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Flood and Drought Strategy of the Tisza River Basin

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2010.11.30.

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1 Introduction

The Tisza[1] River Basin is one of the most picturesque territories of Europe. Mountain streams, meandering rivers, diverse floodplains are characteristic of this region – home to the unique mayfly species called the Tisza Flower (*Palingenia longicauda),* which is only found in the rivers of the plains of the Carpathian Basin.

Ukraine, Romania, Slovakia, Hungary and Serbia share not only the beauties of the Tisza River Basin but also the area's problems related to water supply, severe flooding, droughts, landslides and erosion, accidental pollution by industrial and mining activities as well as pollution from agricultural sources. These problems are influencing water quality and quantity, and the management of land and water.

The Tisza River Basin is the largest sub-basin of the Danube River Basin and the countries of the basin have a long history of cooperation resulting among others in signing the Agreement on the protection of the Tisza and its tributaries in 1986 or in establishing the Tisza Forum to address flood issues in 2000. The Tisza cooperation has been given a new perspective in line with the development of the Danube River basin cooperation and the EU water policy.

In 1994, the Danube River Protection Convention (DRPC) was signed in Sofia. The DRPC forms the overall legislation instrument for cooperation on transboundary water management in the Danube River Basin. It aims to ensure that surface water and groundwater within the Danube River Basin are managed and used sustainably and equitably. To implement provisions and to achieve the goals of the DRPC, the International Commission for the Protection of the Danube River (ICPDR)[2] was established in 1998 following the entry into force of the Convention with a secretariat based in Vienna.

Under the EU Water Framework Directive (2000/60/EC)[33] the ICPDR is the platform for coordination amongst the Danube countries including EU Member States, accession countries and other Danube riparian states for the implementation of the provisions of the Directive at transboundary level. In addition to the Danube River Basin planning, the ICPDR is taking an active role in sub-basin planning as well. One of the key objectives of the EU Water Framework Directive (WFD) is to ensure that all water meets ”good status“ by 2015. A key step towards this objective is the development of a River Basin Management Plan by 2009.

At the first Ministerial Meeting of the ICPDR countries in December 2004, ministers and high-level representatives of the five Tisza countries signed the Memorandum of Understanding (*Towards a River Basin Management Plan for the Tisza River supporting sustainable development of the region*). The ICPDR established the Tisza Group for coordination as well as implementation. The Tisza Group is the platform for strengthening coordination and information exchange related to international, regional and national activities in the Tisza River Basin and to ensure harmonisation and effectiveness of related efforts. The Tisza Group countries agreed on to prepare a sub-basin plan (the

[1] The spelling of the river name differs from country to country (UA: Tysa; RO: Tisa; SK: Tisa, HU: Tisza; RS: Tisa; UK: Tisza). In the context of this report, the English spelling `**TISZA**` will be used.
[2] http://www.icpdr.org
[3] http://ec.europa.eu/environment/water/

Tisza River Basin Management Plan) by 2009, which integrates issues on water quality and water quantity, land and water management, flood and drought.

The first step towards the objective is the preparation of the Tisza Analysis Report by 2007, which is the first milestone in implementing the Memorandum of Understanding. It characterises the Tisza River and its basin, identifies the key environmental and water management problems, in relation to water quality and water quantity, and creates the basis for further steps.

This analysis presents the issues of the two extremes: floods and droughts.

A) Floods

Floods are natural phenomena, but they can turn into disasters causing widespread damage, health problems and even deaths. This is especially the case where rivers have been cut off from their natural floodplains or are confined to man-made channels where houses and industrial sites have been constructed in areas that are naturally prone to flooding. Recent years have seen an increase in extreme events in the Tisza River Basin with devastating results.

The lowland area of the Tisza River Basin can be extensively inundated due to sudden snowmelt, heavy precipitation or as a result of the rise in groundwater level. This excess water can cause significant damage to agriculture or infrastructure and settlements. In addition, flood waters can also wash pollutants directly into the river, further endangering the ecosystem.

2 Characterisation of Current Flood Situation

2.1. Floods in the Tisza River Basin

Floods in the Tisza River Basin can form at any season as a result of rainstorm, snowmelt or the combination of the two. Snowmelt flooding without rainfall rarely occurs in the Tisza Basin and floods resulting from this account for no more than 10-12% of the total amount. The rise in temperature is almost always accompanied or introduced by some rain. Thus large flood waves are generated more frequently in late winter and early spring.

The warm period from May to October accounts for nearly 65% of total floods, and the cold period from November to April accounts for only 35%. However maximum discharges and the volume of restricted flow of floods in the cold period generally exceed those observed in warm period.

The floods generated in Ukraine, Romania and Slovakia are mainly rapid floods and last from 2-20 days. Large floods on the Tisza in Hungary and in Serbia, in contrast, can last for as long as 100 days or more (the 1970 flood lasted for 180 days). This is due to the very flat characteristic of the river in this region and multi-peak waves which may catch up on the Middle Tisza causing long flood situations. Also characteristic of the Middle Tisza region is that the Tisza floods often coincide with floods on the tributaries, which is especially dangerous in the case of the Someş/Szamos, Crasna/Kraszna Bodrog, Criş/Körös and Mures/Maros Rivers.

Long-observations of level regime and maximum flow provide evidence of the distribution of extremely high severe floods in the Tisza River Basin along the Upper, Middle and Lower Tisza and its tributaries. However, not all high upstream floods cause severe floods along the Middle or Lower Tisza due to attenuation.

Following a relatively dry decade, a succession of abnormal floods has annually set new record water levels on several gauges over the last four years. Over 28 months between November 1998 and March 2001, four extreme floods travelled down the Tisza River. Large areas were simultaneously inundated by runoff and rapid floods of abnormal height on several minor streams. The extreme Tisza flood in April 2006 was preceded by several floods in February and March generated by melting snow and precipitation. The situation was worsened on the lower Hungarian stretch and in Serbia by the extreme flood on the Danube that very seldom coincides with that of the Tisza.

In the 19^{th} century, river floodplains traditionally supported flood-tolerant land uses, such as forests, meadows and fishponds. Since then, land development interests have changed to modern agricultural production demanding low and tightly-regulated water levels and protection from seasonal inundation. This trend has been facilitated by the availability of arable land, crop intervention payments and grant aid for drainage, including pumped drainage within floodplains. This has led to the development of arable agriculture that demands low water levels in associated rivers. Industrial and urban building has also increased within drained floodplains lasting recent decades. In Hungary, work to drain the Tisza wetlands began in the 19^{th} century and today some 500,000 people – 5% of Hungary's population – live on land reclaimed from the Tisza. Efforts to reduce flood impacts by building higher dikes and continued river bed regulation have resulted in a deposit of silt within the main bed which has inadvertently increased flood risks.

In addition to the altered nature of floodplains, the reduction in upper and mid-catchment water retention leads to more flood events downstream where river channels and small floodplains no longer can contain peak water levels, even for minor flood events. The lack of coordinated mechanisms to mitigate floods in the upper catchment may lead to compounded impacts downstream. When flooding occurs, industrial sites, mining areas, agricultural fields and municipal waste facilities can become inundated and pollute the waters of the Tisza Basin.

The Danube River Protection Convention emphasises the need for transboundary level cooperation in forecasting and monitoring flood events if their impacts are to be minimised. In response to this, the Danube countries have decided to establish joint emergency plans. The *'Action Programme for Sustainable Flood Protection in the Danube Basin'* was endorsed at a Ministerial Conference in December 2004.

Another type of inundation in the lowland areas of the Tisza River Basin originate from unfavourable meteorological, hydrological and morphological conditions on saturated or frozen surface layers as a result of sudden melting snow or heavy precipitation, or as a result of groundwater flooding. This undrained runoff or excess water cannot be evacuated from the affected area by gravity and may cause significant damages to agriculture or even to traffic infrastructure and settlements.

The appearance of the inundation caused by *excess water* (undrained runoff) is determined together by natural and artificial circumstances. Natural circumstances can be the meteorological conditions (temperature, precipitation), morphological conditions (altitude, geographic structure), soil properties (permeability, physical structure, reservoir ability, type of soil, frozen soil), hydrogeological conditions (groundwater level state), geological conditions (soil, rock, impermeable layer). Artificial conditions include drainage networks (the capacity of the network during the excess water's period, its construction, backwater effect, pumping capacities), agricultural practice (irrigation, used agricultural technologies, type of cultivated plant) and the increase in urbanised areas.

There are more than 50 definitions for this phenomenon in Hungarian alone. The large number of definitions shows that this phenomenon has an effect on several parts of the catchment and several elements of the economy.

Lowland drainage systems are characteristic attributes of the Tisza Valley. These networks determine surface water accumulation and effect runoff in the whole lowland area along the Tisza River. These networks have been always connected to the everyday life of the population living in the lowland. Small local depressions and small valleys were the first elements of these networks, and were later modified for a higher capacity.

Experience with the formation of the undrained runoff phenomena shows that the most critical period is the springtime. The most serious inundations are registered at this period when the natural conditions are unfavourable for natural runoff. In spring rapidly melting snow combined with rains may cause inundations over significant areas.

Undrained runoff has also been observed in the summer, when heavy rainstorms trigger inundations. This type of inundation causes extensive damage in settlements and in plough-lands, as plants can't tolerate the inundations in that period of their growth.

In autumn undrained runoff have been registered on only a few occasions in connection with heavy rainfalls.

Man-made facilities have a strong effect on runoff, as they can modify the flow conditions such as the backwater effect (at the mouth of canals) or the effect of pumping stations (where there isn't conformity between the concentration time and the capacity of pumping station).

2.2 Flood protection systems and the status of flood protection structures

In the Tisza Valley, organised, systematic flood protection started in the mid 19th century. The backbones of these works are the flood protection dikes along the main river and tributaries, but also include river training works, bank protections, flood retention reservoirs and polders. At the same time drainage systems with pumping stations were also built. As the hydrological regime of the Tisza River became better understood and some dikes breached or failed to meet the design criteria, the dikes had to be reconstructed, upgraded and strengthened. This repeated upgrading and heightening of dikes resulted in the so called ”onion type” cross sections that are characteristic feature of these type of old dikes and can cause severe problems during flood fighting.

Generally, the main dikes are designed for the “one in hundred year” return period floods. Although this is a general design criterion, there is still a major difference between the approach used in Ukraine, Romania and Slovakia as compared to the method used in Hungary. In upstream countries where reliable rating curves are available, the “$Q_{1\%}$” is used for the design of the structures. On the flat region of the Tisza the rating curves are not single-valued, hence the discharge statistics are not reliable and water level statistics are used to provide the “$h_{1\%}$” design level. This leads to a different degree of protection at border sections, but in the frame of the existing bilateral agreements, this problem is relaxed during negotiations.

To provide security against wave actions and to compensate for the uncertainty in the calculation of design flood level and in the dimensioning of dikes, a freeboard of 1 m is generally applied with positive and negative deviances in justified cases.

Reservoirs are mainly multi-purpose in mountainous area and are used for water management, fish farming, electricity production, providing ecological flow and some are also used for flood retention. The polders (dry flood retention basins) on the lowland regions are used for emergency flood retention only.

Table 1. Flood protection structures in the Tisza River Basin

Country/River	Length of the dike [km]	Reservoir and/or polders[4] [$10^6 m^3$]
Ukraine		
Tisza River Basin	726 (embankments) + 276 (bank protecting and training structures)	65.8 in 9 reservoirs an 59 ponds
Romania		
Tisza	5.56	-
Viseu	7.85	-
Iza	13.53	-
Tur	77.12	28.09 in 4 reservoirs
Someş	1 198.00	557.0 in 35 reservoirs
Crasna	163.39	28.79 in 1 reservoir and 1 polder
Barcau	336.00	-
Crişul Alb	210.19	-
Crişul Negru	378.10	45.50 in 2 polders
Crişul Repede	55.40	117.25 in 3 reservoirs
Mures	825.00	524 in 31 reservoirs and polders
Bega-Veche	104.30	46.94 in 9 reservoirs and polders
Bega	115.40	65.43 in 15 reservoirs and polders
Slovakia[5]		
Tisza	6	-
Slana	5.7	-
Tributaries of Slana	107.8	14.1 in 4 reservoirs
Bodva	28.6	-
Tributary of Bodva	41.0	25.6 in 2 reservoirs
Hornad	34.2	62.7 in 2 reservoirs
Tributaries of Hornad	-	11.5 in 1 reservoirs
Bodrog	22.12	-
Tributaries of Bodrog	230.87	631.9 in 3 reservoirs and

[4] Total storage

[5] Note: Total reservoir volumes as in the text and table taken from Abaffy, D., Likáč, M., Liška, M.: Dams in Slovakia. T.R.T. Medium, Bratislava 1995.

