Global Water Partnership
Central and Eastern Europe

NATURAL SMALL WATER RETENTION MEASURES

combining drought mitigation, flood protection, and biodiversity conservation

– GUIDELINES –

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1. Introduction

Human activities, and climate change have caused an increase in the frequency of extreme climate events, including floods and droughts. At the same time, there is a clear need to implement measures that mitigates the negative impacts of fluctuating water availability on human economic activities and the environment (Cambridge University, 2012).

Most of the Central and Eastern European countries (CEE) have well-developed meteorological and hydrological monitoring systems. Nonetheless, there still exists a need to develop and implement both short-term and long-term measures, for limiting the adverse effects of extreme climatic events (Commission of the EU Communities, 2007; EU Commission, 2011; EU Commission, 2012c).

The CEE Region of the Global Water Partnership has been involved in the project called "The Integrated Drought Management Programme (IDMP)", a project situated within the wider framework of the joint World Metrological Organisation (WMO) and the Global Water Partnership (GWP) Integrated Drought Management Programme. The scope of the IDMP Programme is to support stakeholders at all levels to provide them with policy and management guidance, through globally coordinated generation and scientific information, and sharing of best practices and knowledge for integrated drought management.

Within the IDMP, a specific project on Natural Small Water Retention Measures (NSWRM) has been implemented by a group of experts from four CEE countries: Poland, Slovakia, Hungary, and Slovenia. The outcome of this project, and the lessons learnt from the activities carried out in the period 2013–2015 are summarised and presented in these Guidelines: "Natural Small Water Retention Measures: Combining drought mitigation, flood protection, and biodiversity conservation".

By using small water retention measures, the natural retention capacity improves, which contributes to the potential for an increased amount of water that can be naturally stored in the environment, and used for alimentation of water courses during droughts (Mioduszewski, 1997; EU Commission, 2014).

The idea of NSWRM is consistent with the broader framework of Natural Water Retention Measures (NWRM). NWRM, which are measures taken with the aim to restore the natural water retention capacity of catchments, have previously not included active human involvement in the maintenance and the exploitation of the existing water systems. However, aligning with the idea of NSWRM, small hydro-technical investments such as small damming reservoirs or damming on watercourses have been advocated for. Additionally, new methods for utilising water systems, including drainage systems in river valleys, and irrigation have been suggested.

The climatic and topographic conditions of the countries participating in the NSWRM project are a representative sample of the existing conditions in the whole ECC area. Poland is the northernmost country with low precipitation, and with higher evapotranspiration than precipitation during the summer. Vast and flat areas with significant water deficit exist in Hungary, whilst Slovakia and Slovenia represent mountainous areas.

These Guidelines exploring "Natural Small Water Retention Measures" is as mentioned previously a part of a bigger project on "Integrated Drought Management Programme in Central and Eastern Europe (IDMP CEE)", conducted by GWP and WMO. It is worth to stress that some other activities carried out under the IDMP CEE also have close links to addressing water retention problems. These include for example the guidelines on drought planning, activities dealing with drought management by agricultural practices, and measures increasing soil water holding capacity, and explorations of drought impact on forests.

Why do we have to increase water retention of river basins?

Water fulfils many important features in the natural environment. As a resource within agricultural production, it impacts the amount and quality of yields. Water is also a crucial factor for economic growth, and for human development. It also plays a vital part in biological systems, and for growing and sustaining natural capital. However, water resources are characterised by a significant seasonal and spatial variability (Kowalczak et al., 1997). Extreme weather events like floods and droughts can cause significant loss, both in economic and environmental term (Linnerooth-Bayer et al., 2013). The four maps in Figure 1 illustrate the need for water retention in Central Europe. The maps show elevation and hydrography (1a), Climatic Water Balance (CWB) (1b), soil water capacity (1c), and existing water management systems (1d). Examining Figure 1b, it can be stated that the most significant precipitation deficit (yellow) occurs in the lowlands in the vicinity of the Black Sea, and in Hungary. The available water storage capacity of the soil in these areas is high, which favours rain water retention and alleviates rain water deficit. In these areas, water management system for water logging and drought stress mitigation was adapted (Figure 1d). The smallest available soil water storage capacity can be noted in mountain areas, particularly in the Czech Republic, Slovakia and Slovenia.

The intensification of agriculture, the unification of natural habitats, the construction of drainage systems, and urbanisation, have caused changes in the soil cover, which means that a smaller amount of water is being retained in catchments than before caused that the water and matter cycle in catchments is being more quicker than many years ago. (Gutry-Korycka, 2003; Mosný, 2004; UNESCO, 2012; Meijer et al., 2012). These factors all contribute to an increased frequency of droughts and floods. As the natural retention capacity of a catchment decrease, natural runoff paths filled with precipitation and snowmelt develop as a result . The above mentioned phenomena result from rapid precipitation and snow melt waters runoff to the river. Moreover, the intensification of water circulation. In addition to the water, this also causes an increased amount of nutrients to be transported to rivers and lakes. It is worth to mention that some scientists are proving that the influence of men economy on water balance is not so big, for example agricultural drainage has no impact on river hydrology (Ilnicki et al., 2013).

