is excellent, due to the drastic interventions to reduce nutrient load and subsequent eutrophication since the 1980s. Lake Velencei (25 km^2) and Lake Fertő (322 km^2, of which 75 km^2 belongs to Hungary) are the westernmost examples of steppe lakes. Water levels of both lakes are low, and large proportion their surface area is covered by reed. The Western part of Lake Velencei is a bird preserve, while the entire Lake Fertő is under protection. In the Great Plain area, salt pans with high alkalinity, salinity and a unique flora and fauna are predominant. Several lakes were created by artificial dams, such as Lake Tisza or the Orfű lakes. The reservoirs have significant ecological and touristic value, often comparable to natural lakes.

Almost half of the country's area is lowland, often without runoff. Flooding threatens more than 20000 km^2 area, one fourth of which is in the Danube sub-catchment, the rest is in the Tisza sub-catchment. 60 % of the lowlands are at risk of inland water coverage, 5 % are considered highly vulnerable. Most of them are situated on the Great or the Small Plains.

Though the area of Hungary comprises only 1 % of Europe, its natural resources contribute a much larger share. The flora and fauna of the Carpathian Basin is a unique combination of submediterranean continental, Atlantic, alpine and Carpathian species, with many endemic plants and animals. The habitats are also diverse, many of them were preserved in a near-natural form, but they are often small and confined. Forests are key elements of hydrology, influencing precipitation runoff and drainage. Approximately 20 % of the country area is covered by forests, showing a slow increase in the past decades. 42 % of the forest is under protection, 3 % under enhanced protection. Climate change is expected to negatively affect biodiversity; the severity of the impact depends on the meteorological water balance and the resilience of the regions.

Hungary is an urbanized country, 69 % of its population lives in cities. Budapest alone has 1.745 million inhabitants, while the second largest, Debrecen only slightly over 200000, and 7 more exceeds 100000. In the past decades, more than 1.5 million people moved from rural areas to industrialized regions. The proportion of very small communities (less than 500 inhabitants) increased to 1/3 of all municipalities, but these give only 3 % of the entire population. The population density (107 persons/km^2) is slightly lower than the European average, with large difference between the end-points (3305 persons/ km^2 in Budapest and 52 persons/ km^2 in Somogy county). The population is decreasing, it is slightly below 10 millions.

Majority of the land (74000 km^2) is used for agricultural purposes, mostly as cropland (58.7 %) or pastures (10.3 %). Vineyards, orchards and horticultures comprise only 3.5 %. Forests account for 26 % of cultivated lands, reed and fishfarms 1.4 %. The ratio of developed (communal) lands is 6 % nationally, and increasing, especially in Central-Hungary (the Danube sub-catchment). Biological activity is medium (54 %) or poor (30 %), while only 2.1 % qualify as excellent. Good and excellent biological activity mainly appears in the wooded hill regions and Hortobágy.

2. Ecological assessment of freshwater in Hungary

2.1. Introduction

According to the EU Water Framework Directive (WFD, European Commission 2000) determination of ecological status of freshwater is based on the assessment of specific aquatic assemblages, termed Biological Quality Elements (BQEs).

The directive determines the scope of analysis necessary for the evaluation of the water bodies, the minimum number of analysis and the basis of the classification system but the classification itself is performed by national assessment methods developed individually by the member states along the given normative definitions.

Member states are required to determine the reference conditions and the boundaries of the specific ecological classes for all types of water and all important quality elements.

The classification systems of the member states are compared in the course of an intercalibration process among groups having water bodies of similar bio-geophysical types.

Hungary successfully passed the 1st and 2nd phase of the international ecological intercalibration process in 2012. As a consequence, many Hungarian biological methods have internationally accepted, intercalibrated boundaries, and have become part of the international law of the European Commission Intercalibration.

Determination of specific biological elements - like abundance or species composition – is required by the WFD, and results of biological monitoring must be presented in a comparable way. Biological classification results are presented in the form of ecological quality ratio (EQR), which is the ratio of an index concerning the quality of the monitored water body compared to the reference state.

Analyses are based on the quantitative and qualitative status of the following living organisms (BQEs):

- microscopic floating algae (phytoplankton),
- microscopic algae forming layers on solid substances (phytobenthos),
- macroscopic aquatic plants (makrophyton),
- macroscopic invertebrate animals living on the sediment (macrozoobenthos),
- fish

After evaluation, water bodies are categorised in one of the five ecological states of high, good, moderate, poor or bad.

The aim of the WFD is to reach at least good ecological and chemical state of all freshwater bodies. Ecological status is based on the above BQEs, the physical-chemical quality elements, the specific pollutants and the hydromorphological elements.

In the course of the explorative and operative monitoring programs in Hungary, measurements took place in all together 1279 sampling sites of 863 water bodies during the evaluated period of time (Figure 2-1). This is 80.1% of the total 1078 water bodies.

As part of the international intercalibrating network Hungary has 16 monitoring points on rivers and 5 on lakes as reference sites which are undisturbed or very slightly disturbed.

2.2. Classification methods

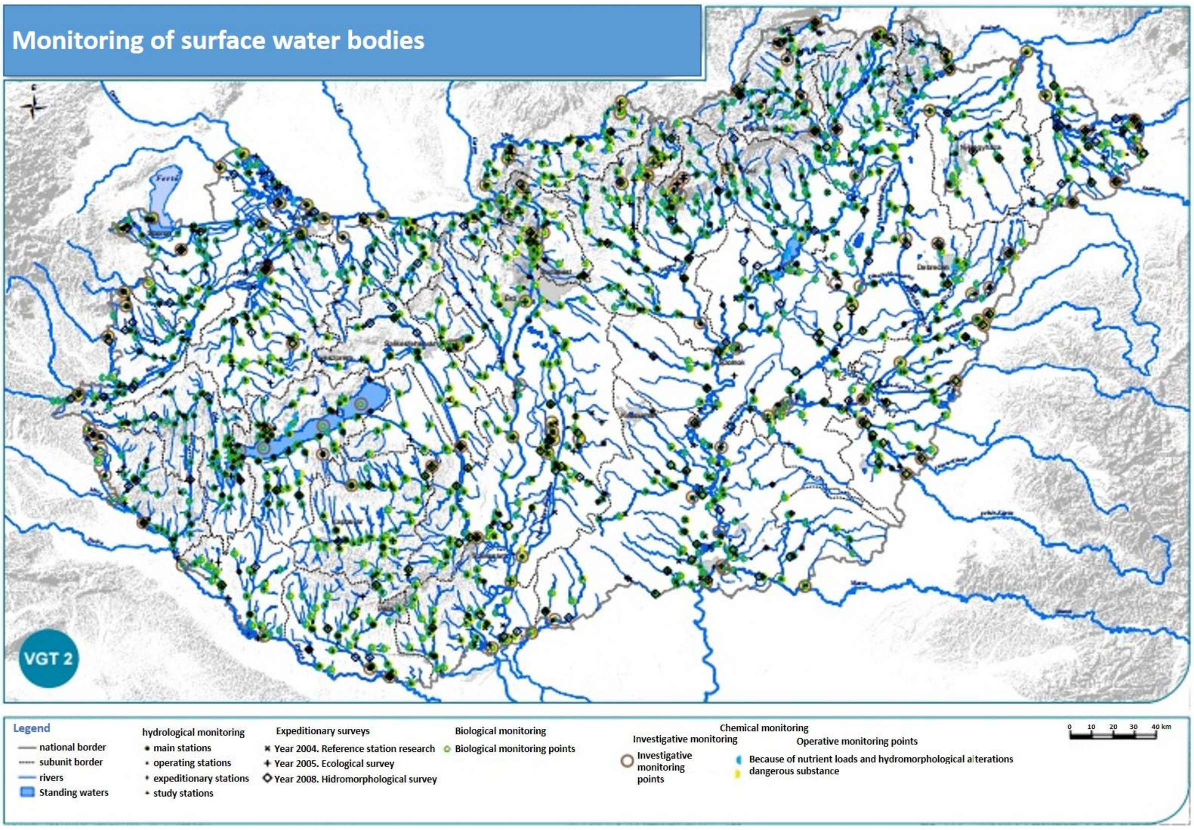
In the course of the first survey in 2004, reference locations and water bodies were explored and the hydrogeographic typology of waters was established.

In 2005, within the scope of the ECOSURV project, samples were taken and evaluated from almost 400 locations in order to develop methods for biological quality elements assessment.

In 2008, hydromorphological surveys were performed at 172 locations, where – in the absence of an established hydrological station – hydrographic knowledge was insufficient. At the same time, methodology for the analysis of hydromorphological elements was better specified.

During this period hydromorphological and macrophyte surveys were carried out for small and medium-size water flows by experts of the Directorates of Environmental Protection and Water Management and biologists, concerning more than 700 water bodies.

Figure 2-1 Monitoring sites of surface waters in Hungary.



The methods and guidelines for evaluation of each BQE and the determination of the EQR boundaries were developed by experts of the Ecological Research Center of the Hungarian Academy of Science (Table 2-1).

Table 2-1 EQR boundaries determined by the National assessment methods for biological assessment, based on WFD.

BQE	National assessment method		Boundary (EQR)	
			High/good	Good/moderate
Phytoplankton	Methodological guide for sampling and analyzing phytoplankton according to the WFD	lakes	varies according to lake type (0.60-0.73)	varies according to lake type (0.40-0.63)
		rivers and streams	varies according to water type (0.80-0.95)	varies according to water type (0.70-0.80)
Phytobenthos	Methodological guide for sampling and evaluation of phytobenthos according to the WFD	lakes	varies according to water type (0.78-0.80)	varies according to water type (0.58-0.60)
		rivers and streams	0.80	0.60
Macrophytes	Methodological guide for sampling and analyzing macrophytes according to WFD		varies according to water type (0.60-0.70)	varies according to water type (0.30-0.54)
Benthic invertebrate fauna	Methodological guide for sampling and analyzing macroscopic invertebrates in waters according to WFD		0.80	0.60
Fish	Methodological guide for sampling and analyzing fish according to WFD and ecological classification of water flows based on fish		0.80	0.60

The water quality indices were developed by taking anthropogenic pressures into consideration (Table 2-2).

In case of rivers, phytoplankton index is sensitive to nutrient load and the presence of reservoirs/damming, in case of lakes to organic pollution and nutrient load, land use and salinity for sodic lakes.

The OMNIDIA program is used for the evaluation of phytobenthos data. Because organic and non-organic pollution often occurs simultaneously in Hungarian waters, for certain types a multimetric index (IPSITI) was used, which is the average of IPS (Specific Pollution Sensitivity index), SI (Austrian Saprobic Index) and TI (Austrian Trophic Index) indices, because it showed better correlation with chemical variables. Other indices are also used, e.g. for lakes: MIL (Multimetric Index for Lakes), MIB (Multimetric Index for Balaton), H index (Halobity) and MISL (Multimetric Index for Sodic Lakes). Phytobenthos indices show correlation with eutrophication, organic pollution, hydromorphological alterations, land use, and for sodic lakes, with salinity.

Hydrological classification for ecological assessment using macrophytes is made based on the German Reference Index (RI). RI is given by water body type, of which EQR can be determined. Macrophyte index shows the effect of eutrophication, land use and hydromorphological alterations.

In the course of the international ecological intercalibration process, a new stressor and type-specific, multimetric assessment method was developed (Hungarian Multimetric Macro-invertebrate Index, HMMI). Macrozoobenthos index is sensitive to pressures of organic pollution and nutrient load, land use, salinity and the quantitative ratio of dissolved oxygen. Moreover, the index is sensitive to changes of conductivity, so it is not appropriate for the special Hungarian sodic lakes, which lakes are also different based on their aquatic community.

Type-specific index for fish is sensitive to organic pollution, nutrient load and land use. The natural or non-natural occurrence of fish was taken into consideration as well.

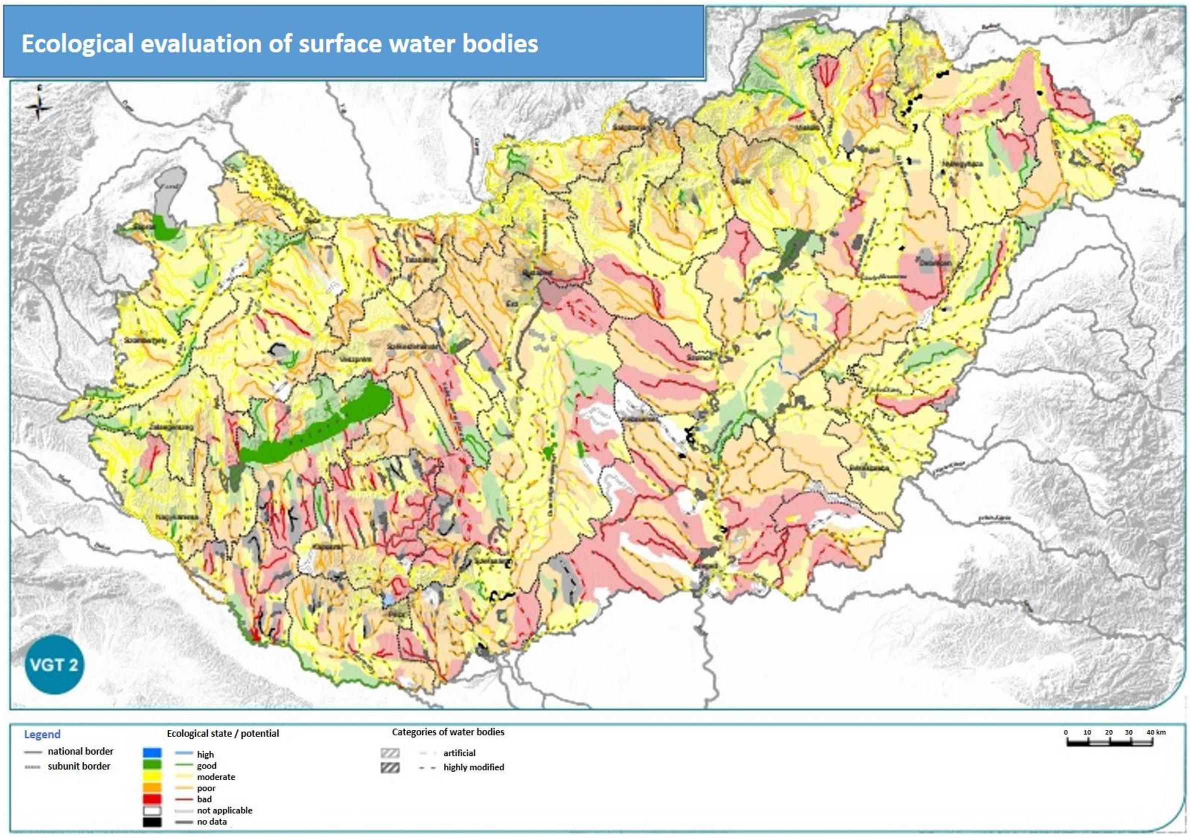
Table 2-2 Effects of anthropogenic pressures

BQE	National assessment method (indices)	eutrophication (nutrient load)	organic pollution	land use	hydro morpho-logical alterations	non-native species
Benthic Invertebrate Fauna	HMMI		+	+		
Macrophyte	RI	+		+	+	
Phytobenthos	IPSITI, MIL, MIB, MISL	+	+	+	+	
Phytoplankton	HLPI (lake)	+	+	+		
	HRPI (river)	+			+	
Fish	HMMFI		+	+	+	+

2.3. Classification results

As the results of classification, ecological states of surface water bodies in Hungary were evaluated based on the evaluation period of 2009-2012 for biological, physical-chemical elements, specific pollutants and hydromoprphological data (except fish where data from 2015 were used). Data from 2008-2012 was used for hazardous subtances, 1981-2010 for water runoff and 2013 for water usage (Figure 2-2).

Figure 2-2 Ecological evaluation of surface water bodies



Only 9% of all surface water bodies have at least good ecological status (Figure 2-3, Table 2-3).

Figure 2-3 Ecological evaluation of surface water bodies in the percentage of the ecological states

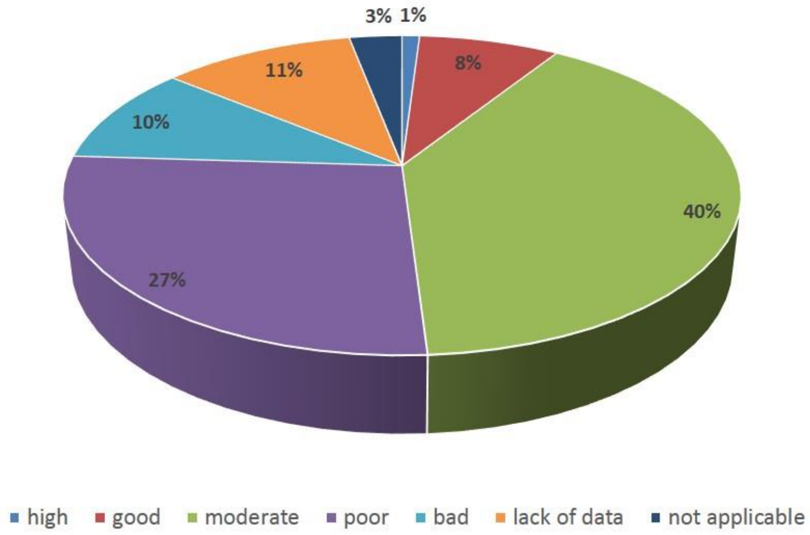


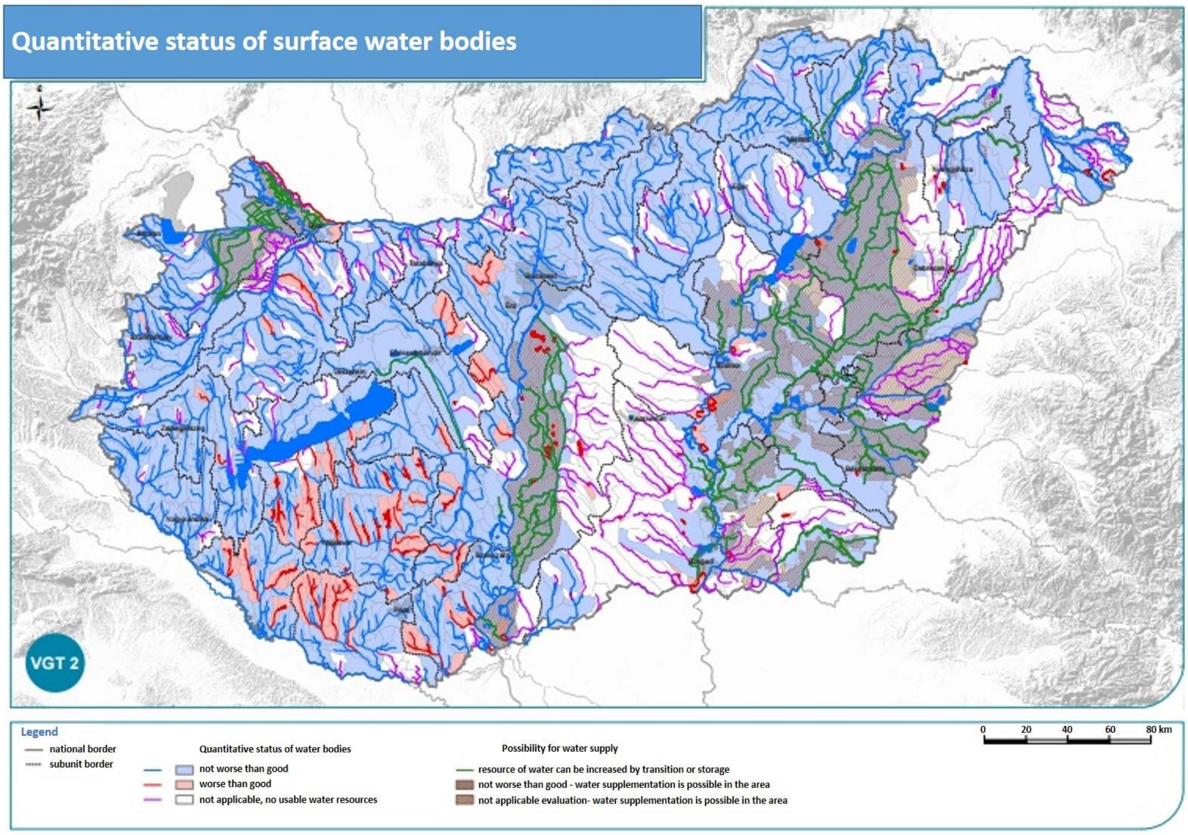
Table 2-3 Number and ratio of surface water bodies of the different ecological status in different classification types separately and summarized.

Status/ potential category	Biological classification		Hydromorpho-logical classification		Physical-chemical classification		Specific pollutants (metals)		Ecological classification	
	Number	%	Number	%	Number	%	Number	%	Number	%
High	9	1%	227	21%	105	10%	82	7%	6	1%
Good	97	9%	488	45%	379	35%	407	38%	83	8%
Moderate	388	36%	281	26%	238	22%	75	7%	439	41%
Poor	294	27%	19	2%	92	9%	0	0%	293	27%
Bad	113	10%	44	4%	32	3%	0	0%	113	10%
Not applicable	40	4%	0	0%	0	0%	0	0%	30	3%
No data available	137	13%	19	2%	232	22%	514	48%	115	11%
All water bodies	1078	100 %	1078	100 %	1078	100%	1078	100%	1078	100%

Note: Ecological assessment follows the rule that the worst status is the strongest one in the evaluation process.

In the quantitative assessment, Hungarian water bodies categorized as „reaching at least good status" and „not reaching at least good status" (Figure 2-4.)

Figure 2-4 Quantitative status of surface water bodies



2.3.1. Rivers and streams

From the 889 watercourses, altogether 845 (95%) were evaluated based on ecological status (Figures 2-5, 2-6, Table 2-4).

Figure 2-5 Ecological evaluation of rivers and streams in the percentage of the ecological status

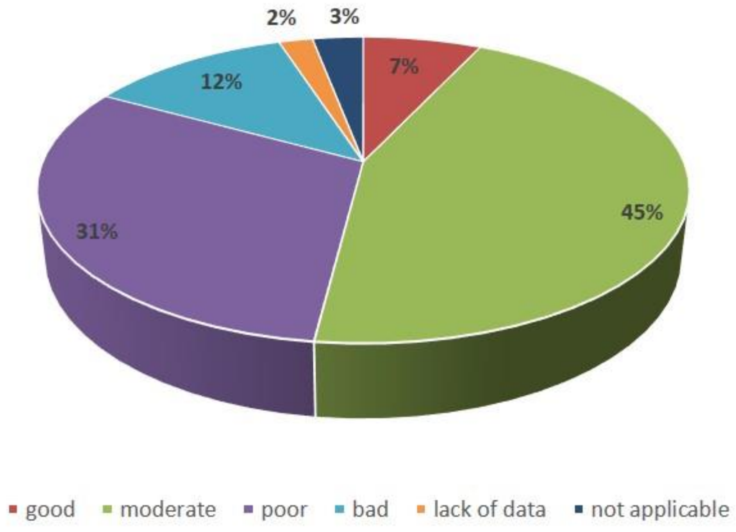
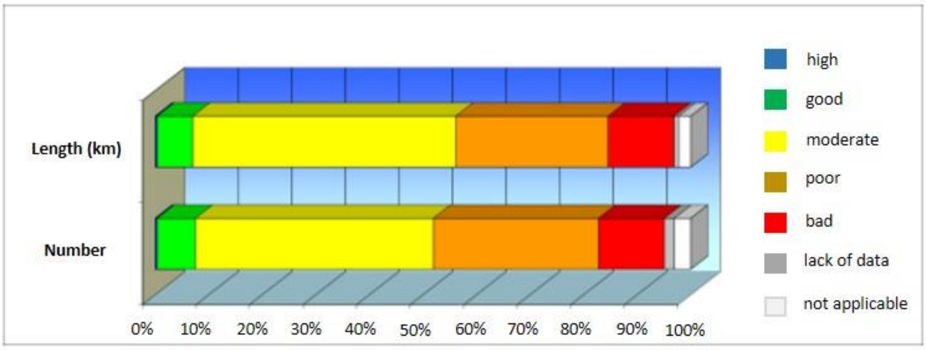


Table 2-4 Number and ratio of rivers and streams of the different ecological status in the different classification types separately and summarized

Status/ potential category	Biological classification		Hydromorpho-logical classification		Physical-chemical classification		Specific pollutants (metals)		Ecological classification	
	Number	%	Number	%	Number	%	Number	%	Number	%
High	3	0,4%	151	17%	97	11%	78	9%	3	0.3%
Good	78	9%	439	50%	351	39%	358	40%	64	7%
Moderate	359	40%	250	28%	206	23%	70	8%	395	44%
Poor	274	31%	11	1%	81	9%	0	0%	274	31%
Bad	109	12%	38	4%	28	3%	0	0%	109	12%
Not applicable	29	3%	0	0%	126	14%	383	43%	17	2%
No data available	37	4%	0	0%	0	0%	0	0%	27	3%
All water bodies	3	0.4%	151	17%	97	11%	78	9%	3	0.3%

Note: Ecological assessment follows the rule that the worst state is the strongest one in the evaluation process.

Figure 2-6 Ecological evaluation of rivers and streams based on their length and number



The results show that 7% of flowing waters are in good ecological status/potential (no high status) and 88% are in worse than good status/potential.

2.3.2. Lakes and reservoirs

Evaluation of Hungarian lakes and reservoirs and ecological status classification was also carried out (Figures 2-7, 2-8, Table 2-5).

Figure 2-7 Ecological evaluation of lakes in the percentage of the ecological status.

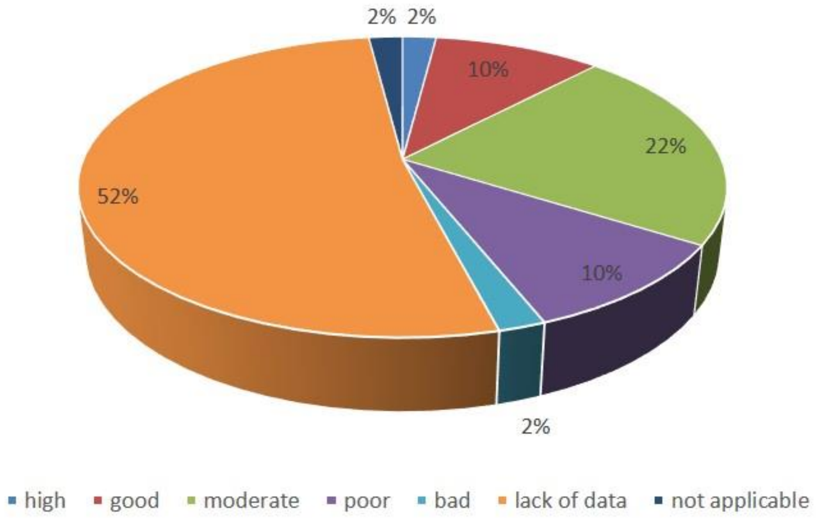
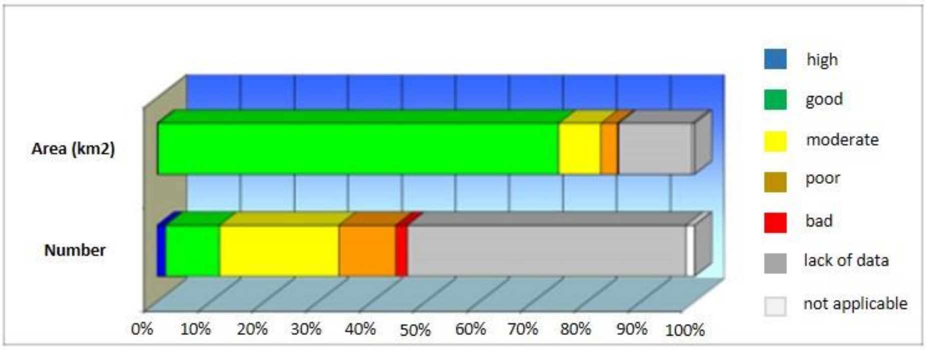


Table 2-5 Number and ratio of lakes of the different ecological status in different classification types separately and summarized

Status/ potential category	Biological classification		Hydromorphological classification		Physical-chemical classification		Specific pollutants (metals)		Ecological classification	
	Number	%	Number	%	Number	%	Number	%	Number	%
High	6	3%	76	40%	8	4%	4	2%	3	2%
Good	19	10%	49	26%	28	15%	49	26%	19	10%
Moderate	29	15%	31	16%	32	17%	5	3%	42	22%
Poor	20	11%	8	4%	11	6%	0	0%	20	11%
Bad	4	2%	6	3%	4	2%	0	0%	4	2%
Not applicable	108	57%	0	0%	106	56%	131	69%	98	52%
No data available	3	2%	19	10%	0	0%	0	0%	3	2%
All water bodies	6	3%	76	40%	8	4%	4	2%	3	2%

Note: Ecological assessment follows the rule that the worst state is the strongest one in the evaluation process.

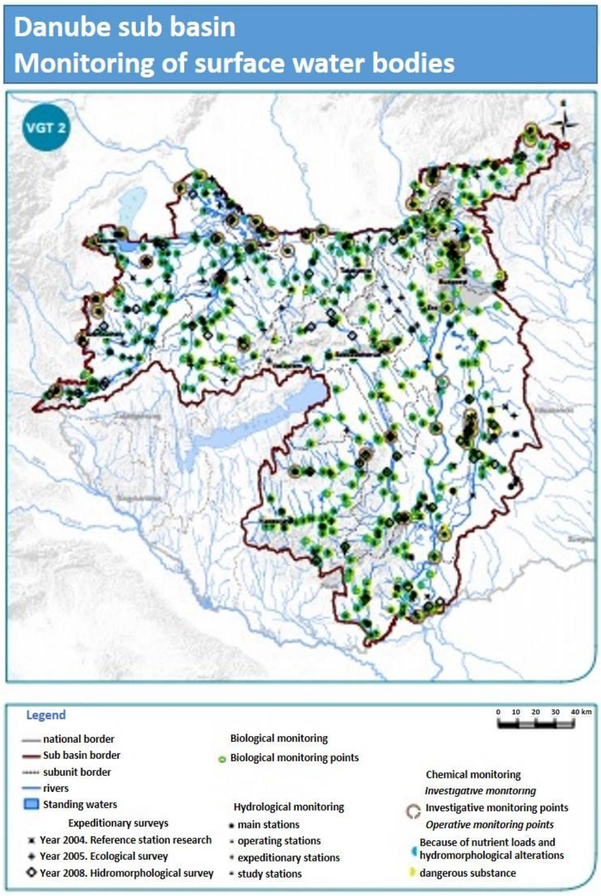
Figure 2-8 Ecological evaluation of lakes based on their area and number



2.3.3. Danube sub-basin

Monitoring the sub-basin of the Danube was designed according to the biological, hydromorphological, physico-chemical and chemical elements, the type of water and the level of antropogenic pressure, and it contains two major and 10 subprograms with 498 sampling sites on 352 water bodies (Figure 2-9).

Figure 2-9 Monitoring sites on the Danube sub basin



There is no information on 11% of waters, therefore ecological assessment was not carried out (small streams, artificial lakes), 29% was not assessed because of the lack of monitoring, 26% was not incorporated in the investigation, and 45% was evaluated based on fish (Figure 2-10). 10 % of the waters in the Danube catchment is at least of good quality (Figure 2-11, Table 2-6).

Figure 2-10 Ecological evaluation of surface water bodies on Danube catchment

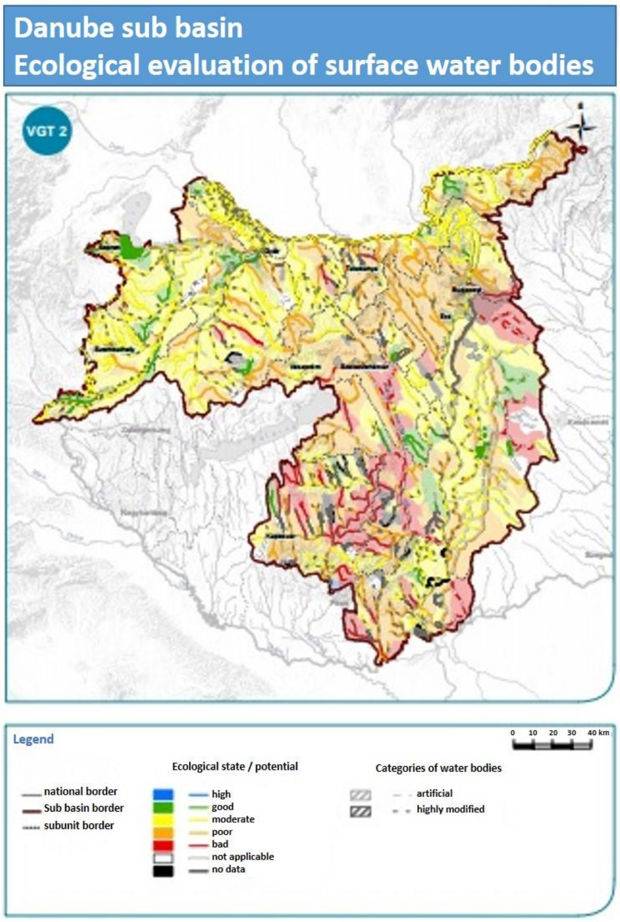


Figure 2-11 Ecological evaluation of surface water bodies of the Danube sub-basin in the percentage of the ecological status

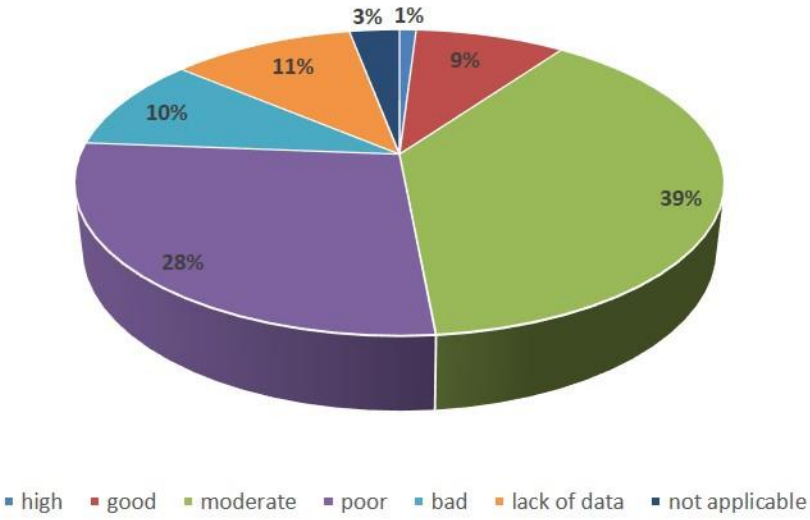


Table 2-6 Number and ratio of surface water bodies on the Danube sub basin of the different ecological states in the different classification types separately and summarized

Status/ potential category	Biological classification		Hydromorpho-logical classification		Physical-chemical classification		Specific pollutants (metals)		Ecological classification	
	Number	%	Number	%	Number	%	Number	%	Number	%
High	4	1%	96	21%	36	8%	50	11%	3	1%
Good	43	9%	185	41%	140	31%	187	41%	39	9%
Moderate	148	32%	130	28%	116	25%	0	0%	177	39%
Poor	129	28%	7	1%	40	9%	0	0%	129	28%
Bad	45	10%	17	4%	16	4%	0	0%	45	10%
Not applicable	17	4%	0	0%	0	0%	0	0%	13	3%
No data available	70	15%	21	5%	108	24%	204	45%	51	11%
All water bodies	4	1%	96	21%	36	8%	50	11%	3	1%

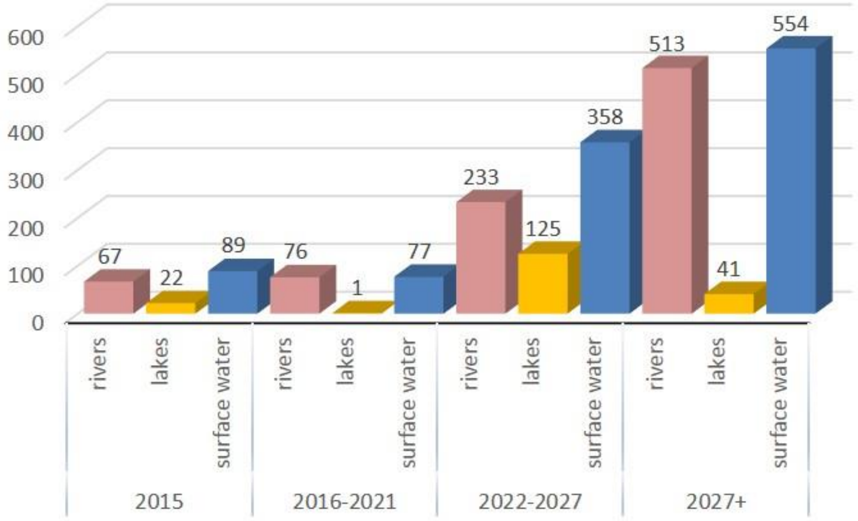
Note: Ecological assessment follows the rule that the worst state is the strongest one in the evaluation process.

2.4. Future plans and measurements

Significant pressures challenge Hungarian water management, such as waste water and rainwater disposal into surface waters, sewage from livestock and agriculture areas, water abstraction for agricultural purposes (irrigation, livestock) or human consumption, thermal water use for energy etc.

The Hungarian River Basin Management Plan contains detailed action plans for these issues. The aim is to reach at least good ecological status/potential for more than 300 water bodies by 2027 and increase this number to more than 500 after 2027 (Figure 2-12).

Figure 2-12 Number of water bodies (rivers, lakes and combined) reaching good ecological status/potential from 2015 to 2027+



3. Pressures and ecological status of surface waters

3.1. Introduction

In this chapter, multiple pressures on Hungarian surface waters are presented, describing the main drivers/sectors which are responsible for these pressures.

Generally, the main pressures affecting European surface waters are nutrient pollution, hydrological alterations and hydromorphological modifications, and that is also the case in Hungary. The above pressures are discussed below, including the relevance of sectors responsible for water abstraction and pollution.