Country/River	Length of the dike [km]	Reservoir and/or polders[4] $[10^6 m^3]$
		1 polder
Hungary		
Tisza	1 064.1	-
Túr	75.7	-
Szamos	93.0	-
Kraszna	62.3	-
Lónyay Main Canal	102.8	-
Bodrog	57.9	-
Sajó (incl. Takta)	119.6	-
Hernád	62.0	-
Zagyva-Tarna	389.0	46.0 in 3 reservoirs and 2 flood retention basins
Körösök (incl. Berettyó, Hortobágy-Berettyó)	747.9	295.0 in 6 flood retention basins
Maros	95.1	-
Tisza River Basin in Hungary	2 869.3 (primary defences) and 407.6 (confinement structures)	326.0 in 3 reservoirs and 8 flood retention basins
Serbia		
Tisza	314.8	-
Old Bega	71.5	-
Bega	62	-

In **Ukraine** the flood protection system in Zakarpattia District was created to protect the area against water during frequent floods that can take place at any season and includes: protection embankments, bank strengthening, regulated reaches of river, main and incoming canals with structures, pumping stations on reclamation systems, reservoirs and ponds.

Protection embankments were constructed beginning in 1863 with the use of various technologies, for various probabilities, and according to present norms they no longer constitute a reliable flood protection complex.

The extent of the embankment accounts for 726 km and bank protecting and training structures on 276 km are constructed as rubble concrete bulkheads, rock paving, gabions and bank heads. Severe floods, especially those in 1998 and 2001, damaged bank protection at many places and the flood protection system now requires reconstruction and strengthening.

There are 9 reservoirs within the district of a total volume over 41.8 10^6 m^3 and 59 ponds. The volume of all reservoirs totals up to 65.8 10^6 m^3, and their surface area is 1,563 thousand ha.

In **Romani**a the main objectives of the water management works in Tisza River Basin are to:

- Satisfy the water needs for population, industry and other water usages;
- Protect water quality;
- Mitigate the destructive effects of water;
- Capitalise on the hydropower potential of main watercourses;
- Assure the ecologic and health needs of people.

Flood protection is achieved through regulation works, bank protections, embankments and reservoirs with high flows attenuation role.

Levees along both-side of the Bega Veche River were built at the end of the 19th century in the scope of overall river training. After a disastrous flood in 1932, levees were reconstructed and the riverbed deepened to enable safe flood conveyance.

The Bega River is fully canalised. The Topolovac weir, the furthest upstream, holds inflow into the channel lower than 83.5 m^3/s. Excess waters are routed into the Timis River through an outflow channel.

In **Slovakia** flood protection is provided by dikes. In general the dikes are dimensioned to $Q_{1\%}$, – but at certain location (Bodva for example) $Q_{5\%}$ is used – valid before the floods in 1972-1976. Values of high waters for 1% exceedance were reconsidered and increased by 25-40%. Flood retention reservoirs are used to reduce peak discharges, and where this possibility is available the design discharge has been reduced. Several dams and reservoirs have been built to store water for economic use and to protect against flood.

In **Hungary** approximately half of the territory of the country is situated in the Tisza Basin, and the present level of flood protection development has been attained by almost two centuries of planned water management efforts. In the early years of the 19th century, parts of the 20,000 km^2 floodplain (about 20 % of the Hungarian plains) were inundated permanently or for periods of differing lengths of the year. Flood control development in the Tisza Valley was introduced by training isolated sections of some of the tributaries and building embankments along them. The ambitious comprehensive project was launched in 1846 and 4,500 km of embankments were built over 150 years (according to the data of 1980), offering flood safety for an area of 27,000 km^2. The present shares of Hungary are 2,869 km of embankment and 15,354 km^2 protected area.

Flood control has been extended to 97% of the flood plains along the Hungarian section of the Tisza. These flood plains are subdivided into 96 flood plain basins (flood areas). The ratio of the flood plains in the Danube and the Tisza catchments is approximately 1:3, clearly demonstrating the importance of flood control in the latter. The 96 flood areas in the Tisza Valley cover an area of 15,354 km^2 with a total population of 1 448 702 and 418 communities including 60 towns. These communities rely on 2,869 km of embankments (levees) for their flood safety.

Flood waves rushing down mountain catchments enter the lowlands before the national boundary. River and levee sections of common interest have been designated with the neighbouring countries, where streams form or cross borders. The total length of levees covered by international agreements amounts to 1,055 km (one-fourth of the defences).

Embankments of 1,704 km (59% of the total) comply with the dimensional specifications. The rest of the levees (1,194 km) offer safety against floods of 60-80 years return period, though at the price of considerable emergency efforts. It should be noted that even the improved, strengthened levee sections include local weak spots, with properties poorer than those of the connecting parts, which fail to meet the safety criteria. Regular levee surveillance reveals several hundred sections where the level of safety is dangerously low (such as the crossing of ancient meanders, streams, cracked embankments). The total length of these sections is approximately 560 km.

There are 1,800 structures (sluices and culverts) which cross the levees. Some of these were built 80-100 years ago and are in a very poor state and in need of repair. These and other crossing structures represent potential safety risks and are monitored with special care.

In **Serbia** flood protection for the Tisza River is based on 314.8 km of levee lines along both riverbanks. Levees were built in the 18th century and heightened and improved after each large flood (in 1919, 1924, 1932, 1940, 1944, 1947, 1965 and 1970). After a long-lasting and costly flood defence in 1970, a systematic reconstruction of existing levees was carried out and new levees were built. The conditions of floodwater conveyance were also considerably improved by engineering works in the riverbed (enlargement and shortcutting) and on the floodplain (correction of levee lines). In some parts, floodplain areas are protected and cultivated with ”summer dikes” for floods of 10% probability.

2.3 Drainage systems

The total area covered by lowland drainage networks in the Tisza Valley is 56,789.37 km^2. The area and the numbers of the sub-drainage systems, length of canals, the average discharges and the number and capacity of pumping stations can be seen in the Table below.

Country	No of sub-drainage systems	Total areas [km^2]	Length of canals [km]	Average discharges [$l/s/km^2$]	No of pumping stations	Total flow [m^3/s]
Ukraine	5	1 093.70	1 296	384	35	NA
Romania	273	10 964.37	16 409	138	860	1 524.00
Slovakia	12	1 205.30	633	115	16	115.20
Hungary	64	33 765.00	37 083	31	609	266.00
Serbia	10	10 745.00	8 515	59	70	145.53
Sum	*364*	*57 773.37*	*63 936*		*1 590*	*2 050.73*

According to geomorphological conditions, the longitudinal slope of the canals is very small (0.05-0.2 m/km). Consequently grass and water-receptive vegetation decrease the conveyance capacity of the canals, and the backwater effect (at the mouths) can cause similar difficulties in the systems.

Reservoirs are used in several locations to reduce damage caused by undrained runoff. Most of them are former wetlands or other low value areas where the morphological conditions are advantageous for the storage. The utilisation of these areas is complex – outside of the inundation period they function as fishponds, wet meadows or wetlands and they provide free storage capacity at inundation times for excess water. This may cause conflicts between operational and storage functions. The reservoirs play a key role in the lowland drainage in Hungary, with a total volume of 227 million m^3.

The biggest inundated areas were observed in 1942 when 9,000 km^2 along the Tisza Valley were under water due to undrained runoff. At the end of 1999 the inundated areas were about 8,000 km^2, which represented the second largest inundation in the region. The database doesn’t have precise or homogeneous inundation data because the registration of the inundated areas was made with different procedures and with different precision. While these inundations cause damages to the rural areas they can possibly mitigate the negative consequences of water scarcity.

For the effective prevention and mitigation of the consequences of inundations, the capacity of the lowland drainage networks are very important. For this reason continuous maintenance activities have to be carried out. These activities should include mowing the grass and water-receptive vegetation in canals; dredging canals; stabilising canal beds and banks; depositing and treating dredged material and maintenance and repairing pumping stations, weirs and bridges. Unfortunately, the lack of financial resources has caused difficulties in maintenance activities, and inundations have occurred in some cases as a consequence.

With the transition to a more market-based agriculture after 1989, state subsidies for agriculture declined and state funding for large-scale drainage operations was reduced as well. These factors, along with low productivity of “converted wetlands”, have resulted in a decline in agricultural activity.

In most Eastern European countries, the policy is changing. New policies call for approaches that rely on ecological means to control flood and on defining water management priorities more broadly, but also focus on preserving natural habitat for biodiversity conservation, on water quality and other more broadly defined benefits. Governments have made great efforts to comply with the EU legislation and seek ways of improving water management and encouraging appropriate agricultural practices in the region. The transition from conventional water and agricultural management techniques to an integrated ecosystem management should lead to an effective utilization of the Tisza Valley.

The inner area of settlements represents a key question in connection with the lowland drainage networks. The increasing areas of the settlements are accompanied with an increase in the paved impervious areas and the increase in urban runoff in terms of volume and peak discharge as well. To reduce urban flood risk, storm water reservoirs should be constructed (wet ponds and dry ponds).

The increased threat from flooding – let it be fluvial or excess water flooding – has mobilised the Tisza countries to develop long-term national flood action plans. The transboundary water management commissions helped harmonising the plans and the different interests of the countries. The *‘Action Programme for Sustainable Flood Protection in the Danube Basin’* endorsed at a Ministerial Conference in December 2004 made recommendations to refine the Danube Basin Level Flood Action Plan on sub-basins. The Ministerial Meeting charged the Flood Protection Expert Group to develop flood action plans (for 17 sub-basins) among them the Sub-Basin Level Flood Action Plan of the Tisza Basin. The following two Chapters summarize the results of these activities.

3 Targets and Measures

3.1 Target settings

The national flood plans set some high level priorities. These targets have then been further refined using all available techniques (structural vs. non-structural measures, prevention vs. protection, land use planning etc.) of the modern flood protection or rather flood risk management.

Ukraine set the targets for Tisza basin flood protection in the “Complex Flood Protection Program in the Tisza river basin in Zakarpattia District on 2002-2006 and forecast until 2015” as follows:

- To create safe conditions for human settlements and industry operation in Upper Tisza;
- To improve hydrological regime of rivers and ponds;
- To ensure surface water run-off regulation in order to optimize water discharge during flood events;
- To provide effective spatial use of agricultural lands, cities and other settlements;
- To minimize possible losses from floods.

This Program was revised in 2005 and is planned for the period 2006-2015 (See Table below).

Stages	Years	Actions
1	2006-2015	- Identification of flood zones of different probability based on modern technologies of hydrological investigations, geodesic and mathematical calculations; - Reconstruction and construction of the new dikes - River bank enforcement - River bed training and other actions
2	2006-2015	- Construction of accumulative dry polders in the plain part of the region
3	2008-2015	- Construction of dry flood protection reservoirs in the mountainous part of the region.

The **Romanian Action Plan** for flood protection on medium-term (2009-2012) launched and comprises new hydraulic structures in frequently affected zones, higher safety degree of existing works and finalization of ongoing ones. For the entire territory of Romania the Action Plan foresees 1850 km river regulation 976 km of dikes, 810 km riverbank consolidation, finalization of two wetlands in Crişul Negru basin and identification of new zones as wetlands and DESWAT (Destructive Water) and Water Management (WATMAN) projects finalisation.

The prioritisation criteria for promoting investments for flood protection have been made following:

- Inclusion of the proposed works in the Strategy of Ministry of Environment;
- Actual safety degree of the flood protection structures;
- Amplitude of avoided damages as result of the projects;
- The elaboration status of technical and economic documents;
- Financing possibility
- Occupied field status.

The **Slovakian** measures for mitigating of adverse impacts of floods for human life and health, the environment, economic activities, cultural and historical heritage result from the sources of menace and conditions in the given endangered localities. It is impossible to find universal solutions and measures valid everywhere, because they have to respect at least:

- Sources and pathways of floods;
- Nature of runoff conditions in the individual watersheds;
- Natural conditions in endangered territories;
- Charges of the flood protection measures and their comparison to the value of protected properties.

The “Renewal of Vásárhelyi Plan” in **Hungary** defines the following targets:

- Provide protection against 1:100 year floods for the floodplains of the Tisza River by
  - strengthening the existing dykes to withstand the design flood and
  - restoring the former conveyance capacity of the flood bed
- Reduce the level of 1:1000 year flood by about 1 m by
  - giving “more room to river” (construction of regulated dry flood retention reservoirs),
- Provide opportunities to nature development and land use change by
  - creating (restoring) wetlands
  - providing “irrigation” water on the polders during smaller floods
  - creating technical background for better water management on the polders by construction of water distribution system.

Implementing criteria from the Water Management Master Plan of the Republic of **Serbia**, and taking into account the actual flood protection conditions and problems (especially the size of flood prone areas and possible damages) the long term flood protection strategy in the Tisa River basin in Serbia will comprise of:

- The existing layout of flood protection structures remains the same, while the following is planned:
  - regular maintenance of the flood protection structures, according to criteria, standards and norms
  - reconstruction or/and construction of the flood protection structures to decrease flood hazard
- Gradual and broad implementation of non-structural flood protection measures (as upgrade of the flood forecasting and warning procedures; introduction of flood maps into spatial plans, etc.)
- International cooperation in flood management on rivers which cross the state borders with Hungary and Romania.

3.2 Regulation of land use and spatial planning

All five countries consider land use and spatial planning as a crucial point in flood risk management. Flood risk mapping is on top of the agenda. The flood risk maps have to be reflected in the spatial planning and construction licences. Limitations on regularly or potentially flooded regions are to be set.

The following table shows the individual targets set and measures planned by the countries. Although there are similarities the original text written by each country is retained to better reflect the actions.

Targets	Measures
Ukraine	
- establishment of protective strips along the banks of watercourses as required by Water Code (Art. 88) and the Land Code (Chapter 13); - resettlement of people from flood prone	Reconstruction of roads
	Actions to prevent land erosion: - Amelioration (sediment retention volumes and reforestration) - Hydrotechnical (earth mounds, backfilling of

Targets	Measures
zones, which cannot be protected by technical flood defences; - prohibition to construct houses and industrial sites in flood prone zones; - renaturalisation of lands by means of reconnection of former floodplain; - development of flood hazard and flood risk maps, as required by EU Flood Directive; - introduction of environmentally friendly technologies of water and land use; - further development of amelioration channel work.	ravines, embankment walls and construction of terraces on the hills) - Agrotechnical (recultivation)
	Actions to prevent mud flow
Romania	
- Show the flooded areas on local urban plans using historical data and/or study results. These maps are from the Local Flood Protection Plans and are updated every 4 years.	Implementation of the medium- and long-term flood risk management strategy by - Land-use control - Relocation, land purchasing & cultural changes
	- Including the results of the study “Identification and delimitation of the natural hazards (earthquakes, landslides and floods). Hazards maps at county level” into local and regional developing plans
	- Including the maps from Local Flood Protection Plan (Contingency Plans) into the Urban Development Plans
Slovakia	
- Landscape development plans and spatial plans contain and respect flood hazard maps and flood risk maps. - Limitations related to land use in flood prone areas are defined.	- Transposition of EU Directive 2007/60/EC on the assessment and management of flood risks to the Slovak national Flood Protection Act
	- Implementation of the Slovak national Flood Protection Act (i.e. also EU Directive 2007/60/EC on the assess-ment and management of flood risks)
	- Introduction of flood maps into spatial plans of regions, districts, municipalities
	- Application of Land use limitations introduced in spatial plans
	- Creation of river basin management plans and application of authorised measures
	- Respect of the flood protection principles by spatial planning and land use
	- Strengthen the law and competencies of the river basin administrator
Hungary	
- Transposition of the EU Floods Directive into the Hungarian Water Act - Preparation of flood risk maps - Preparation of flood risk management	- Modify the text of the Water Act to incorporate the aim of the EU Floods Directive
	- Methodological development of flood hazard and risk mapping

Targets	Measures
plans	- Data collection - Flood hazard mapping - Flood risk mapping
	- Preparation of flood risk management plans
Serbia	
- Spatial plans of municipalities contain flood hazard maps (both for potentially and actually flooded areas) and flood risk maps - Limitations related to land use in flood prone areas are defined	- Defining water estate
	- Introduction of flood maps into spatial plans of municipalities
	- Preparation of instructions for limitations on land use
	- Land use limitations applied

3.3 Reactivation of former, or creation of new, retention capacities

To reduce runoff each country in the Tisza Basin considers some kind of actions to hold the water on their territory for a longer time than present. Wetlands, dry reservoirs and polders are the tools in consideration. The complex utilisation of reservoirs (energy production, irrigation, flood risk management etc.) is a less preferred solution though some nature development, wetland construction and water management options in the polders make the picture more divers.

Targets	Measures
Ukraine	
- Reactivation of former floodplain by construction of polders in plain part of Tisza river basin; - Creation of retention capacity by construction of dry flood protection reservoirs in the mountainous part of the river basin.	- Construction of 42 dry flood retention reservoirs in mountainous part of Tisza basin.
	- Construction of 24 polders on the floodplains.
	- Reconstruction of 5 water reservoirs
Romania	
- Construction/restoration of two wetlands has been considered (in Crişul Negru Basin near to Sudrigiu and Tinca localities). Feasibility studies of them have been prepared.	- Two wetlands in Crişul Negru (Black Criş) Basin near Sudrigiu and Tinca
Slovakia	
- Water in every sub-basin is detained as long as possible - realization of non-structural measures within whole sub-basins in the forested and agricultural lands either. - Provision of suitable tools for the retention of the water - water management reservoirs and polders. - Provision of adequate space for flood waves routing in settled areas especially.	- Tighten the rules applied during giving permission for activities within whole sub-basin
	- Integration of Ecosystem Management Principles and Practices into Land and Water Management of Laborec-Uh region (Eastern Slovakian Lowlands)
	- Design and building of new polders, retention reservoirs
	- Reassessment of rivers retention and detention capacities
	- Updating and implementation of results of the study “The survey of water courses in towns and villages (SWME)”.

Targets	Measures
	- Revitalization of the death arms of Latorica
	- Revitalization of the death arms of Bodrog
	- Revitalization of the death arms of Čierna voda
	- Revitalization of the death arms of Uh
Hungary	
- Reactivation of former retention capacities by building flood retention reservoirs along the Tisza River; - Maintenance of existing retention capacities along the tributaries of Tisza River.	- Creation of 14 flood retention reservoirs - Modernisation of existing flood retention reservoirs
Serbia	
- Retention capacities along the Tisa are re-considered.	- No measure has been decided upon yet

3.4 Structural flood defences

There is a fairly large flood protection infrastructure in the Tisza Basin. The construction of it has started almost 200 years ago. The maintenance and the reconstruction of it are high on the agenda of the Tisza Basin countries. New protective structures are also considered mainly in the upper parts of the Basin. Erosion control is also a topic of the mountainous regions.

Targets	Measures
Ukraine	
- reconstruction and construction of the new dikes - river bank enforcement - riverbed training - construction of dams, - reconstruction railway and road bridges, - erosion prevention actions.	- Reconstruction and construction of the new dikes - River bank enforcement - Riverbed training
Romania	
The Action Plan (2009-2012) foresees - 1850 km river regulation - 976 km of dikes, - 810 km riverbank consolidation[6]	Implementation of the medium- and long-term flood risk management strategy- Improvement & maintenance of defence structures - 224 objects (4 polders, 211 riverbank regulations, 9 dams)[7]
	In the Tisza Sub-Basin - Improvement of Tarna Mare river at Tarna Mare locality, Satu Mare county - Regularization of Tarnava Mica river on the sector Cetatea de Balta – Blaj, Alba county - Construction of Bedu Dam – Maramureş County - Construction of Varsolt Dam – Salaj County - Construction of Lesu Dam – Bihor County - Construction of Runcu Reservoir and

[6] For the whole Romanian territory including the Tisza Basin as well
[7] For details see „Sub-Basin Level Flood Action Plan Tisza River Basin”

Targets	Measures
	- improvements of some river sections – Someş-Tisza - Construction of Valea Moneaseóa, Ginta, Valea Craiasa, Valea Hotarel , Poiana and Corbesti polders and improvements of some river sections – Crişuri Basin - Construction of Mikoiesti Reservoir and improvements of some river sections – Mureş Basin In the Banat Sub-Basin - Improvement of Bega river and its tributaries on the sector Balint-Bethausen – Timiş County - Bega river improvement between Leucuşeşti-Curtea – Timiş County
Slovakia	
- Maintenance of existing retention volumes (removal of sediments) in reservoirs and polders. - Design and construction of reservoirs with flood retention volume and polders. - River training works in urban areas and rural municipalities. - Reconstruction of the trained stretches in the towns and villages in order to achieve sufficient discharge capacity. - Removal of obstacles in the channels, like bridges of insufficient flow capacity, improperly designed culverts and other barriers. - Realization of ordinary maintenance in trained river stretches. - Design and construction of measures to decrease erosion and to increase water retention in the river basins (trenches, ditches, canals, etc.) - Torrents regulation in the mountainous areas.	Regular maintenance of dams, water courses and water structures, e.g.: - recovery of water courses vegetation protection - technical-farming activities at embankments and in river beds - maintenance of natural river beds - removal of obstacles from river beds - removal of sediments etc.
	- Systematic technical monitoring of key water structures
	Contsruction and reconstruction of polders - Polder Borša, - Ružín Water reservoir – Hornád River, - Choňkovce polder – Sobranecký creek, - Majdan – Východ polder – Lutinka creek, - Majdan – Sever polder – Horošov creek
	Construction and reconstruction of flood protection structures - Hornád River, Košice - Vyšné Opátske water structure - Torysa River and tributaries, Prešov – river bed reconstruction - Hornád River, Košice – flood protection - Ondava River, km 12,500 – 17,800 left-side flood protection dike - Ondava River, km 7,070 – 14,200 right-side flood protection dike
Hungary	
- Improvement of present flood protection structures to meet the existing safety standards - Removing bottlenecks	Strengthening and heightening flood protection dykes to resist the 1:100 year floods
	Improve flood conveyance capacity
	Dyke relocations to give more room to Tisza River
Serbia	

Targets	Measures
- Provide protection for the adopted design 100-year flood along the Tisa River. This is an adequate criterion for the protection of the Tisa riparian lands, considering the size of the potentially endangered areas, number of inhabitants and infrastructure value. - Provide permanent preparedness of the flood defence system.	Reconstruction of levees on the right bank of Tisa
	Maintenance of flood protection structures
	Maintenance of dam on Tisa and weirs on tributaries
	Purchase and repair of machinery, tools, materials, equipment and communications
	Rehabilitation of weak points at levees

3.5 Non-structural measures

The non-structural measures (preventive actions, capacity building of professionals, raising awareness and preparedness of general public) are effective tools to reduce flood risk. The Tisza Basin countries use this tool to complement the structural interventions

Targets	Measures
Ukraine	
Prevention actions are aimed at improvement of the level of knowledge about flood events, their prognosis and regulations in complex Carpathian ecosystem in conditions of climate change. The following measures are envisaged here: - Fundamental and applied researches of floods, torrents, erosion and other events, human impact at their development, preventative actions to be taken and adaptation measures; - Scientific grounding of flood protection actions at regional and local levels; - Use of the best available techniques for modelling, construction and maintenance of flood protection structures taking into account national and international experience; - Development of methodology of riverbed regulation in Carpathians; - Development of new models of banks enforcement and dikes; - Scientific grounding of dry flood protection reservoirs and dry polders. - Improvement of monitoring networks and establishment of integrated environmental assessment - Further metrological and hydrological researches; - Establishment of databases based on GIS and space images; - Improvement of weather forecast, water level and flood prone zones modeling, and	- Flood risk mapping (topographic and geodesic survey, hydrological assessment, hydraulic calculations and inundation zones) - Development of automatic hydrometerological stations network (Tisza 2) - Scientific studies, assessment, investigations - Design and research works - Resettlement of the population from the flood prone zones