3.2. Multiple pressures on surface waters

3.2.1. Pollution (N, P)

Pollution originates from point sources or diffuse sources. Main point sources are sewage originating from wastewater treatment plants and urban precipitation, but agriculture (especially livestock and fishery) can also be an important source. Diffuse sources usually pollute the surface water through a transmitting agent (soil), therefore prediction of their polluting effect is more difficult. Point source emission is more direct and easily monitored.

In Hungary, the ratio of diffuse source originated total nutrient pressure is larger than that of point source origin (Figures 3-1 and 3-2).

Figure 3-1 Division of diffuse and point source total N

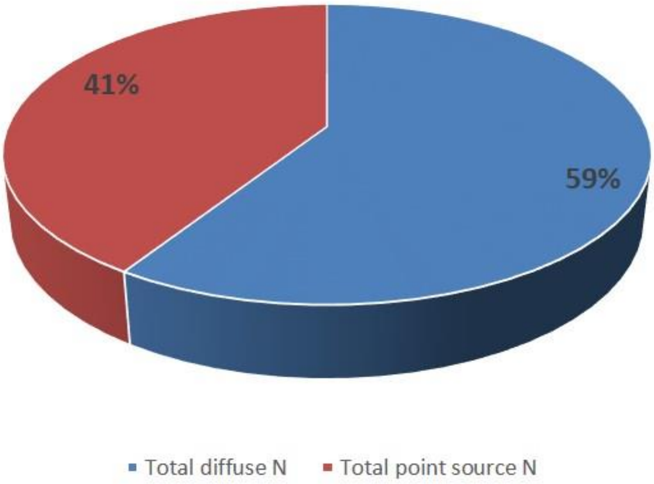
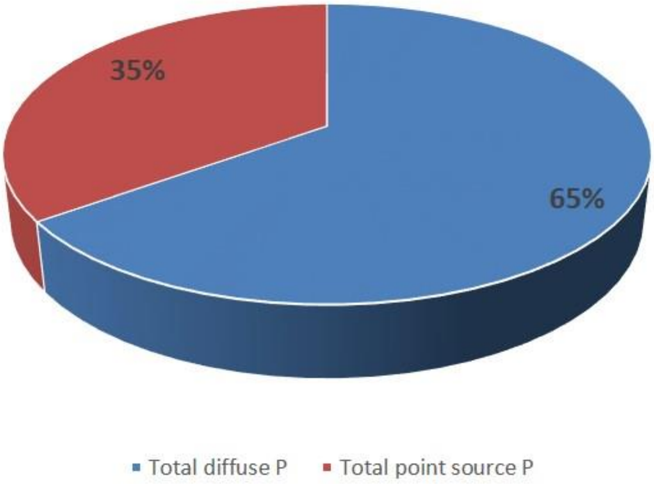


Figure 3-2 Division of diffuse and point source total P

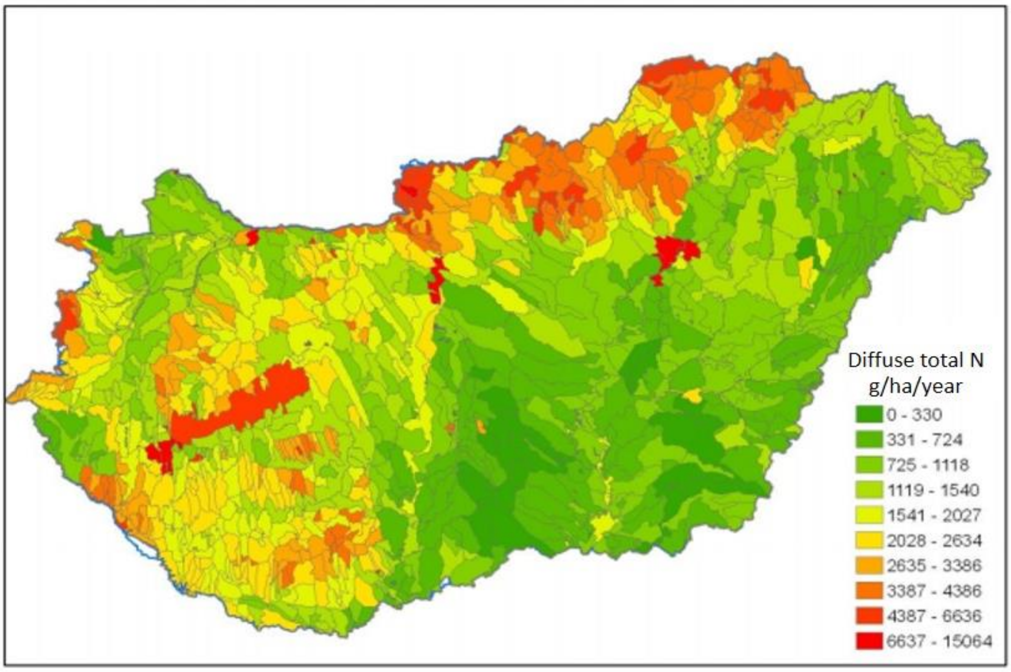


The primary (47%) diffuse source of N pollution in surface waters is soil, which contains high levels of of nitrate and natural ammonium. The second main source (more than 13%) is agricultural erosion and surface inflow. Other significant sources are sedimentation from air and precipitation.

Majority (two-third) of diffuse P pressure is due to soil erosion (both agricultural and natural). The rest is mainly coming from small, scattered municipal wastewater treatment plants.

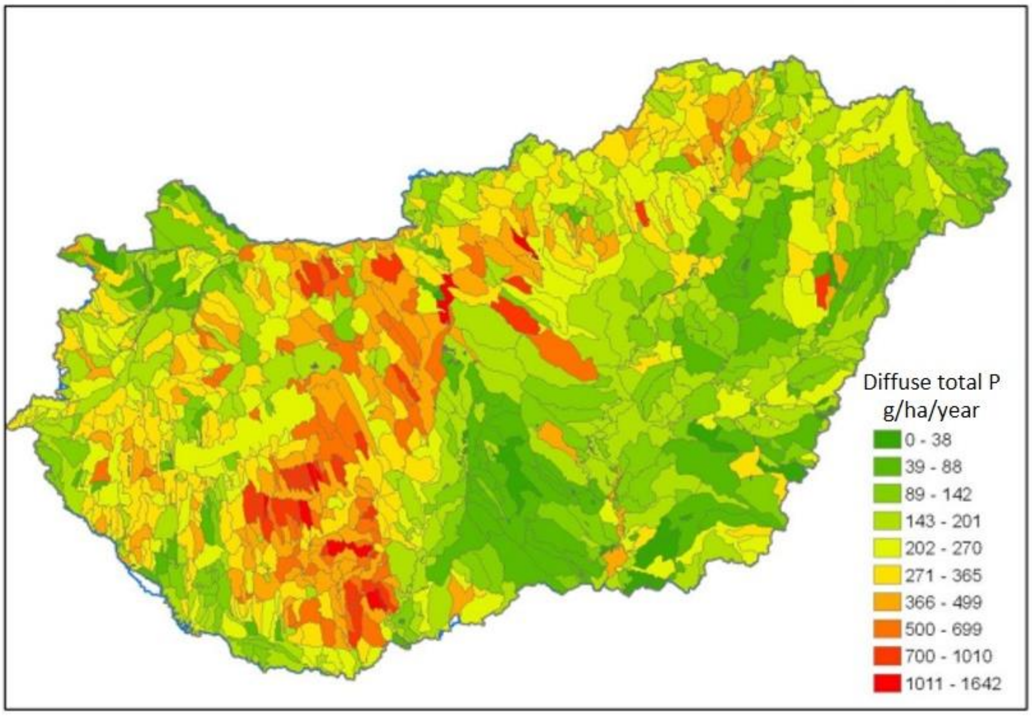
The pressure of diffuse-originated total nutrient load on water catchments in Hungary shows that the Western and Northeastern part of the country is more exposed to total N emission than the Eastern and South-Eastern part (Figure 3-3)

Figure 3-3 Diffuse TN emission in g/ha/year based on average data from the period 2009-2012.



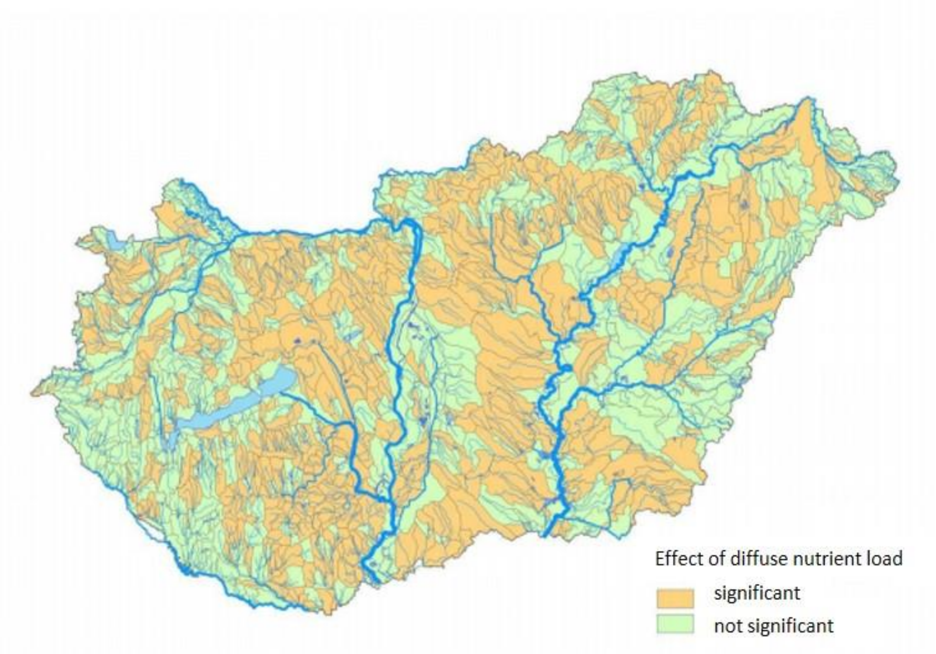
In case of total P load, heavier diffuse-originated pressure is characteristic on the sub basin of the Danube and the Northern part of the area between the Danube and the river Tisza (Figure 3-4).

Figure 3-4 Diffuse TP emission in g/ha/year based on average data from the period 2009-2012.



From the 1078 surface water bodies, 469 (43.5%) are under significant nutrient pressure. The effect of diffuse pollution is calculated by MONERIS model (Figure 3-5; see also Chapter 5 on the model).

Figure 3-5 Effect of diffuse nutrient pressure on the catchments (MONERIS model)



Data on main point sources of pollution are shown in chapter 3.4.2. (Nutrient pollution per sector).

3.2.2. Hydrological alterations

Hydrological alterations are based on the total water demand and the amount of available water source (Table 3-1).

Table 3-1 The standard surface water runoffs, natural small water, ecological small water (ecological demand) and available supply of water (based on calculation using hydrological data from the period 1981-2010).

Component of surface water runoff	Natural small water	Ecological small water	Available water
All runoff	2243 m^3/s	1184 m^3/s	1059 m^3/s
Of this inland formation	46.8 m^3/s	26.6 m^3/s	20.2 m^3/s

The smallest water flow in the summer and at the same time the biggest water demand is in August. The disposable quantity of water in at least 80% of this period (at least across 25 days) is the measure of usable water supply. Water abstraction is always a potential ecological pressure, especially during small water period.

Of the 1078 surface waters, 131 temporary small flow or temporarily fed standing waters suffer from continuous sewage pollution. In 59 cases the pollution is significant. In 875 permanent watercourses the water level of the standard August period is higher than its natural level because of the wastewater inflow. In 88 cases the inflow results in 5 times higher flow level than the natural state, which is a notable pressure.

Of the 1078 surface waters, in 84 cases the effect of water abstraction is significant, which means that it exceeds the usable amount. The effect on 8 water bodies is evaluated as important. The quantitative state of surface freshwaters is based on the pressures of ecological supply of water and the possibilities for replacement (see also Figure 2-4).

3.2.3. Hydromorphological modifications

Hydromorphological modifications are caused by cross-direction effects (transportation, dams, reservoirs etc.) or vertical intervention (river control). In Hungary, more than 70% of natural waters are effected by some kind of cross-modification and 40% of water flows are effected by significant regulation.

The most significant cross-direction hydromorphological modifications concerning ecosystem are made for energy industry (water energy) and fish farming, but potable water supply, agriculture and recreation are also important factors.

Transportation (roads and railways, Figure 3-6), dams, reservoirs and other constructions (Figure 3-7) can also influence ecological status of affected water bodies and aquatic ecosystems. The effect of modification is evaluated from the aspects of influence on hydromorphology (Figure 3-8) and on hydrology (Figure 3-9).

Figure 3-6 Transportation (roads, railways, shipping routes) infrastructure in Hungary

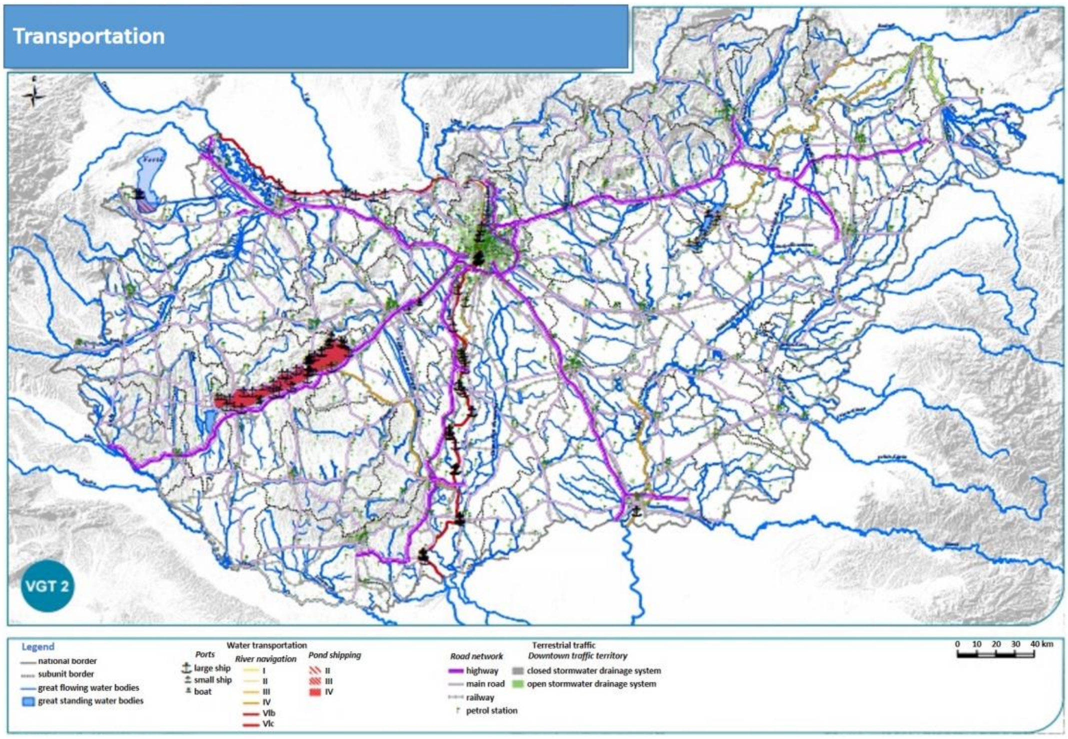


Figure 3-7 Dams, reservoirs and other type of hydromorphological constructions

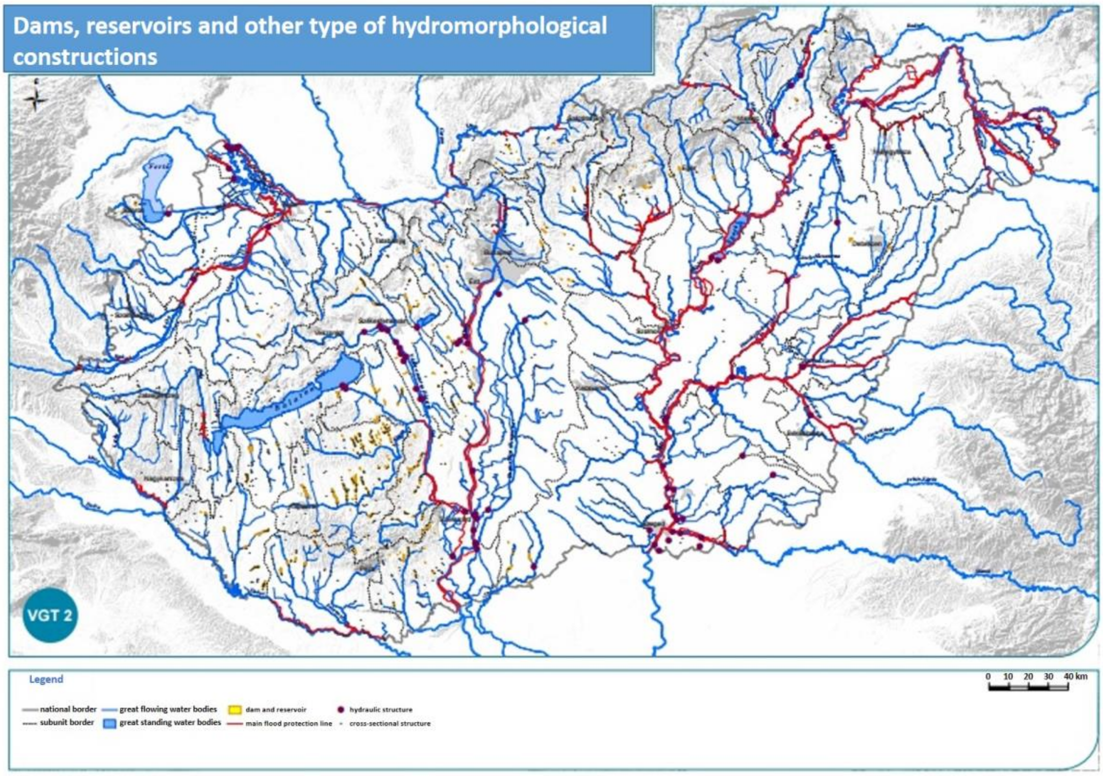


Figure 3-8 Influence of hydromorphological alterations on the morphology of water bodies

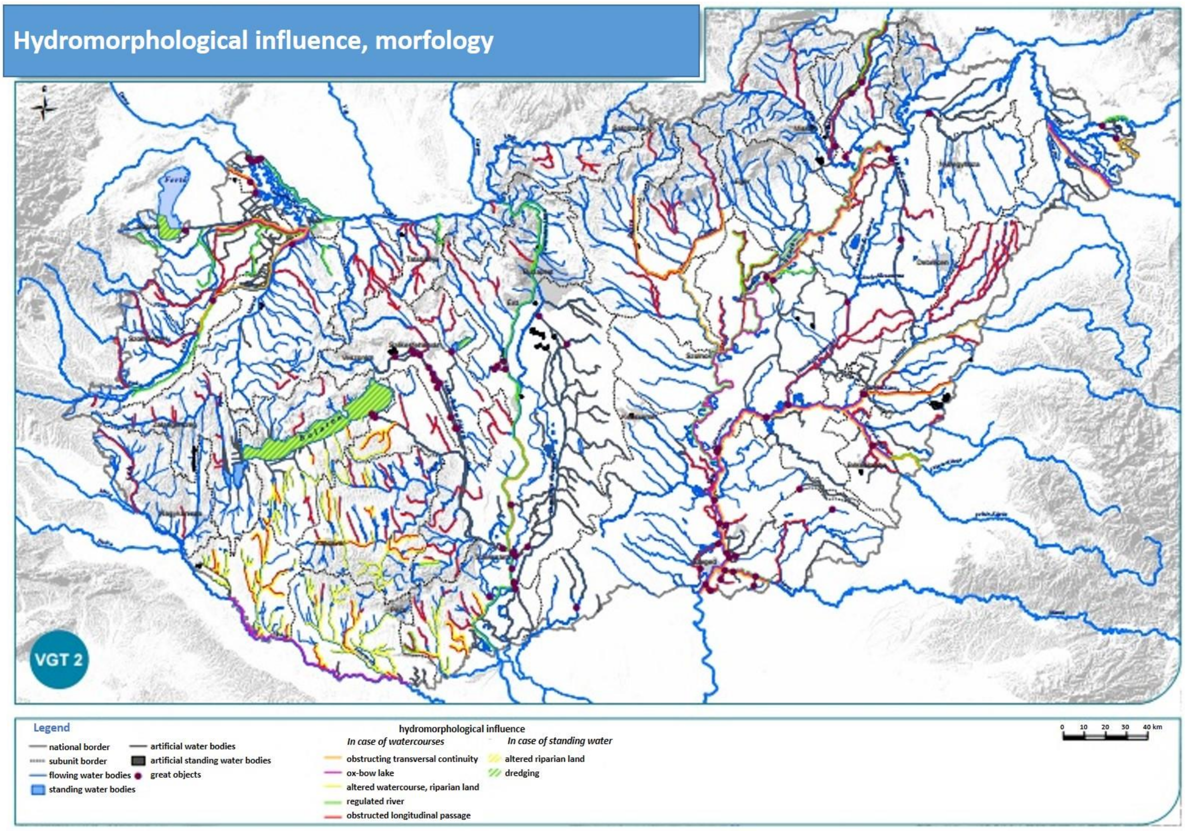
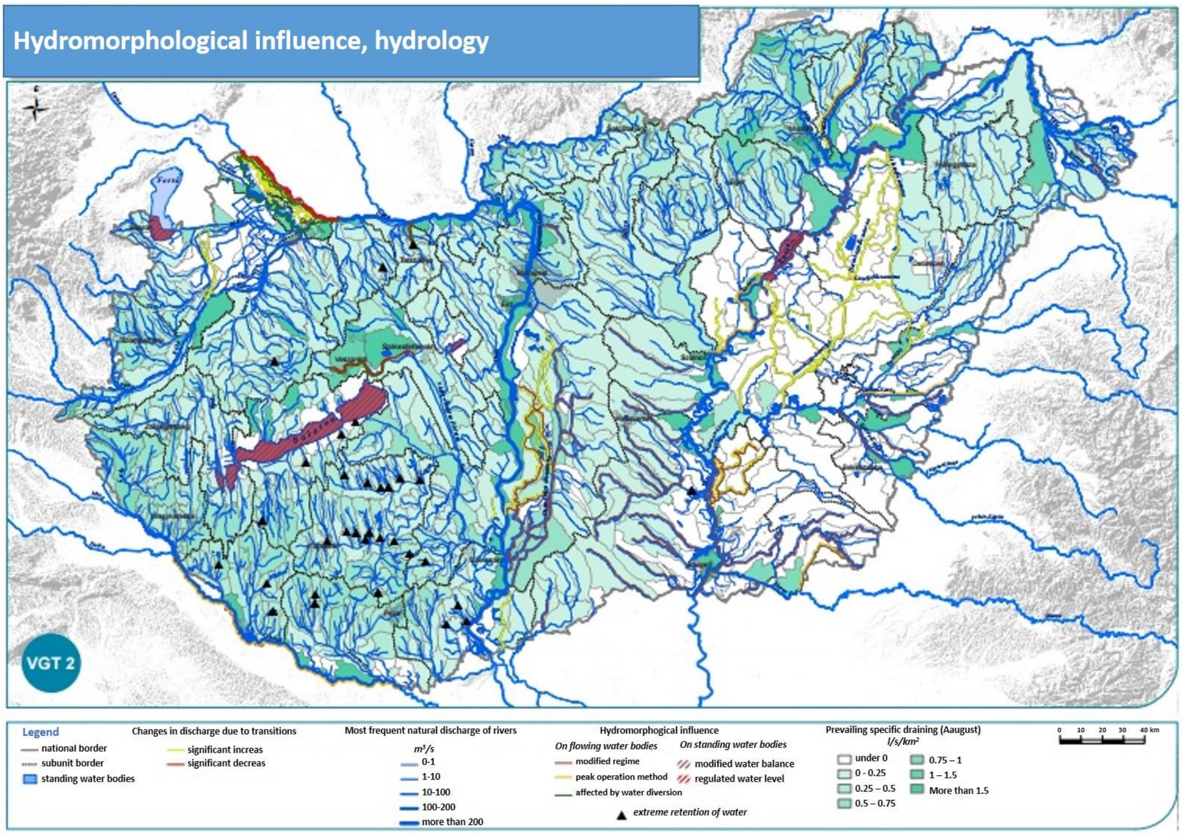


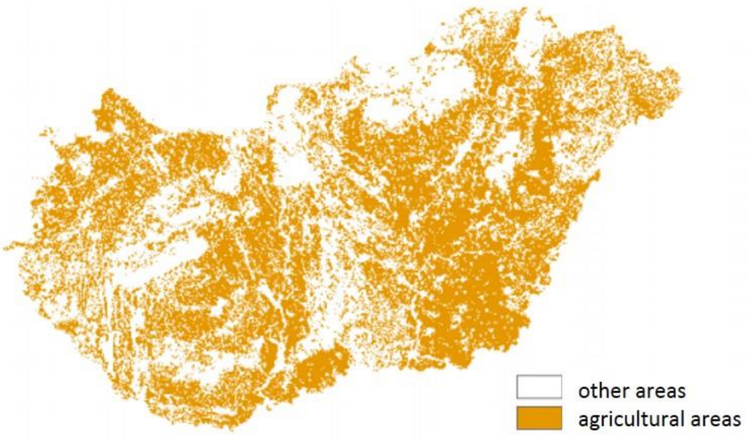
Figure 3-9 Influence of hydromorphological alterations on hydrology



3.2.4. Integrated indicators of pressures

Integrated indicators of pressures are based on land use in the catchment. Detailed mapping of land use in Hungary is presented in Chapter 5.3. Herein it is important to emphasize that considering its great extension, agricultural land use of the country is responsible for a significant load of pollution (Figure 3-10).

Figure 3-10 Agricultural land use in Hungary



3.3. Estimated ecological status of waters

The ecological status of waters based on dataset from 2009-2012 is presented in Chapter 2.

3.4. Drivers and sectors responsible for water pressures

3.4.1. Water abstractions and inflows per sector

The major user of surface water is energy industry (77%), and especially the atomic power industry, though only for cooling purposes (Figure 3-11). Water demand of public use, irrigation and fish farming is also significant (Table 3-2, Figure 3-12). Water usage for irrigation is the most demanding because plants completely use or evaporate the received water.

Figure 3-11 Distribution of water use among the different sectors (2013)

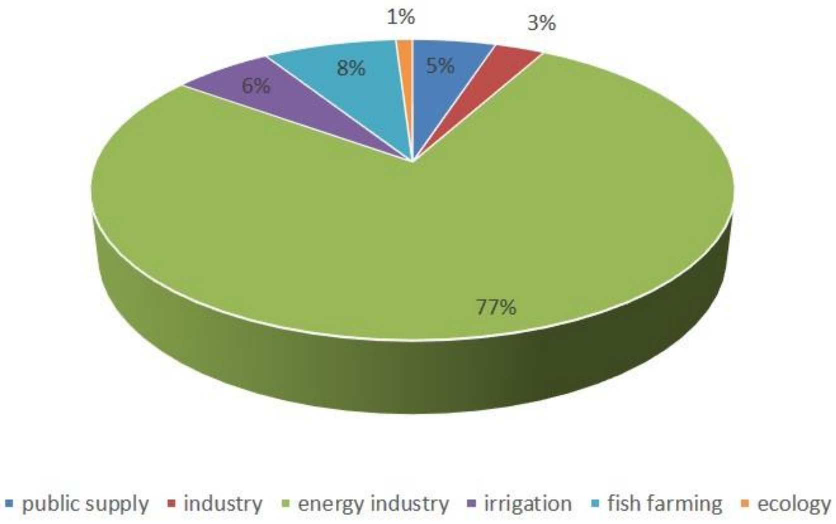
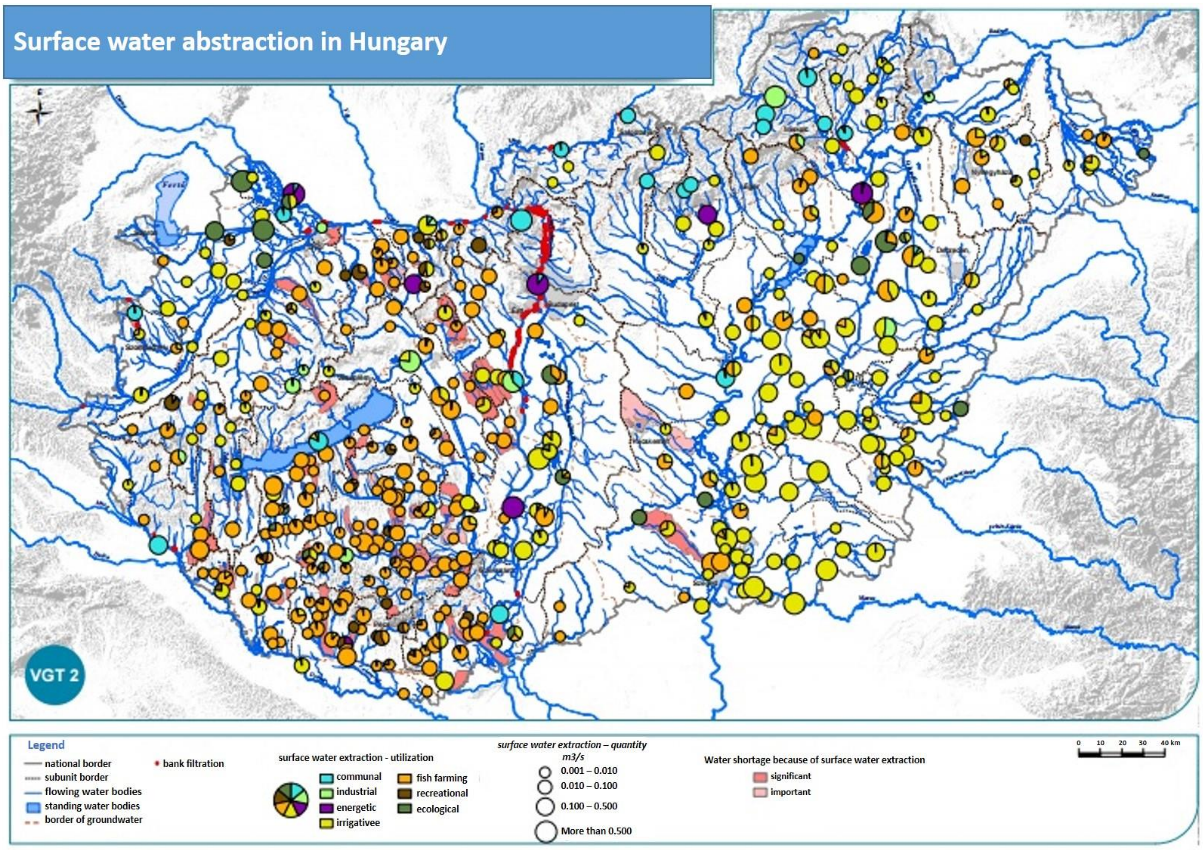


Table 3-2 Amount of abstracted surface water of the main users in 2013.

Water abstraction	Annual quantity [million m^3]
Communal	247
Industrial	124
Energy	3535
Irrigation	242
Fishery	308
Recreational	3
Ecological	38
Total:	**4636**

Figure 3-12 Surface water abstraction in Hungary. Locations, magnitude of abstraction, ratios of usage per sectors.

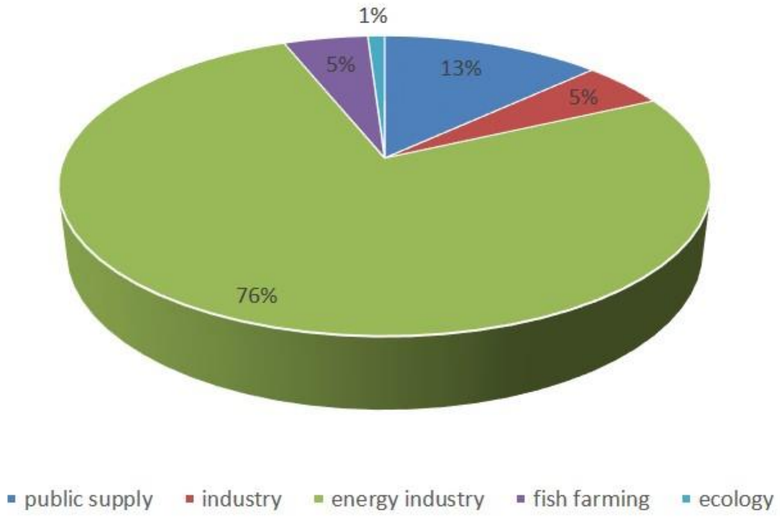


Polluted water input usually comes from municipal wastewater treatment plants, while energy industry (especially the atomic power plant) has the largest load of used water (from cooling water), which causes thermal pollution. Point source water inflow into surface waters is split by the different users, like public, industry, energy-industry, agricultural irrigation, fish farming, recreation and ecology (Table 3-3, Figure 3-13)

Table 3-3 Yearly amount of water inflow into surface waters by different users (2013).

Water discharge	Annual quantity [million m^3]
Communal	571
Industrial	199
Energy	3281
Irrigation	0
Fishery	184
Recreational	2
Ecological	22
Total:	**4259**

Figure 3-13 Point source water inflow into surface waters by the different users (2013).



3.4.2. Nutrient pollution per sector

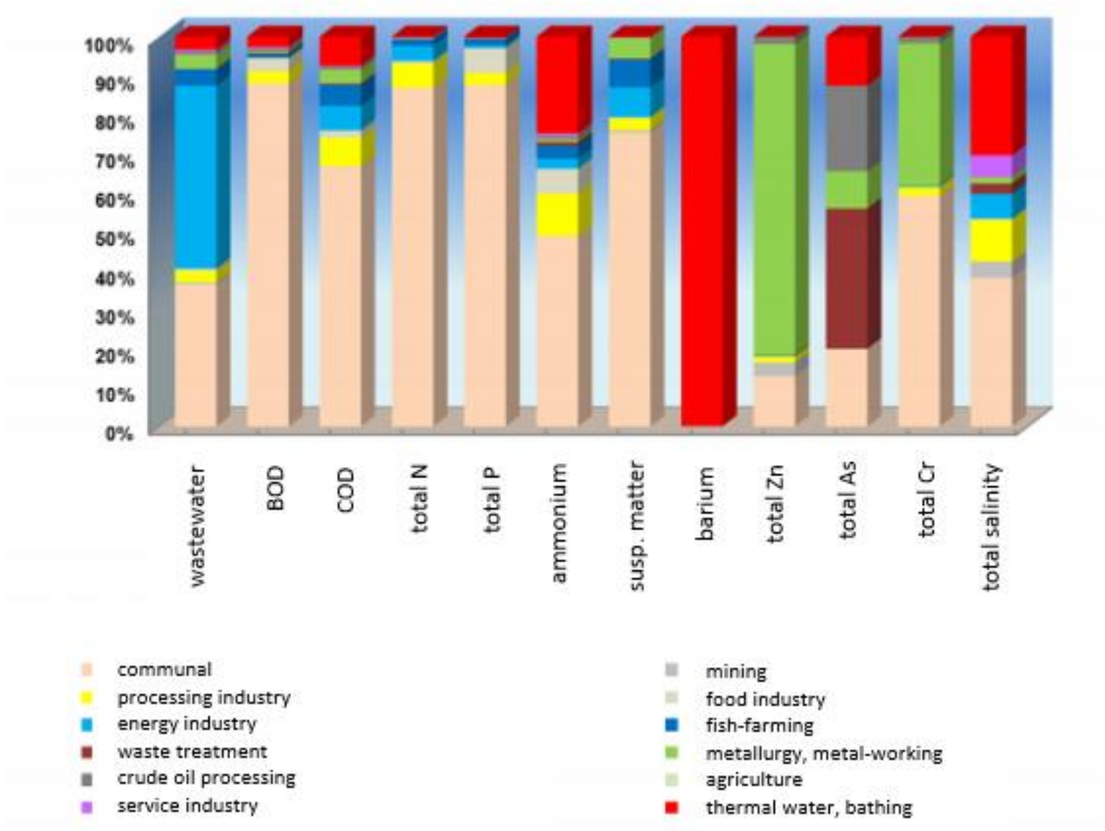
Results presented in this chapter are derived from data for the period 2010-2012.

Energy industry and thermal water usage are the most relevant source both by the amount of water used and the number of direct inflows (Table 3-4). Municipal wastewater is responsible for most of the organic matter and nutrient load, which means that quality of surface waters depends more on municipal wastewater treatment than industrial use and industrial wastewater (Figure 3-14).

Table 3-4 Direct industrial sewage and pollutant pressure of surface waters by sectors and its ratio to the municipal wastewater pressure (2010-2012).

Sector	Wastewater/used water [million m^3/year]	COD tons/year	BOD tons/year	Nitrogen tons/year	Phosphorus tons/year	Number of inflows
Thermal water, pool water	48	3506	303	14	4.5	297
Service industry	7	145	32	18	1.8	47
Agricultural	0.15	7	0.82	1.3	0.11	6
Oil processing	10	297	96	24	0.85	3
Metallurgy, metal processing	53	1665	49	19	0,6	22
Waste treatment	0.75	142	61	8.5	0.4	8
Fishery	61	2530	64	170	21	48
Energy industry	671	2927	35	418	9.2	33
Food industry	9,1	843	381	63	83	66
Other processing industry	41	3420	347	657	38	64
Mining	5.6	38	0.4	0.3	0.006	8
Other	0.005	no data	no data	no data	no data	2
Total	**907**	**15 519**	**1368**	**1392**	**159**	**604**
Rate of industrial and communal pressure (%)	**63%**	**33%**	**12%**	**13%**	**12%**	

Figure 3-14 Percentage of the involvement of different sectors in polluting surface waters by emission of sewage or used-water.



Industrial and municipal waste water inflows and point source pollution from agriculture (livestock and fish farming) across the whole country were measured in detail (Figures 3-15 and 3-16).

Figure 3-15 Pollution sources of municipal and industrial sewage water inflow.