<table>
<tr><th>Targets</th><th>Measures</th></tr>
<tr><td>further improvement of early warning system, namely AIMS TISZA II.
- identification of flood zones of different probability based on modern technologies of hydrological investigations, geodesic and mathematical calculations, which goes in line with EU Flood Directive.</td><td></td></tr>
<tr><td>Capacity building of professionals includes the following actions:
- proficiency courses for water management specialists, including intercalibration exercises;
- further improvement of co-ordination between different authorities in case of floods;
- improvement of technical capacities of the professionals, namely hardware and software purchasing.</td><td>- Proficiency courses for staff</td></tr>
<tr><td>Raising awareness and preparedness of the general public include:
- Dissemination of the information concerning actions during the floods among population in flood prone zones;
- Publications of informational materials;
- Development of Internet based real time sources;
- Development of storage places for goods and equipment.</td><td>- Media support in flood awareness raising (TV programs, web-sites, articles, publications)</td></tr>
<tr><td colspan="2">Romania</td></tr>
<tr><td>These actions are concentrated towards prevention/mitigation of potential damages generated by floods through:
- avoiding houses, social and cultural or/and economic objectives constructions in potentially flooded area;
- realisation of structural and non-structural measures for protection;
- geographical delimitation of natural flood risk zones and noting these in the general urban planning studies;
- modern forecast, warning and alarming systems implementation in case of floods;
- existing infrastructure for flood protection and Riverbed maintenance;
- effective communication and people education regarding flood risk and the action ways in emergency situations.
- financial insurance for flood risk (On 1 January 2010, a law referring to the obligatory insurance for houses against</td><td>Implementation of the medium- and long-term flood risk management strategy
- Elaboration & implementation of Flood Risk Management Plans
- Forecasting, monitoring & warning
- Emergency plan & management
- Flood Risk Assessment
- Run-off control
- Improvement of flow conditions in river beds
- Improvement of the flood defence capacity
- Reduction of flood vulnerability of infrastructures and agriculture
- Reduction of flood vulnerability of the environment
- Social vulnerability to floods
- Individual vulnerability mitigation
- Funding & compensation
- International Cooperation
- DESWAT – Carrying of a hydrologic information-decisional system for the management of emergency situations (265</td></tr>
</table>

Targets	Measures
natural disasters such earthquakes, landslides and flooding will come into force).	automatic stations) - WIMS – Investment supporting the information system and database for water management (PHARE project) at national level
Raising awareness and preparedness of general public: - Improvement reaction capacity, response and intervention; - Information and awareness of the population regarding floods and its effects; - Eco-centres setting-up in frequently affected zones; - Public meeting presenting the local flood protection plans and the warning procedures based on colours code; - Exercises for flood simulation at basin and county level with the participation of population.	- Contributions to the development of the flood risk management strategy - Information system for integrated water management (WATMAN) - Danube Floodrisk - flood risk reduction: risk assessment, risk mapping, involvement of stakeholders, risk reduction by adequate spatial planning.
Capacity building of professionals: - An intensive programme for raising personnel capacity of the water management units of Romanian Waters responsible for the maintenance and operation of flood defences has been planned. - A training action of new elected mayors and public local administration is being developed.	- High-flood forecasting and flood management in Romania – feasibility study – the analysis for implementing of the decision support system - Update the Water Law - Update the Flood Protection Plans at basin, county and local level - Update the Plan for warning-alarming for downstream localities in case of accidents at dams
Slovakia	
- Reduce flood risk - Introduce principles of EU flood directive - Build capacity of professionals and institutions responsible for flood management - Upgrade flood monitoring, forecasting and warning services - Introduce regulations for emergency situations response - Prepare flood risk management plans - Improve awareness of stakeholders on floods - Update/build scientific base for flood management - Improve international cooperation in flood management - Improve information system on floods and flood risk management accessible to public	- Implementation of the Slovak national Flood Protection Act (i.e. also EU Directive 2007/60/EC on the assessment and management of flood risks)
	- Regular updating and implementation of the Slovak National Flood Protection Plan
	- Implementation of flood forecasting and early warning system POVAPSYS
	- Introduce directive for emergency situations response
	- Bring into force bilateral agreements
	- Improvement and formalizing of international basin wide online flood related meteorological and hydrological data and operative flood defense information exchange
	- Introduce and carry on the web sites focused on floods and flood risk management
	- Support scientific base for flood management
	- Organize vocational retraining for water professionals of SWME, SHMI, WRI, EPDO and municipalities that participate in flood

Targets	Measures
	protection
Hungary	
- Improvement of flood forecasting system - Improvement of flood warning system - Capacity building of professional staff - Increase PR activity to raise awareness of general public	- Incorporate the newest monitoring data available (automatic station, ECMWWF etc.) and improve the algorithm - Intensive use of EFAS - Regular, yearly training of professional staff; improve vocational and post-graduate education to bring up new generation of staff - Production and distribution of leaflets and other PR materials; paid programmes on broadcasting stations
Serbia	
- Preventive and operative tasks (setting up or improving the data base on natural events and protection system characteristics, modification of the existing plans for flood coping practices, adoption of reservoir operational rules, development/improvement of flood forecast and warning system); - Regulative and institutional measures (zoning of floodplains, floodplain management policy, construction standards etc.); - Managerial and technical education, as well as public awareness building. - Reduce flood risk - Introduce principles of EU flood directive - Build capacity of professionals and institutions responsible for flood management - Upgrade flood monitoring, forecast and warning - Introduce regulations for emergency situations response (natural disasters) - Prepare Flood risk management plan - Improve awareness of stakeholders on floods - Update/build scientific base for flood management - Improve international cooperation in flood management	- Implementation of operative flood defence measures - Preparation and adoption of new Water Law - Preparation of bylaws according to new Water Law - Regular upgrade of General and Annual Flood Defence Plans for the Republic of Serbia - Preparation and regular upgrade of General and Annual Flood Defence Plans for municipalities - Characterisation of current situation - Update/preparation of technical documentation for all existing flood protection structures (incl. data on water estate) - Update/preparation of flood defence manual - Preparation of bylaw for establishment and management of cadastre of water structures - Preparation of cadastre of flood protection structures - Improvement of the system of automated weather and gauging stations - Improvement of the system of hydrological and weather forecasting - Improvement of alarm systems and systems for issuing timely warning to population at risk - Preparation of strategic, tactical and operative disaster management plans for catastrophic flood - Training exercises - Preliminary flood risk assessment - Preparation of methodology for flood risk mapping - Adoption of bylaw on methodology for flood risk mapping

Targets	Measures
	- Preparation of flood hazard maps
	- Preparation of flood risk maps
	- Preparation of draft Flood risk management plan
	- Public information and consultation on draft Flood risk management plan for the Tisa River basin in Serbia
	- Bring into force Flood risk management plan for the Tisa River basin in Serbia
	- Introduction of flood insurance
	- Introduction of water management issues into schools
	- Preparation of flood leaflet, film, TV broadcasts etc.
	- Preparation of studies and design
	- Bring into force bilateral agreement with HU and RO
	- The Tisa River basin wide online flood related meteorological and hydrological data exchange
	- The Tisa River basin wide on line operative flood defence information exchange

3.6 Prevention and Mitigation of Water Pollution Due to Floods

Water pollution due to flooding is considered a threat to nature in two of the five countries.

Targets	Measures
Ukraine	
- Inventory of industrial and agricultural objects on flood prone zones with potential impact of water quality - Development of pollution prevention plan for industrial sites - Water quality control in surface water bodies	- Inventory of industrial and agricultural objects on flood prone zones with potential impact of water quality - Development of pollution prevention plan for industrial sites - Water quality control in surface water bodies.
Romania	
- The Law 466 (regarding dam safety) covers the safety problems of dams and dikes of the mining waste deposits.	- According to the EU Directive 1999/31/CE and Governmental Decision 349 from 2005 the major part of the mining ponds with high risk stopped the activity. - The actual legislation foresees the continuous monitoring of the closed ponds
Slovakia	
- The Decree No. 100/2005 lays down the details on handling the hazardous substances and the protection of surface and ground water during flood situations	- Tighten the rules applied during giving permission for activities within whole sub-basin - Increasing the number of control sections - Improving the information exchange about

Targets	Measures
	any accidents in the neighborhood countries - Upgrading technology to eliminate water pollution due to accidents - International exercises designed to remove pollution due to accidents during floods - Supervision and monitoring of potential pollution sources in the flooding area of rivers

B) Droughts

A drought is an extended period of time when a region experiences a shortage of water. Even a short intense drought can cause significant damage to the ecosystem and agriculture and harm the local economy. Water shortages in Serbia and Hungary have caused substantial damage to agriculture in recent years.

In the most general sense, drought is characterized by conditions which reflect a significant moisture deficit that may have an adverse impact on vegetation, animals and humans in a particular region. Drought events can be classified into four types: meteorological, hydrological, agricultural and socio-economic.

Meteorological drought can be defined as a significant decline of precipitation from average levels for a given region. The definition of meteorological drought is region-specific, since the atmospheric conditions which result in a lack of precipitation are variable and differ from region to region. Meteorological drought is defined usually on the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. Human perception of these conditions also varies.

Prolonged meteorological drought may be followed by hydrological drought and result in a significant reduction in reservoir and lake water levels, river discharges and stages, and groundwater levels. There is a noticeable time lag between a meteorological drought and a hydrological drought.

Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (i.e., stream flow, reservoir and lake levels, ground water). Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, stream flow, and ground water and reservoir levels. As a result, these impacts are out of phase with impacts in other economic sectors. Competition for water in storage systems escalates during drought and conflicts between water users increase significantly.

When defining agricultural drought, precipitation deficit must be taken into consideration along with the physical and biological aspects of plants, the interactions which take place within the soil/plant/atmosphere system, and the balance which exists between plants' water demand and available water reserves. Agricultural drought occurs when soil moisture and precipitation levels are inadequate during the vegetation period and fail to meet the requirements for optimum growth and development of crops to maturity, resulting in stress situations and a significant reduction in yield levels.

Agricultural drought links various characteristics of meteorological (or hydrological) drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced ground water or reservoir levels, and so forth. Plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per hectare and a reduction of final yield. However, if topsoil moisture is sufficient for early growth requirements, deficiencies in subsoil moisture at this early stage may not affect final yield if subsoil moisture is replenished as the growing season progresses or if rainfall meets plant water needs.

During a meteorological drought (i.e. absence of precipitation for an extended period of time), there is a significant reduction in productive moisture reserves in the root zone of the soil, leading to agricultural drought. Plants' water demand depends on prevailing weather conditions, genetic makeup and stages of development of the plants, and hydro-pedologic properties of the soil. A working definition of agricultural drought must take into account crop sensitivity to extreme weather conditions in the various stages of plant development. For example, varying moisture content levels in deeper layers of soil will have little effect on the ultimate crop yield, if the moisture content of the surface layer of the soil is adequate during the early stages of development. However, if the water deficit in the deeper layers is constant, it may result in significant yield reduction.

Finally, socio-economic drought can be defined as an event where water demand is greater than the potential to meet that demand, and the lack of adequate water is the result of weather conditions. This drought concept reflects a strong interdependence between drought and human activity. This type of drought is also linked with factors such as the distribution of plant and animal life, the distribution of the human population, the way of life, land uses, and the like.

Socioeconomic definitions of drought associate the supply and demand of some economic good with elements of meteorological, hydrological, and agricultural drought. It differs from the aforementioned types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on weather. Because of the natural variability of climate, water supply is ample in some years but unable to meet human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

Drought is often confused with water scarcity. To clarify the difference between the two a definition of the European Union is quoted here[8]:

> **"Water Scarcity & Droughts in the European Union**
> **About Water Scarcity and Droughts**
> Water scarcity and drought are different phenomena although they are liable to aggravate the impacts of each other. In some regions, the severity and frequency of droughts can lead to water scarcity situations, while overexploitation of available water resources can exacerbate the consequences of droughts. Therefore, attention needs to be paid to the synergies between these two phenomena, especially in river basins affected by water scarcity.
> **What is Water Scarcity?**
> **Water scarcity** occurs where there are insufficient water resources to satisfy long-term average

[8] Source: WISE - http://ec.europa.eu/environment/water/quantity/about.htm

requirements. *It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system*.
Water availability problems frequently appear in areas with low rainfall but also in areas with high population density, intensive irrigation and/or industrial activity. Large spatial and temporal differences in the amount of water available are observed across Europe.
Beyond water quantity, a situation of water scarcity can also emerge from acute water quality issues (e.g. diffuse or point source pollutions) which lead to reduced fresh/clean water availability.
Currently the main way of assessing Water Scarcity is by means of the Water Exploitation Index (WEI) applied on different scales (i.e. national, river basin). The WEI is the average demand for freshwater divided by the long-term average freshwater resources. It illustrates to which extent the total water demand puts pressure on the available water resource in a given territory and points out the territories that have high water demand compared to their resources (1)."

"What is Drought?

Droughts can be considered as a temporary decrease of the average water availability due to e.g. rainfall deficiency. Droughts can occur anywhere in Europe, in both high and low rainfall areas and in any seasons. The impact of droughts can be exacerbated when they occur in a region with low water resources or where water resources are not being properly managed resulting in imbalances between water demands and the supply capacity of the natural system.
Over the past thirty years, droughts have dramatically increased in number and intensity in the EU. The number of areas and people affected by droughts went up by almost 20% between 1976 and 2006."

There are a large number of drought definitions or concepts which have been used in the past or which are in use today in various parts of the world. A selection and overview of these definitions is given below, based on meteorological, hydrological, soil moisture, and crop parameters used. The most commonly used indices are:

1. Pálfai Aridity Index (PAI - Serbia, Slovakia, Romania, Hungary)
2. Standardized Precipitation Index (SPI - Serbia, Hungary)
3. Palmer Drought Severity Index (PDSI - Serbia, Hungary)
4. Aridity Index (Serbia, Romania)
5. Water Balance (Serbia)
6. Parameters of soil drought: values of hydrolimits: point of plant withering, point of lowered water availability, field water capacity (Slovakia)
7. Agronomical Classification (Slovakia)
8. Relative Evapotranspiration (Hungary)
9. Amount of precipitation for vegetation period (%N)
10. Hydrothermic Parameter (Slovakia)
11. Relative soil humidity (Hungary)

Effective monitoring and early warning systems for meteorological, agricultural and hydrological droughts require standardized indices.

Experts participating in the Inter-Regional Workshop on Indices and Early Warning Systems for Drought, held at the University of Nebraska-Lincoln, USA, from 8 to 11 December 2009 made a significant step through a consensus agreement that the **Standardized Precipitation Index** (SPI) **should** be used to **characterize meteorological drought**s by all National Meteorological and Hydrological Services around the world.[9]

[9] WMO Press Release 872

The **SPI** is an index based on the probability of precipitation for any time scale using the long-term precipitation record. A drought event begins any time when the SPI is continuously negative and ends when the SPI becomes positive.   Early detection of the onset of drought, and its intensity, through the use of the SPI, will help improve crop insurance schemes for farmers and enhance their livelihoods.

The experts decided to undertake a similar, comprehensive review of agricultural and hydrological droughts in order to develop common indices for better early warnings in the agricultural and water sectors. The following text is from the recommendations of the WMO/UNISDR Expert Meeting on Agricultural Drought Indices held on 2-4 June 2010 in Murcia, Spain.

“To meet the increasing global demand for cereals to feed the growing populations, the world's farmers will have to produce 40 percent more grain in 2020. The challenge is to revive agricultural growth at the global level and extend it to those left behind. The causes for the current food crisis are varied but civil strife and adverse weather predominate. In the developing countries, where adoption of improved technologies is too slow to counteract the adverse effects of varying environmental conditions, climate fluctuations, especially droughts, are indeed the main factors which prevent a regular supply and availability of food, the key to food security.

There is an urgent need to develop better drought monitoring and early warning systems. Hence the WMO/UNISDR Expert Meeting on Agricultural Drought Indices was organized from 2 to 4 June 2010 in Murcia, Spain. Nineteen experts from eight countries participated in the meeting. The meeting, hosted by the Hydrographic Confederation of Segura, reviewed drought indices currently used around the world for agricultural drought and assessed the capability of these Indices to accurately characterize the severity of drought and its impact on agriculture. The meeting also reviewed and provided a detailed description of the strengths, weaknesses and limitations of the primary agricultural drought indices. The main objective was to examine the options for consensus standard indices for agricultural drought that take into account soil, climatic, and cropping factors; and develop guidelines for Members in implementing the recommended indices including a description of the indices, the computation methods, specific examples of where they are currently being used, the strengths and limitations, mapping capabilities, and how they can be used.”

Recommendations

1) Given the enhanced availability and access to data, tools and guidance materials, the meeting recommends that countries around the world should move beyond the use of just rainfall data in the computation of indices for the description of agricultural droughts and their impacts.
2) This issue becomes very relevant, especially in the context of climate change, water scarcity and food security and hence it is important to use more comprehensive data on rainfall, temperature and soils in computing drought indices. Hence greater cooperation is required between different ministries and agencies responsible for addressing drought issues at the sub-national, national and regional levels.
3) Recognizing that diverse data and information are required for the use of a composite approach (such as the U.S. Drought Monitor), the meeting recommends that all countries examine this option.
4) Given the urgency to address drought monitoring and early warning in a comprehensive manner, there is a need to increase the efficiency in maintaining and enhancing weather data collection networks.
5) There is a strong need for better soils information and establishment of soil moisture monitoring networks where they do not currently exist.
6) Closer cooperation in data sharing and applications between meteorological, agricultural, hydrological and remote sensing agencies and institutions is required for drought monitoring and impact assessment.

7) The systematic collection and archiving of drought impacts on agriculture is imperative and more efforts should be made in this area.
8) There is a universal interest in understanding and reducing drought risk and impacts on agriculture. In this context, the effective communication of drought information to policy makers, managers, user community and media is essential.
9) Deliverables such as maps, reports and press advisories need to be produced at regular intervals and disseminated in a timely manner.
10) Realizing the need for easy exchange of data coming from different sources and institutions, enhanced access to a wide range of weather and soils data for drought monitoring is recommended.
11) Taking into account the increasing importance of applications of GIS, there is a need to explore existing capabilities of such systems and enhance the interoperability between different data platforms, particularly at the regional level.
12) In order to encourage the use of common agricultural drought indices around the world, there is an urgent need to develop common frameworks for drought monitoring/early warning.
13) In order to achieve this goal, an inventory of operational capabilities in the areas of data networks, deliverables, indices used/calculated and dissemination along with an assessment of user needs should be prepared.
14) To this end, the meeting recommends that the WMO conducts a survey to compile and assess the capacities and future needs of National Meteorological and Hydrological Services around the world in building such common frameworks for national agricultural drought early warning systems.

In 2007 the European Commission adopted a Communication on water scarcity and droughts[10]. The Communication identified seven policy initiatives that had to be addressed if Europe was to move towards a water-efficient and water-saving economy. In October 2007[11] the Council supported the options identified in the Communication and invited the Commission to review and further develop the evolving strategy for water scarcity and droughts by 2012.

In October 2008 the European Parliament adopted a report on the Communication and supported the proposed first set of policy options for action. Parliament's Resolution underlines that urgent action is needed - particularly to promote water savings, exchanges of good practice, awareness raising campaigns, putting the right price tag on water - and more funds are needed to support these actions.

The first follow-up report to the Communication[12] was adopted in December 2008 and detailed the progress made in implementing the Communication's proposals. It identified some encouraging policy initiatives at both EU and national levels that had contributed to the results but concluded that there was still a great deal to be done. The report was accompanied by a work programme that was also to be monitored regularly. As announced in the report, the Commission will assess on an annual basis progress towards implementation of the set orientations with a view to the 2012 policy review, in line with the Council Conclusions of 30 October 2007. The second report[13] assessing progress made in implementing the options of the Communication and the work programme for the medium and long term. The aim of the report is to present the progress that has been achieved across Europe over the last year.

The following short list highlights the major policy elements set out in the document:

[10] COM(2007) 414 final 18.7.2007
[11] 13888/07, 15 October 2007, ENV 515, DEVGEN 182, AGRI 325
[12] COM(2008) 875 final, 19.12.2008
[13] COM(2010)228 final, 18.05.2010

1. Putting the right price tag on water
2. Allocating water and water-related funding more efficiently
   2.1. Improving land-use planning
   2.2. Financing water efficiency
3. Improving drought risk management
   3.1. Developing drought risk management plans
   3.2. Developing an observatory and an early warning system on droughts
   3.3. Further optimising the use of the EU Solidarity Fund and the European Mechanism for Civil Protection
4. Considering additional water supply infrastructures
5. Fostering water-efficient technologies and practices
6. Fostering the emergence of a water-saving culture in Europe
7. Improving knowledge and data collection
   7.1. Water scarcity and drought information system throughout Europe
   7.2. Research and technological development opportunities

As it can be seen from the analysis above drought has become a major concern worldwide. In the following Chapters the reaction to this challenge of the Tisza countries will be presented.

4 Characterisation of Current Drought Situation in the Tisza Countries

The Tisza River Basin runoff is highly variable – there are alternate periods of drought and flooding that are difficult to forecast and manage effectively. The droughts of recent years, such as the drought of August 2003, had severe effects in the region, particularly on the Hungarian Plain where agriculture was extremely affected. The lack of water reduces not only agricultural activity, but also the development of industry and urbanisation. Cities and other communities demand more water than the quantity available from rainfall and it has always been difficult to get enough water for settlements far away from rivers.

There is no general definition of drought, but it is commonly understood to be a less than usual natural water supply. According to the Working Group on Water Scarcity and Drought at the Water Directors, water scarcity refers to long-term water imbalances, combining an arid or semi-arid climate (low water availability) with a level of water demand exceeding the supply capacity of the natural system (See also the different definitions in the previous Chapter).

In **Ukraine** the term 'Drought management' has never been applied to the Ukrainian part of the Upper Tisza River Basin due to the fact that in Transcarpathia the annual surface water resources potential per capita (3130 m^3) is three times as much as the same index for the whole country (1000 m^3). In this case the only terms which fit are 'water scarcity' or 'water deficit'. In the set of observations available there were examples of dry years (1961, 1963) but which didn't result in water shortage.

The most comprehensive studies in this field were carried out in the "Scheme of multi-purpose use and protection of water and land resources of the Soviet part of the Tisza River Basin" dated 1974. This document compared the design annual runoff for a dry year of 95% probability and design aggregated water consumption for defined future periods. The calculations were done based on the prognosis of population growth and industry and agriculture development.

In **Romania** the identification of high drought risk areas in the Tisza River Basin was made on the basis of the correlation of the aridity index calculated through the reporting of precipitations to the potential evapotranspiration with the one of the aridity index Pálfai (PAI) which takes into consideration the frequency of the dry years. It was considered that the affected areas comprise the territories in which the aridity index has values under 0.65 and the ones with sensitivity to drought for which the Pálfai index is between 4 and 8. For the basins afferent to the Tisza River tributaries, the areas with PAI index values between 4 and 6 (moderate sensibility) and 6 and 8 (high sensibility) are only encountered in the Salaj Hills and in the Western Plain, at the border with Hungary and Serbia. The respective areas are fragmented and comprise a relatively small surface.

For the **Slovak part** of the Tisza River Basin, the PAI index was used during the evaluation of drought**, and showed that** the most unfavourable year was 2003. Most of the Slovak part of the Tisza River Basin was classified as having ‘moderate draught’, with the exception of the Somotor station (in the vicinity of the Bodrog River), with value of 10.4 meaning ‘severe draught’, and the Michalovce station (Laborec Valley) with value of 8.41 as ‘medium draught’. Return periods were not calculated.

Drought is a recurrent feature of the **Hungarian** climate and can cause substantial damage to the nation’s agriculture. Statistics shows that 36% of the overall agricultural loss originates from drought, followed by hail, floods and frosts, in order of importance. Each year from 1983 to 1995, with the exception of 1987, 1988 and 1991, were drought years. This long period of drought was unprecedented in the 20th century in the region and comparable in length only to the ten-year period from 1943 to 1952 or in severity to the 1779-1794 drought events. Since eight of the twelve years were disastrous drought years, this series of dry years has increased the scientific and political interest in climate variability and climate change and the importance of drought as an extreme meteorological event. After a couple of normally wet years, Hungary experienced very dry years again in 2000 and 2003.

In **Serbia** drought has been the subject of much research and investigation by a number of Serbian authors. This research and investigation encompasses all aspects of drought: from global and regional problems, environmental impacts, morphological, physiological and biochemical aspects of plant resistance to drought, to irrigation problems. Some of the drought indices or indicators (such as the deviation from average precipitation levels, seasonal fluctuations of precipitation, relationship between precipitation and potential evapotranspiration, water balance, occurrence of dry periods or development of semi-arid areas in Serbia) are being used in regional drought assessments from the hydro-meteorological perspective.