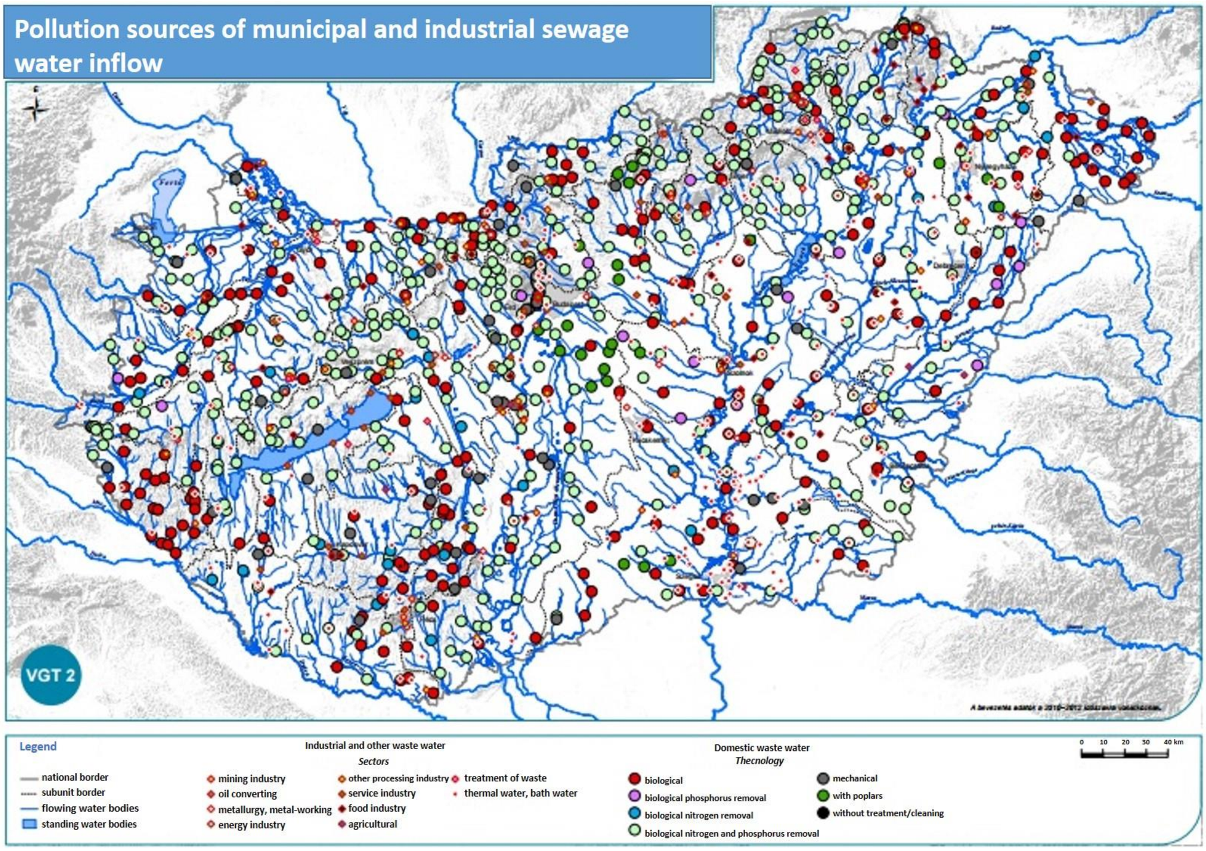
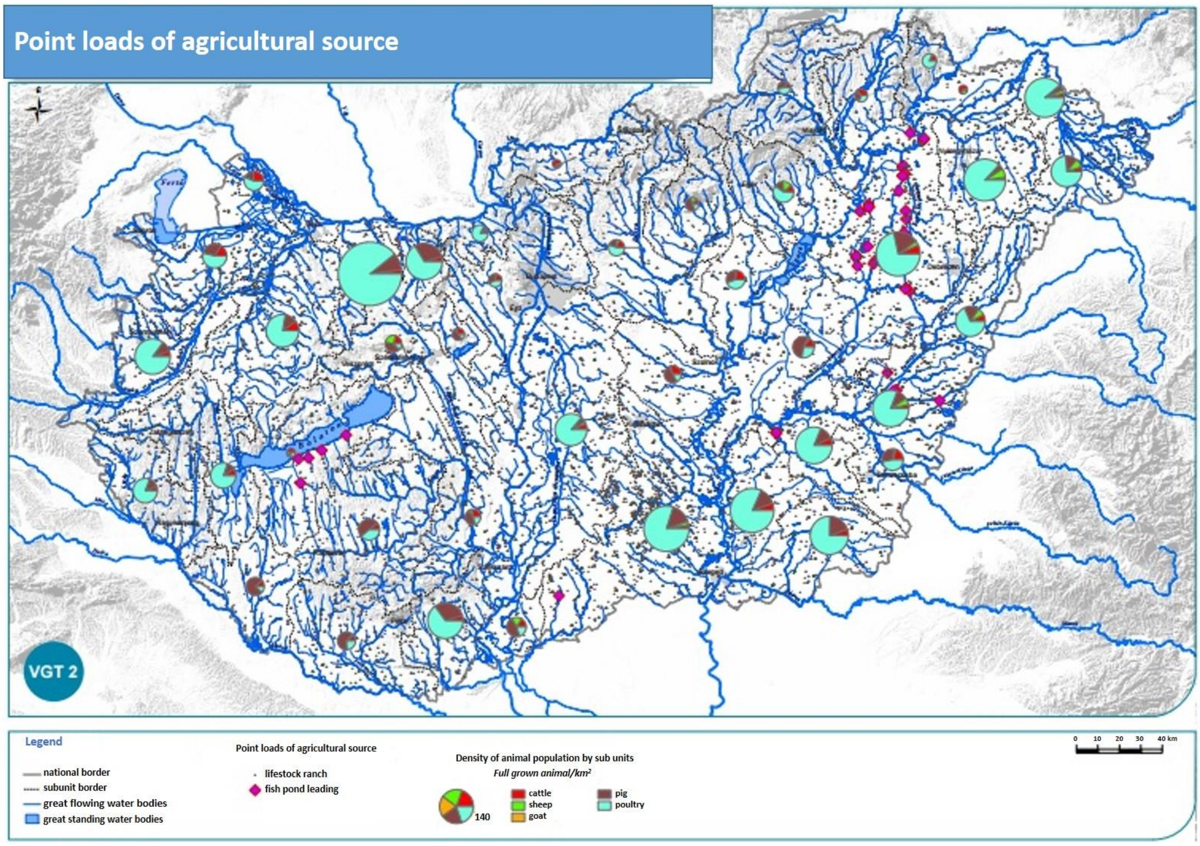


Figure 3-16 Pressures from agricultural point source pollutions of livestock and fishponds



In spite of the fact that emission of N and P in the treated sewage water significantly decreased due to the general increase of treatment efficiency, municipal sewage inflow is the main source of direct pollution of surface waters in the different sub basins. The most affected area is the Danube subcatchment (Table 3-5).

According to Dec. 31, 2012 data, the removal efficiency of N is 73.1 % and of P 74.4%, which values are close to the 75% required under the Urban Wastewater Directive.

Table 3-5 Average pollutant pressure of the different subbasins from municipal sewage inflow (data based on 2010-2012).

Name of sub basin	Discharged waste water (million m³/year)	Average annual discharge (tons/year)			
		BOD	COD	Total N	Total P
Danube	328	6 836	19 856	5 308	651
of this Budapest	161	4 360	10 119	1 929	243
Tisza	158	2 858	9 892	3 283	398
Dráva	22	258	815	431	67
Balaton	15	133	475	220	9,8
Country total	**523**	**10 085**	**9 243**	**9 243**	**1 127**

The effect of sewage pressure is determined by a water quality model. The model considers the point source and diffuse source inflows and the pressures coming from outside of the country, the degradation process and ratio of the examined parameters (KOI, BOI, TN, TP) and the runoff of the given watercourse (calculation derived from 1981-2010 data). For diffuse source pollution the MONERIS model is used. Model parameter adjustment is based on data from 2009-2012.

For evaluating the effect of sewage input on a given water body, only point source events were considered. Calculating the increase of nutrient concentration at the point of the inflow, the result indicate if the obtained value potentially allows the water body to reach at least good quality (WFD) along anthropogenic pressures. If not, the effect is significant to a certain extent (Figures 3-17, 3-18).

Figure 3-17. Significance of nutrients and organic pollutants emitted by sewage water treatment plants on water quality.

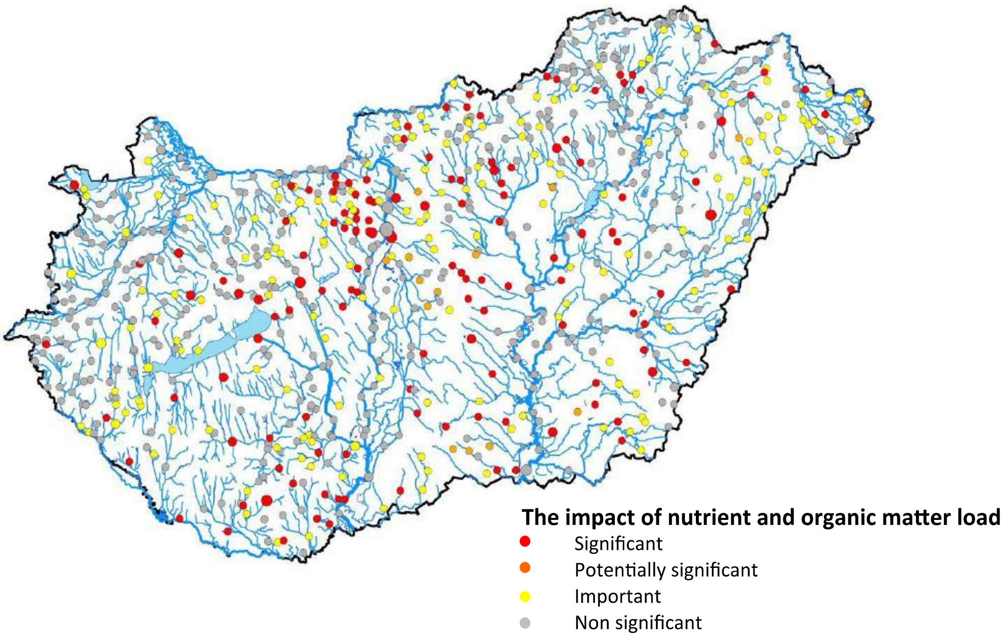
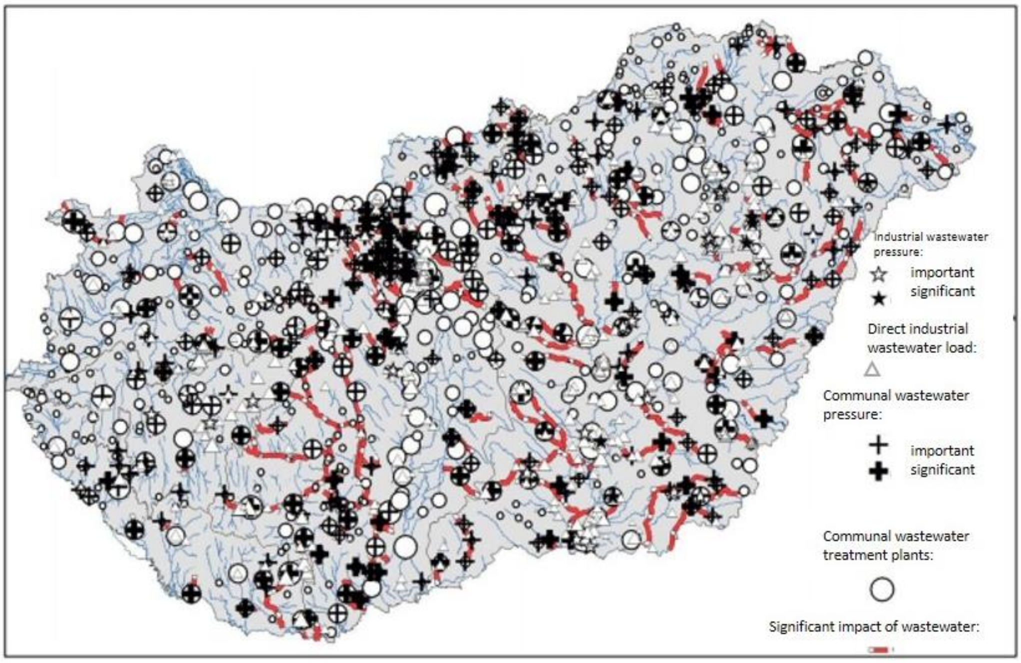


Figure 3-18 Modeled effects of point source organic pollution and nutrient load emitted from industrial or municipal wastewater treatment plants.



4. Groundwater in Hungary

4.1. Introduction

Groundwater sources play a major role in Hungary's drinking water supply system. More than 95% of our drinking water is provided from groundwater sources, meanwhile Hungary is famous for its mineral, therapautic, and thermal water supplies. Hydrogeologists have high professional responsibility to safeguard our groundwater resources and manage their sustainable utilization in quantitative and qualitative terms. During the past years, hydrogeologist experts had to face numerous global or local environmental and social threats that have significant adverse effect on the environmental elements, especially on groundwater. Hydrogeologists of our day and the future have to provide new and effective answers to new type of technical problems using innovative solutions.

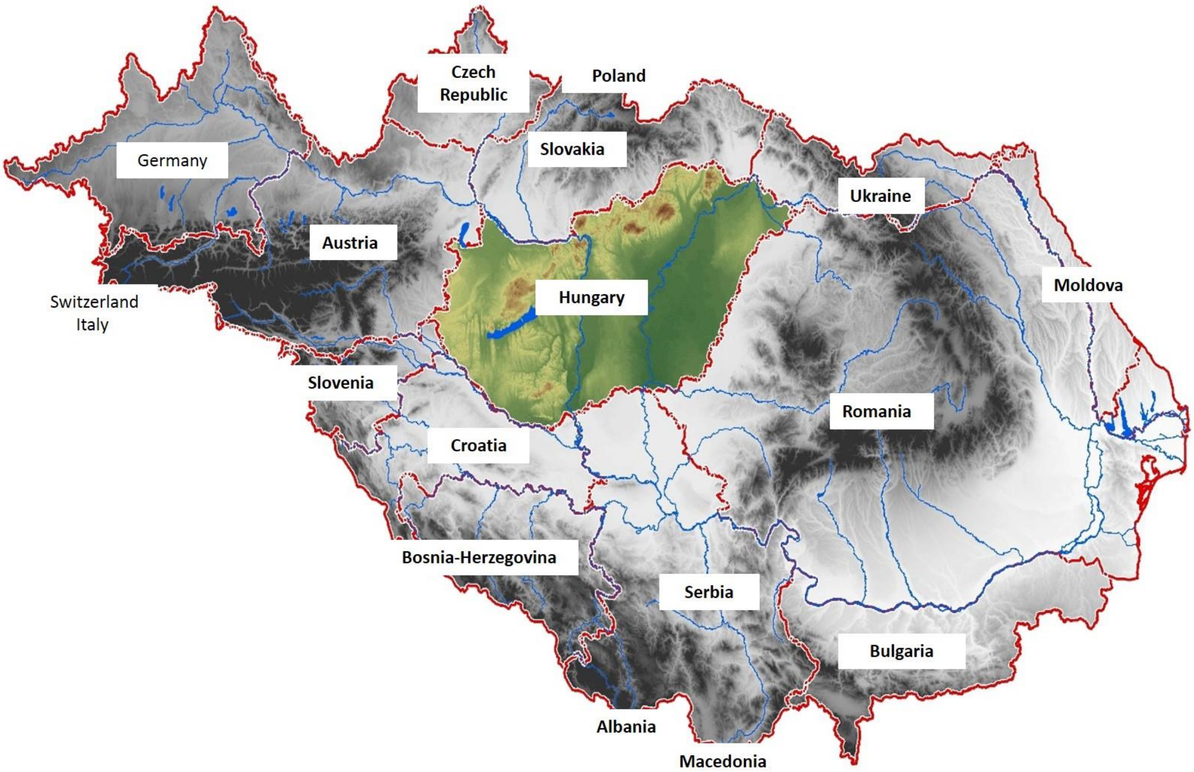
4.2. Hydrogeological conditions in the inner Carpathian basin

Hungary is located on the Danube watershed in the Carpathian basin, which is one of the most closed basins of the world (Figure 4-1). This geographical feature has especially important effects on surface waters and our groundwater resources. The fact that our relatively small country is neighboring with seven other countries creates special conditions in groundwater management by Hungary having the most transboundary aquifers in Europe. The River Basin Management plan of Hungary contains 185 groundwater bodies, out of which 40 are officially registered as transboundary aquifers, however the actual dependency is even higher. Approximately 50% of the groundwater bodies is divided by national border, thus external effects influence the quantity and quality of our groundwater resources. More commonly known is the fact that 96% of our surface waters arrive from the Western, Southern and Eastern neighbors. Hungarian groundwater bodies near the borders have downstream characteristics being exposed to transboundary influences. These areas are more sensitive to changes in environment and climate, and our hydrogeologists must be prepared to cope with such changes. Most of our neighbors are members of the European Union, Austria (since 1995), Slovakia and Slovenia (since 2004) and Romania (since 2007), and Croatia (since 2013). Technical collaboration is more fluent with these countries along the common European values and the harmonized legal framework, than with the non-member Serbia and Ukraine, although they have joined to the Danube program.

The hydrogeological makings of Hungary on one hand are considered to be very good, however hydrogeologists can expect various geological, hydrogeological, meteorological and geothermal conditions in the Pannonian basin as detailed bellow.

On rather large areas of our country within the same year one can observe flooding, inland water and drought all effecting also the groundwater resources, thus experts dealing with water resources must be prepared not just for the proper utilization practices of resources but also for protection against water related threats.

Figure 4-1 Location of Hungary on the Danube watershed in the Carpathian basin (Source: VKKI)



Hungary shows a rather diverse geological and hydrogeological scene, where almost every unique and interesting feature can be observed in close vicinity to each other. Beside the hydrogeological features of our karstic mountains (that have significant role in drinking water supply) one can study the rather interesting water bearing parameters of fractured volcanic, plutonic and metamorphic rocks. The Great Plain (Alföld), which attracts international attention, and the Small Plain (Kisalföld) geographical units provide several problems to be solved by hydrogeologist experts. Among others, the reason of the unique natural variations is due to the relative thinness of the Earth' crust under the Pannonian basin and due to the even recently observed tectonic compression causing increasing pore pressure of deeper reservoirs and fluid containing strata of the basin.

To interpret the reconstructed subsurface flow pattern of the Great Plain we must divide the role of two driving energy sources. A gravity-driven flow system is found in shallow depth and underneath there is a pressurized flow system controlled by the tectonic compression. The anticlines of the preneogene basin are the source areas of these highly pressurized regions. The pressure conditions are driven by sedimentation, raising fluid temperature and tectonic compression. The vertical flow component shows uniformly upward in these deep, suppressed hydraulic flow systems. The contact zone of the two mentioned flow systems is very complex, and its depth is still unknown at certain points of the Great Plain. The shape and dynamic feature of the interaction zone varies significantly depending on the local topographical, meteorological and geological conditions. The geological matrix of the Great Plain consists of a complex, at some points 7000m thick neogene overburden above the pre-neogen basin. The porous structures in Hungary contain approximately 5000 km^3 of water at a given time. This volume is the so-called static groundwater resource. Dynamic groundwater resources play more important role in sustainable groundwater utilization; its estimated volume is approximately 2-3 km^3/year.

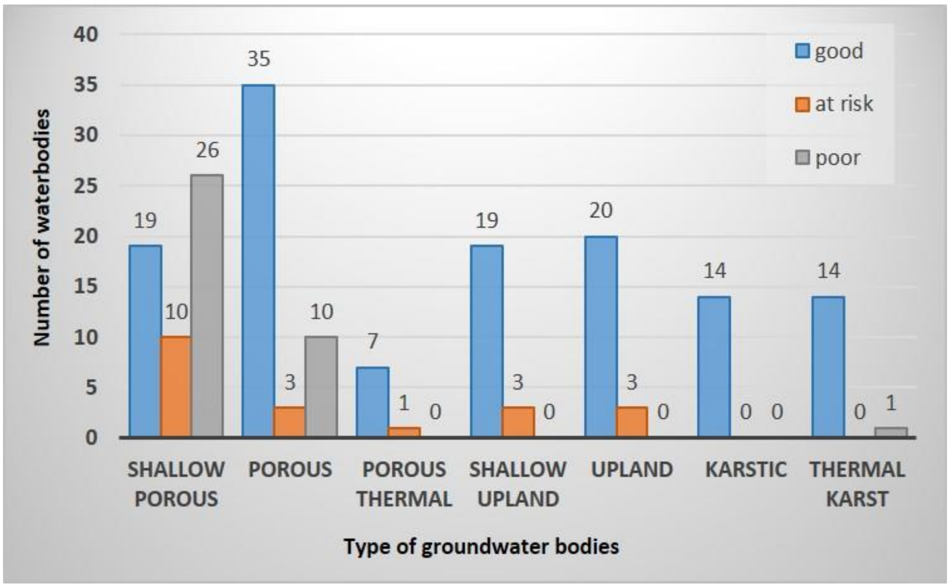
4.3. Quantitative and qualitative state of groundwater bodies

State of groundwater bodies is characterized by quantity and chemical quality. Quantitative state includes the following five tests:

- water level decrease (trends of water level in the monitoring wells);
- water balance (whether recharge of the water body covers both the water demands of groundwater dependent ecosystems and human society; including all direct and indirect water abstraction),
- surface water test (recharge of springs and other water flows from groundwater);
- ecological state ecosystems on the water body;
- intrusion test (impact of water abstraction on the hydrology, and as a consequence, temperature and chemical quality of the water).

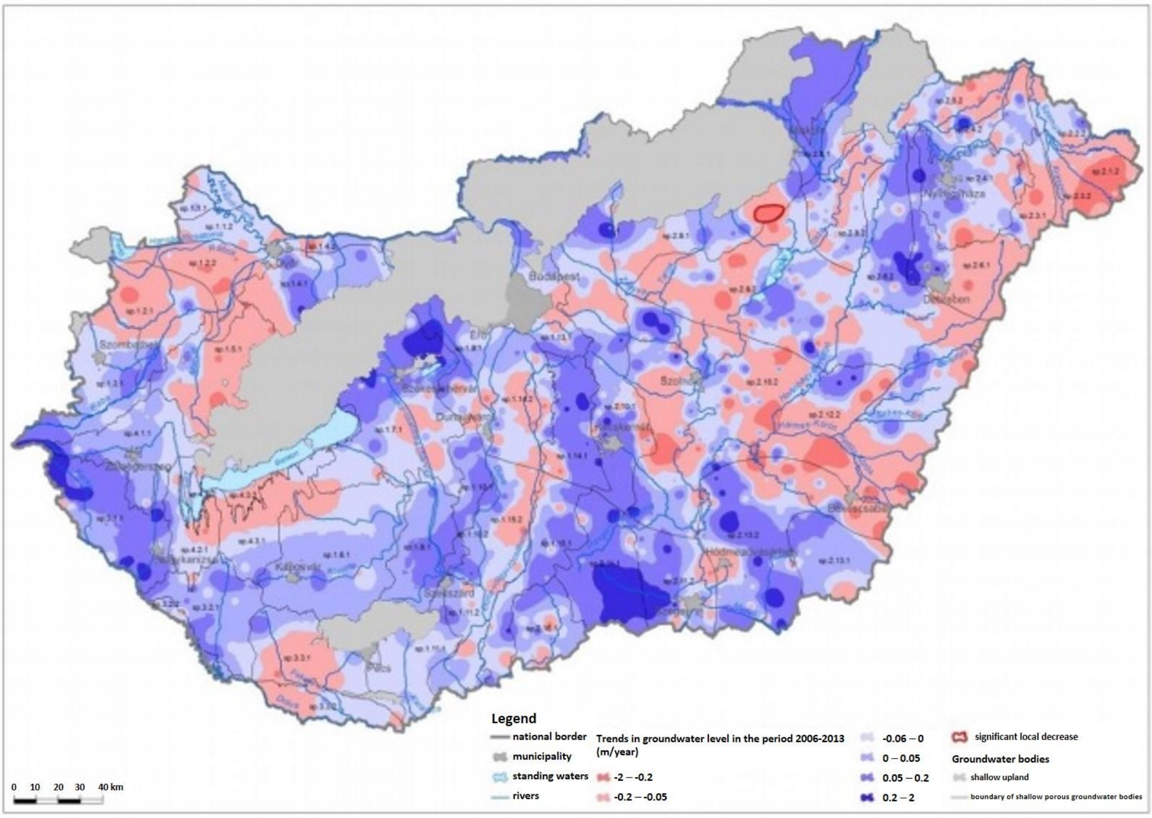
The first and the fourth tests are considered most reliable. Of the 185 identified groundwater bodies, 37 were classified as poor, and 20 as good, but at risk of becoming poor. Water balance and ecological state were the most frequently failed tests (19 and 18 water bodies, respectively). Most poor water bodies were shallow porous or porous (27 and 9, respectively). None of the porous thermal, shallow upland, upland and karstic water bodies and a single thermal karst water body were classified poor (Figure 4-2).

Figure 4-2 Qualification of quantitative state of groundwater bodies



One of the major challenges is the decrease of groundwater levels of shallow porous groundwater bodies (Figure 4-3).

Figure 4-3 Trends in groundwater level for shallow porous bodies in the period 2008-2013

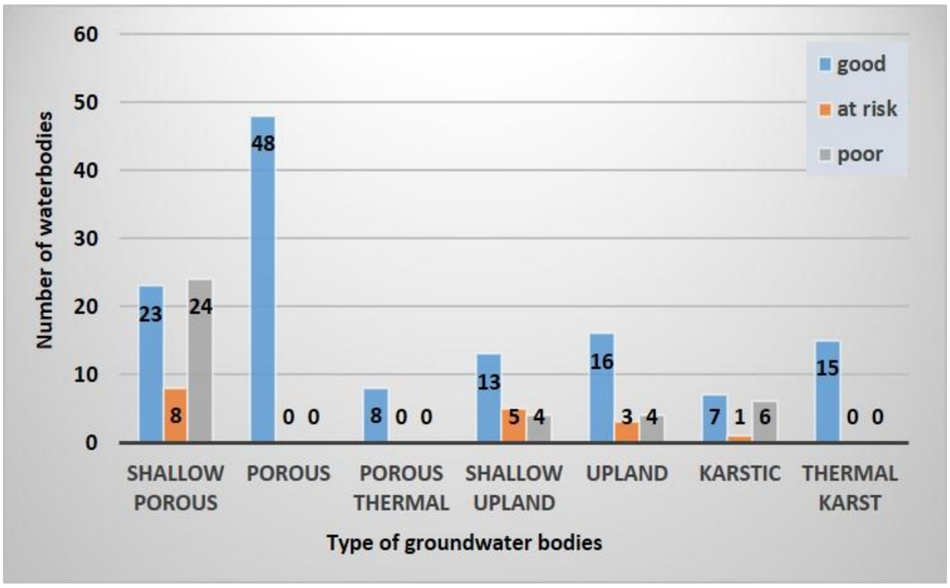


Chemical quality is determined by diffuse and point source surface pollutions. A large proportion of the groundwater bodies is vulnerable to such impact. Chemical quality is defined by the pollutant concentrations in the monitoring wells. If the concentration of a pollutant exceeds the threshold value, which may pose a risk to human health or the environment, the water body is considered poor. Threshold values were set for nitrate, chloride and sulphate, heavy metals (Cd, Pb, Hg), pesticides, trichloro- and tetrachloro-ethene and absorbable organic halogenated compounds (AOX). The hazard attributed to exceedance at a monitoring point is checked by the following criteria:

- diffuse pollution (by nitrate, ammonium and pesticides) of a water body cannot influence its future exploitation;
- point-source pollution (by organic micropollutants and chlorinated hydrocabons) of a water body cannot influence its future exploitation;
- pollution detected in drinking water abstraction or monitoring wells cannot result in closure of the water supply or modification of the treatment technology
- the pollution cannot pose a risk to the ecological or chemical state of surface water bodies
- the pollution cannot pose a risk to the ecological state of water or subsurface land ecosystems
- abstraction cannot lead to qualitative stress of the water body (intrusion test)

Water bodies are considered to be at risk if the level of a contaminant is increasing or the temperature is decreasing. Trend analysis is the main tool in identifying potential future risks at water bodies currently in good state. Chemical state was poor for 38 groundwater bodies (of 185 total), and 17 are at risk of becoming poor. Most groundwater bodies fell into poor category because of pollution in drinking water sources, pollution affecting surface waters or diffuse nitrogen pollution (20, 13 and 10 water bodies respectively, some may be multiply affected). No water body failed the ecosystem or the intrusion test. Most poor water bodies as shallow porous waters, but several upland, shallow upland and karstic waters fell into this category as well (Figure 4-4).

Figure 4-4 Chemical state of groundwater bodies



4.4. Groundwater for water supply

Groundwater resources took over the leading role in drinking water supply all over the world in front of surface water. Its share in Europe has reached 74%, while in Hungary drinking water supply is provided from groundwater at the rate of 95%. Although the total nominal capacity of drinking water supply systems in Hungary is approximately 4,5 million m^3 per day, the total annual production volume is only around 600 million m^3. Besides drinking water sources, the value of those reservoirs providing mineral waters, therapeutic waters and thermal waters shall be increasing in the future to cope with water supply related problems affecting more than half of the increasing population of the globe. Beyond the threats caused by changing natural condition,s there are unfortunate anthropogenic impacts on the groundwater resources such as contamination of environmental elements or our human impacts on climate change. It is a remarkable difference that the majority of drinking water of the neighboring Romania is still today provided mainly from surface waters.

The practical groundwater classification in Hungary defines the following groundwater categories: river bank filtered water sources that are closely dependent on gravel terraces of rivers are also classified as groundwater in the Hungarian nomenclature. These resources – providing almost 40% of the drinking water supply – prove the interconnection of surface waters and groundwater bodies. The most critical premise of its utilization is the production driven formulation of an active microbiological filter layer on the river bed. The protection of these water sources is crucial since almost the total 2 million inhabitants of Budapest are supplied by river bank filtered water. The main threat of these sources is the contaminations approaching from the river. Besides the riverbank filtered sources, mainly on the flat areas of the country deeper groundwater bodies provide the key resources for water supply. In the vicinity of the Trans-Danubian Mountains and the Bükk mountains the vulnerable karst water has a remarkable share in drinking water supply. Unfortunately our shallow groundwater aquifers are contaminated to such a level that they cannot be utilized in drinking water supply systems.

To maintain safe national water supply network the implementation the national water resource protection program should be continued, applying it both to active and perspective water aquifers. More than half of the 1700 drinking water sources are considered to be vulnerable, thus the strategic importance of safe drinking water supply can only be guaranteed by proper diagnostics, and well-head protection of our water resources. In the frame of the Drinking Water Quality Improvement Programme such hydrogeological and water management solutions should be applied that do not depend significantly on expensive water treatment technologies. From technical perspective it is inevitable to implement the reform of the water supply network in which hydrogeologists have some responsibility. It is a common interest that the technical expectations regarding the water supply network should increase significantly in the future, by this serving the further improvement of drinking water service quality and reliability, and the renewal of the aging infrastructure of water works and distribution. To date the significant water loss in the distribution systems (in cases over 20-30%!) can negatively influence at certain places both the quality and quantity parameters of the water sources. As far as the perspective water resources considered our country is in a rather good condition. Taking into consideration the 2–2,5 million m^3/day water discharge from groundwater bodies, our country has approximately 1 million m^3/day total capacity perspective water resources, delineated mostly along the Danube and Tisza rivers' gravel terrace.

4.5. Utilization of mineral waters, therapeutic waters and thermal waters

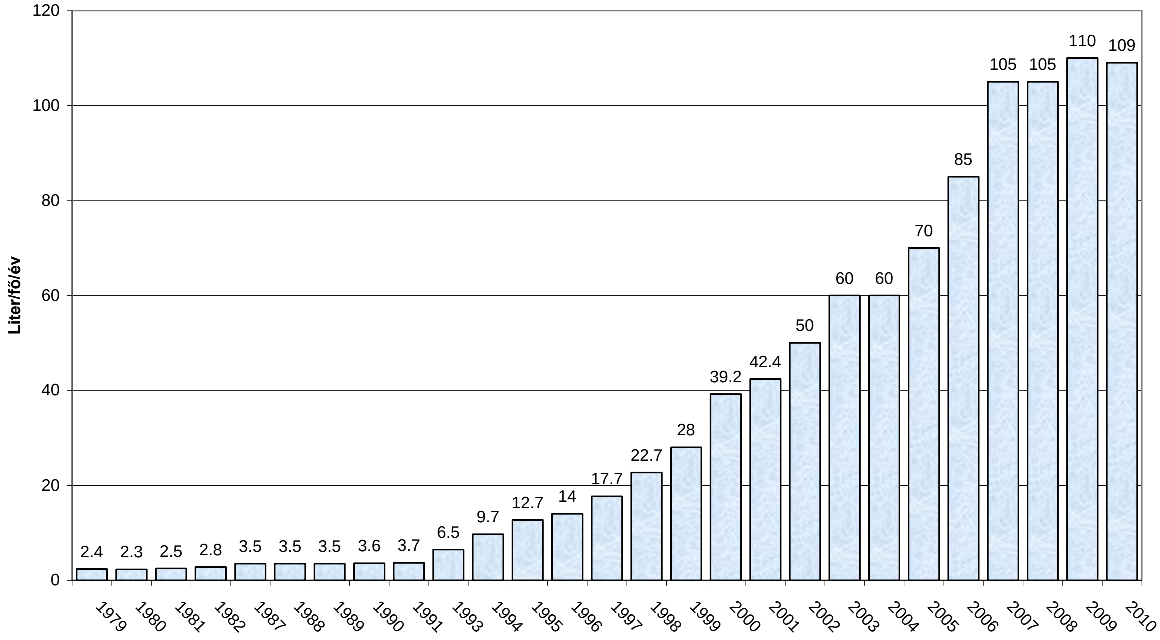
Hungary's mineral, therapeutic and thermal water resources are outstanding even in a global context, which has remarkable potential on macroeconomic scale. This natural resource can provide for several settlements and regions further progress and labor market development. It is also relevant that the qualitative and quantitative protection and sustainable abstraction of groundwater resources demands new scientific results, innovative technical solutions and interdisciplinary collaboration, wide scope of expert consultation and new water management strategy. The utilization and protection of the complex groundwater system of the Carpathian basin requires complex and transboundary approach, research and water management practice. There is a need for harmonized planning with international organizations and acting along international trends in the field of environmental friendly extension and quality improvement of mineral and therapeutic water supply and in meeting of medicinal, recreational and wellness requirements. Similar integrated approach is needed to increase the efficiency of geothermal energy utilization.

According to the domestic and European legislation, natural mineral water is a obtained from protected aquifer, clean and free of contamination in its source, has known mineral composition which can be considered constant within a range of natural fluctuation. It must comply with strict microbiological requirements as well. Mineral water can only be bottled on the site of abstraction, cannot be treated and should not contain added material except carbon dioxide. Mineral waters are officially approved.

Therapeutic water is a mineral water that has a medicinal effect due to its dissolved gas or mineral content. The health impact is proved for specific health infirmities by strict medical professional protocols. According to the registry of the National Directorate of Health Resorts and Spas, Hungary has 195 registered mineral waters and 220 approved therapeutic water sources. The Healing Hungary and Health Industry Program of the New Széchenyi Plan included the effective and diverse utilization of Hungary's especially rich thermal, mineral and therapeutic water resources and its geothermal capabilities.

In the last 20 years, the mineral water consumption increased significantly not just in Hungary but worldwide. Mineral water consumption is an important element of the healthy lifestyle concept. The domestic mineral water consumption in 2009 and 2010 was around 110 liter/capita/year (Figure 4-5). The excellent natural provisions are characterized by the fact that almost all mineral water classes can be found in Hungary. According to one's taste and health conditions one can choose from among sulphuric, radon containing, alkaline, sodium chlorite or sulfate containing, ferric, iodic and bromic mineral waters. Presently there are more than 50 domestic bottled mineral waters brands are commercially available. Mineral water is important not just for its medicinal effect on the human body but also provides raw material for the beauty industry (e.g. cosmetics based on natural mineral water). It is also worth mentioning that drinking water in certain regions of Hungary meet the quality requirements of mineral waters, although due to sanitational requirements they are usually treated and/or chlorinated. For this reason often the more expensive and better personalized bottled mineral waters are preferred against the cheaper and readily available tap water.

Figure 4-5 Consumption of mineral water per capita in Hungary (source: Hungarian Association and Product Union of mineral waters)



According to the registry of the National Directorate of Health Resorts and Spas, Hungary has approximately 1200 thermal wells, 70 medical spas, 5 medical caves, 5 locally extracted mud sources, 1 mofetta and 13 health resorts. In the international context, Hungary is considered to be in the top 5 countries in terms of thermal water resources. As the results of development, currently there are approximately 40 major, internationally acknowledged centers and resorts established on mineral and therapeutic water resources. Therapeutic water resources have a unique value on a global scale, considering the variety of medical effects. Balneology deals with the spa utilization of therapeutic water springs and therapeutic waters. During the medical bath cures on one hand the physical parameters of the water (e.g. temperature, pressure, buoyancy) have impact on human body. These effects are utilized during hydrotherapy. These impacts are supplemented by the dissolved mineral contents and elements of the therapeutic water.