5 Tisza River Basin – Drought Map

There are plenty of drought definitions and as it follows there are plenty of drought indexes around (*See Chapter B*). Though there is not a single drought index used by the Tisza countries, the Pálfai Drought Index (PAI) is commonly applied to characterise the drought conditions. The PAI is a relative number characterising the whole agricultural year using the evaporation and precipitation conditions.

The basic PAI is the quotient of the mean air temperature calculated for the period of April-August and the sum of the weighted monthly precipitation for the period of October-August. The basic PAI is then modified by three correction coefficients representing the effects of heat waves, the longest period without precipitation and the position of groundwater relative to ground level.

As it follows from the way the PAI is calculated, the larger it is the more severe the drought is. Based on Hungarian experience the limit value of drought is at PAI≥6. Below this threshold there is no drought. The different levels of drought can be characterised by the figures in the table below.

PAI	Drought degree
6-8	modest
8-10	medium
10-12	severe
>12	very serious

The calculation of the PAI is relatively easy using historical meteorological and hydrological data, thus it is a practical tool to investigate the drought phenomena.

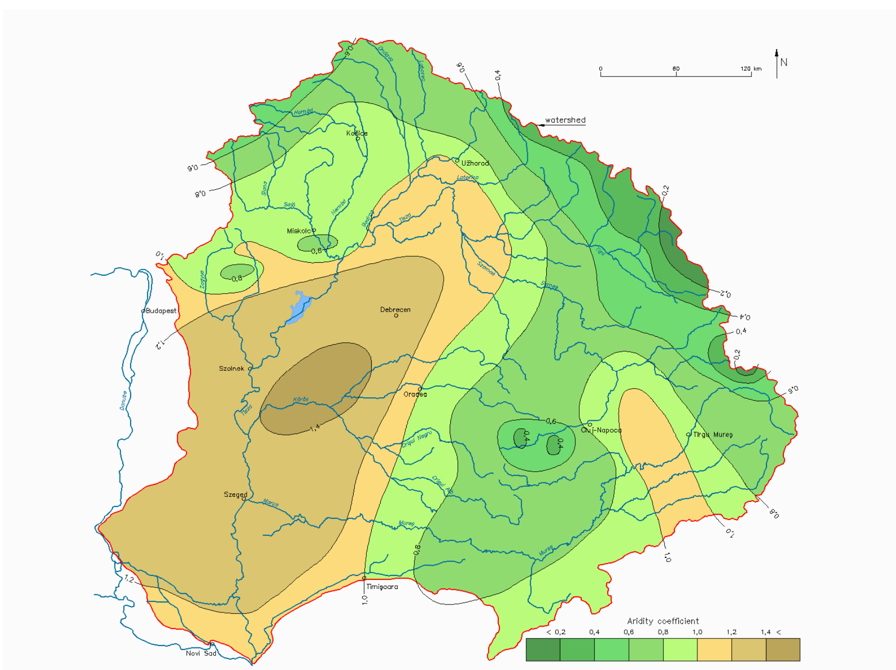

Fig.8. Distribution of the aridity factor in the Tisza River Basin

Figure 1 Distribution of PAI in the Tisza River Basin

The figure clearly shows that most seriously affected area is the central part of the Great Hungarian Plain and the northern part of Serbia. The PAI exceeding 12 is characteristic for this region. The area of severe drought spans over the western part of Zakarpattia, the south-eastern part of Slovakia, western part of Romania and the rest of Serbia and the Great Hungarian Plain. The extent of the area prone by drought underlines the necessity of dealing with this problem.

6 Targets and Measures

Countries of the Tisza River Basin have defined targets and measures to mitigate the negative effects of drought. In this Chapter we will present these national drought risk management plans.

As it was explained in *Chapter 4* Ukraine doesn't consider drought a major threat in the Zakarpattia region thus no targets and measures are set by the Ukrainian government.

6. 1 Slovakia

Drought is one of the major weather related disasters and recent events have demonstrated Europe's continuing exposure to this natural hazard. Drought is a recurrent feature of the European climate, occurring in both high and low rainfall areas and season. Also many parts of Slovakia suffer water stress, and it is these areas which are most at risk from drought especially in Eastern Slovakia Lowland in the Tisza basin (Bodrog sub-catchment).

Generally, the **main impacts of droughts** can be divided into three main categories:

6.1.1 Economic impacts of droughts

- Losses to agricultural producers (annual and perennial crop losses, damage to crop quality, reduced productivity of cropland, plant diseases, insect infestation, wildlife damage to crops, increased irrigation and water resource costs)
- Losses to livestock producers (reduced productivity of rangeland, reduced milk and meat production, high costs/unavailability of water and feed for livestock, costs of new/supplemental water resources, high livestock mortality rates, decreased stock weights, increased predation, range fires)
- Loss from timber production (wildland fires, tree diseases, insect infestation, reduced productivity of forest land)
- Loss from fishery production (damage to fish habitat, loss of fish and other aquatic organisms due to decreased flows)
- Loss to recreation and tourism industry (related to reduced activities: hunting and fishing, bird watching, boating, etc.)
- Energy-related effects (increased energy demand and reduced supply because of drought-related power curtailments)
- Losses to water suppliers (cost for water transport or transfer, costs of new/supplemental water resource development)
- Losses to transportation industry (loss from impaired navigability of streams, rivers, canals)
- Food production (increase in food prices)

6.1.2 Environmental impacts of drought

- Damage to animal species (reduction, degradation of fish and wildlife habitat, lack of feed and drinking water, greater mortality also due to increased contact with agricultural producers, disease, increased vulnerability to predation, migration and concentration, increased stress to endangered species, loss of biodiversity)

- Hydrological effects (reduced streamflow, lower water in reservoirs, lakes and ponds, reduced flow from springs, loss of wetlands, estuarine impacts (e.g. changes in salinity levels), increased groundwater depletion, land subsidence, reduced recharge, water quality effects
- Damage to plant communities (loss of biodiversity, loss of trees)
- Increased number and severity of fires
- Wind and water erosion of soils, reduced soil quality
- Air quality effects (dust, pollutants)

6.1.3 Social impacts of drought

- Health (mental and physical stress, health related low-flow problems, reductions in nutrition, loss of human life (heat stress, suicides), public safety from forest and range fires, increased respiratory ailments, increased disease caused by wildlife concentrations)
- Increased conflicts (water users conflicts, political conflicts, management conflicts, other social conflicts)
- Reduced quality of life (increased poverty in general, population migrations, loss of aesthetic values, reduction of recreational activities)
- Disruption of cultural belief systems (religious, scientific views of natural hazards)
- Reevaluation of social values
- Increased data/information needs
- Recognition of institutional restraints on water use

Drought management is an essential element of water resources policy and strategies. There are signs that drought planning is moving from a crisis management to risk management based approach. Establishing a reliable early warning system based on hydrological indicators is needed. The presence or lack of different parameters (indicators of drought) in local indicators will depend on their local relevance. All indicators require a complex combination of different parameters and numerous samplings and monitoring systems. The definition of an indicator for all the EU countries necessarily implies reaching a common measuring system. A critical component within drought management is the continuous observation and evaluation of the development of a drought event. General criterion, environmental objectives and limitations included in the River Basin Management Plan should be respected. These may include ecological flows, groundwater inputs to wetlands, maximum aquifer abstractions, aquifer and reservoir levels of maintenance, or volumes flowing to the sea.

In Slovakia there is a need to consider climatic change in hydrological planning strategies and assess its direct effects on demands, available water resources and ecological status of water bodies.

Drought indicators are available. Different indicators are needed to reflect the nature of the different types of drought and to accommodate the requirements of the different water -related sectors. Models and process understanding-hydrological models are important to help us to understand process. Detection space and temporal patterns/trends in drought-changes in climate and catchment process and anthropogenic interferences cause trend. Prediction of low flow characteristics at ungauged sites deals with uncertainty of the process. Drought monitoring and forecasting – there is high importance of development of drought monitoring and early warning systems.

6.1.4 Recommended mitigation tools:

- establishing a reliable drought monitoring and early warning system based on hydrological indicators
- common measuring system in European countries
- clear and correct definitions of drought hydrological characteristics
- consider climatic change in hydrological planning strategies
- integrated management of water resources included technical solutions, economics and legislative tools applied in water usage
- need for a specific European Drought Policy, within the context of long term sustainable use of water resources in Europe
- address emerging issues in drought research and management
- monitoring of vulnerable public water suppliers

In Slovakia at present, the increased occurrence of drought and water scarcity is one of the most significant problems of 21st century. Water is primary means between potential climate changes and the future development of natural subsystems and socioeconomic sectors. There is evidence that as a society we are attempting to consume this precious resource in a conservative manner, this is particularly important in regions that are suffering from drought.

Decreasing runoff in Slovakia, mainly southern part, also in Eastern Slovakia Lowland in the Tisza basin calls for use of water balance methods:

- Drought indicators are available in Slovakia
- Water balance assesses all aspects of water management, including water quality and quantities. Water balance is utilized as a key tool in the assessment of available water resources. The aim of the water balance is to specify where and when water requirements have or have not been met.
- It is important to clearly identify any discrepancies and build strong points of contact between individual balance procedures.
- Any future assessment of water resources needs to be consistent with the water balance.
- Integration of drought and water scarcity into water policy and planning is needed

In the Water Management Plan of Slovakia for the first period according the WFD there are several measures dealing with drought management (implicitly):

- water saving measures
- water measuring especially for irrigation
- water pricing and other economic instruments

6.2 Romania

On the Romanian part of the Tisza River Basin, the intensity of the drought expressed through a high frequency of the dry years isn’t a characteristic phenomenon, as the areas with high values of the Pálfay index are small and discontinuous. This area is, to a great extent, classified as a dry/sub/humid area. In this region there are still dry years and even dry periods, the most important being the 1961 – 1973 period, but interrupted by excessively rainy years. Analyses emphasise that the driest season is autumn, especially in September and October.

The aridity factor – defined as the relation of annual potential evaporation to a mean annual precipitation – is below 0.2 at the eastern border of the Tisza Basin (in the Carpathian Mountains) and increases from northeast to southwest up to 1.4 in the middle of the Hungarian Plain (at the mouth of the Körös Rivers).

6.2.1 Measures related to drought management

Water resource development and drought management must be set in a framework of comprehensive water policy and integrated planning and must take into account socioeconomic issues. Unconventional sources may be necessary, such as water importation or desalination. Grey water reuse has significant potential to reduce demand; new approaches to sanitation may be appropriate to reduce the use of potable quality water. Alternative patterns of domestic water use and impact on demand of water saving measures should be considered in the context of appraisal of the role of demand management.

The Water Framework Directive acknowledges (Article 4 [6]) that extreme drought events can adversely affect the status (both quality and quantity) of water bodies. In order to minimise these risks and help water bodies achieve the requirements of the Directive, certain conditions need to be met including taking all practical steps to alleviate drought and prevent further deterioration in status. Furthermore, in droughts periods it is not considered an infraction of the Directive if a deterioration of the water takes place, in particular, for reasons of major force or natural causes that have not been able to foresee reasonably lingering droughts.

Selected demand reduction options should be related to the degree of water shortage that exists. For example, you would not want to impose water rationing upon your customers if you only had a five percent deficit in your normal water supply. Stages of a water shortage and corresponding demand reduction measures include:

- Water demand management
- Water conservation

The water conservation includes measures for storing, saving, reducing or recycling water.

- for farmers who irrigate:
  - improving application practices
  - increasing uniformity of application, thereby allowing less water to be used;
  - using weather date to balance water applications with available soil moisture and crop water needs;
  - lining diversion canals and ditches to minimize seepage and leaks.

- for municipalities:
  - encouraging residents to install and use high efficiency plumbing fixtures and educate them about water-saving habits;
  - reducing peak demands to avoid the extra costs of investing in additional pumping and treatment plants;
  - metering water (customers pay for what they use).

- for industry:
  - identifying other resource-conserving methods for the production processes;
  - reusing water used in manufacturing and cooling.

6.2.2 Drought management plan

Romania adopted a comprehensive, long-term drought preparedness policy and plans of actions. The drought management plan provides a dynamic framework for an ongoing set of actions to prepare for, and effectively respond to drought, including:

- periodic reviews of the achievements and priorities;
- readjustment of goals, means and resources; as well as strengthening institutional arrangements, planning, and
- policy-making mechanisms for drought mitigation.

In addition to an effective early warning system, the drought management strategy include sufficient capacity for contingency planning before the beginning of drought, and appropriate policies to reduce vulnerability and increase resilience to drought.

Drivers (supply/demand) for implementing common measures are not at all the same in all countries and measures are implemented at very different scales. Different measures that can be taken are the following:

- Enhance reservoirs operations/strategies to improve quality and quantity
- Increase the supply and reduce the demand
- Planning strategies at basin level, conservation measures
- Use of non conventional resources (desalinisation), recycling
- Demand/use prioritisation
- Enforcement
- Best scale to address the issues
- Measure for impact mitigation

6.3 Hungary

Hungary is often threatened by droughts beside the floods, as well. Elaborating a “Drought Strategy” became a valid and pressing task because of the serious agricultural damages caused by droughts during the last decade and because of the presumed increase of drought likelihood as a result of climate changes. The underlying principles of the Drought Strategy are the prevention, the integration and the water management based upon the habitats.

According to experiences up till now, a damaging water shortage must be taken into consideration in 4 out of 10 years on average. For instance, between 1976 and 1985 there were 3, between 1986 and 1995 there were 7 droughty years. These numbers confirm that Hungary must be prepared to avoid and prevent damages during periods of water shortage. For preventing the drought damages the following civil engineering tasks are required:

- creating and operating systems ensuring the water importation between areas;
- furthermore creating water retention and preserving the water resources.

The farmers on the area can protect themselves against the damages of the agricultural vegetation life with melioration, irrigation and the initiation of the irrigation management. The drought forecast introduced in the beginning of 90s helps largely in preparing for the irrigation. The extent of developed drought can be characterized by the so called “Drought Index”, which describes the agricultural year with one number based upon the evaporation and precipitation relations, and on time varying water needs of the plants (Pálfai, 1984).

The drought indexes at national average scale are:

- during moderate drought: 5-6;
- during average drought: 6-7;
- during serious drought: 7-8;
- during extremely serious drought the drought index can exceed 8.

Since 1990 the following years were considered extreme concerning drought: 1990, 1992, 1993, 1994, 2000 and 2001. There was a period of extreme water shortage in 2002 which affected the Great Plains and the area of River Rába; though in the same year significant flood occurred on the Danube. It highlights that flood and drought can affect the Tisza River Basin shortly after each other. River basin management plans should deal with both aspects in the basin.

6.3.1 Drought and Drought Management

The Ministry of Agriculture and Rural Development has drafted the National Drought Strategy in 2005. This document was going through a long inter-ministerial discussion and it has not been submitted to approval to the Parliament, yet. However, the document provides a comprehensive strategic guidance concerning water management and irrigation that should be taken into account in the formulation of river basin management plans especially for the Tisza River Basin, which is the most drought affected region in Hungary:

1. The water management should be prepared for periods of more and more frequent and intensive droughts and excess surface waters. In case water resources management and water diversions expressive attention should be paid to build up all water retention possibilities that could be implemented with optimal costs (keeping in place the rain water, retaining river water, construction of small and medium reservoirs, building water transition structures).
2. Special emphases should be paid to irrigation in reducing drought. The special features of irrigation have to be taken into account:
    - The irrigation can be used only at well-defined areas within the river basin. Irrigation has limited significance concerning general drought reduction effects, when even utilizing all potential irrigation opportunities then the favourable effects influence only a small portion of cultivated agricultural land. However, on irrigable land and those which could be supplied with irrigation water economically and in case of certain plants (i.e. horticultural plants) that can be grown efficiently only with irrigation, there irrigation has decisive role. Thus the introduction and development of irrigation is important part of the drought strategy.
    - The irrigation as water substitution means basically should be rest on the water demand of the plant at the given location and on the agro-ecological circumstances. Introduction and stable usage of irrigation can be expected only that case when the irrigation is profitable for farmers.
    - It should be unconditionally kept in mind that irrigation should not cause harmful effects on the soil, thus not all kind of water resources is suitable for irrigation.

There are two scenarios concerning irrigation:

Scenario 1 - Presumable

> The extent of irrigable land provided with irrigation water licence will be enlarged by about 20%. Consequently the irrigation water demand will also increase by 20%.

Scenario 2 - Realistically optimistic

> The irrigation water demand will follow the volumetric increase of cultivated plant production. It is predicted that the plant production will be 1.8 times higher within 15 years. As much as the water demanding products increase, it will be compensated by the increase of the competitiveness of the production and development of the irrigation technology. There will be no significant increase of irrigation water demand.

6.3.2 Economic impacts of drought

Among *economic impacts* the harmful effects of drought on *agriculture* are standing on the first place, such as damages caused by drought on plant production, both field crops, vegetables, and fruits, on forestry, and on animal husbandry.

There is a great importance of the length of the growing period of the species and varieties. It is necessary to reduce the effect of the previous crop in the crop rotation, and to ensure the best crops and best crop rotations in the region by which the impact of drought can be minimized. Important question is also the effect of the number of plants on a piece of land, because the very dense plant-stands in most cases increase the drought sensitivity of the crops cultivated. The other elements of the used agro-technology are the soil cultivation and tending, the soil conservation methods, the nutrient supply system, the protection against weeds and plant diseases, etc. The most effective protection against drought is *irrigation*; therefore the use and potential possibilities of irrigation in the given region should be promoted.

In case of *horticultural crops*, especially in case of orchards and vineyards the spatial placement of these fruit production plants, their species and varieties, their cultivation technologies have of great importance in the minimization of drought effects on these plant-stands. In vegetable and ornamental plant growing - especially in forcing houses - the application of irrigation is indispensable.

In *forestry* drought is the greatest abiotic factor in forest damages, however the harmful effects are not as well noticeable by the public as in the case of crop production. Forests have extremely important role in global ecology; therefore the fate of forests and tree-plantations has of great importance in the global life of the population of the region. Drought impacts on existing forests and evaluation of their damages caused by drought have to be in taken into account. Special attention should be paid to the forest fires which cause extremely big economic and ecological losses.

Drought impacts on *animal husbandry* are direct and indirect. Animals suffer from continuous hot whether and water shortage, but their answer on long-term dryness is different by species and varieties and by husbandry conditions as well. Major indirect effects are realized by fodder shortage and influence the state of health of the animal population, which has great effect on animal production and the economic value of the whole animal husbandry.

Besides of agricultural impact drought has direct harmful effects on *water management,* too. Long-term water shortage directly influences water resources of a region, disturbs water balance conditions, and makes difficulties in water supply. Therefore it is important to estimate exactly the surface and subsurface water resources of the given region, the possible changes of these resources, and to make water balance calculations for different whether and hydrological conditions. During water scarcity the importance of water quality conditions is increasing, especially in case of lakes and surface waters, therefore the impact of continuous dryness on water quality should be studied and evaluated more carefully.

Third field of economic impacts of drought is *industry.* The effects here are indirect, more directly *food industry* is involved which can lose considerable part of its raw material for processing coming from agriculture. This can cause a very unstable situation in different branches of food processing and this has also negative effect on the wide range of *services.* All these effects should be taken into consideration and - if possible - express them financially in the national drought strategy.

Drought has very strange effect on *tourism:* the whether conditions may be favourable for people who like hot and dry conditions, but the general bad effects can cause a rapid decrease in national and/or international tourism which may cause significant losses in those countries where tourism has of great importance.

Because of the general decreasing effect on many branches of the economy drought has indirectly negative impact on *energy industry,* too. Decreasing energy consumption creates unstable situation in power economy and it can contribute considerably e.g. to the increase of energy prices which has of unavoidable impact on the whole economy in long run.

Causing decrease in the production of basic raw material drought generally negatively influences *trade conditions,* especially the *export-import relations.* The losses in commodity stocks upset the goods exchange agreements between countries and can overbalance export plans and obligations. At the same time the economy need to balance the internal losses by increasing import especially in food and fodder, and this means an extra expenditure both for individuals and for the government.

Among economic impacts finally the effects on *financial affairs* have to be examined. On the losses in production of agricultural products, in food processing, in goods exchange and in energy consumption the financial world usually answers with increasing of prices which speeds up inflation and stimulates unhealthy processes and tendencies in the financial affairs: farmers and producers become bankrupt, investments are put off, renovation in production conditions are cancelled, etc.

6.4 Serbia

The Hydro-meteorological Service of Serbia (orig. abbr. RHMZ), Department of Agrimeteorology, uses several types of indices: SPI, Palmer Z-index, Thornwaithe and aridity (AI), and water balance, and CROPSYST model (weather – crops) for one-month, ten-day and one-day time intervals. Most of these indices are used in day-to-day monitoring of moisture conditions, while others are used for research and investigations.

Standardized precipitation index (SPI) belongs to the parameters, indices that characterize the moisture conditions. Only data on precipitation amount are used for its calculation. Operative procedures within monitoring of moisture conditions carried out by the Department of

Agrometeorology of the RHMS of Serbia also include calculating of SPI values on the basis of precipitation amounts recorded in previous 30, 60 and 90 days. Besides these calculations that are made in time step of one day, SPI values are also calculated for previous 1, 2, 3, 4, 5, 6, 9, 12 and 24 months after the passing of each calendar month. Values of SPI index are presented as cartographic surveys and in the form of tabular surveys as per meteorological stations and some of them are available on Internet presentation of RHMS.

Thus, SPI values defined for the periods of one to three months are relatively well correlated with storage of productive moisture in surface soil layers so that they can be used for the assessment of moisture conditions for the growth and development of agricultural crops. SPI values defined for longer time periods indicate to prevailing characteristics of moisture conditions during vegetation period, calendar year etc., and there is often a correlation of these values with the levels of surface and ground waters in observed area.

Appearance of drought is happening every time when SPI is negative and its intensity comes to -1.0 or lower. Drought stops when SPI is positive. The duration of every drought appearance is determined by negative index values. Accumulated totals of negative values of SPI could also be used as a measure of drought severity.

CROPSYST (Cropping Systems Simulation Model)[14] is a multi-year, multi-crop, daily time step crop growth simulation model, developed with emphasis on a friendly user interface, and with a link to GIS software and a weather generator. The model's objective is to serve as an analytical tool to study the effect of cropping systems management on crop productivity and the environment. For this purpose, CROPSYST simulates the soil water budget, soil-plant nitrogen budget, crop phenology, crop canopy and root growth, biomass production, crop yield, residue production and decomposition, soil erosion by water, and pesticide fate.

6.4.1 Drought Research and Investigation in Serbia

The drought phenomenon has been the object of much research and investigation by a number of Serbian authors. This research and investigation encompasses all aspects of drought: from global and regional problems, environmental impacts, morphological, physiological and biochemical aspects of plant resistance to drought, to irrigation problems. Some of the above-mentioned drought indices or indicators (such as decreasing from average precipitation levels, seasonal fluctuations of precipitation, relationship between precipitation and potential evapotranspiration (PET), water balance, occurrence of dry periods, development of semi-arid areas in Serbia, etc.) are being used in regional drought assessments from the hydro-meteorological perspective.

A study of droughts in Serbia was conducted recently, following an analysis of all relevant meteorological parameters (precipitation, temperature, radiation balance components, evapotranspiration, etc.), including their trends in the latter half of the 20th century. The Standardized Precipitation Index (SPI) was applied to periods of 1-24 months (Spasov, et al. 2002)[15].

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[14] http://www.bsyse.wsu.edu/CS_Suite/CropSyst/documentation/articles/description.html

[15] Spasov P., Spasova D., and Petrović P. (2002): Changes in drought occurrences in Serbia. u: Drought mitigation and prevention of land desertification, International Conference, ICID, ERWG-ERWTD-SINCID, Bled, Slovenia

When temperature and precipitation trends were analyzed for the territory of Serbia over the second half of the past century using a series of temperature trend characteristics, the data showed significant and increasing air temperature growth, of more than 0.3^{o}C per decade on average. This trend is expected to continue and grow.

On average, the total reduction in annual precipitation was about 8.6%, with most of the decrease occurring in the past two decades.

As might be expected, of all drought events, regardless of duration, about half belong to the moderate drought category while the other half can be classified as either intense or extreme droughts.

The analyzed data indicate a large concentration of dry years during the last two decades.