In the future, hydrogeology must play major role to increase the use of geothermal energy sources. The thermal waters with temperatures above 30 °C has significant role in dredging and utilization of heat and energy. The situation is more complicated because the thermal waters of the Carpathian basin are often interconnected hydraulically with the aquifers used for drinking water purposes. Special water management strategy is needed to meet in a sustainable manner both the groundwater-based drinking water, medical and energy demands at a given location. The excellent geothermal potential of our country and the Carpathian basin, its hydrogeothermal systems and thermal water utilization options were introduced in numerous remarkable studies published during the past years. In Hungary, under the surface the average geothermal heat flux is approximately 90 mW/m^2, while the geothermal gradient ranges between 30–50 °C/km. Knowing this, one can determine the theoretically available total dynamic heat reserve, which exceeds geothermal 8000 MW. In spite of this, currently the actual utilization of geothermal energy is very low. The very heterogeneous geological and hydrogeological situations provide a good basis to extend the scope of various types of geothermal energy utilization methods. Hydrogeologist must expect unique features in the pore pressure values of the sites. The neogen thermal water bearing formations are usually pressurized. At various locations the pre-neogen formations and in the bedrock the pressurized level exceeds 50%, making the utilization alternatives more difficult and expensive.

The geological conditions are generally favorable (except karstic systems) for the installation of low enthalpy systems, with temperature ranges less than 30 °C, primarily for open (production and injection) and closed loop (borehole heat exchangers and soil collectors) heat pumps systems. Hungary’s alluvial formations are ideal for open system installations – which are especially interesting in hydrogeological terms – , where remarkable heat fluxes can be obtained due to excellent water bearing and favorable hydrogeological features and the shallow depth aquifers. These installations are capable of providing warm water heating for domestic and commercial buildings as well. For the installation of systems with borehole heat exchangers and soil collector systems, the upper 80–100 m (max. 250 m) thick layers are available (except karstic systems). These systems are capable of utilizing the stored and replenished heat of these mostly quaternary, pannonian and miocen layers. The most favorable areas of utilization for borehole heat exchangers are the already mentioned gravel terraces. In these sandy gravel layers instead of the average 60–70 W/m specific heat performance, the heat probes can reach up to 80–90 W/m heating and cooling capacity, if the water flow velocity reaches 100 m/year. It must be noted however, that on the same areas heat performance reached with open systems are higher than that of the borehole heat exchangers’. The smaller performance heat probe systems require the permission of the mining authority or a simplified building permit protocol, while for the installation of open systems a longer, more expensive and complex hydrogeological accreditation protocol is needed, which narrows down the scope of potential users. The obstacle for the spreading of vertical, closed probe systems is the geological formations. In unconsolidated and fine grained sedimentary formations (sand, silty sand, silt, and clay) considering the present drilling costs the installation of such systems is financially viable, with a return period of 8-12 years. With the involvement of investment subsidies, the return period can be decreased to 5-7 years. In solid pebble stone formations, volcanic and sedimentary formations, due to the increased drilling costs these systems cannot be installed in a financially profitable way even if the geological conditions were favorable. The main obstacle in extending the use of heat pump systems is the investment costs of the systems. In case of a more favorable subsidizing and conditioning system, the fast uptake of heat pump systems is anticipated.

The waters of medium enthalpy systems (temperature range 30-100°C) are utilized mainly in cascade-type municipal heating systems, municipal and industrial hot water supplies, in wellness and medical spas and in agricultural facilities (glass houses, plastic tunnels, stables, and dryers). According to the domestic distribution of thermal water bearing formations, one can conclude that Hungary's geothermal features are well over average in terms of medium enthalpy systems. In case of the most favorable locations at the Southern part of the Great Plain, from geological point of view practically every municipality could install medium enthalpy heat utilization units. It is also clear that the production rate of our thermal water resources at several locations is above the sustainable production volumes. At these sites we can register continuously decreasing water heads. Thus, in case of the energy utilization purpose thermal water discharges it is very important and legally binding to set up reinjection systems, which might cause conflicts of interest in areas, especially where the lack of injection (former practice) resulted significant financial benefits. For greater thermal water users (e.g. municipal public works) the financial benefit remains even if the infiltration system is installed. In case of outdated technologies or systems with one or two wells, the specific operational costs might exceed that of the natural gas heating systems, due to the installation of injection systems, especially if the accommodating formations are porosous. The protection of our groundwater systems however must have higher priority than the local financial interests. Due to the above mentioned hydrogeological reasons, the overproduction of the thermal aquifers on one hand might have unfavorable effect on the quality of our mineral and therapeutic water resources, on the other hand unfavorable changes of hydraulic heads may occur in the upper layers that serve as drinking water resources. For this reason, the technology of infiltration should be developed to reduce costs. However, from the water management perspective it is not tolerable that out of the approximately 50 million m^3/year energy driven thermal water production only approximately 1 million m^3 is reinjected to the underground formations. In the past, the cooled waters with often very high salt content have caused severe environmental stress and left the country through the major rivers. In the future, high priority must be given to the heat energy optimalisation of existing water discharges, to the planning and implementation cascade type utilization plants, and to increased utilization efficiency.

The ultimate purpose of the high enthalpy system installations (water temperature is above 100 °C) is electricity generation, or the joint utilization of 6-8 unit heat waste generated during 1 unit electricity production. Although there are numerous locations in the country (e.g. Fábiánsebestyén, Makói-árok, Békési-süllyedék, Derecskei-árok), where the available groundwater temperatures are suitable for energy protection with the temperatures of 180–200 °C, but such investments were not yet implemented in the Carpathian basin. Currently there are running national research projects to develop EGS- (HDR) type power plant. Its prototype operates in South Germany. Although during the safe operation numerous technical issues must be solved, the high depth EGS systems could be installed to the bedrock at many locations in Hungary. The great technical challenge is the generation of controlled fracturing in large volumes of rocks at great depth and approximately 250 °C temperature. The generations of such fracture systems can create unexceptable environmental risks at certain vulnerable areas.

5. Water quality assessment in the Hungarian River Basins

5.1. Introduction

The aim of measuring and analyzing the antropogenic load on waters is to indentify the relevant water management problems.

Following the methodology of ICPDR (International Commission for the Protection of the Danube River), MONERIS model (a half-empirical, conceptual model which was basically developed for the estimation of the total phosphorus and nitrogen emission, and it takes seven transportation routes into account) was used for the territorial overview of diffuse and point-source nutrient load (on the level of water-body and larger catchment). Large amount of data was retrieved from various sources to operate the model, which was applied for the period 2009-2012.

The MONERIS (Modelling Nutrient Emission into River Systems) model is applied by the ICPDR57 for modelling nutrient loads of the Danube River Basin, but on a larger (sub-unit level) territorial scale. The comparison of the results derived from modelling at different scale is the basis for getting a more realistic image of loads from other member states. At the same time, the received data can be the barrier of building a model that extends to every detail, so it would be desirable to develop and use a model that is adjusted to the national data supplement and follows the philosophy of MONERIS.

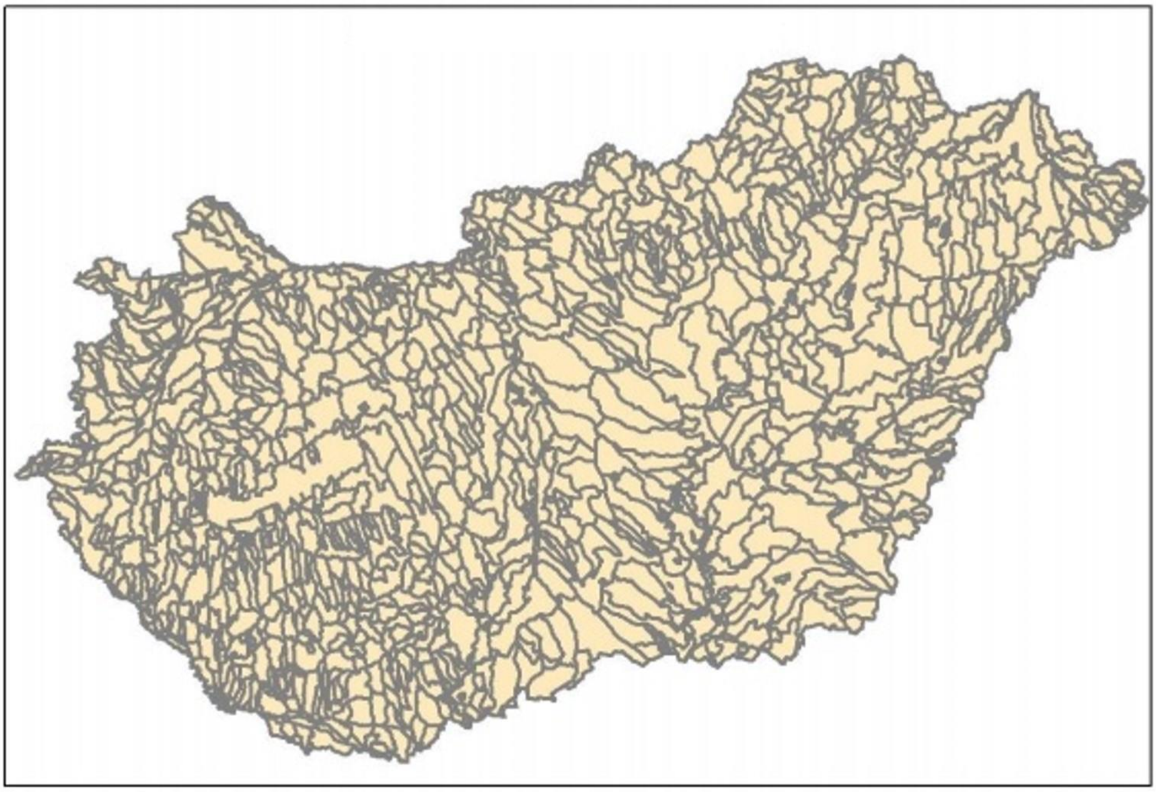
5.2. The modeling approach

The data used in the model was calibrated using date from Germany and validated using European water systems. Loads were summarized in two steps in the model, first emissions and loads were cumulated on a larger water-catchment level calculated by ICPDR and next the nutrient load was determined for the water-bodies. The objectives of the model include checking point source loads and loads predicted by diffuse source load models. The diffuse source load model estimates diffuse pressure for all catchments of all assigned water bodies (1078) of Hungary.

5.3. Representation of the study area

The area of Hungary can be divided into 4 sub-basins: the Danube (34,730 km2), the Tisza (46,380 km2), the Balaton (5,765 km2) and the Dráva (8,431 km2). According to the River Basin Management Plan, 42 planning subunits are distinguished, and 1078 surface water bodies are identified. The water bodies are the analytical units for the model calculations (Figure 5-1).

Figure 5-1 The analytical units used in MONERIS model in Hungary



The CORINE LC 2012 data set was the input data of the MONERIS land cover module. The data set incorporates 28 land cover classes for Hungary (Figure 5-2). However, it was necessary to harmonize the CORINEs classes with the related MONERIS land cover categories (Table 5-1).

The study area is mainly in agricultural use (79%), consisting primarily of of arable lands (58.7%) and pastures (10.3%). The overall proportion of vegetable gardens, fruit trees and vineyards is approximately 3.5%. In 2014, 5.3 million hectares (from the overall 7.4 million hectares of agricultural areas) were permanently used for agricultural production. For the period 2000–2012, the overall area of arable lands, fruit trees, vineyards, forests and wetlands shows a decreasing trend, while the overall area of meadows, pastures, complex agricultural cultivations and urban areas is increasing.

Figure 5-2 Land use in Hungary, Corine 2012

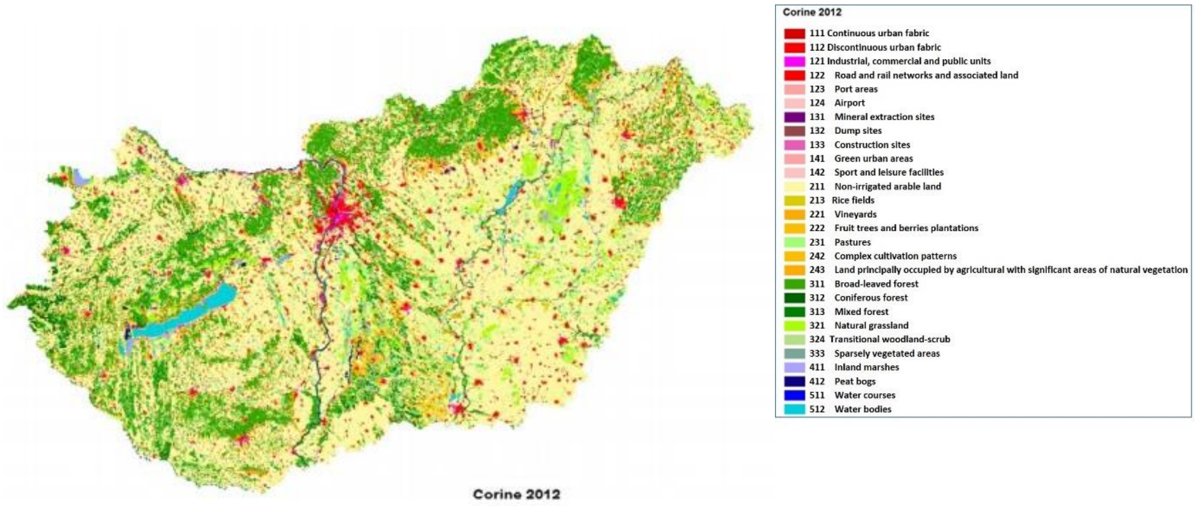


Table 5-1 Reclassification of Corine categories in conformity with input parameters of MONERIS model

categories of MONERIS	categories of Corine
1 Urban	111 112 121 122 124
2 Agricultural Area	211 212 213
3 Grassland	231
4 Natural coverage	141 221 222 223 241 242 243 311 312 313 321 322 323 324
5 Water surfaces	511 512
6 Mine field	131 132
7 Spread	331 332 333 334 335
8 Marsh, wetland	411 412 421 422 423

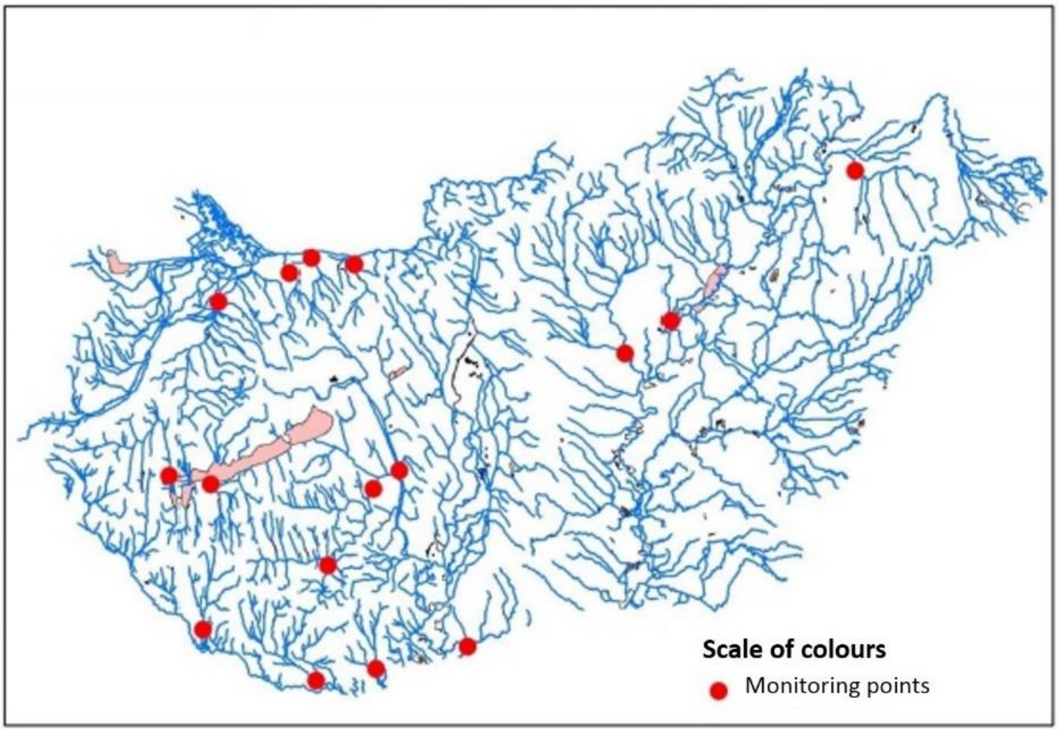
5.4. Data availability

The applied data shows a diverse picture since the data sources have different timescale (i.e. daily, monthly and annual). The parameters of the MONERIS model were set using data from the national water quality monitoring system from the period 2009–2012. The nutrient data for the analytical units were derived from the Hungarian Central Statistical Office‘s county statistics. Other national databases were used to satisfy the required specifications, e.g. waste water quality and discharge.

5.5. Results: Nutrients

The model was tested on individual monitoring points. The model results are compared with the national nutrient balance and the smaller sub-catchment monitoring points (Figure 5-3).

Figure 5-3 Purely inland runoff monitoring points used for checking the model



According to the monitoring points, the model underestimated the total nitrogen (with 30% on average) and the total phosphorus (with 25% on average) load. However, the tested sub-basins show similarity in their topography. In case of total nitrogen, the Figure 5-4 represents the scatter plot of the observed and estimated values. In case of total phosphorous the situation is almost the same (Fig. 5-5).

Figure 5-4 Comparison of calculated cumulative total N load with measured values for all well-investigated monitoring points

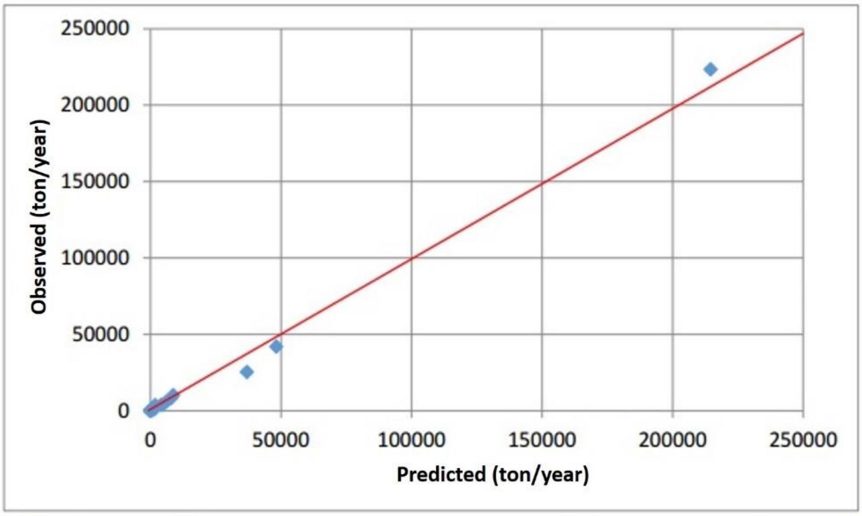
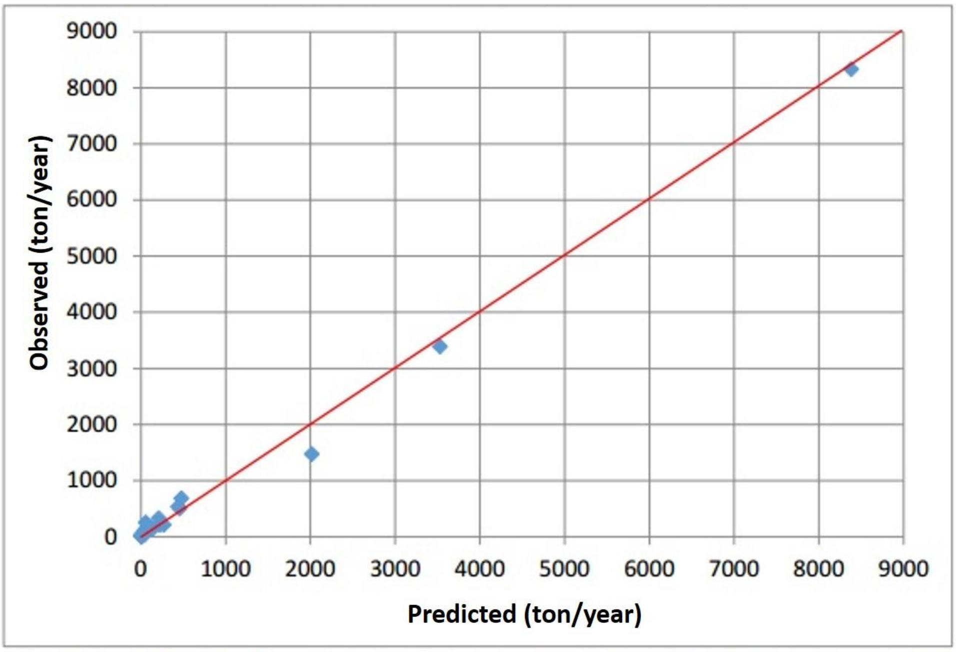


Figure 5-5 Comparison of calculated cumulative total P load with measured values for all well-investigated monitoring points



As next step, the model validation was expanded to other monitoring points. Although the further monitoring points also have reliable number of total nitrogen and phosphorous observations, there was a lack of discharge measurements. In these cases, the model calculated discharges were used to calculate the total nitrogen and phosphorous concentrations. The scatter plots (Figures 5-6 and 5-7) show that the differences between the modeled and observed values are relatively low. The accuracy of the model estimation is 97% and 105 % on average for total nitrogen and total phosphorous, respectively. This means that the model overestimates the phosphorous concentration with 5%.

Figure 5-6 Comparison of measured and calculated loads for all monitoring points where appropriate number of (at least monthly) monitoring data is available, but not necessarily data on runoff - TN

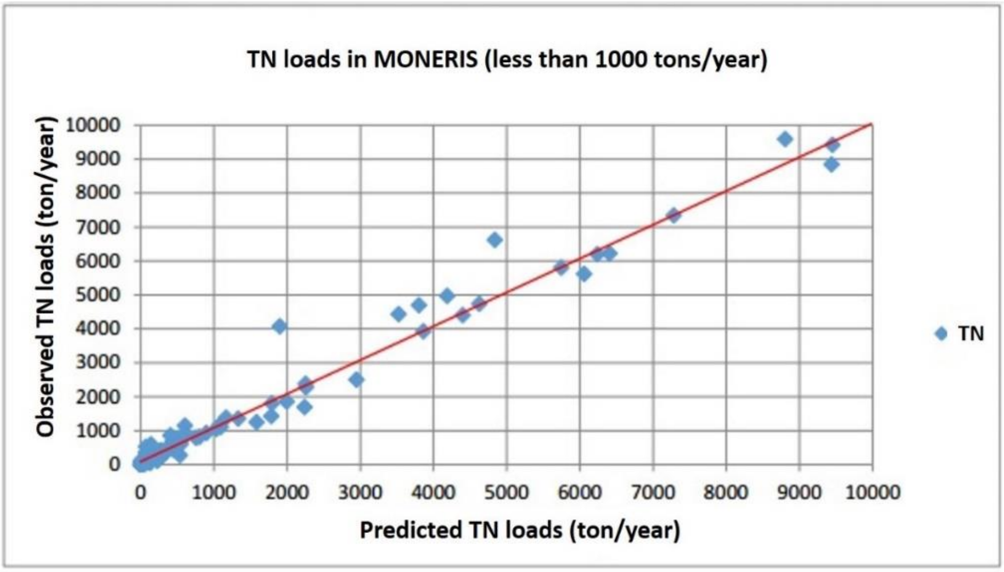
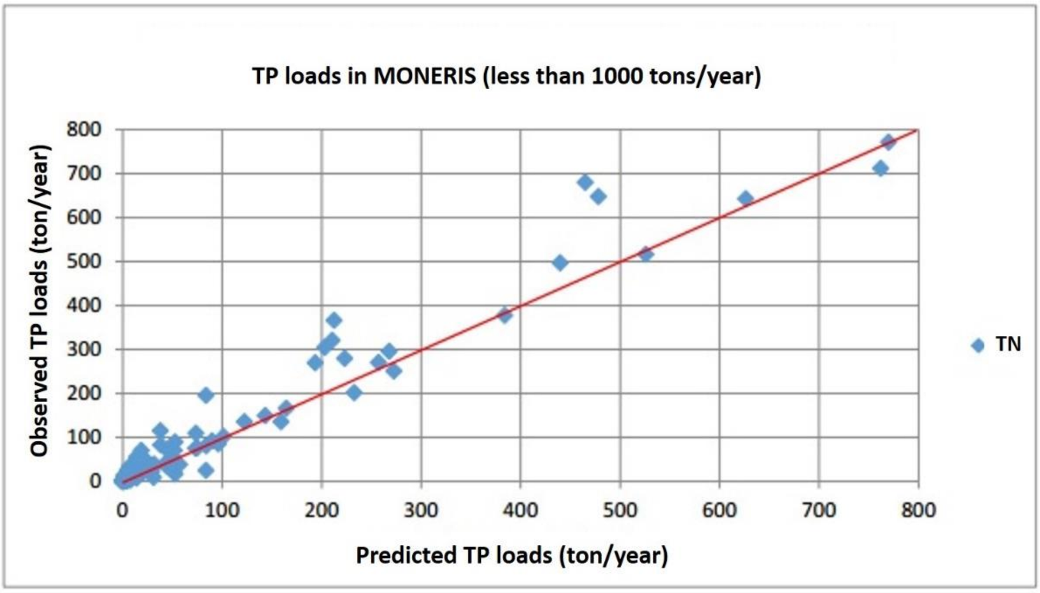


Figure 5-7 Comparison of measured and calculated loads for all monitoring points where appropriate number of (at least monthly) monitoring data is available, but not necessarily data on runoff – TP



Comparing MONERIS models made by ICPDR and Hungary (Table 5-2) with values of loads calculated for the period 2009-2012, it can be generally stated that differences of evaluation are due to the use of different scales. ICPDR model predicted about 8 thousand tons higher nitrogen load and 600 tons lower phosphorus load. The biggest insecurity is in the amount of groundwater-transported nitrogen. Most probably this transportation mode is responsible for the significant under- or (in case of highland watercourses) overestimation experienced at many control sites (Figure 5-8). On average, 20 % underestimation is typical at the investigated sites. As Figure 5-9 shows, in case of phosphorus the variance is not so high, but more than 20% differences are also found on the different transmitting routes.

Overall, in case of point sources of nitrogen emissions the estimates of the Hungarian model were better than ICPDR.

Table 5-2 National cumulative nutrient emissions in ICPDR program and with MONERIS model run for watershed management planning

		Atmospheric deposition	*Surface runoff*	*Tile drainage*	*Erosion*	*Groundwater*	*Point sources*	*Paved urban areas*	*Total*
					ton/year				
TN	**ICPDR**	**1605**	**3403**	**483**	**1006**	**16143**	**7852**	**2527**	**33019**
	HUN	**1646**	**886**	**555**	**2761**	**7075**	**10314**	**1876**	**25113**
TP	**ICPDR**	**0**	**19**	**4**	**773**	**585**	**1062**	**541**	**2984**
	HUN	**60**	**43**	**4**	**1440**	**263**	**1253**	**460**	**3523**

Figure 5-8 TN emissions according to the two MONERIS models

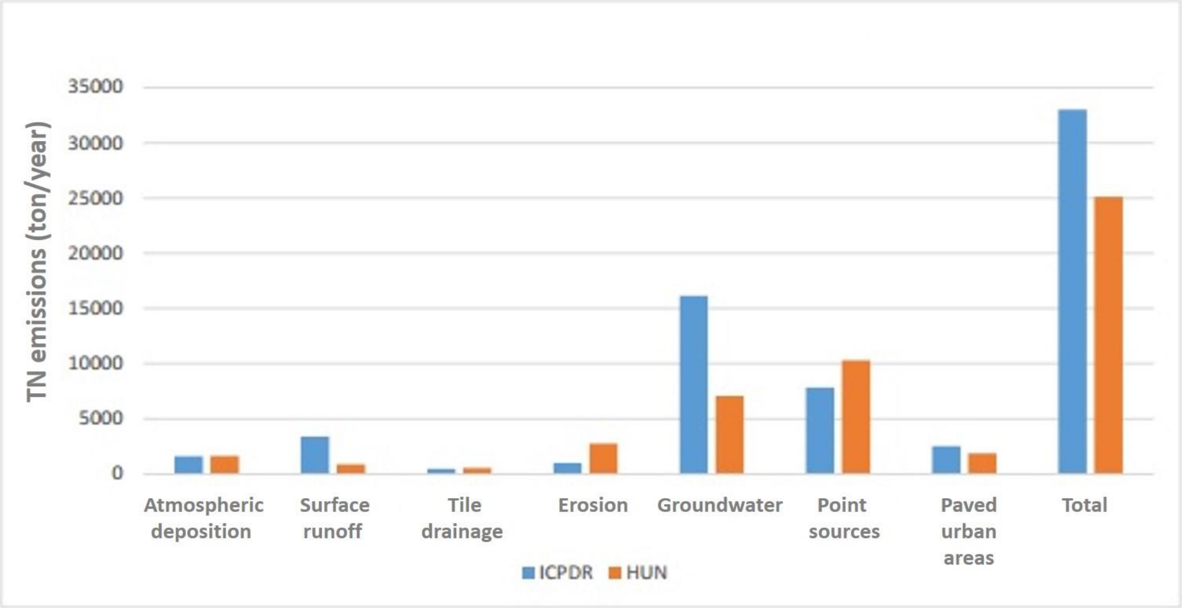
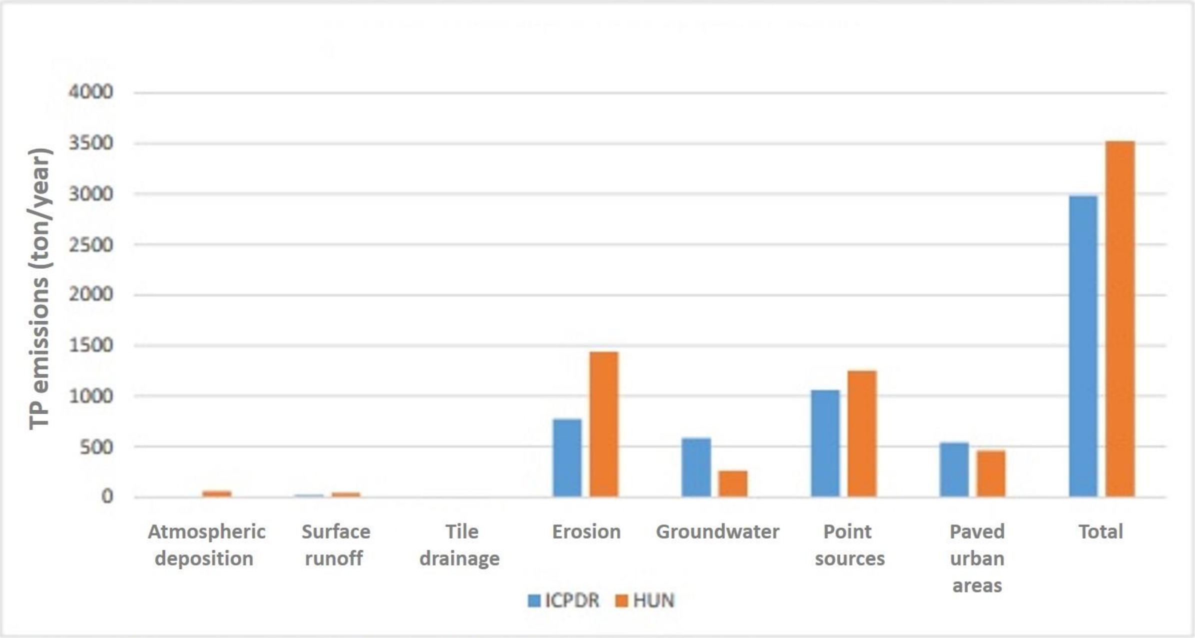


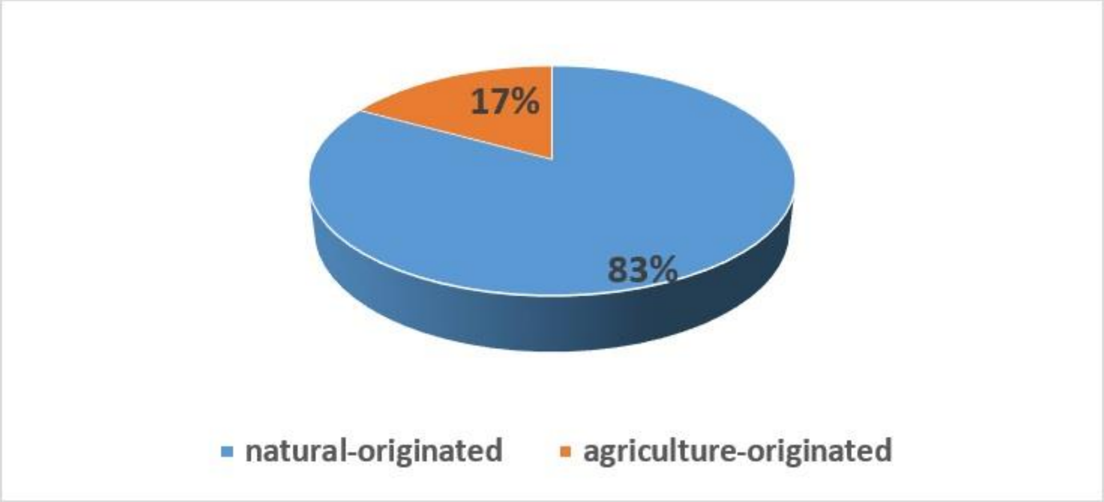
Figure 5-9 TP emissions according to the two MONERIS models



5.6. Results: Sediments

MONERIS model calculates the amount of alluvium getting into surface waters on the basis of land use, soil erosion and the landscape. Two sediment categories are distinguished, agriculture-originated and sediment from areas covered by natural vegetation. Results of calculations of the model are as follows: Total eroded alluvium is 2.62 million tons/year, of which natural-originated is 2.18 million tons/year and agriculture-originated is 0.44 million tons/year (Figure 5-10).

Figure 5-10 Distribution of the total eroded sediment



Calculation of soil-erosion is made by USLE (Universal Soil Loss Equation) equation adapted to the Hungarian circumstances. The R factor representing the erosion-energy of precipitation is calculated from the yearly amount of precipitation and from proportion of the different intensity classes of precipitation along the year. LS factor expressing the effect of terrain conditions can be calculated from cell size (slope length) and slope itself. Other parameter values are determined by the type of soil and land use, conditions of cultivation, slope and humus content.

The USLE equation:

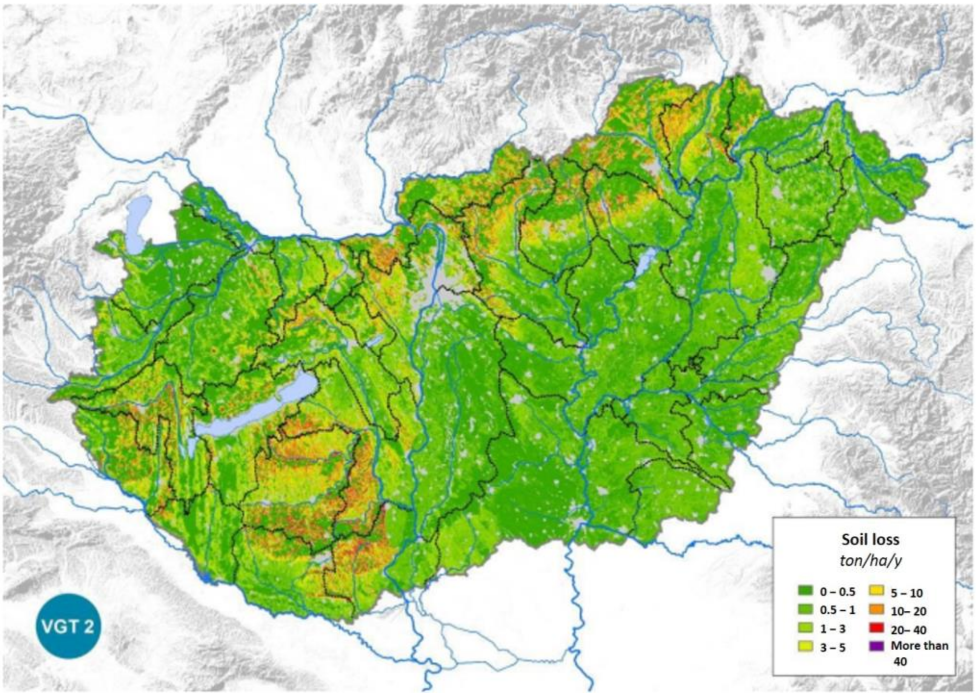
$$A = R * K * LS * C * P$$

Where,

A= predicted soil loss (tons per hectare per year)
R= rainfall and runoff factor
K= soil erodibility factor
LS= topographic factor (length and steepness)
C= crop and cover management factor
P= conservation practice factor

Soil erosion calculated to Hungary (Figure 5-11) is the main source of diffuse phosphorus load.