Of all droughts occurring during vegetation periods and calendar years, the two driest seasons were in the years 2000 (SPI <-2.0 as average for whole Serbia, but for Tisza catchment, SPI was between -3 and -4) and 1990 (drought assumed extreme characteristics in wide area in North-East part of Tisza catchment (Kikinda). However, based on the extent of impact the years 1961, 1993 and 2003 can also be included in this category. The study of SPI series indicate an increasing frequency of droughts over the last 20 years (1981-2000) in Serbia, and that severe drought tend to concentrate near the end of the time series which even resulted with an extreme drought in 2000**.**

6.4.2 Temporal and Spatial Drought Variation in the Tisza River Basin

A detailed analysis of low flow conditions for the Tisza River near the town of Senta was prepared applying the Zelenhasić method. The highest deficit and longest duration of low flow, as well as the rare and extreme low flows, were determined using a distribution pattern (which is based on the law of exponential probability) in combination with the time-dependent Poisson process. This method can also be used to compute/synthesize low flows of 10-, 20-, 50- and 100-year return periods. The method required, however, that the reference discharge Qr be selected so as to clearly distinguish discharges which belong to the lower extreme zone from those which belong to the wider zone of average values, including 20 most extreme low flows on record of the Tisza near Senta during the period from 1931 to 1983.

Applying the same methodology, meteorologic drought was analyzed based on duration of dry periods lasting longer than 15 days (Spasov and Zelenhasić, 1990; Berić et al.,1989). The results show (*Figure 2*) that marked droughts do occur in Banat and Bačka regions, that is, in the Tisza River Basin. The longest computed dry period in this area, based on vegetation season data for the period 1950-1980, is more than 32 days for a return period of 5 years, and 44-54 days for a return period of 20 years. For a 100-year return period, the duration of the dry period increases to 60-70 days.

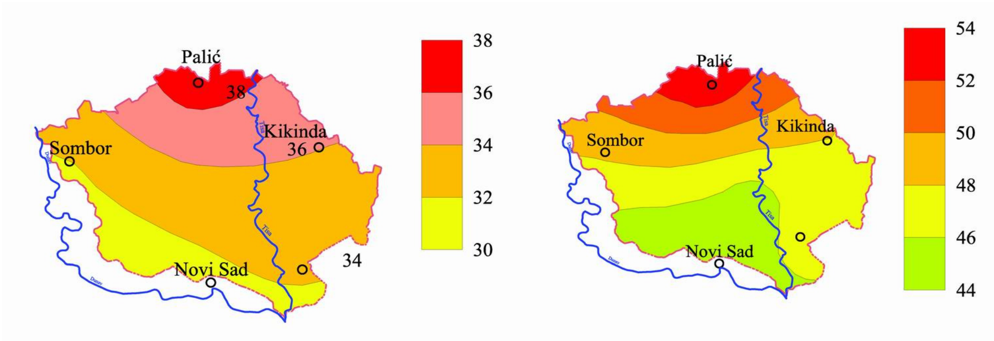

Figure 2 Isometric line computed dry period longer than 15 days (a return period of 5 years– left, and a return period of 20 years - right), based on vegetation season data for the period 1950-1980

According to USDA Report for 2003[16], the area most seriously affected by drought conditions in Serbia during 2003, are north and central Banat, all of Bačka, and east and central Srem. Instead of average rainfall of 40 liters per square meters during April and May 2003 those regions received only 12 liters per square meters in total.

However, as already mentioned above, a more complete drought picture can be obtained by using a crop water balance model.

The RHMZ Department of Agro-meteorology determines the major water balance components for different time intervals: one-month, ten-day and one-day periods. A standard soil depth of 1 m was selected. The investigations and analyses of hydropedologic properties conducted for 30 sites in Vojvodina, where weather and hydrologic monitoring is already in place, constitute a sound basis for proper use of the soil water balance model.

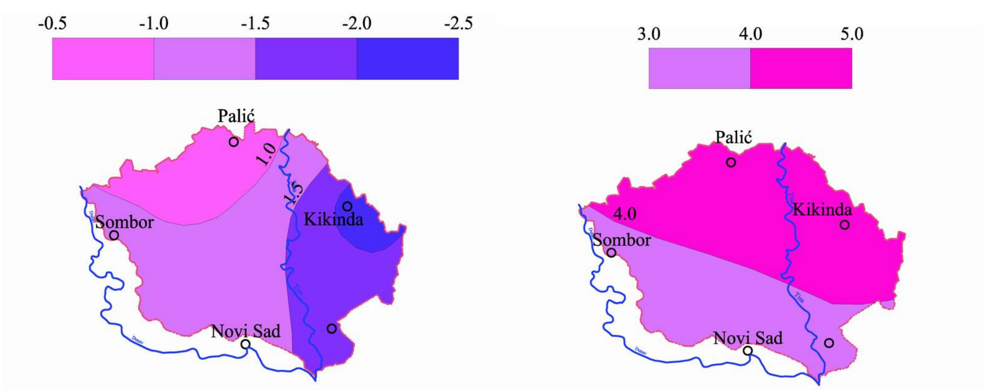

Figure 3 Spatial drought distribution in the Tisza River Basin: 1990 (left) and 2000 (right), and drought intensity expressed in SPI 12

Analyzing crop performance in the Vojvodina Province, Bošnjak (1997)[17] concluded that the genetic yield potential of rain fed crops is reduced by 50%.

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[16] USDA (2003) GAIN Report #YI3009, Grain and feed - Serbia and Montenegro Grain and Feed Update 2003, Approved by: Holly Higgins U.S. Embassy, Sofia Prepared by: Tatjana Buric http://www.fas.usda.gov/gainfiles/200307/145985405.pdf

[17] Bošnjak, Đ. (1997) Suša i navodnjavanje stanje i perspektive. Zbornik radova Naučnog instituta za ratarstvo i povrtarstvo, Novi Sad, Sv. 29, str. 85-93

6.4.3 Socio-economic aspects

In the climatic conditions of the Serbia, irrigation is a supplementary practice that favorable affects the yield performance and stability of cultivated crops, especially in dray years. Effects of irrigation and cultural practices vary from one year to another. Annual yield variations are pronounced with favorable years, yield losses in dry years may range from a few percents to 50%, while in years with extremely severe droughts the losses may be as high as 80-100%.((Dragović *et al*., 2005)[18] Positive effects of irrigation are evident, to a variable degree, almost every year, while in extremely dry years irrigation doubles or even 3-4 times higher yields of field's crops than those in the non-irrigated conditions.

According to local law each region in Serbia can announce a “Natural Disaster” if damage is higher then 10% of the total GDP of that region. In 2003, Kikinda region (East part of Tisza catchment) has announced a “natural disaster”. In addition to petitioning the Ministry of Agriculture for drought relief, community was planning to give some financial help to local farmers. Grain farmers in the Kikinda region were received assistance, because 40 percent of planted wheat area was destroyed by spring frost, and then by drought. (USDA GAIN Report #YI3009, 2003)

7 Summary

The Tisza River Basin is the largest sub-basin of the Danube River Basin and the countries of the basin have a long history of cooperation resulting among others in signing the Agreement on the protection of the Tisza and its tributaries in 1986 or in establishing the Tisza Forum to address flood issues in 2000. The Tisza cooperation has been given a new perspective in line with the development of the Danube River basin cooperation and the EU water policy.

In 1994, the Danube River Protection Convention (DRPC) was signed in Sofia. The DRPC forms the overall legislation instrument for cooperation on transboundary water management in the Danube River Basin. To implement provisions and to achieve the goals of the DRPC, the International Commission for the Protection of the Danube River (ICPDR) was established in 1998 following the entry into force of the Convention with a secretariat based in Vienna.

Under the EU Water Framework Directive (2000/60/EC) the ICPDR is the platform for coordination amongst the Danube countries including EU Member States, accession countries and other Danube riparian states for the implementation of the provisions of the Directive at transboundary level. In addition to the Danube River Basin planning, the ICPDR is taking an active role in sub-basin planning as well.

At the first Ministerial Meeting of the ICPDR countries in December 2004, ministers and high-level representatives of the five Tisza countries signed the Memorandum of Understanding (*Towards a River Basin Management Plan for the Tisza River supporting sustainable development of the region*). The ICPDR established the Tisza Group for coordination as well as implementation. The Tisza Group is the platform for strengthening coordination and information exchange related to international, regional and national activities in the Tisza River Basin and to ensure harmonisation and

[18] Dragovic,S., Maksimovic,L, Radojevic, V., Cicmil, M.(2005): Irrigation Requirements and their Effects on Crop Yields in Serbia and Montenegro, Proceeding of ICID 21st European Regional Conference: Integrated Land and Water Resources Management: Towards Sustainable Rural Development, Frankfurt (Oder), Germany and Slubice, Poland,15-19 May, CD

effectiveness of related efforts. The Tisza Group countries agreed on to prepare a sub-basin plan (the Tisza River Basin Management Plan) by 2009, which integrates issues on water quality and water quantity, land and water management, flood and drought.

This analysis presents the issues of the two extremes: floods and droughts.

Floods in the Tisza River Basin can form at any season as a result of rainstorm, snowmelt or the combination of the two. Snowmelt flooding without rainfall rarely occurs in the Tisza Basin and floods resulting from this account for no more than 10-12% of the total amount. The rise in temperature is almost always accompanied or introduced by some rain. Thus large flood waves are generated more frequently in late winter and early spring.

The floods generated in Ukraine, Romania and Slovakia are mainly rapid floods and last from 2-20 days. Large floods on the Tisza in Hungary and in Serbia, in contrast, can last for as long as 100 days or more (the 1970 flood lasted for 180 days). This is due to the very flat characteristic of the river in this region and multi-peak waves which may catch up on the Middle Tisza causing long flood situations. Also characteristic of the Middle Tisza region is that the Tisza floods often coincide with floods on the tributaries, which is especially dangerous in the case of the Someş/Szamos, Crasna/Kraszna Bodrog, Criş/Körös and Mures/Maros Rivers.

Another type of inundation in the lowland areas of the Tisza River Basin originate from unfavourable meteorological, hydrological and morphological conditions on saturated or frozen surface layers as a result of sudden melting snow or heavy precipitation, or as a result of groundwater flooding. This undrained runoff or excess water cannot be evacuated from the affected area by gravity and may cause significant damages to agriculture or even to traffic infrastructure and settlements.

The Danube River Protection Convention emphasises the need for transboundary level cooperation in forecasting and monitoring flood events if their impacts are to be minimised. In response to this, the Danube countries have decided to establish joint emergency plans. The *"Action Programme for Sustainable Flood Protection in the Danube Basin"* was endorsed at a Ministerial Conference in December 2004.

The *Action Programme* made recommendations to refine the Danube Basin Level Flood Action Plan on sub-basins. The Ministerial Meeting charged the Flood Protection Expert Group to develop flood action plans (for 17 sub-basins) among them the Sub-Basin Level Flood Action Plan of the Tisza Basin.

The Sub-Basin Level FAP of the Tisza Basin reflects the recommendations of the Danube Basin Level AP, namely:

- A shift from defensive action against hazards to **proactive management of risk**.
- The **river basin approach**, taking into account the EU Water Framework Directive.
- **Joint actions** by governments, municipalities and stakeholders geared to flood risk management and awareness raising.
- Reducing flood risks via **natural retention**, **structural flood protection** and **hazard reduction**.
- **Solidarity**: the belief that one region should not pass on water management problems to another.

The countries in the Tisza Basin FAP first set targets and then defined measures to achieve those targets.

The Sub-Basin Level FAPs show a clear shift from the sole structural measures to a combined use of structural and non-structural measures. The improvement of natural retention capacities of the basins and the hazard reduction approach calls for a substantial reconsideration of the relation between the land use and the functions/use of floodplains.

A drought is an extended period of time when a region experiences a shortage of water. Even a short intense drought can cause significant damage to the ecosystem and agriculture and harm the local economy. In the most general sense, drought is characterized by conditions which reflect a significant moisture deficit that may have an adverse impact on vegetation, animals and humans in a particular region. Drought events can be classified into four types: meteorological, hydrological, agricultural and socio-economic.

The Tisza River Basin runoff is highly variable – there are alternate periods of drought and flooding that are difficult to forecast and manage effectively. The droughts of recent years, such as the drought of August 2003, had severe effects in the region, particularly on the Hungarian Plain where agriculture was extremely affected. The lack of water reduces not only agricultural activity, but also the development of industry and urbanisation. Cities and other communities demand more water than the quantity available from rainfall and it has always been difficult to get enough water for settlements far away from rivers.

In Ukraine drought, in contrast to floods, is not consider a major threat in the Zakarpattia region thus no targets and measures are set by the Ukrainian government. The other four countries followed the same procedure as with floods: they set targets and measures to achieve those targets. In spite of this it can be seen that drought management in the Tisza countries is not as advanced as the flood management.