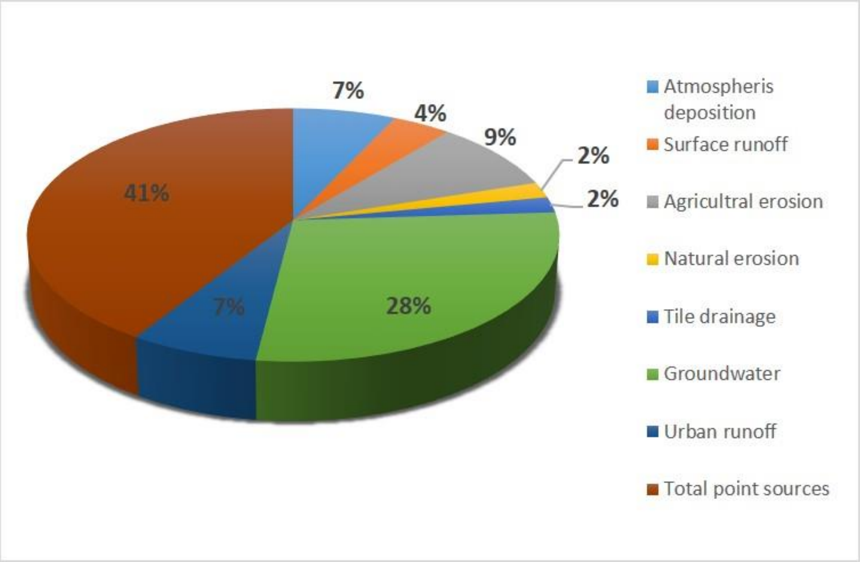
Figure 5-11 Soil loss map of Hungary



5.7. Analysis of the nutrient pollution in the Hungarian River Basins

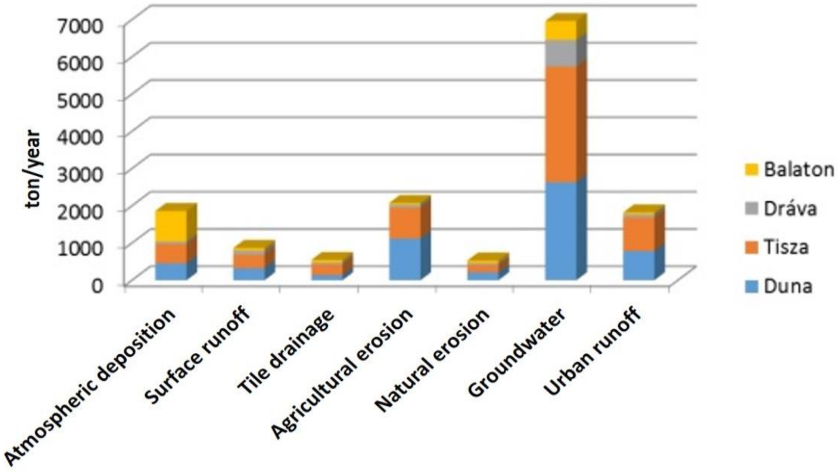
The cumulated total nitrogen load of surface waters in Hungary is 25.3 thousand tons/year in the period 2009-2012, of which 59% is from diffuse source (15 thousand tons/year).
As far as routes of pressure are concerned, the most important nitrogen source is groundwater, which stands for almost half of the total diffuse load (47%). It is important to mention that the Model probably underestimates this rate, because data taken into account to calculated long-term nitrogen balance is a regional average. The pressures linked closely to agriculture are the second major source of nitrogen (9%). Mostly organic nitrogen gets into surface water by agricultural erosion and surface runoff. Further significant pressures (7-7% of the total load) originate from atmospheric deposition and from urban pollution (Figure 5-12).

Figure 5-12 Proportion of integrated TN load by the different routes concerned all surface water bodies of Hungary in the percentage of the total pressure



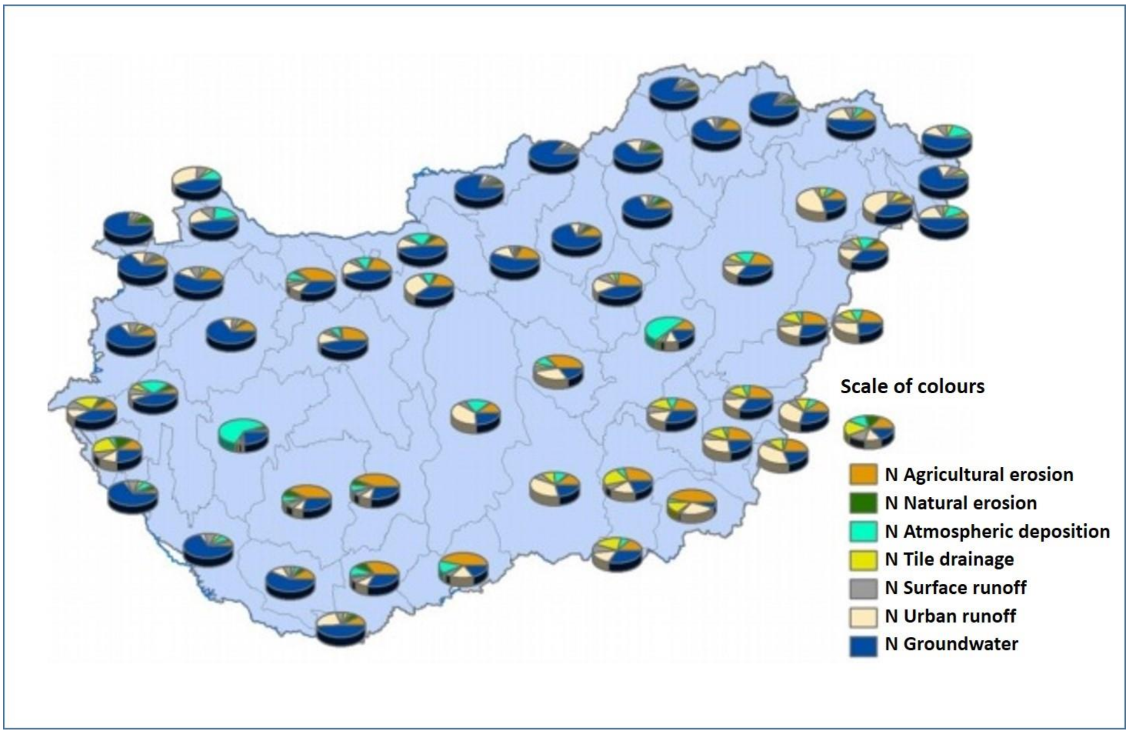
The spatial distribution of the cumulative nitrogen load on a large scale reflects well the division according to the four sub-basins (Figure 5-13) The majority of the load is on the Danube and the Tisza rivers. In the Danube sub-basin, load from erosion, in the Tisza sub-basin the load from groundwater is the main driver. The distribution of the various transportation pathways of nutrient load shows the significant contribution of groundwater, and the load from urban runoff is close to the quantity of diffuse nutritent pollution coming of agricultural erosion. In case of the Lake Balaton the dominance of load from atmospheric deposition is evident. The surface area of the lake explains this phenomenon, as the nitrogen content of the precipitation is a direct load.

Figure 5-13 Average TN loads for all surface water bodies of sub-catchments of Hungary for the period 2009-2012 by the different routes of pressure.



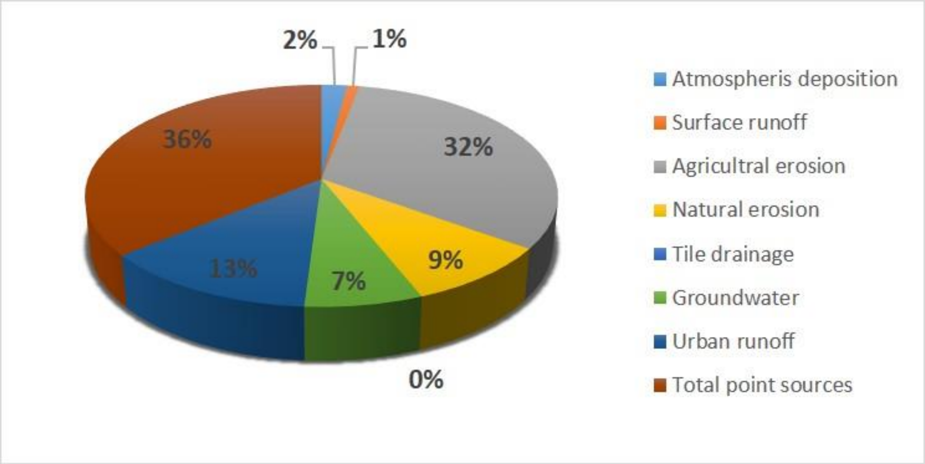
Regional differences are observed in the nitrogen load pathways of surface water bodies (Figure 5-14). In the Western part of the country and Northern hills nitrogen load from groundwater is more dominant, while in the central part between the Danube and the Tisza rivers and on the Great Plain urban runoff and agricultural erosion have higher relevance.

Figure 5-14 Average proportion of TN load for surface water bodies of Hungary by the different routes for the period 2009-2012, by subunits.



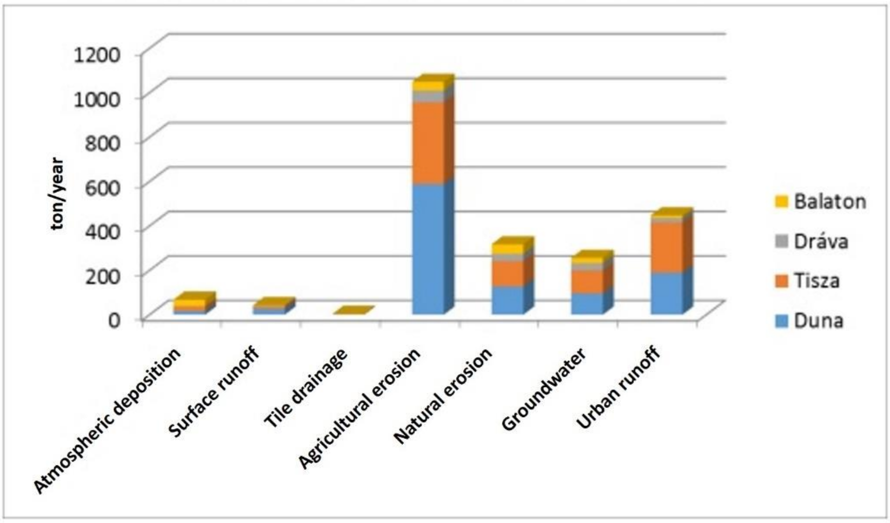
All together, 3530 tons/year phosphorus load is identified on the average of 4 years for the whole country, of which 1250 tons/year is originated from point sources and 2280 tons/year (almost 65 %) from diffuse sources (Figure 5-15). Among the pressure routes, agricultural erosion is the most significant one (32%). In contrast with nitrogen load, groundwater as a transmitting agent is not so important (7%).

Figure 5-15 Proportion of cumulated TP load by the different routes concerned all surface water bodies of Hungary in the percentage of the total pressure



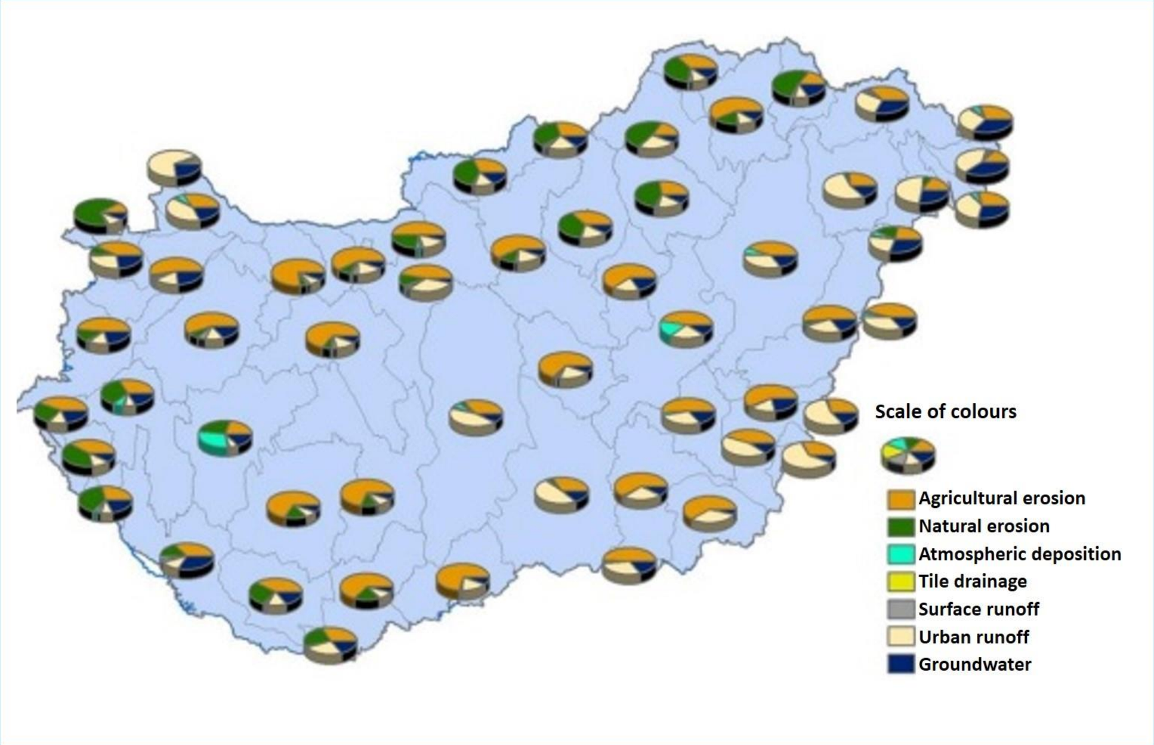
The Danube and the Tisza rivers are responsible for most of total phosphorus load (Figure 5-16). In case of the Danube sub-catchment agricultural erosion, in case of the Tisza sub-catchment urban runoff is the main source of phosphorus load. There is no visible difference in ratio of phosphorus load originated from groundwater of the different catchments.

Figure 5-16 Average TP loads for all surface water bodies of partial water-catchments of Hungary for the period 2009-2012 by the different routes of pressure.



The geographic distribution of loads by the different pollution routes (Figure 5-17) reflects the landscape formations of Hungary. On the plains, load from groundwater and from runoffs are typical, on hilly parts, soil erosion is the dominant source. Even though on the plains the erosion-potential is low, in several catchments it is the main source of pollution (e.g. Southern part of the Great Plain). This is due to the fact that according to modelled calculations phosphorus content of groundwater and urban runoff are so low in these areas, that overall the slight pressures are proportioned similarly to the hilly parts. There are small catchments where natural erosion is the most important factor for phosphorus load (e.g. Ikva, Bodrog, Rinya-mente), which is due to the larger proportion of forest cover. Areas that are mostly under the pressure of agricultural erosion are in the Northwestern part (Átal-ér, Concó, Marcal) and the Southwestern part (e.g. Mezőföld, Kapos catchment) of the country and the Northern part of the intertributary region between the Danube and the Tisza rivers.

Fgure 5-17 Average proportion of TP loads for surface water bodies of Hungary by the different routes for the period 2009-2012, by subunits



5.8. Conclusions

The MONERIS model was applied in Hungary to determine nutrient emissions, and estimate the nitrogen and phosphorus loads in surface water bodies in different scales. Further validation of the model should be performed for the different Hungarian watersheds, but this requires more data which is not available in Hungary at this moment. Improvement of adjusting the parameters of the model is in progress.

6. Data on chemicals in the Hungarian waters

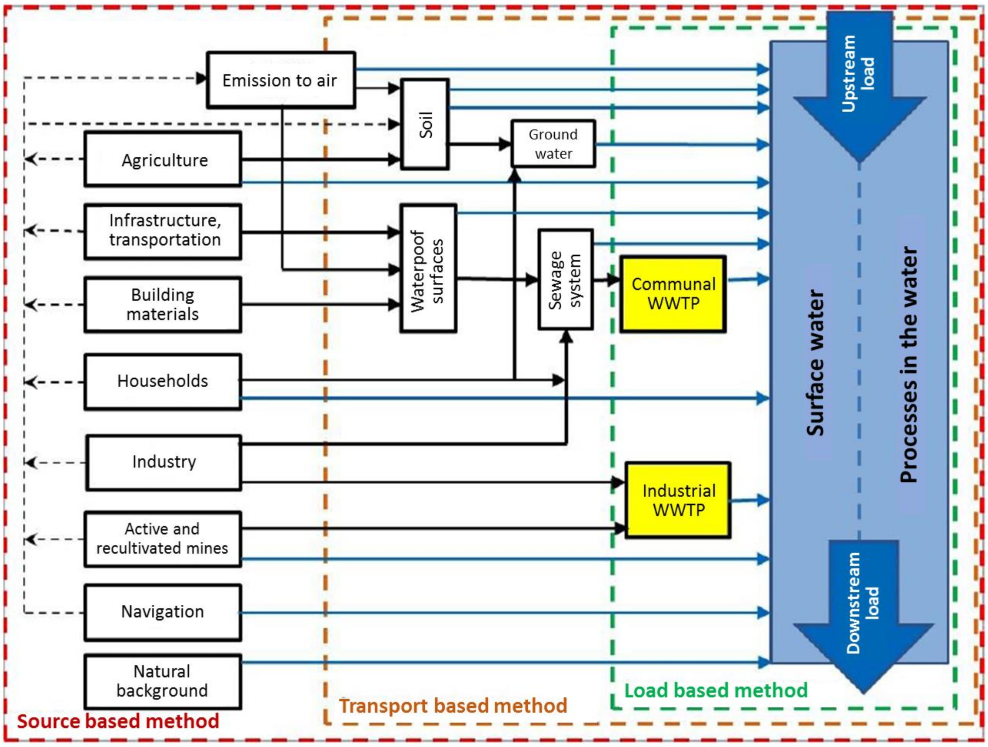
6.1. Introduction

Chemicals of natural or antropogenic origin in surface and subsurface water may pose a risk to human health and the environment. Human activities, such as agriculture, industry, mining, transportation and community services contribute to contamination via various transport pathways (Figure 6-1).

The present chapter summarizes the main sources of contamination (point sources and diffuse), their relative load, and identifies priority compounds currently monitored or proposed for monitoring.

The main source of data was the revised Hungarian River Basin Management Plan adopted by the Hungarian Parliament in March 2016. The assessment covers the 2010-2012 period, the last one with complete analysed monitoring datasets.

Figure 6-1 Transport pathways of hazardous chemicals and the possible methodologies of categorisation



The load based method calculates diffuse emission from difference of the upstream load and point-source emission. The pathway based method estimates the load by transportation pathways. This is used for instance for the estimation of heavy metal load, as a large proportion of it is derived from precipitation runoff and other not well defined, combined sources. The source based method follows the chemicals from manufacturing through use to point and diffuse pollution. All three methods can be used to derive a list of relevant substances for water monitoring.

6.2. Chemicals in water

Relevant substances fulfill one of the following criteria:

- Hinders achieving good status for at least one water body (criteria 1)
- Exceeds the half of the environmental quality standard at least in two water bodies (criteria 2)
- Exhibits an increasing trend according to water monitoring results
- Point source emission or manufacturing data renders it significant.

Relevant substances identified from surface water monitoring are listed in Table 6-1. Surface water monitoring points used for hazardous substance measurements are shown in Figure 2-1.

Table6-1 Relevant hazardous substances in surface water

Hazardous substance	Exceedance by water body	Primary use	Sector	Average over EQS/2[a]	Maximum EQS/2	Criteria of inclusion[b]
Mercury and mercury compounds	24	chloroalkali industry	industry	individual classifi-cation	individual classifi-cation	1.
Cadmium and cadmium compounds	46	galvanic industry	industry	155	159	1.
Nickel and nickel compounds	0/33	metallurgy, metal processing	industry	12/137	0/39	2.
Lead and lead compounds	25	galvanic industry, production and dissembling of batteries	industry	64/145	0/94	1.
Trichloromethane	1	solvent and base material in chemical industry	industry	16	0	1.
Tetrachloroethylene	0	solvent and base material in chemical industry	industry	2	0	2.
Di(2-ethylhexyl) phthalate (DEHP)	0	plastic products	industry	12	0	
Nonylphenol (4-nonyphenol)	1	herbicide	industry	6	6	1.
Diuron	1	herbicide, detergent	agriculture	10	7	1.

		degradation product				
Endosulfan	3	herbicide, insecticide	agriculture	3	7	1.
Atrazine	0	herbicide	agriculture	1	3	2.
HCH	0	herbicide	agriculture	2	6	2.
Hexachlorobenzene	0/1	herbicide, base material chemical industry	agriculture, industry	2/0	2	2.
Anthracene	1/8	processing of coal-tar, pyrolysis	industry	2	5/22	1.
Fluoranthene	3/78	petroleum industry, asphalt production pyrolysis	industry	53/198	17/138	1.
Benz(a)pyrene	0/0	petroleum industry, asphalt production pyrolysis	industry	2/28	3/1	2.
Benz(b)fluoranthene Benz(k)fluoranthene	0	petroleum industry, asphalt producion, pyrolysis	industry	22	0	2.

[a] EQS: environmental quality standard

[b] 1. Hinders achieving good status for at least one water body, 2. Exceeds the half of the environmental quality standard at least in two water bodies

The list of relevant substances in groundwater was compiled using monitoring data from 2000-2012 (Table 6-2). Main categories of substances where the quality standards shall be defined are pesticides and their relevant metabolites, ions of natural or antropogenic origin (arsenic, lead, cadmium, mercury), and industrial micropollutants (e.g tri- and tetrachloroethene).

Diffuse pesticide pollution was investigated by the analysis of over 40000 water samples since 2008. Altogether, 80 pesticide compounds were targeted from the following categories: DDT/DDD/DDE, drines, phosphate esters, phenoxy-carboxylic acids, triazines, carbamates, pentachloro-benzene, other pesticides (Figure 6-2).

All analyzed pesticides were below the limit of detection in 93 % of the samples. Atrazine and other triazines were present in over half of the positive measurements. Pesticide concentration exceeded the threshold value in 11 % of the positive samples (17 % of the samples containing triazines). Overall, no groundwater body was classified poor as a result of diffuse pesticide pollution.

Figure 6-2 Number of pesticides meausrements below and above the limit of detection in Hungary in the period 2008-2013

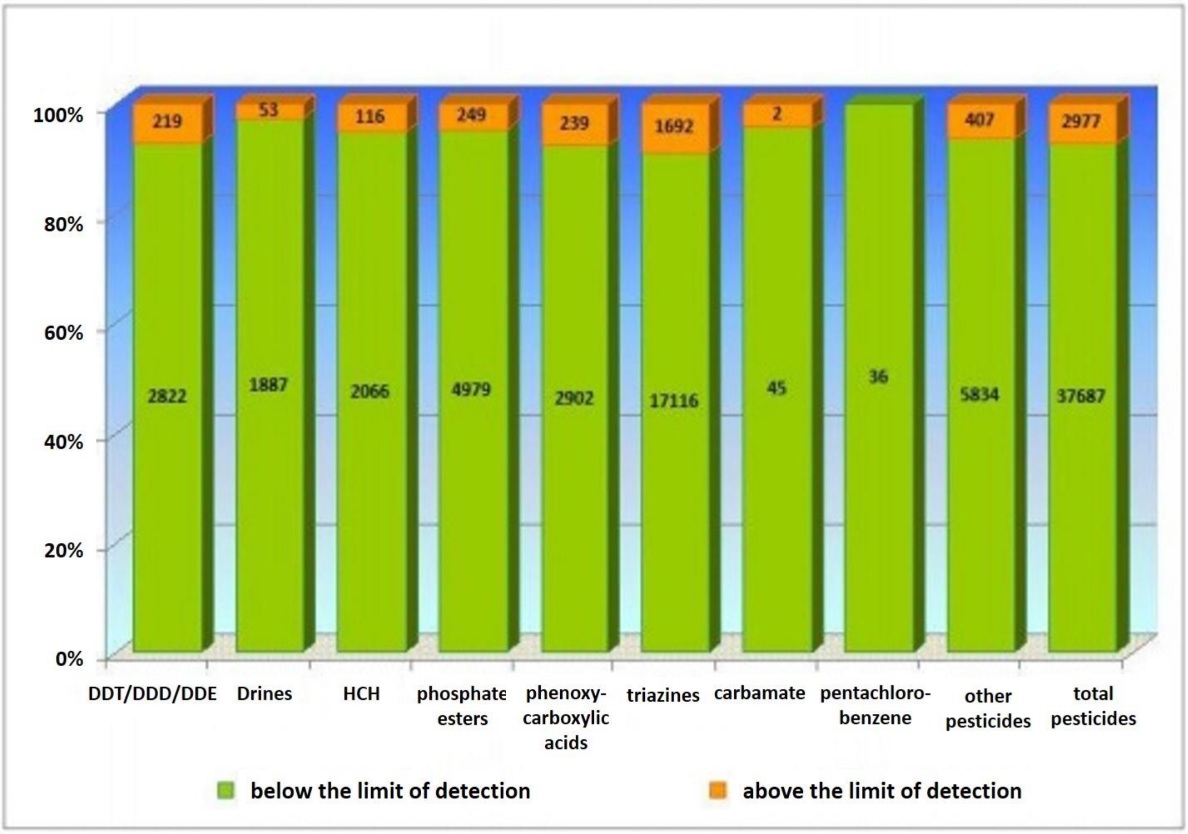


Table 6-2 Hazardous substances detected in groundwater (2000-2012)

Compound	Use
1,3-dichloro-propan-2-ol	Chemical and pharmaceutical industry
2,4,5-trichloro-toluene	Chemical and pharmaceutical industry
2-chloro-ethanol	Chemical industry
2-chloroethyl-vinyl-etherKlóretil-vinil-éter	Chemical and pharmaceutical industry
4-methyl-2-pentanone (izobutyl-ketone)	Chemical industry, petrol production, octan increase
Acetone	Chemical industry, paint industry
Acrylamide	Chemical industry, plastics
Alkyl-benzenes (ethyl, isopropyl, 1,2-, 1,3-, 1,4-methyl-ethyl, 1,2-, 1,4-diethyl, 1,2,3-, 1,2,4- and 1,2,5-trimethyl, 1,3,5-triethyl, 1,3-diisopropyl, n-propyl, n-butyl, sec-butyl, terc-butyl)	Chemical and pharmaceutical industry
Alkyl-toluenes (2-, 3-, 4- ethyl, isopropyl)	Chemical and pharmaceutical industry
Benzene	Chemical and pharmaceutical industry

Bromobenzene	Chemical industry
Chlorobenzenes (monochloro,1,2-, 1,3-, 1,4-dichloro; 1,2,3, 1,2,4- and 1,3,5-trichloro,1,2,3,4-, 1,2,3,5-tetrachloro, pentachloro, hexachloro)	Chemical and pharmaceutical industry, pesticide production, agriculture
Chloroethenes (1,1-dichloro, cis and trans 1,2-dichloro, trichloro, tetrachloro)	Chemical industry, galvanisation, surface treatment, paints, drycleaning
Chloronaphtalenes (1- and 2-chloro)	Chemical and pharmaceutical industry
Chlorophenols (2-,3-,4-monochloro, 2,3-, 2,4-, 2,5-, 2,6-, 3,4-,3,5-dichloro, 2,3,4-, 2,3,5-, 2,3,6-, 2,4,5-, 2,4,6-, 3,4,5-trichloro, 2,3,4,5-, 2,3,5,6-tetrachloro, pentachloro)	Chemical and pharmaceutical industry, pesticide production
Chloropropenes (1,1-, 1,3-, 2,3-dichloro)	Chemical and pharmaceutical industry
Cyclohexane	Chemical and pharmaceutical industry
EPH (C13-C40)	Chemical and petroleum industry, petrol production, solvent
Epichlorhydrin	Chemical industry, plastics
Ethanol	Chemical industry, solvent
Ethyl-acetate	Chemical industry, paints, solvent
Halogenated ethanes (monochloro, 1,1-dichloro, 1,2-dibromo, 1,1,1- and 1,1,2-trichloro, 1,1,2,2-tetrachloro, 1,1,2-trichloro-trifluoro)	Chemical industry, galvanisation, surface treatment, refridgerators, drycleaning
Halogenated propanes (1,2-, 1,3-, 2,2-dichloro, 1,2,3-trichloro, 1,2-dibromo-3-chloro)	Chemical and pharmaceutical industry
Halomethanes (bromo, chloro, dibromo, dichloro, bromo-chloro, bromo-dichloro, dichloro-bromo, bromoform, difluor-dichloro, fluor-trichloro, chlorofom, tetrachloro)	Chemical and pharmaceutical industry, refridgerators, surface treatment, galvanization
Hexachloro-butadien	Chemical industry, tire manufacturing
Hydroxybenzenes (1,2-dihydroxybenzene (catechol), 1,3-dihydroxybenzene (rezorcin)	Chemical and pharmaceutical industry
Methanol	Chemical industry
Methylnaphtalenes (1- and 2-methyl)	Chemical and pharmaceutical industry
Methyl-phenols (2-methyl (o-cresol), 3-methyl (m-cresol), 4-methyl (p-cresol)	Chemical and pharmaceutical industry
Naphtalene-suphonates (1-, 2-mono, 1,5-, 1,6-, 2,6-, 2,7-di, 1,3,5-, 1,3,6-, 1,3,7-tri-	Chemical industry, detergent
Naphthalene	Chemical and pharmaceutical industry
Nonylphenols	Chemical industry, detergent

Octylphenols	Chemical industry, detergent
PAH compounds: acenaphthene, acenaphthylene, anthracene, benzanthracene, benz(a)pyrene, benz(b)fluoranthene, benz(e)pyrene, benz(g,h,i)-perylene, benz(k)-fluoranthene, dibenzathracene, phenanthrene, fluoranthene, fluorene, indenopyrene, chrysene, pyrene,	Coal industry
PCBs (PCB-101, PCB-118, PCB-138, PCB-153, PCB-180, PCB-28, PCB-52)	Hydraulic oil, plastic softener, dielectric (prohibited)
Pesticides and metabolites: 2,4-Dichlorophenoxyacetic acid (2,4 D) 2,4,5-Trichlorophenoxyacetic acid (2,4,5T) acetochlor, AD67, aldrine, alfametrine, ametrine, atrazine, benefine, benfluraline, bentazon, butilate, cycloate, cypermethrin, DDDs, DDEs, DDTs, desethyl-atrazine, desethyl-terbutilazine, desisopropyl-atrazine, diazinone, dieldrine, diethyltoluamide, dicamba, dichlorprop, dimetoate, diuron, endosuphane, endosulphane-I (alpha), endosulphane-II (beta), endrin, alpha-HCH, beta-HCH, gamma-HCH (lindane), delta-HCH, epsylon-lindane (e-HCH), EPTC, esfenvalerate, ethylparation,ethyon, fenarimol, fenpropatrin, folpet, phorate, heptachlor, heptachlor epoxide, hexazinon, carbofuran, chlordane, chlorpyrifos, chlortalonil, lambda-cyhalothrin, linuron, malathion MCPA, methyl-parathion, metolachlor, metoxichlor, metribuzin, molinate, napropamid, pendimetalin, pentaconazol, pyrimifos-methyl, pyrimicarb, prometrin, propachlor, propazine, propisochlor, satochlor, simazine, secbumeton, terbumeton, terbutrin, trifluarin, vincosolin	Agriculture, pesticides
Phenol	Chemical and pharmaceutical industry
Pyridine	Chemical industry
Styrene	Chemical industry, plastics
Tetrahydrofuran	Chemical industry, plastics, glue
Tetrahydrotiophen	Chemical industry, detergent
Tiophen	Chemical industry
Toluene	Chemical and pharmaceutical industry
Vinyl-chlorid	Chemical industry, plastics
VPH (C5-C12)	Chemical and petroleum industry, petrol production, solvent
Xylols	Chemical and pharmaceutical industry

6.3. Sources of contamination

Water pollution is categorized by origin as point source and diffuse source contamination. Point sources by definition are emissions from a well-defined activity, located in a confined area. Diffuse pollution comes from a wider area usually in small concentration, the emission is dispersed and its exact location is unknown. Diffuse pollution is usually the result of intense land use (agricultural or urban). Though the individual emission in this case is usually low, the aggregated impact is significant.

One of the highest priority point sources (due to the volume of emission) is communal sewage, mainly as a source of nutrient and organic matter load, but may also contribute to hazardous chemical contamination (e.g. metals, salts, antibiotics and other pharmaceuticals, household chemicals and personal care products).

Approximately 75 % of the population is connected to centralized public sewage system. Since the start of operation of the Budapest Central Wastewater Treatment Plant in 2009, treatment ratio is close to 100 %. Less than 2 % of the sewage is treated only mechanically, 97.4 % receives at least secondary, and 73 % tertiary treatment. Under legal obligation, all municipalities over 2000 person equivalent (PE) are required to collect and treat sewage at least by biological treatment.

Nutrient emission from communal sewage treatment is monitored and reported (BOD, COD, total N, total P, salt and particulate matter) by treatment plant. However, data on hazardous substance emission is scarce. Figure 6-3 indicates the overall estimated impact of treated sewage emission on surface water quality (including hazardous substances), and Table 6-3 lists the emissions from communal wastewater.

Figure 6-3 Impact of communal sewage emission on water quality

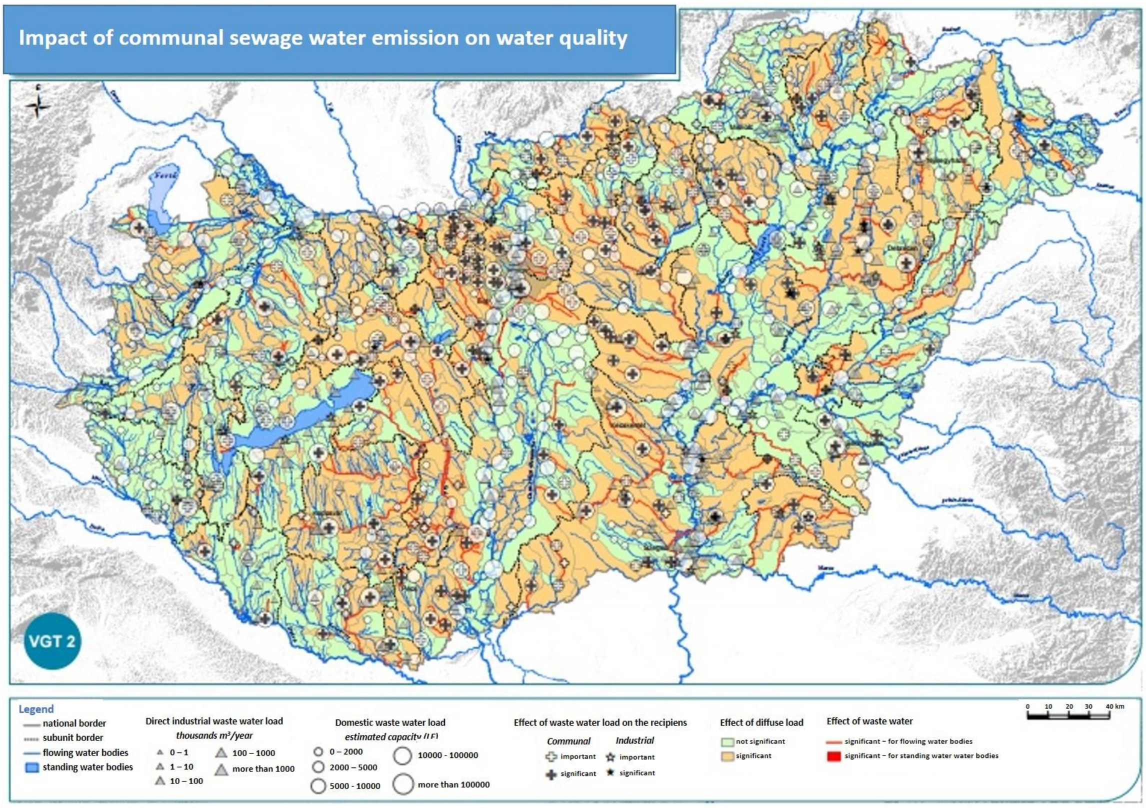


Table 6-3 Hazardous substance emission of communal wastewater treatment plants, 2010

Category	Number of records	Pressure on surface water kg/year	Pressure on soil kg/year	Measured components
Cyanides	1	0,6	n.a.	All cyanides (1)
Other non categorized substances	3	3118	125	Ethyl-mercaptan (1), surfactants (reacting with methylen blue) (2)
Semi-metals and metals	116	16311	200	Chromium (VI) (1), total aluminium (1), total barium (1), total silver (3), total mercury (compounds as Hg) (21), total cadmium (compounds as Cd) (18), total cobalt (1), total nickel (30), total lead (24), total iron
Phenols	8	3729	n.a.	Phenol (3), phenols (phenol index) (5)
Fluorids	3	498	n.a.	Fluorids (3)
Oils, greases	383	1008380	18476	Organic solvent extract (extractible oils and greases), total aliphatic hydrocarbons (TPH) C5-C40; aliphatic hydrocarbons used as a fuel C10-C32 (1)

Urban precipitation runoff is an additional, though not well characterized contamination source. Runoff may carry rubbish, petroleum compounds, salts, and contaminants from air deposition (e.g. heavy metals) (Table 6-4).

Table 6-4 Contaminants from urban precipitation runoff

Pollutant	Source
Rubbish, solid materials	Construction works, erosion from unpaved surfaces, air deposition (of transportation and industrial emission), built environment deterioration, stormwater outlets
Oxigen demanding (organic, degradable) substances	Plant debris (leaves, grass), animal feces, street waste and other organics
Microbial contaminants, pathogens	Animal feces, combined sewage outlets
Nutrients (N, P)	Air deposition, erosion of unpaved surfaces, combined sewage, fertilizer used in gardens or parks
Heavy metals (Zn, Cu, Cd, Ni, Cr, Pb)	Air deposition (of transportation and industrial emission), outdoor metal objects (e.g. gutters), drainage of waste dumps
Oil, grease	Transportation (vehicles), pumping stations, car-wash

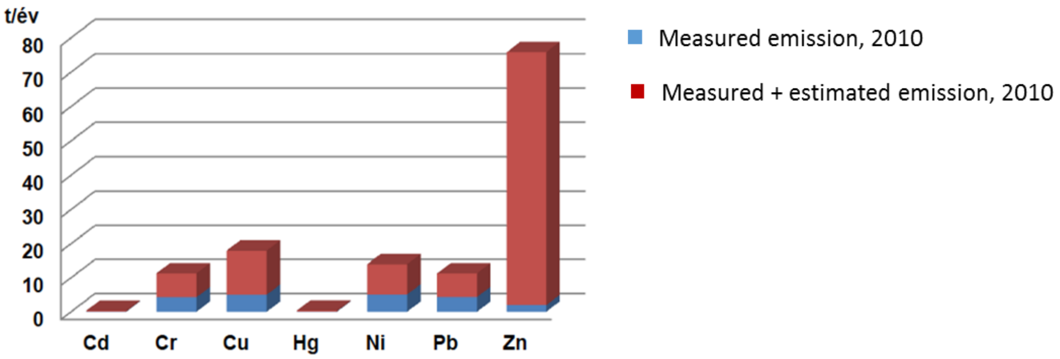
Other organic micropollutants (pesticides, phenols, PAHs)	Air deposition (of transportation and industrial emission), pesticides used in gardens
Salts	De-icing of pavements

In combined sewage systems, heavy precipitation may also lead to combined sewage overflow, increasing the release of contaminants significantly. The estimates for total heavy metal load indicate that urban precipitation runoff is the major source of toxic heavy metals, carrying diffuse pollution from transportation (Cu, Ni, Cr and Cd) or metal roofing (Zn) (Table 6-5, Figure 6-4). While the contamination itself is point source or linear, due to the diverse transport pathways, urban precipitation runoff appears as a diffuse contamination in waters.

Table 6-5 Toxic metal emission in sewage 2010-2012

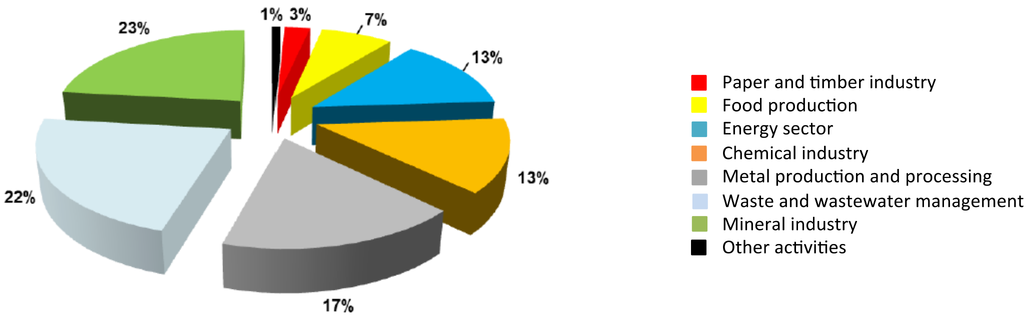
Source	Mercury kg/year	Cadmium kg/year	Nickel t/year	Lead t/year	Zinc t/year	Copper t/year	Chromium t/year
Industrial	23	138	3,0	3,2	17,9	2,8	2,9
Communal	103	178	6,3	3,1	2,6	5,3	4,1
Total	126	316	9,3	6,3	20,5	8,1	7,0

Figure 6-4 Measured and estimated metal emission from communal wastewater treatment plants, 2010



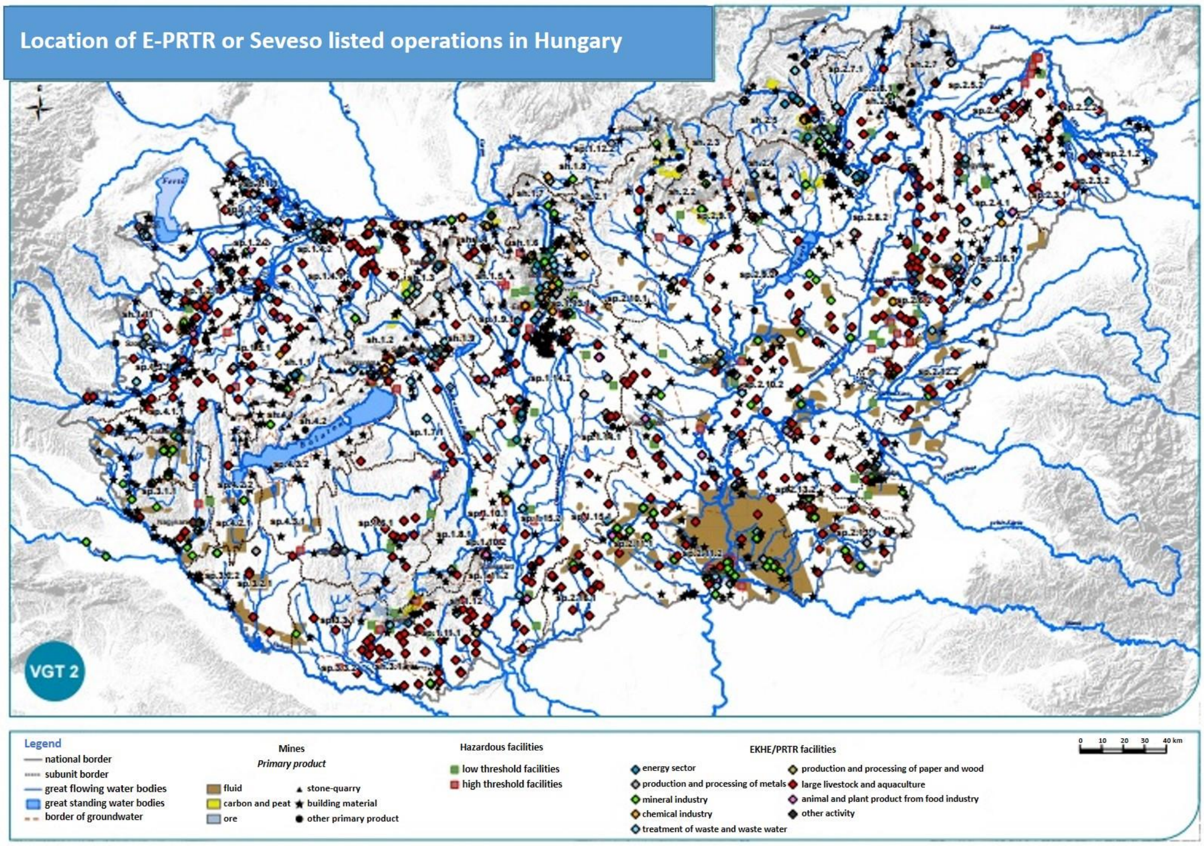
Industrial sewage from industrial or commercial activities is either directly impacts the receiving water, or if the facility is located within a municipality, its sewage is generally combined with communal sewage after pre-treatment or storage if necessary. The emissions from industrial and communal sewage in the latter case cannot be separated at the emission point but are estimated based on the scope of the industrial activity. Operations qualifying as significant sources of pollution are listed in the European Pollution Release and Transport Register (E-PRTR) and report yearly on their emission. The proportion of various activities among the facilities listed in E-PRTR is shown in Figure 6-5.

Figure 6-5 Proportion of various industrial activities in the E-PRTR



Industry using hazardous substances (registered in Seveso) does not necessarily has continuous emission, but it is a risk of pollution in case of industrial accidents, and should be therefore considered. The location of E-PRTR and Seveso facilities is shown in Figure 6-6.

Figure 6-6 Location of E-PRTR or Seveso listed operations in Hungary, with the indication of activity.



All industrial or commercial activity (import, manufacturing, storage, transport, distribution or retailing) related to hazardous substances is to be reported to national authorities. The lists of CLP, REACH, PIC and biocide related activities was used to identify substances which may contribute to water pollution during regular or accidental release (Table 6-6)

Table 6-6 Hazardous substances linked to commercial activities, on national and sub-catchment scale

Compound	Number of activities	Danube	Tisza	Drava	Balaton
1,2,5,6,9,10-hexabromocyclododecane (1,2,5,6,9,10-cyclodecane)	1	1			
1,2- dichloroethane	1	1			
alachlor (technical)	1		1		
Anthracene	1	1			
Benzo(a)pyrene	2	2			
Benzo(b)fluoranthene (benz[e]acephenanthrylen) Benzo(k)fluoranthene (PAH_c)	2	2			
Benzo(g,h,i)perylene, indeno[1,2,3-cd] pyrene	3	3			
Benzol	10	3	5	1	1
cybutryne (N'-terc-Butyl-N-cyclopropyl-6-(methylthio)-1,3,5-triazine-2,4-diamine)	1	1			
Cyclodiene pesticides (aldrin, dieldrin, endrin, isodrin)	4	3	1		
Cypermethrin	14	14			
dichlorvos 2,2-Dichloroethenylphosphoric-dimethyl-ester; 2,2- Dichlorovinyl-dimethyl-phosphate	1	1			
Diuron	6	3	3		
hexachloro-cyclohexane	1	1			
Isoproturon	14		14		
Naftalin	37	23	9	1	4
Heavy metals: cadmium (1), nickel(49), lead (41), mercury (20)	111	92	11	4	4
nonylphenol (4-nonyphenol)	19	4	15		
octyphenol (4-(1,1,3,3 –tetra-me hyl-butyl) phenol)	4	4			
Pentachlorophenol	2	2			

Tetrachloromethane	4	2	2		
terbutryn (2 tert-butylamino-4-etylamino-6-methyltio-1,3,5-triazine)	5	4	1		
tetrachloroethylene (tetrachloroethene)	2		2		
Trifluralin	1	1			
trichloroethylene (trichloroethene)	4	4			
trichloromethane (chloroform)	13	4	6	2	1
Total	264	176	70	80	10

The list of activities clearly shows the location of large industrial zones, and the predominance of Budapest. Other potential point sources include previously contaminated sites and active or recultivated waste dumping sites. Mining is a considered a diffuse source of heavy metals.

Pesticide pollution is derived from agriculture either from current use, drainage water, or from previous soil contamination. Relevant pesticide list (included in Table 6-1 and 6-2) was compiled based on current use (Table 6-7), presence in surface and groundwater and environmental persistence.

Table 6-7 Use of pesticides relevant for water resource protection (2013-2014)

Name of plant protection products	Area treated (ha)	Application cases
2, 4-D (dichlorophenoxy acetic acid)	8599	1302
acetochlor	133	40
atrazine	45	15
dicamba	16530	2999
Dimethenamid-P	7644	1145
captan	7944	3011
sulphur	42331	24930
chlorpyrifos	18536	2799
mancozeb	13013	8144
metazachlor	6023	709
Copper-hidroxide	6586	3817
S-metholachlor	14519	2531
Tebuconazole	50345	10179
terbutilazine	16386	3006

Industrial or other accidents may also heavily impact water quality. Tables 6-8 and 6-9 list the water pollution incidents (Table 6-8) and recurring pollution incidents (Table 6-9) between 2010-2012.

Table 6-8 Water pollution incidents by pollution and water type, 2010-2012

Pollution	Affected water course	Affected water bodies	Affected groundwaters	Total
Oil pollution	111	6	10	124
Other	89	3	3	95
Fish die-off	33	7		40
Discharge of wastewater	48	3		51
Solid pollution	36	1	3	40
Other chemical pollution	10		10	20
Oxygen deficiency	12			12
Animal carcasses	13			13
Excessive vegetation	5			5
Pesticide leaching	1			1
Total	358	20	26	404

Table 6-9 Recurrant water pollution incidents, 2010-2012

Recurring water pollution	Potential or known reasons
Danube at Budapest: oil pollution	navigation, ports, urban rainwater
lowland streams (canals), deadlegs: fish and shellfish die off, oxygen deficiency, excessive vegetation	nutrient stress, insufficient current or flow of the water
Upper-Tisza: floating waste	landfill on the floodplain

7. Scenarios of water availability in Hungary under current and future climate, land use and water use conditions

7.1. Modelling freshwater resources

Water resource modelling is not widely used in Hungary, but more specialised modelling targeting hydraulic and hydrological processes are common in the Water Management sector. Models are used for numerous projects such as: flood mapping, river planning, flood forecasting, sediment transport analyses, flow pattern analyses, ground water modelling, etc.

Models that are often used and have Hungarian references are for example: HEC-RAS, HEC-HMS, MIKE 11, MIKE 21, MIKE SHE, CCHE2D, MODFLOW, FEFLOW, DIWA, SWAN, etc. Special model systems are also is use such as the OLSER developed by the National Hydrological Forecasting Service for the Danube catchment, or the AKIR system developed for interactive flood mapping based on detailed GIS data and 2D HD modelling.

The LISFLOOD model developed in the European Flood Alert System (EFAS) by the floods group of the Natural Hazards Project of the Joint Research Centre (JRC) of the European Commission is not is use, but a few scientific papers can be found about early sample applications.

7.2. Current freshwater resources

The annual precipitation amount is 500-900 mm in Hungary. The distribution of this amount is dependent on the distance from the sea and the altitude. The least precipitation (500-550 mm) is observed on the Great Plain, and along the Middle Tisza valley, while the most is observed on the Western regions (800-900 mm). The temporal distribution is also varying; there are two intense periods, the primary in the early summer (May-June), and the secondary in autumn (October-November). The least precipitation is observed in January and February. The number of days with snowfall is 20-30 in average in the regions with lower elevation, and 50-60 days in the mountainous regions. The number of days with snow cover is 30-35 days in average in the regions with lower elevation, and above 80 days in the mountainous regions.

The natural water balance of Hungary is slightly positive, the total annual precipitation amount is 55 707 million m^3, while the evapotranspiration is 48 174 million m^3, the difference is 7 533 million m^3.

The spatial distribution of precipitation and evapotranspiration is shown on the maps Figures 7-1 and 7-2.

Figure 7-1 The 30 years average of the total annual precipitation amount (1981-2010)

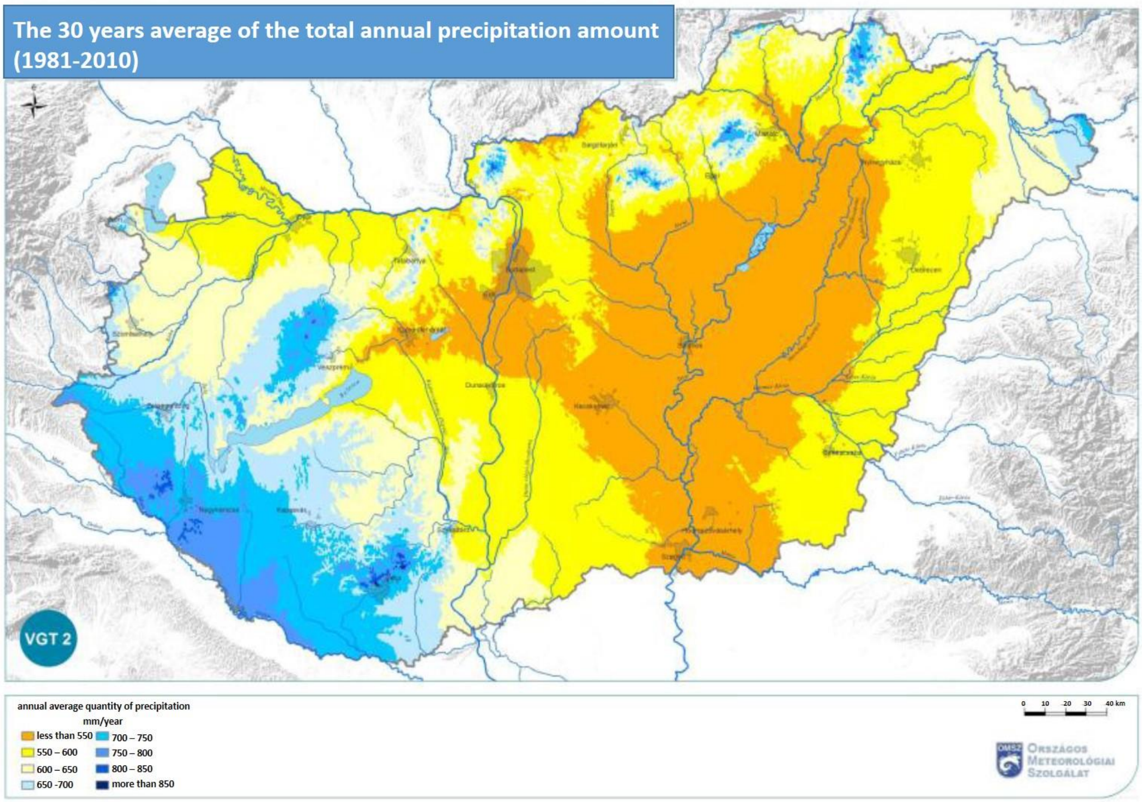
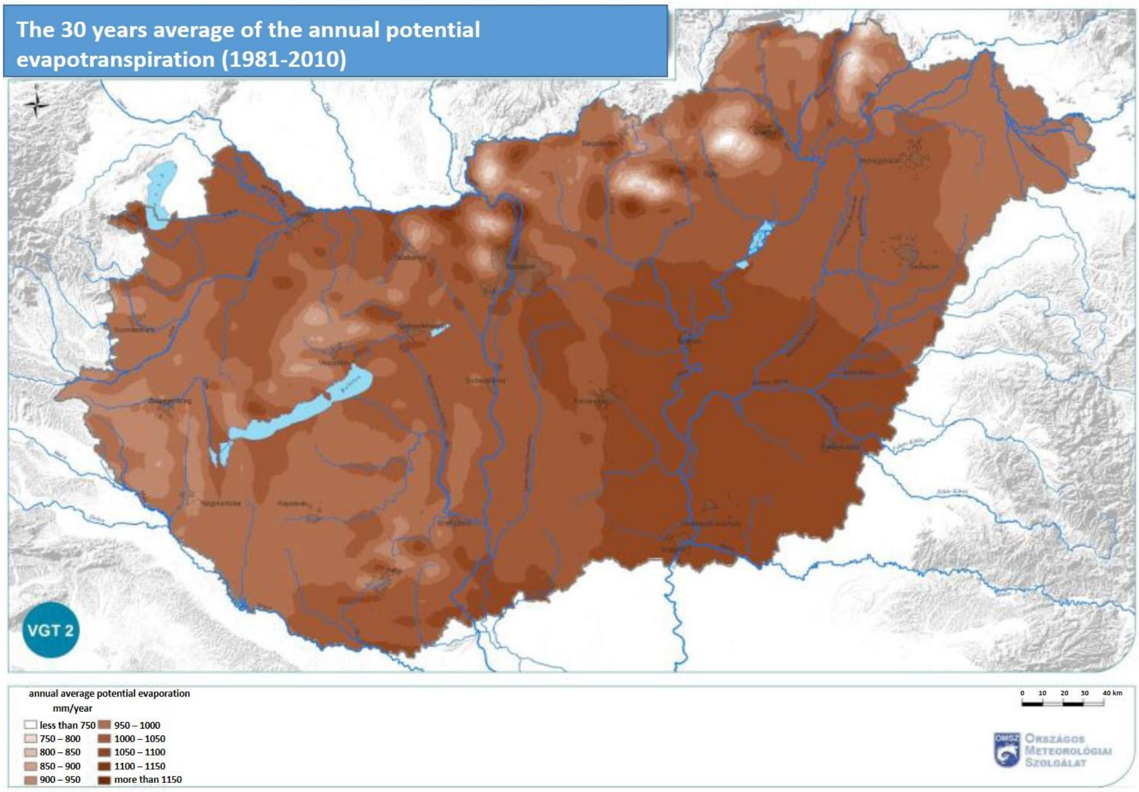
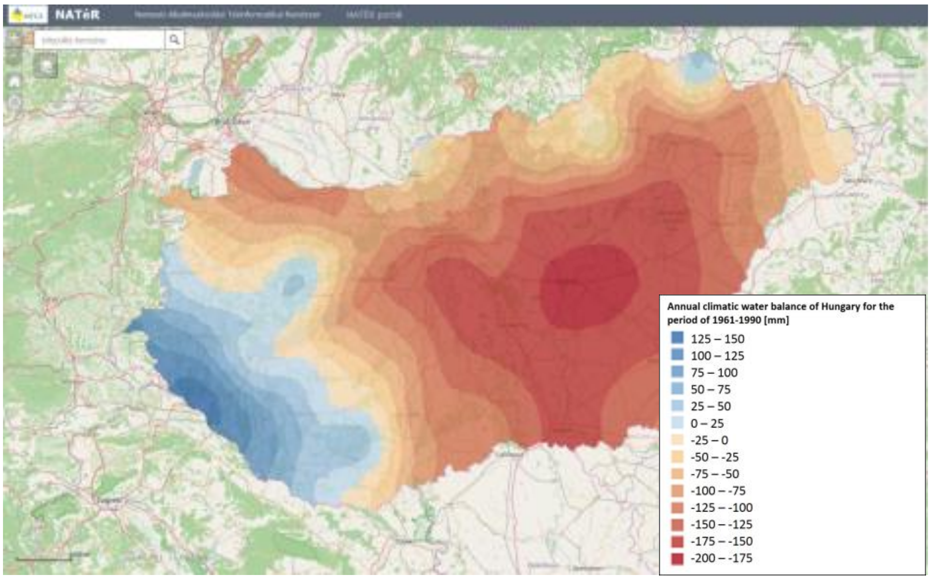


Figure 7-2 The 30 years average of the annual potential evapotranspiration (1981-2010)



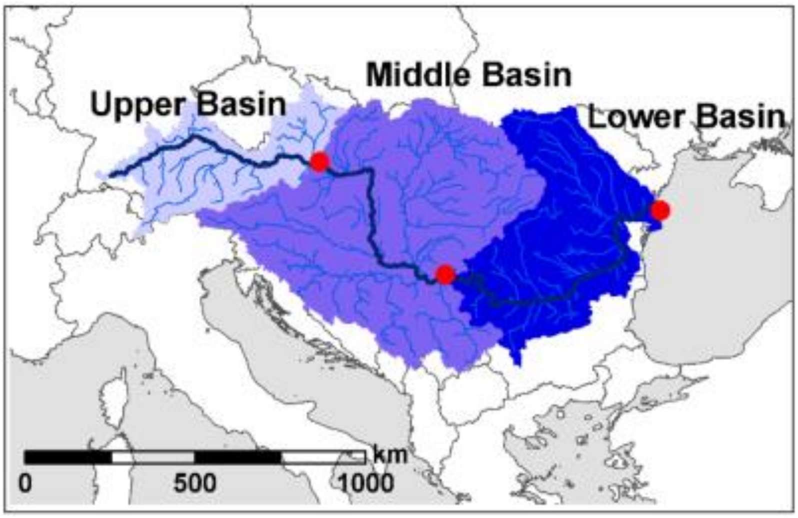
The map on Figure 7-3 is exported from the NAGiS Map Portal, it shows the average values of the annual climatic water balance of Hungary for the period of 1961-1990. The climatic water balance is calculated by subtracting the annual potential evapotranspiration from the annual precipitation amount, where the potential evapotranspiration was calculated with the Thornthwaite method. The values shown on the map are the averages of the annual climatic water balances of the analysed period.

Figure 7-3 Annual climatic water balance of Hungary for the period of 1961-1990, *source: NAGiS*



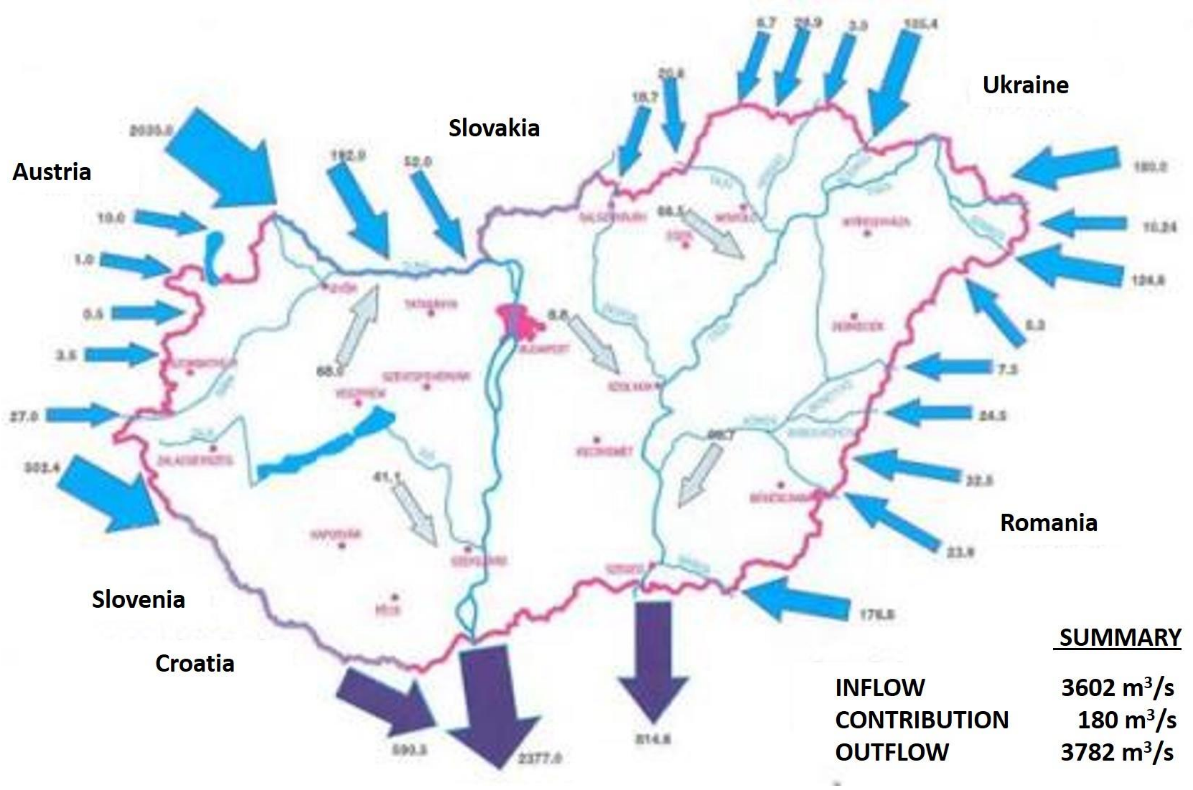
The water balance of surface waters in Hungary is mainly defined by the geographical location of the country, being in the Middle Danube Basin as shown on the map of Figure 7-4. Such heavy downstream characteristics means that more than 95% of the average outflow discharge is coming from the neighbouring countries.

Figure 7-4 The Danube Basin (Stagl and Hattermann, 2015*)*



The average inflow and outflow discharges of rivers are shown on the map of Figure 7-5. The 5% contribution to the average total outflow is generated on small catchments such as the tributaries of Rába, the Zala and Balaton catchments, the Zagyva-Tarna catchment, the tributaries of the northern Tisza and the Körös catchment.

Figure 7-5 Average inflow and outflow discharges (PREGUN AND JUHÁSZ)



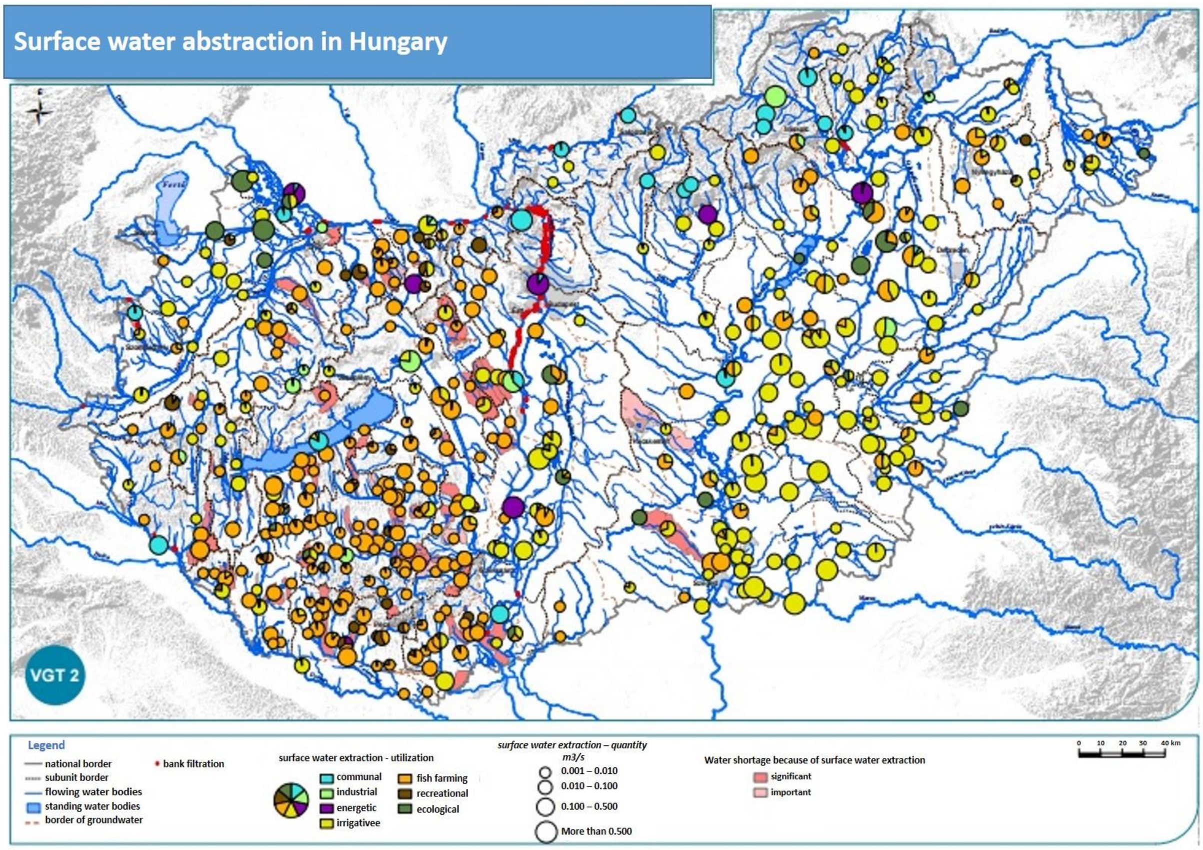
Converting the average discharge to annual total outflow results in an approximate value of 120 km^3/a of annual surface river outflow. Water extractions of the main areas are summarized in Table 7-1.

Table 7-1 Surface water extraction (2013)

Surface water extractions	Annual sum [million m3]
Communal	247
Industrial	124
Energetics	3535
Irrigation	242
Fish Culture	308
Recreation	3
Ecological	38
Total:	4636

Comparing the average annual water extraction and the available surface water resource, less than 4 percent of the available freshwater resource is used, but the spatial and temporal distribution of this resource is highly unequal. This inequality results in areas of water scarcity and drought besides floods and inland excess water. The categories of water extraction and the areas affected by water scarcity are shown on Figure 7-6.

Figure 7-6 Surface water extraction



Groundwater is also a main source of water utilization in Hungary, ranging for example from irrigation to medicinal, communal or mining water abstraction.

Groundwater abstraction data for various aquifer types are shown on Figures 7-7 to 7-10. Abstraction data are given as thousand m^3/years per GWB.

Figure 7-7 Water abstraction data from shallow groundwater bodies

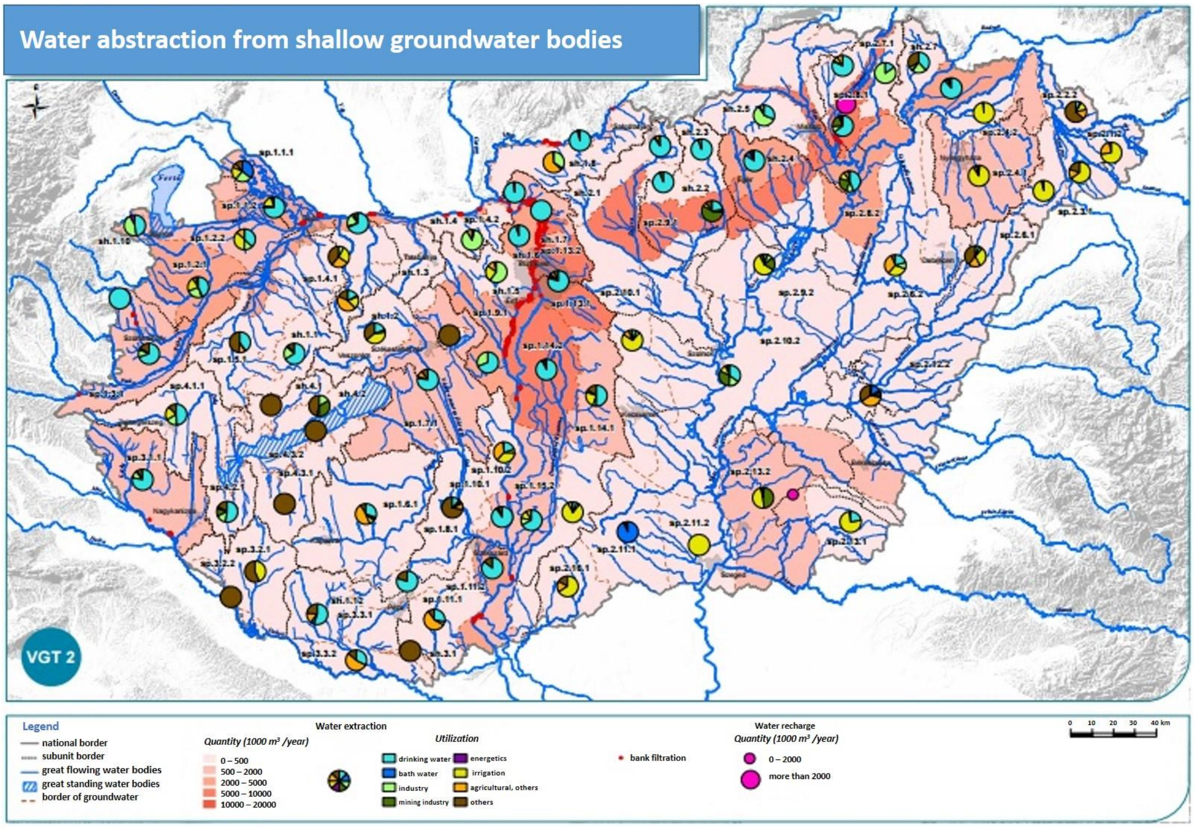


Figure 7-8 Water abstraction data from porous groundwater bodies

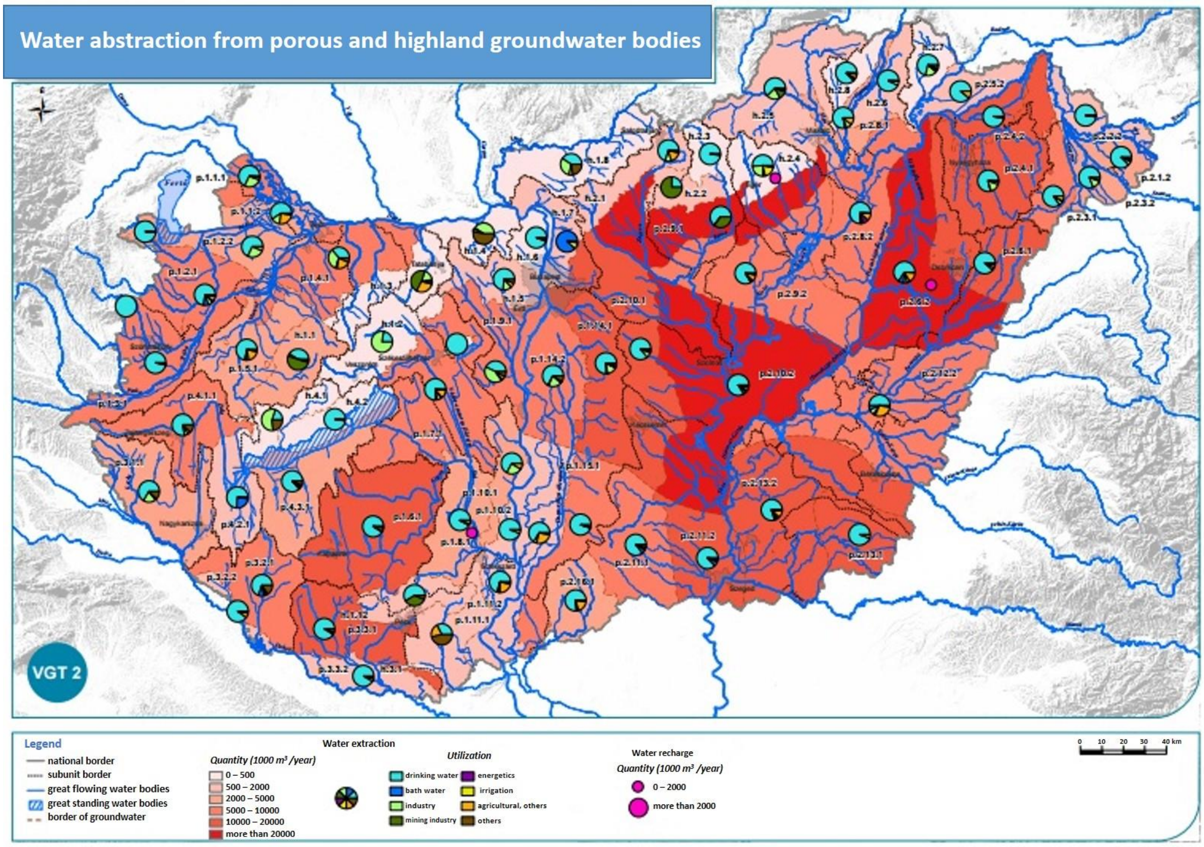


Figure 7-9 Water abstraction data from porous thermal groundwater bodies

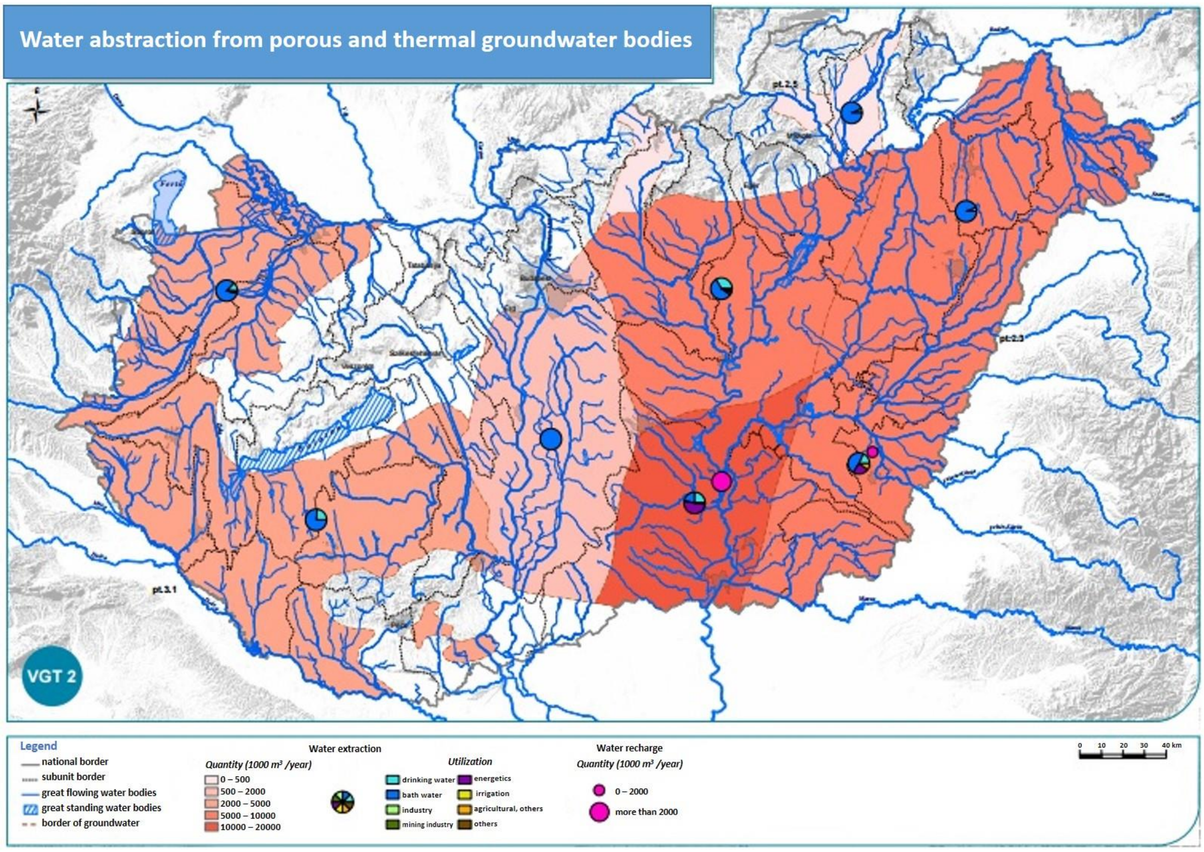
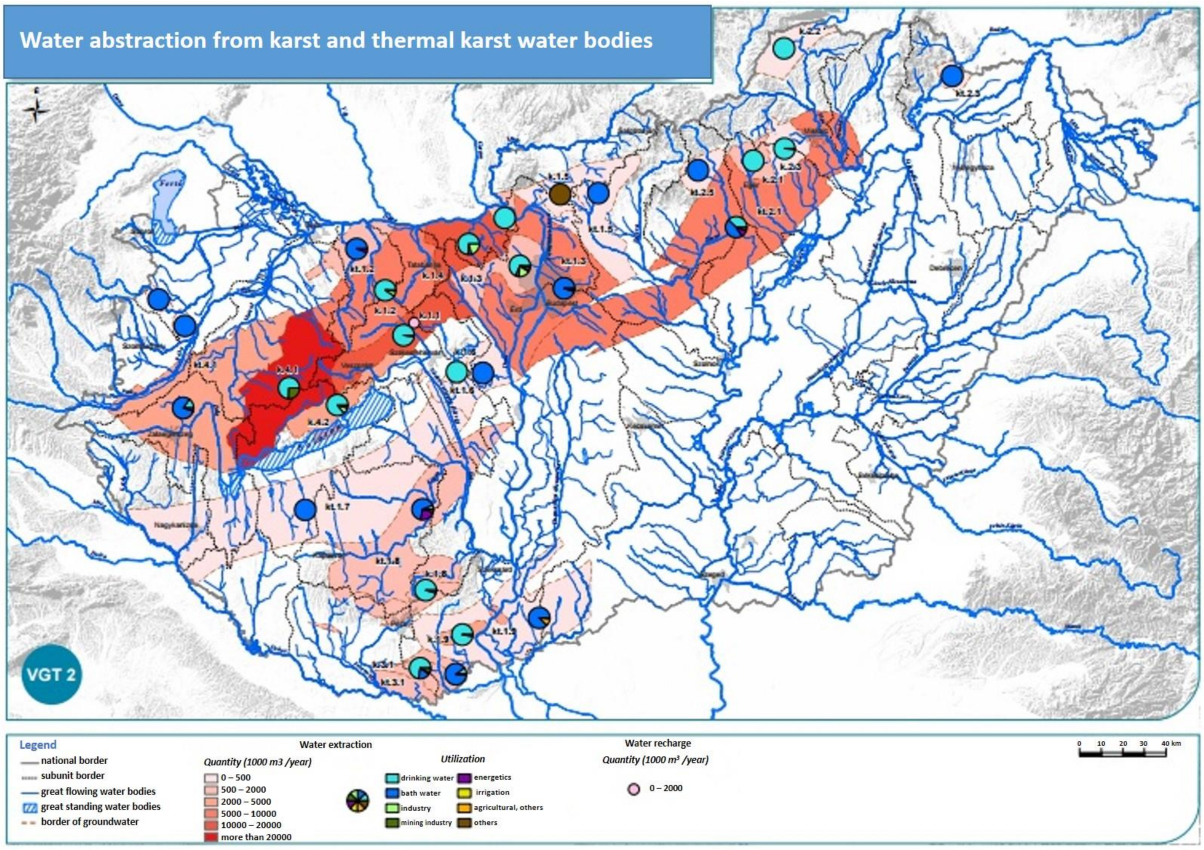


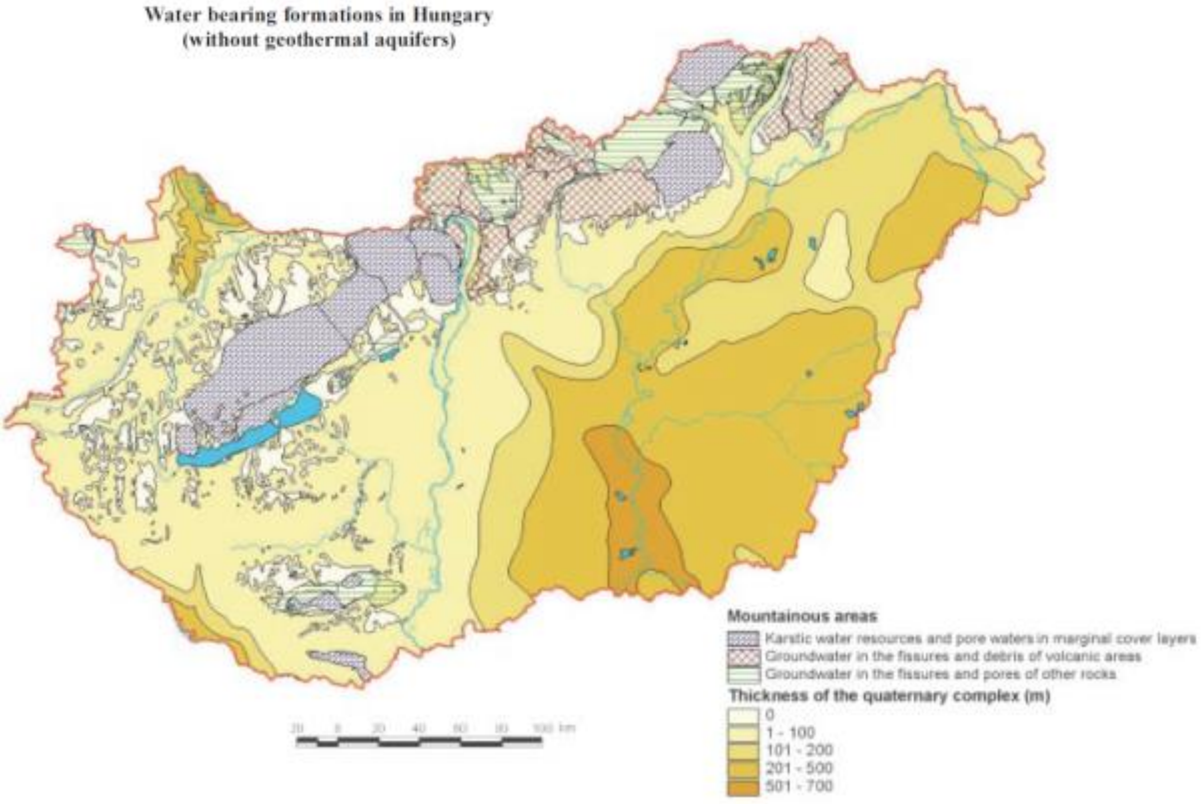
Figure 7-10 Water abstraction data from karst and thermal karst water bodies



Groundwaters in Hungary (VITUKI, 2006)

The various kinds of groundwater are natural resources of outstanding importance in Hungary. More than 97 per cent of drinking water is supplied from groundwater. Springs and wells are filling up the swimming pools in the numerous thermal and therapeutic baths. Groundwaters are utilized in the industry and for irrigation as well, however to a smaller extent and no extension is justified. Nevertheless the significance of groundwater is high in terms of natural vegetation and agriculture as well: for the optimal water supply of vegetation an appropriate depth of groundwater table is essential. There are several nature conservation areas of special importance in our country where the wetness migrating upwards from the deeper horizons is providing the sine qua non for special ecosystems. Captured or noncaptured natural springs may represent special natural values as well. Their water or the groundwater infiltrating into riverbeds ensure that several small watercourses do not dry up in seasons without precipitation.

Figure 7-11 Water bearing formations in Hungary (VITUKI, 2006)



Groundwaters in Hungary (VITUKI, 2006)

A considerable part of Hungary, located in the centre of the Carpathian Basin, is of flat and hilly character. In this basin-type area marine and fluvial deposit, sometimes several kilometres thick, covers the older rocks. The marine deposits situated at larger depth are mainly clays and clayey marls with a very low potential yield for water extraction. As the Pannonian Sea turned into an inland lake inflowing rivers deposited coarser sediments of a thickness sometimes up to 1 to 2 km: in the geological profile of that time there are already several sand and sandstone layers (Figure 7-11.). In the Quaternary exclusively the fluvial sedimentation was already characteristic, with silty, sandy and gravel deposits. The thickness of these complexes is also near 1 km in the Kisalföld and in the southern region of the Great Hungarian Plain. At the border of the basin river fans contain much gravel with a thickness of only some ten meters, except for the Szigetköz region where gravel layers are as thick as several hundred meters. Some parts of our rivers are running in these formations and their water is in direct contact with that of the gravel layers.

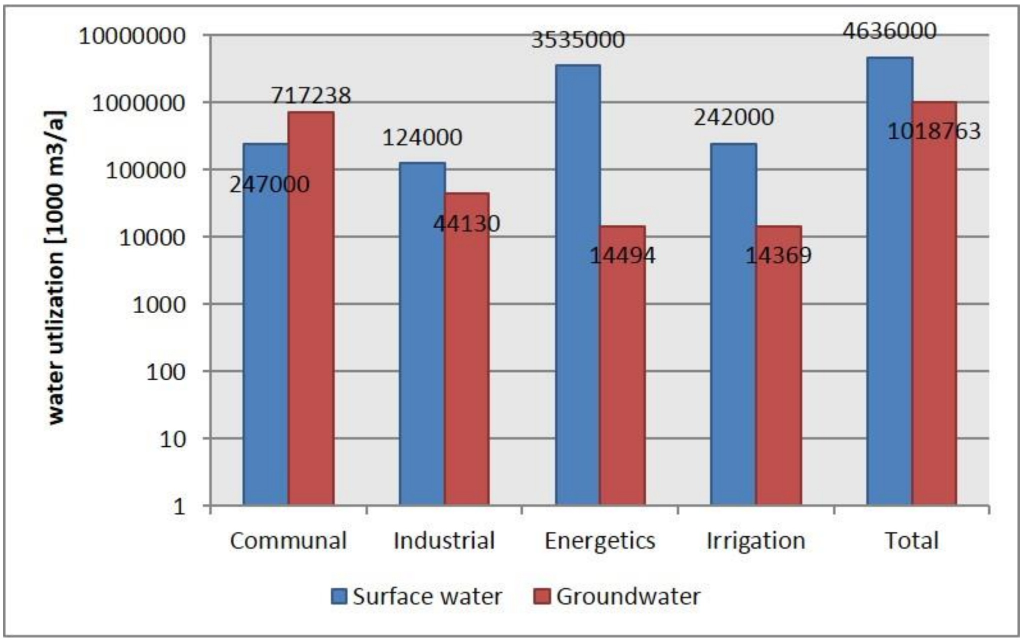
The amount of average water produced the underground in Hungary is 2.7 million m^3/day, which is 985.5 million m^3 annually, 21% of the total annual surface water extraction. The types of water abstractions categorised by water bodies are shown in Table 7-2.

Table 7-2 Direct groundwater abstractions (2008-2013, annual average in 1000 m^3/a), source: VGT2

Type of water body	communal	industrial	energetics	mining	irrigation	other agricultural	spa, medicinal	other	without permission	total
coastal filtration (surface water) (-)	223473	5805	290	0	88	1	350	618	0	**230626**
spring waterworks	40202	0	0	0	0	0	0	0	0	**40202**
karst	55740	4232	63	5946	134	353	1215	391	0	**68074**
thermal karst	4695	178	1058	0	37	51	15701	576	0	**22295**
shallow mountainous	6719	1430	47	15	175	300	222	413	7314	**16636**
mountainous	10550	937	0	3376	198	391	1273	411	14	**17150**
shallow porous	52853	4921	290	5411	7788	2448	1080	4240	68223	**147255**
porous	312236	26219	1013	15970	5901	23904	8935	9944	22113	**426233**
porous thermal	10770	408	11733	0	47	1153	25578	602	0	**50292**
Total water extraction without coastal filtration and springs	**453563**	**38324**	**14204**	**30718**	**14281**	**28600**	**54004**	**16576**	**97664**	**747935**
Total water extraction	717238	44130	14494	30718	14369	28601	54354	17194	97664	**1018763**

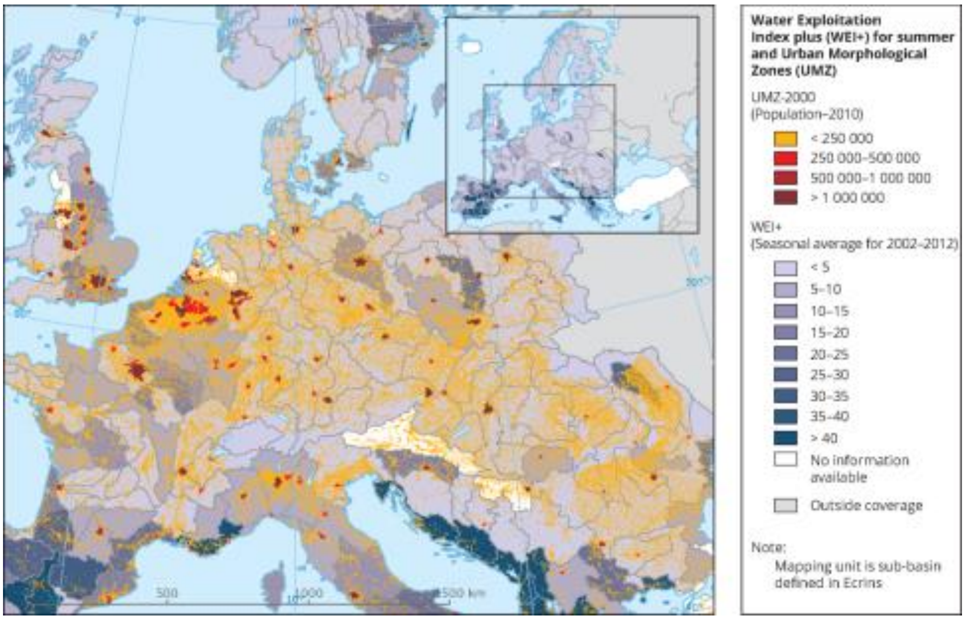
Comparing the values of surface- and groundwater (Table 7-1 and Table 7-2) utilization in the fields they share (communal, industrial, energetics, irrigation), it is clearly visible that groundwater is the major source of water produced for communal used, while surface water is dominating in all other fields (Figure 7-12).

Figure 7-12 Comparing average annual surface water and groundwater utilization



The Water Exploitation Index Plus (WEI+) is a water resource indicator agreed at European level to show the ratio between water consumption and water availability (http://www.eea.europa.eu/data-and-maps/figures/water-exploitation-index-plus-wei). The value shown here (Figure 7-13) is a model simulation, comparing estimates of water demand derived from national and European statistical agencies, estimations of the consumptive fraction, and comparing the net consumption with simulated available water. The present water availability is simulated for 1990-2014, using observed weather data from the JRC gridded meteorological datasets, and applying model calibration against observed discharge for around 700 stations in Europe.

Figure 7-13 The Water Exploitation Index Plus (WEI+), *Copyright holder: European Environment Agency (EEA)*



A further important calculator of available water resources in a country is the so-called Falkenmark index. This index estimates the amount of freshwater available to the population in a year. The following map (Figure 7-14) shows the current available water resource and a prediction for 2070-2099 annual average. The prediction is based on climate change scenario A2.

Intergovernmental Panel of Climate Change

The A2 marker scenario (A2-ASF) was developed using ASF (see Appendix IV), an integrated set of modeling tools that was also used to generate the first and the second sets of IPCC emission scenarios (SA90 and IS92). Overall, the A2-ASF quantification is based on the following assumptions (Sankovski et al., 2000):

- Relatively slow demographic transition and relatively slow convergence in regional fertility patterns.
- Relatively slow convergence in inter-regional GDP per capita differences.
- Relatively slow end-use and supply-side energy efficiency improvements (compared to other storylines).
- Delayed development of renewable energy.
- No barriers to the use of nuclear energy.

Figure 7-14 Annual water availability per person in present time and predicted for the '2080s', Copyright holder: European Environment Agency (EEA)

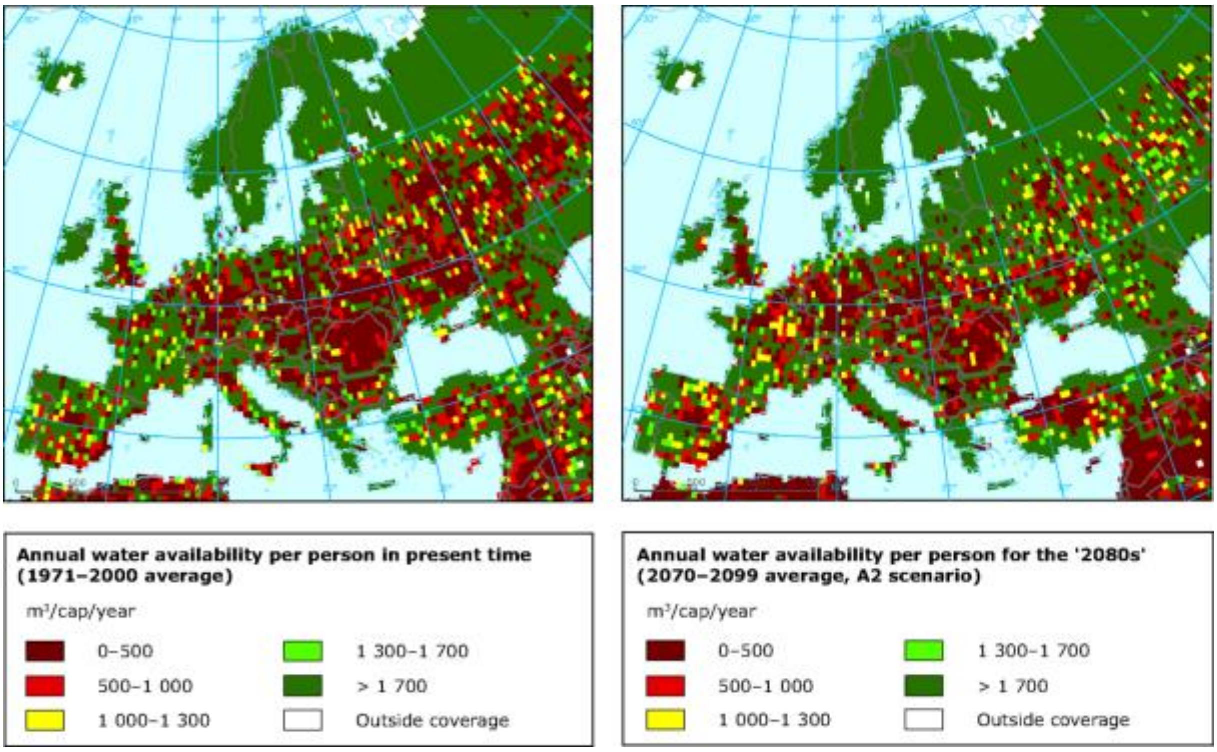
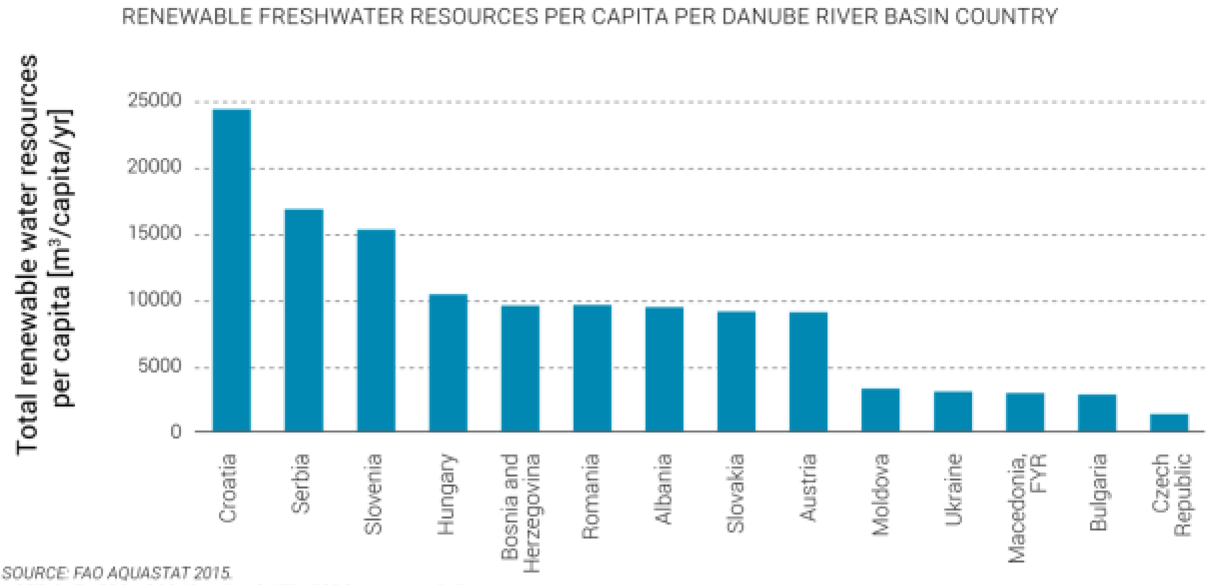


Figure 7-15 from ICPDR compares the available renewable freshwater resources per capita per Danube river basin country in 2015.

Figure 7-15 Renewable freshwater resources per capita per Danube river basin country in 2015, source: ICPDR



SOURCE: FAO AQUASTAT 2015.
NOTE: DATA FOR KOSOVO AND MONTENEGRO UNAVAILABLE.

7.3. Projected changes of water resources

The projected changes of water resources have to be separated due to the special hydrological situation of Hungary. The first part covers the water resources on the area of the country, referring to as local water resources, while the second part needs a wider approach covering the entire Danube Basin, referring to as incoming water resource.

The projected changes in the local water resource are very well documented in the NAGiS system.

NAGiS

The National Adaptation Geo-information System (NAGiS) project is **a multipurpose geo-information system that can facilitate the policy-making, strategy-building and decision-making processes related to the impact assessment of climate change and founding necessary adaptation measures in Hungary**. NAGiS may directly support the implementation, supervision and evaluation of the second National Climate Change Strategy, and the implementation and evaluation of the Environment and Energy Operative Programme (KEHOP).

The three main parts of the NAGiS are:

1. a map-visualization system (with a resolution of 10×10 km, containing hundreds of layers which show the way different aspects of climate change can affect certain areas of the country)
2. a database (GeoDat) containing the calculation results based on modelling (exposure, sensitivity, expected impact, adaptive capacity and vulnerability)
3. a meta-database facilitating navigation through different kinds of information (a sort of "data-map" about what to find and where)

The NAGiS climatic layers show the current climate and information on the predicted change of the climate in map format. The database was made of the controlled, homogenised, and interpolated data of the CarpatClim-Hu, and of the projected data of two regional climate models, ALADIN-Climate and RegCM. The layers showing observed data were generated by the extension of the homogenising and interpolation procedures of the CarpatClim project to entire area of Hungary. During the climate model projections the SRES A1B scenario was used, which predicts an increasing tendency of emission of anthropogenic pollutants and greenhouse gases till the mid of the 21. century, and a decreasing tendency till the end of the century with a 700 ppm value of carbon-dioxide concentration at the end of the century. The data of the climate model cover the period of 1961-1990, 2021-2050 and 2071-2100. Moreover the data of two other projections are also available in the database that rea based on the latest RCP emission scenario. These new scenarios account the international mitigation laws and characterise them by the radiative forcing assumed to 2100. The simulation was made with the pessimistic RCP8.5 scenario in case of the ALADIN-CLIMATE, and with optimistic RCP4.5 in case of the RegCM (assuming 8.5 and 4.5 W/m^2 radiative forcing to 2100). They cover the period of 1971–2000, 2021–2050 (Figure 7-16 to 19) and 2069–2098.

The climate maps of NAGiS show the 30 years average of the climatic factors. The spatial resolution of the databases is 0.1°x0.1° (approximately 10 km x 10 km) and the map visualisation is done by using interpolation and smoothing algorithms. The most accurate representation of the past climate is based on the observations, so in this case the data of the CarpatClim-Hu database are shown. The reference period in the database is 1961-1990 (except the projections made with the RCP scenarios, where it is 1971-2000). The predicted results are presented in format of difference maps generated from the climate model data and the reference period.

The behaviour of the climatic system consisting of non-linear processes can be described by climatic models with the knowledge of the driving physical forces. The model simulations have uncertainty deriving from the natural variability of the climate, the approximation of the physical processes, and the effects of the unpredictable social-economical processes. Different scenarios are created for the major anthropogenic factors – population, energy consumption, changes of industrial-agricultural structure, etc. – and quantify them by the greenhouse gas and aerosol emission for the models. Due to them being hypothetic the climates simulations of the future are not called forecasts, but projections. It is important to note when using the data of the NAGiS database, that these are only possible scenarios, not a sure forecast of the expected effects. This uncertainty is present both in space and time.

Figure 7-16 Projected change of annual precipitation for 2021-2050 (ALADIN-Climate), source: NAGiS

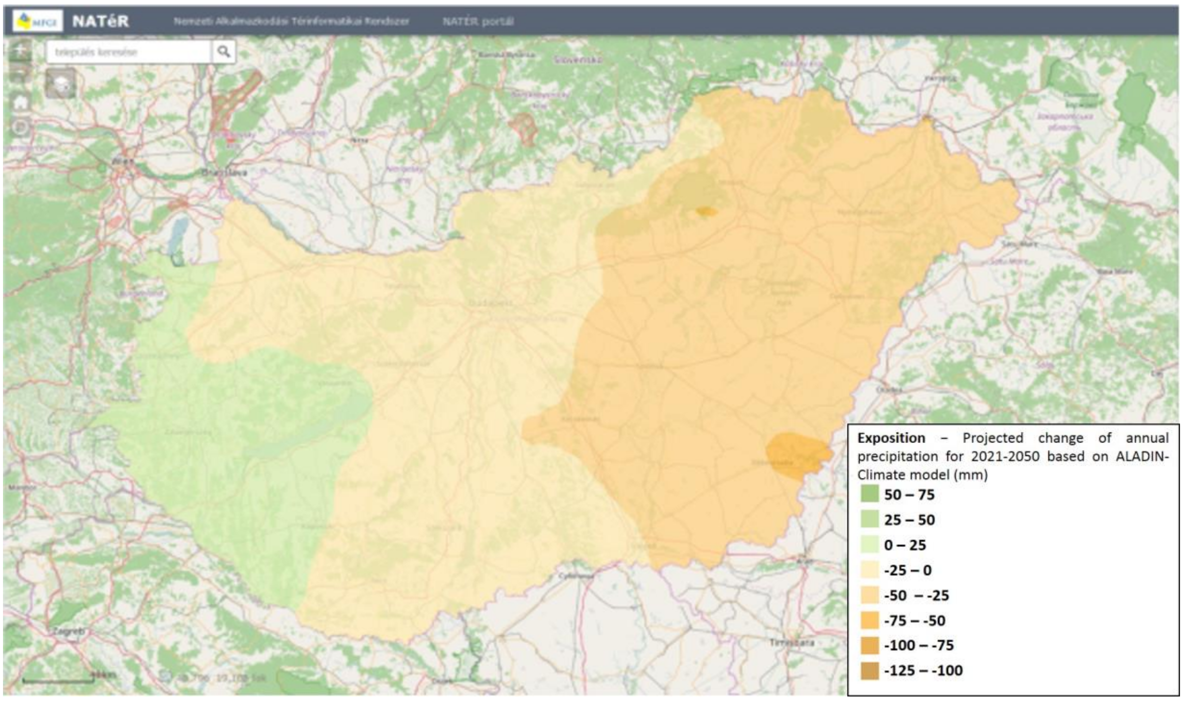


Figure 7-17 Projected change of annual precipitation for 2021-2050 (RegCM), source: NAGiS

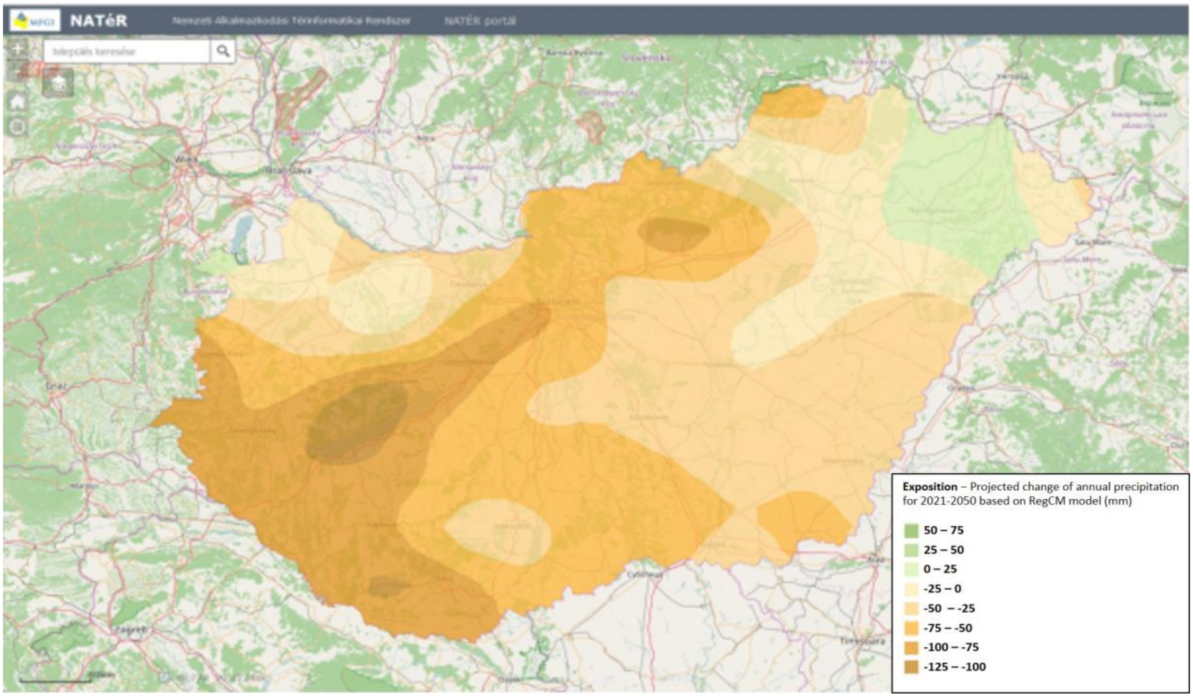


Figure 7-18 Projected change of climatic water balance for 2021-2050 (ALADIN-Climate), source: NAGiS

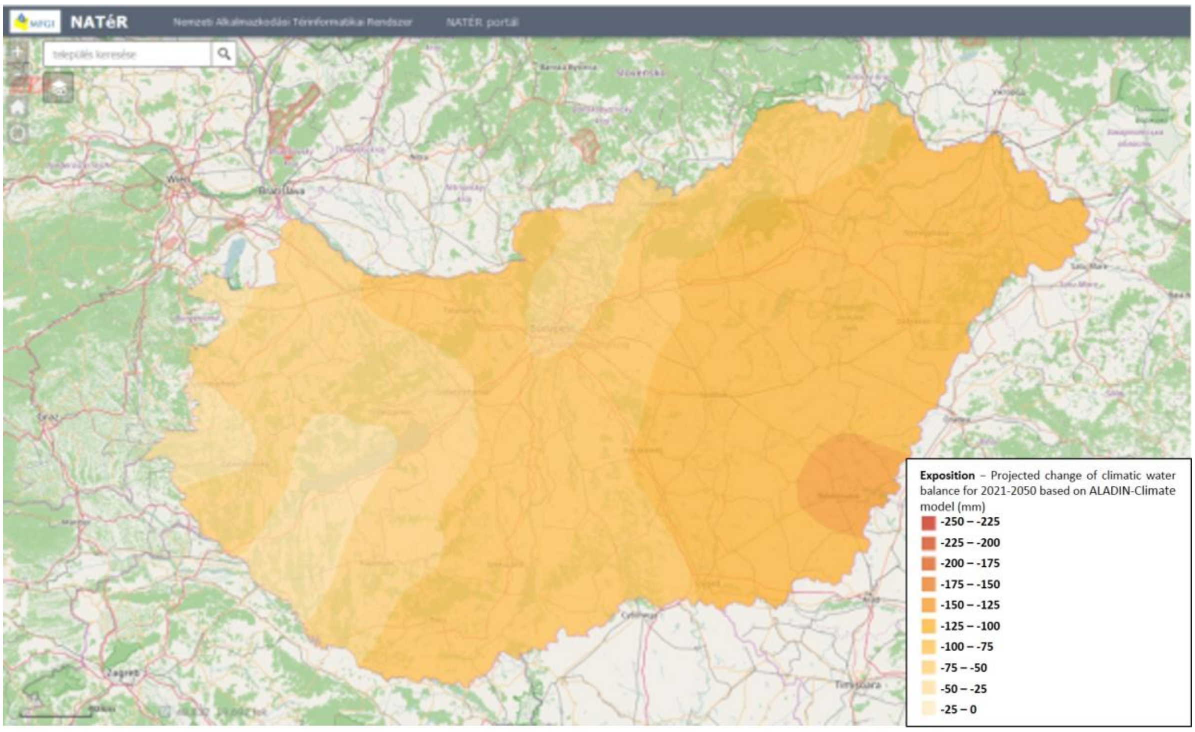
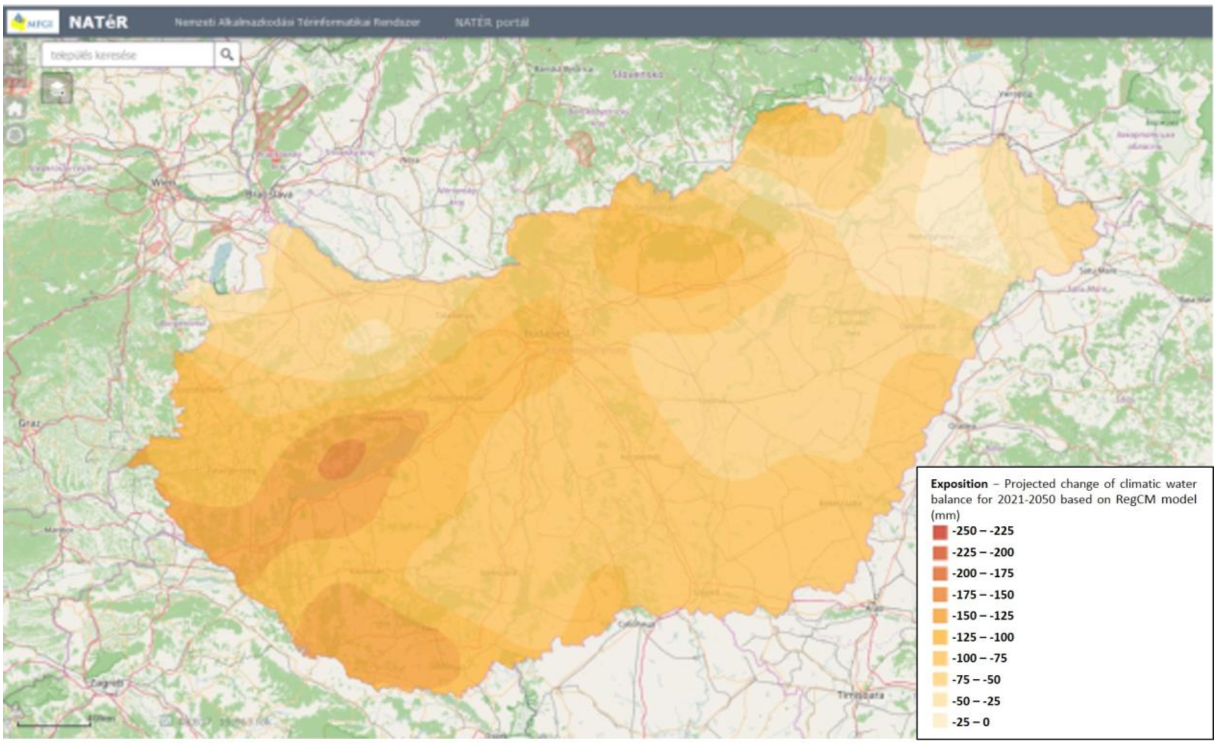


Figure 7-19 Projected change of climatic water balance for 2021-2050 (RegCM), source: NAGiS



Focusing on the incoming water resource the ICPDR published maps of the Danube Basin with projected changes (Figures 7-20 and 7-21).

Figure 7-20 Projected change of annual mean temperature, source: ICPDR

FIGURE 12: ANNUAL MEAN TEMPERATURE CHANGE, 2021-2050

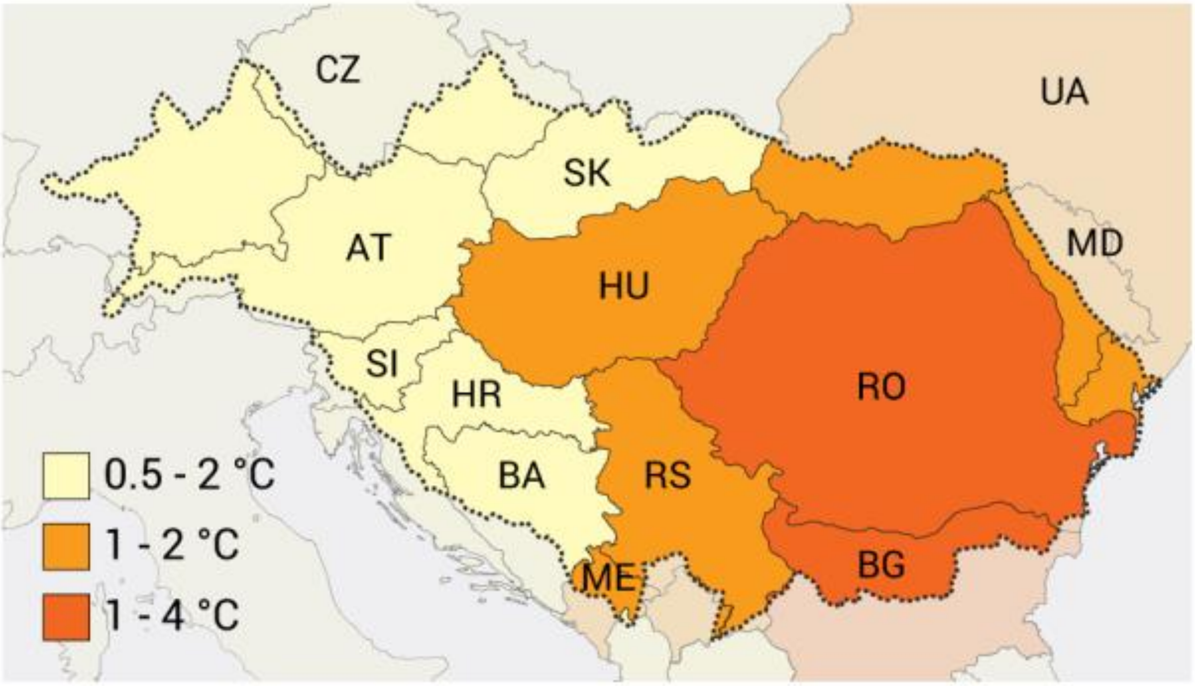
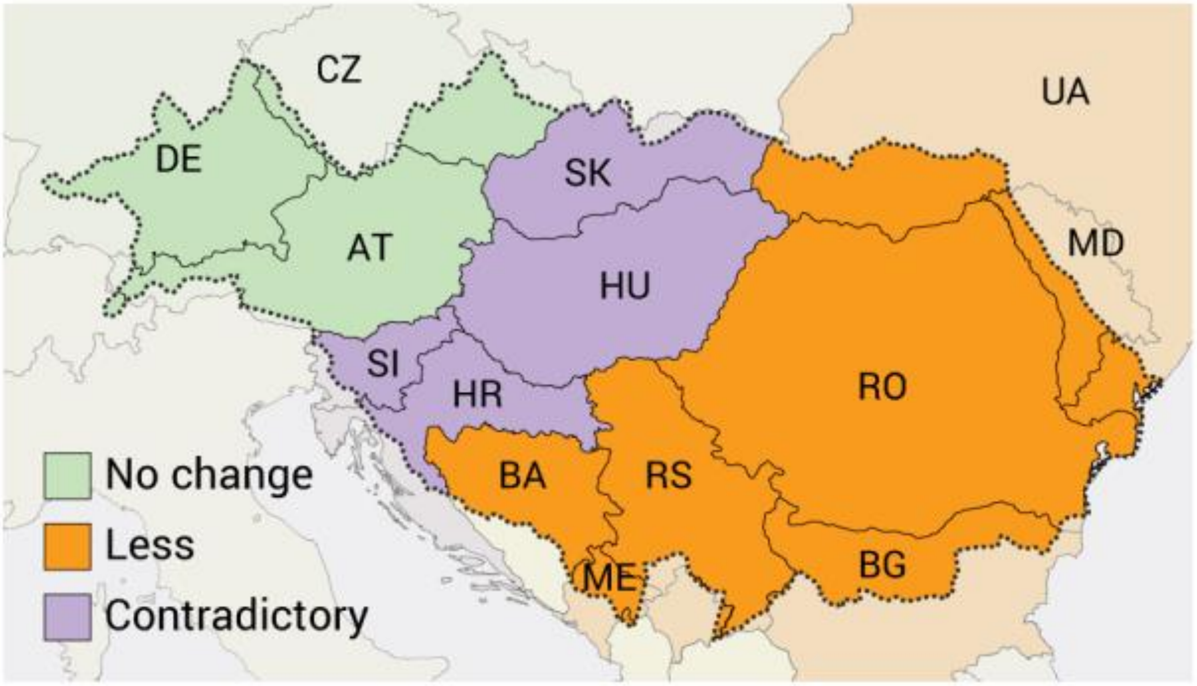


Figure 7-21 Projected change of summer mean precipitation, source: ICPDR

SUMMER MEAN PRECIPITATION CHANGE, 2021-2050



Climate change impacts are already visible in the hydrometeorology of the Danube Basin in the form of increasing number and intensity of extreme weather conditions. Based on studies made for the International Commission for the Protection of the Danube River (ICPDR), the main factors are the temperature and precipitation changes in the following form:

(a) an increase in air temperature with a gradient from northwest to southeast, particularly in summer in the south-eastern Danube region;
(b) overall small annual precipitation changes for the whole basin on average, but major seasonal changes in the Danube River basin (Figure 7-22);
(c) changes in the seasonal runoff pattern, triggered by changes in rainfall distribution and reduced snow storage (Figure 7-23);
(d) the likelihood that droughts, low flow situations, and water scarcity will become longer, more intense, and more frequent; and
(e) an increase in water temperature and increased pressures on water quality.

Figure 7-22 Changes (%) in precipitation between the reference period 1971–2000 and the scenario period 2031–2060 in the Danube River catchment as the multi-model mean from 14 ENSEMLBES scenarios

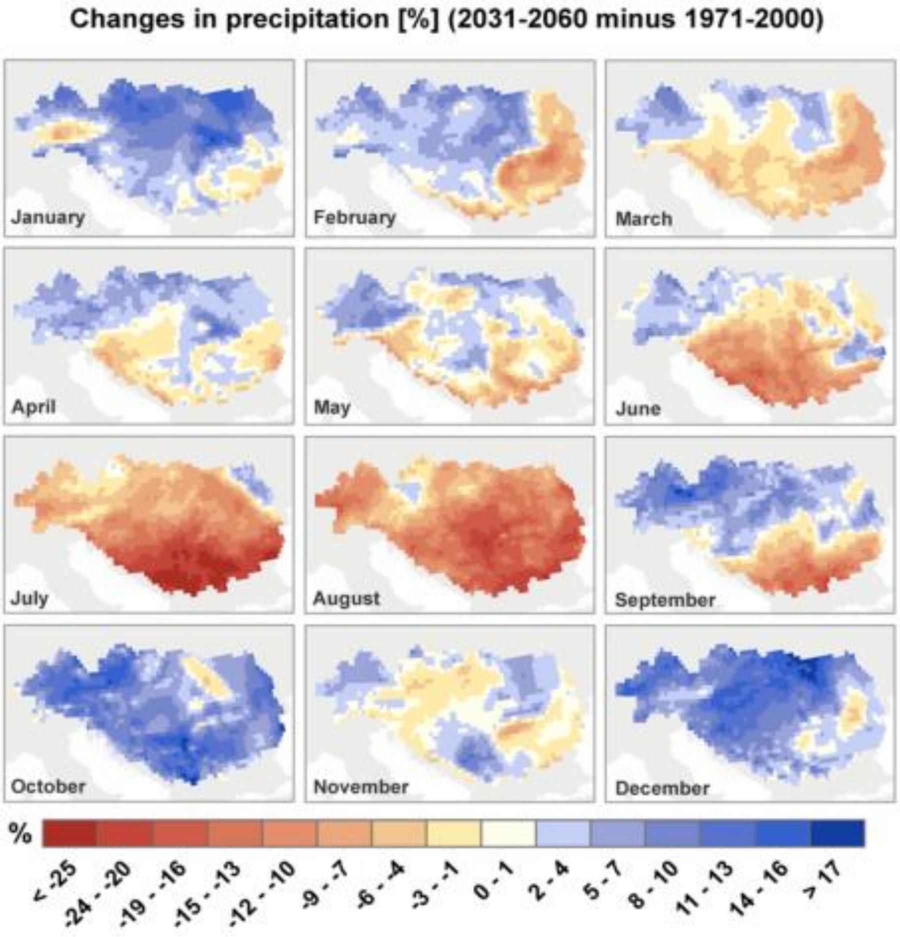
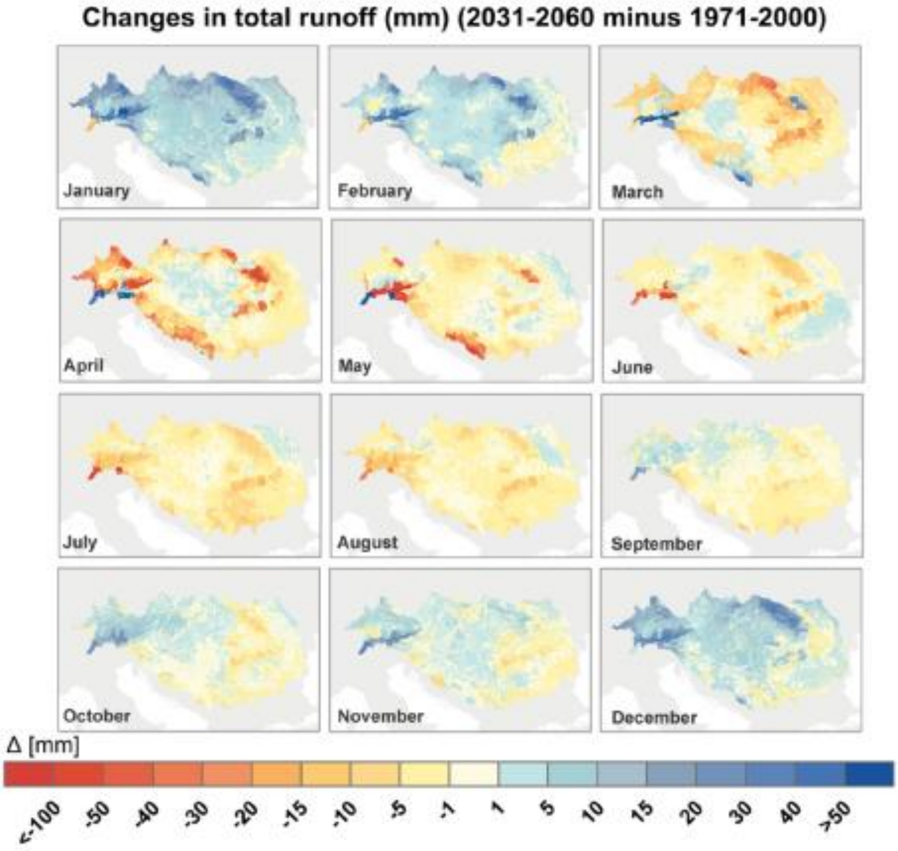


Figure 7-23 Changes in total runoff (mm/month) as the multi-model mean with ENSEMBLES climate data as the input; compared are the periods 1971–2000 and 2031–2060



7.4. Consequences of the projected changes

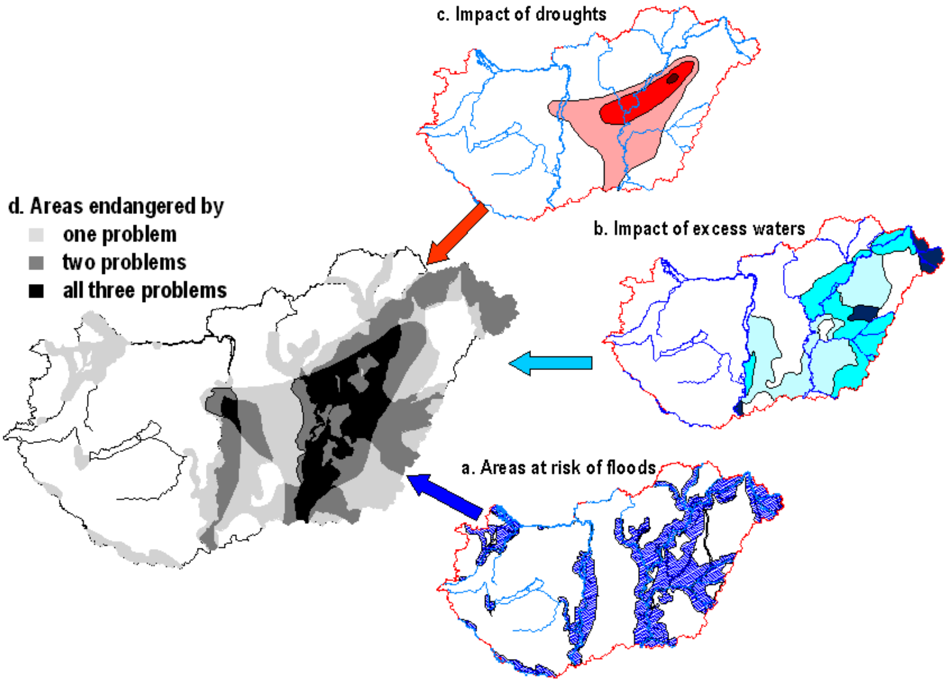
The extreme rainfall events increase the risk of flood and inland excess water. The occurrence probability of flash floods will change locally on small watersheds due to the changing extremes. The amount of the surface water resource will also change due to the temporal change of precipitation. Winter precipitation will be rainfall with an increasing probability, which results in an increasing winter runoff and earlier and higher flood peaks compared the present floods, because what was accumulated as snow will then runoff without any delay. The inland excess water is not primarily affected by the climate change, but late winter and early spring extremes will still occur.

The effect of less summer precipitation and increasing potential evapotranspiration will be the increasing ratio and duration of low-flow periods, which results in the decrement of the water resource without retention (the decreasing low-flow water resource will be significant on the Danube). The capacity of reservoirs will be limited by the winter extremes determining their impounding, and the water loss caused by the increasing evaporation. The water resource of lakes will also drop due to the same reasons, leading to low water levels more often.

Decreasing low flow discharges will also result in more vulnerable rivers against pollutants. Due to the least amount of water the dilution will also decrease, while the higher temperature increases the speed of biochemical processes, thus the decay of the contaminants will be faster. Sudden occurring fast floods will carry more pollutant from the catchments, and will worsen the nutrient balance of the rivers. The probability of havaria events will also increase.

The climate change will also affect the quantity and quality of groundwater. Due to the drier soil circumstances the decreasing refilling effect of precipitation is expected, manly on the Great Plain. The amount of groundwater available for irrigation will decrease on the Great Plain, and in the term of 50-100 years it also threatens the heavily groundwater dependent drinking water supply. The worsening ecological status due to the drier climate will cause problems in the groundwater related ecosystems, wetlands (Figure 7-24).

Figure 7-24 Areas of flood (a), inland excess water (b) and drought (c)



The major challenge of the climate change in Hungary is the struggle with extremes, and based on the national water strategy the adaptation to the climatic (or other natural) circumstances will be much more important.

7.5. Recommendations

As it is visible from the chapters above very detailed studies were made and are publicly available both for surface water and groundwater in Hungary. These studies are based on huge amount of data nowadays more and more often organised into databases and geodatabases. However these databases are individuals they could be interconnected in such a way that could serve as a basis for more complex analyses.

8. Floods in Hungary in a changing climate

The current flood risk of Hungary was analysed in details during the Flood Risk Management Project based on the EU Flood Directive. Two type of water related natural hazards are distinguished; fluvial floods (Figure 8-1) and inland excess water (Figure 8-2).

Figure 8-1 Flood affected regions in Hungary, *source*

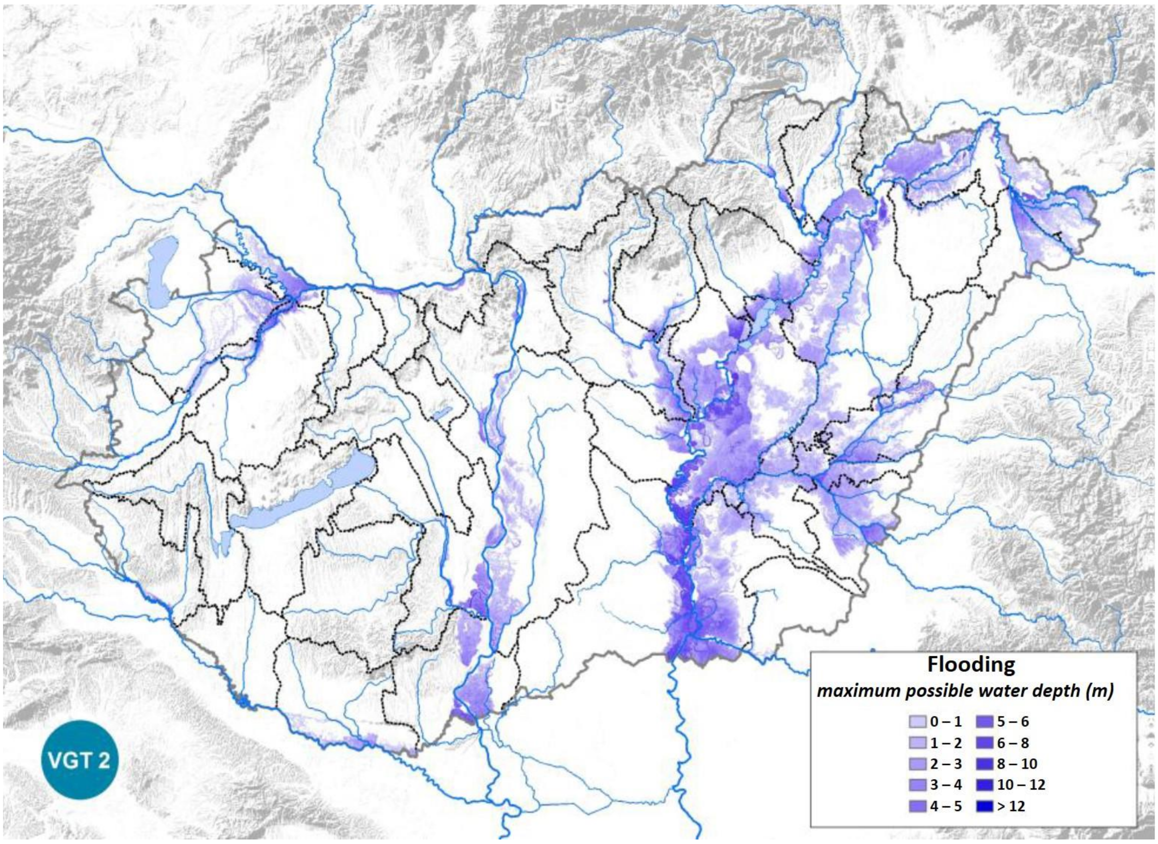
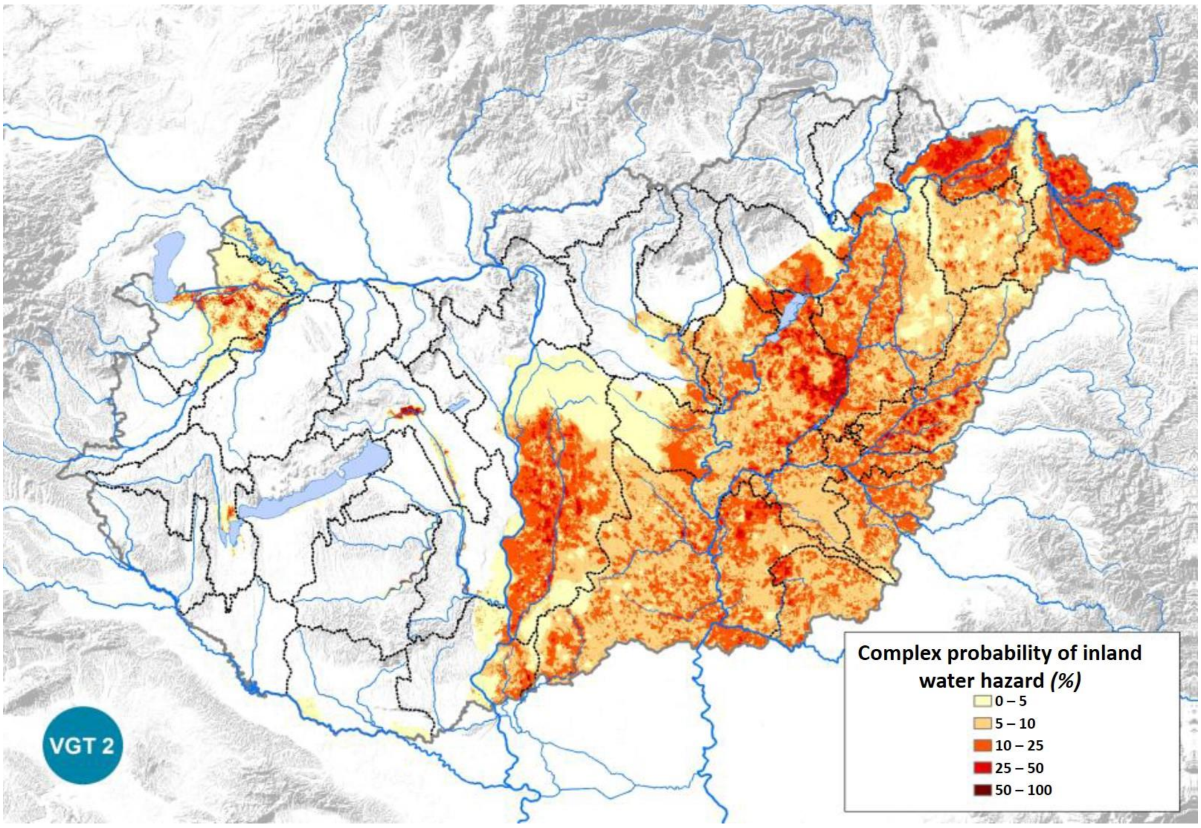


Figure 8-2 Inland excess water affected regions in Hungary



Consequences of the climate change and the projected flood situation is described in chapter 7.4. Detailed modelling are not publicly available for Hungary, but the Danube Basin and Europe in general is more-or-less analysed from this point of view. Some results are shown on Figures 8-3 and 8-4.

Figure 8-3 Average streamflow Q(top), mean annual daily peak flow QMAX (centre) and 100-year daily peak flow Q100 (bottom). Ensemble mean of the baseline (1976–2005) and relative change for the time slice 2066–2095. Data points with CV>1 are greyed out

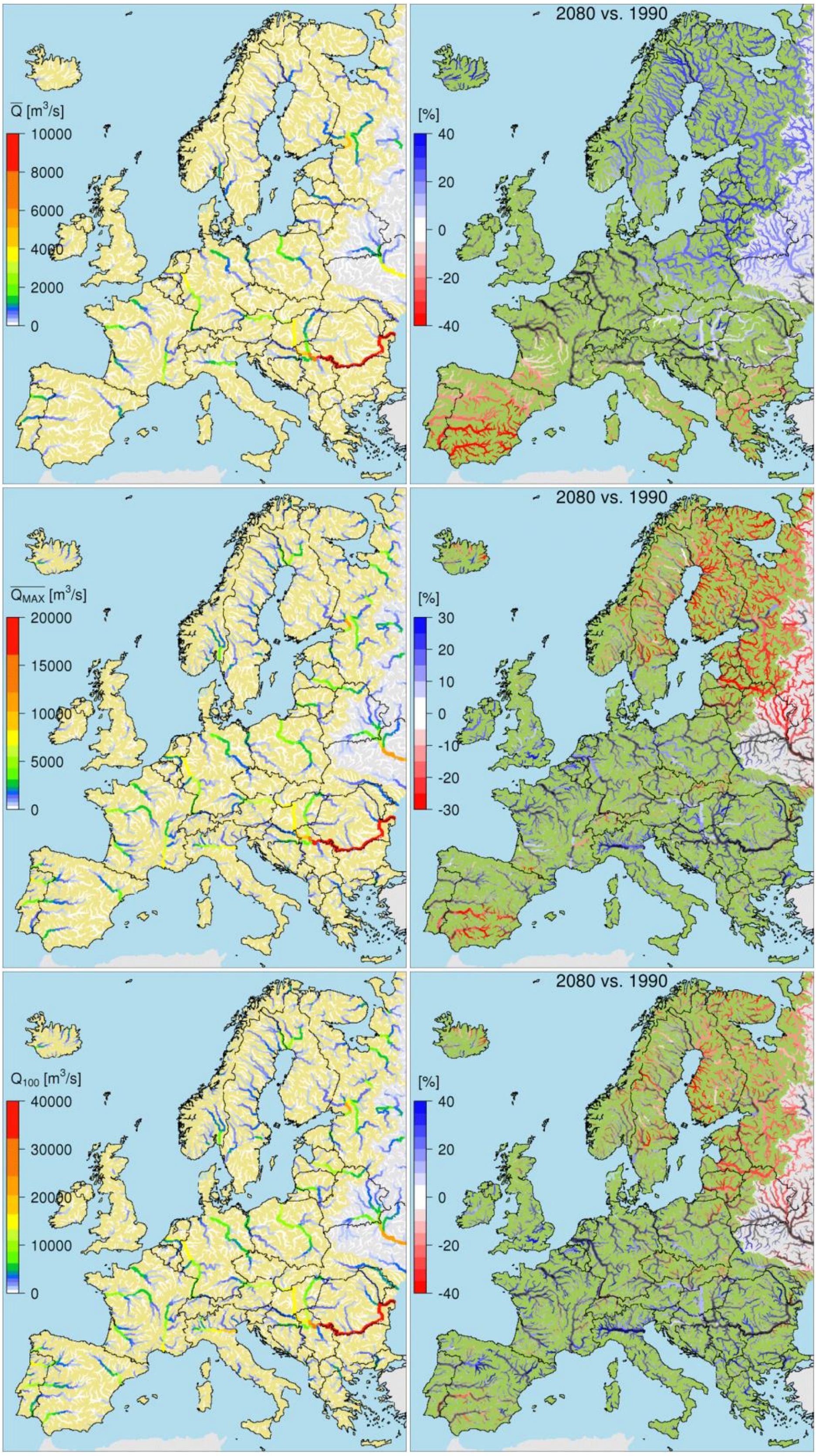
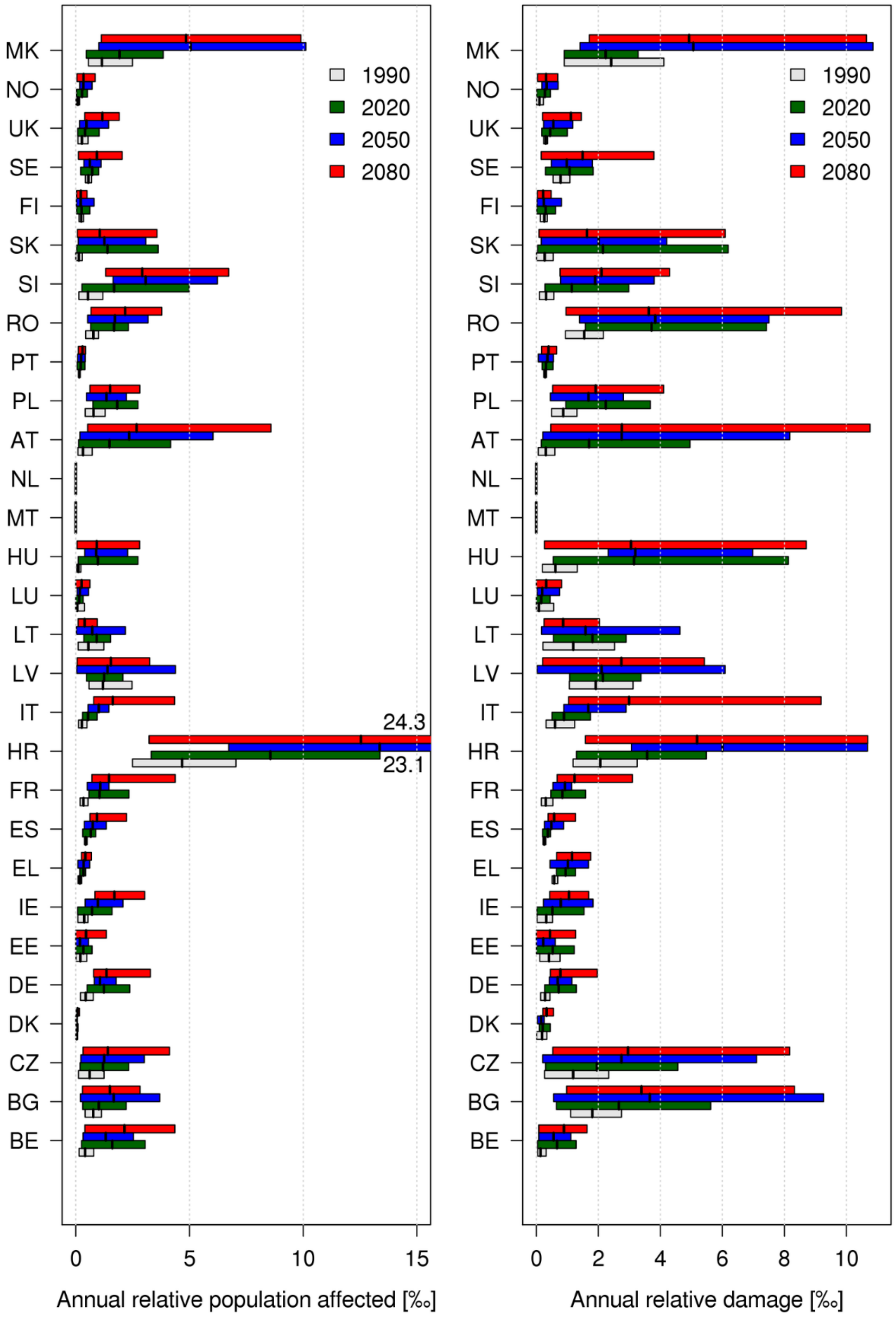


Figure 8-4 Evolution of the population affected and expected annual damage for EU countries based on RCP8.5 (mean value and uncertainty range). Colour bars show relative values rescaled by the country population (left) and GDP (right)

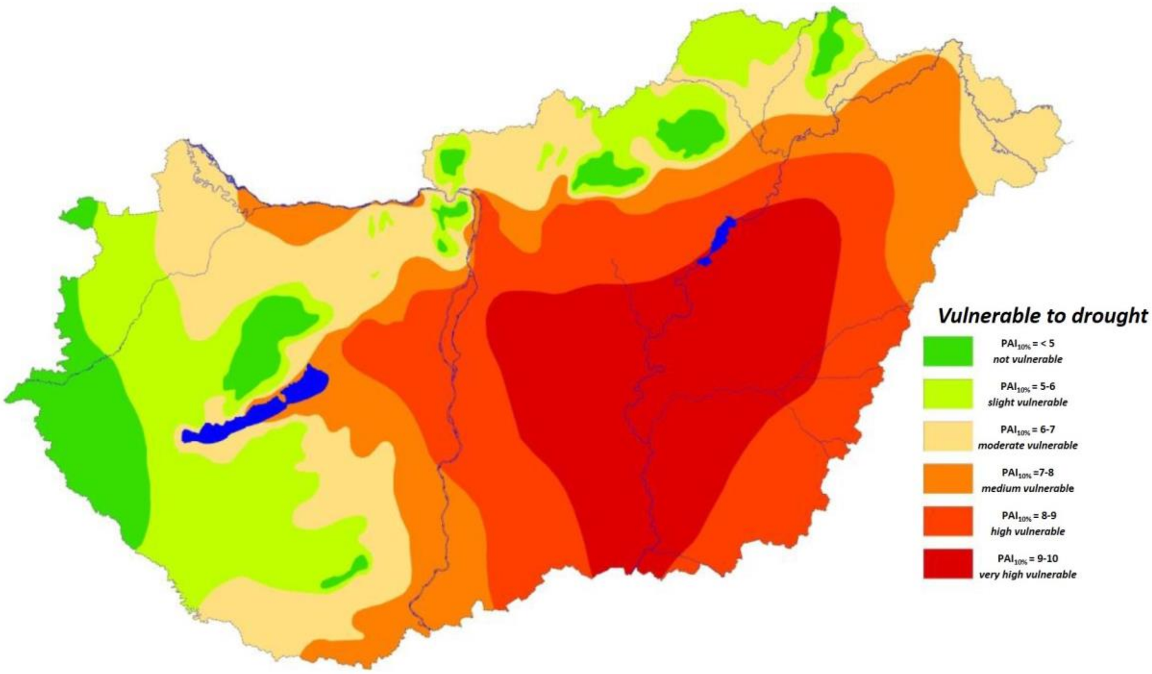


9. Drought analysis, monitoring and projections

Due to the unequal distribution of precipitation in time and space 28 years from 100 years is expected to be droughty in Hungary. The drought primarily affects the centre of the Great Plain, where the evapotranspiration usually exceeds the precipitation amount (climatic water scarcity). The climatic water scarcity/excess is ranging from 100mm/a excess to 350 mm/a scarcity, with the peaks in the southern Tisza catchment (Figure 9-1). This periodically occurring phenomena – causing long-term water scarcity for the flora and the fauna, the agriculture and for the society – will be worsen by the climate change. Due to the interventions after the mid of the XIX. century, the reduction of floodplains and the changing land use the area and duration of drought also increased.

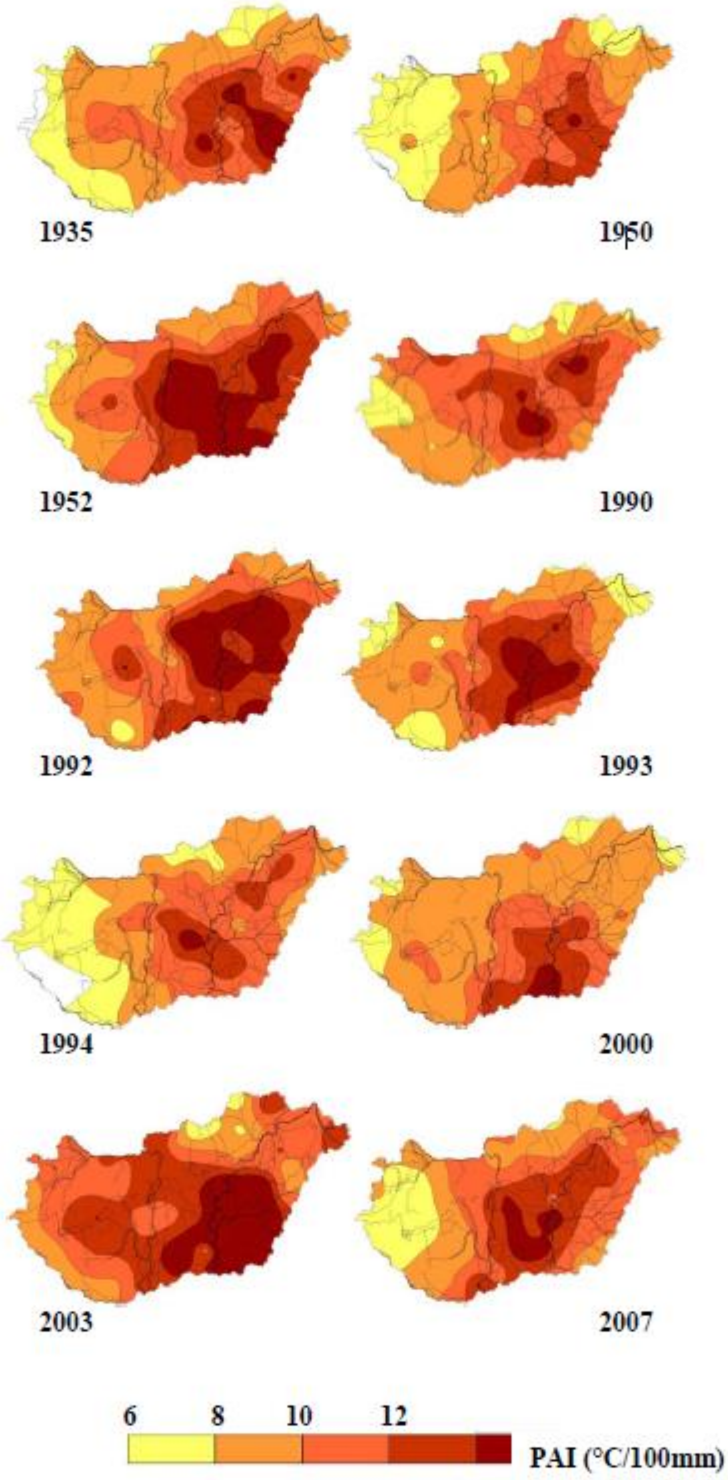
The fight against the extreme water management circumstances is major driving force in Hungary. The flood protection, inland excess water protection, the protection against drought damages are all on a national scale, but are especially important on the Great Plain and the Tisza catchment.

Figure 9-1 The zonal drought map of Hungary (1931-2000)



The occurrence probability of drought shows an increasing tendency on distinct regions of Hungary. The chance of a moderate drought significantly increased in the last years - most probably due to the more and more significant change in the climate – and the probability of extreme droughts in winter and spring also increased. Hungary can be divided into two regions by the scale of the climate change effect on droughts. The Transdanubian region and the northern mountainous region is not effected even in extreme climate change, but the Great Plain is vulnerable, especially the: Duna-Tisza közi Homokhátság, the Közép-Tisza region, the Berettyó-Körös region, the Nagykunság, the Hevesi-sík, the Borsodi-mezőség and the Nyírség (Figure 9-2). The different drought sensitivity of the distinct soil types, local climatic effects, and the adaptation potential of the region defines its resistance against drought.

Figure 9-2 Zonal drought maps of Hungary



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The current document is predominantly based on the revised River Basin Management Plan of Hungary, compiled with the coordination of the General Directorate of Water Management. The full text and all attachments (charts, tables, maps and supporting materials) are available online (in Hungarian) at http://www.vizugy.hu/index.php?module=vizstrat&programelemid=149

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