In the future, it is expected that climate change will cause a decrease of precipitation during summers, and an increase of precipitation during winters in Europe. Furthermore, it is estimated that the infiltration of water to the deeper aquifers will be higher because of temperatures reaching above 0°C during winters (Kundzewicz and Kowalczak 2008; Lancaster, 2010; UK Parliament, 2014).

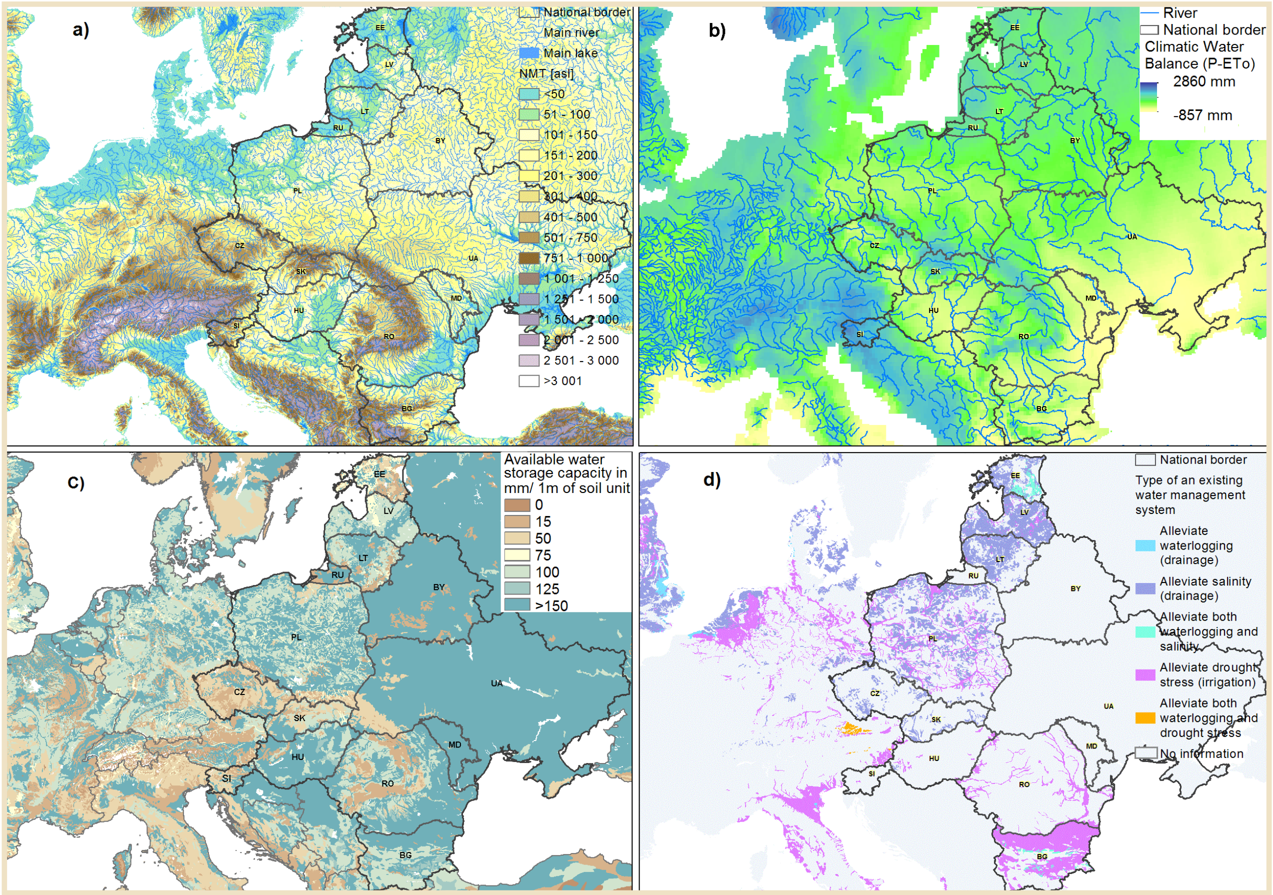


Figure 1. The review maps for Central Europe a) NMT& hydrography (source: Jarvis et al., 2008 & European water archive, 2012), b) Climatic water balance for period 1961-90 (difference between precipitation (P) and reference evapotranspiration (ETO) (source: New et al. 2002 - CRU CL 2.0 data-set), c) available water storage capacity in upper 1m soil in mm (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2008 - HWSD), d) Type of existing water management system (Panagos el al. 2012 - ESDB)

Climate change is the most significant challenge that faces society today. The influence of the expected increase in temperatures, and anticipated fluctuations in the precipitation regime will be particularly noticeable on agricultural production. The forecasted influence of climate change on agriculture in Europe is illustrated in Figure 2. The increased speed of surface runoff, combined with urban development will become an increasingly significant problem since it increases the floods discharge. Moreover, changes in surface infiltration capacity does not only decrease the risk of drought and floods, but it also increases the holding capacity of soils, and consequently makes more water available for plants. (International Food Policy Research Institute, 2002; Acteon Environment. Research and Consultancy, 2012; COPA European farmers, 2013).

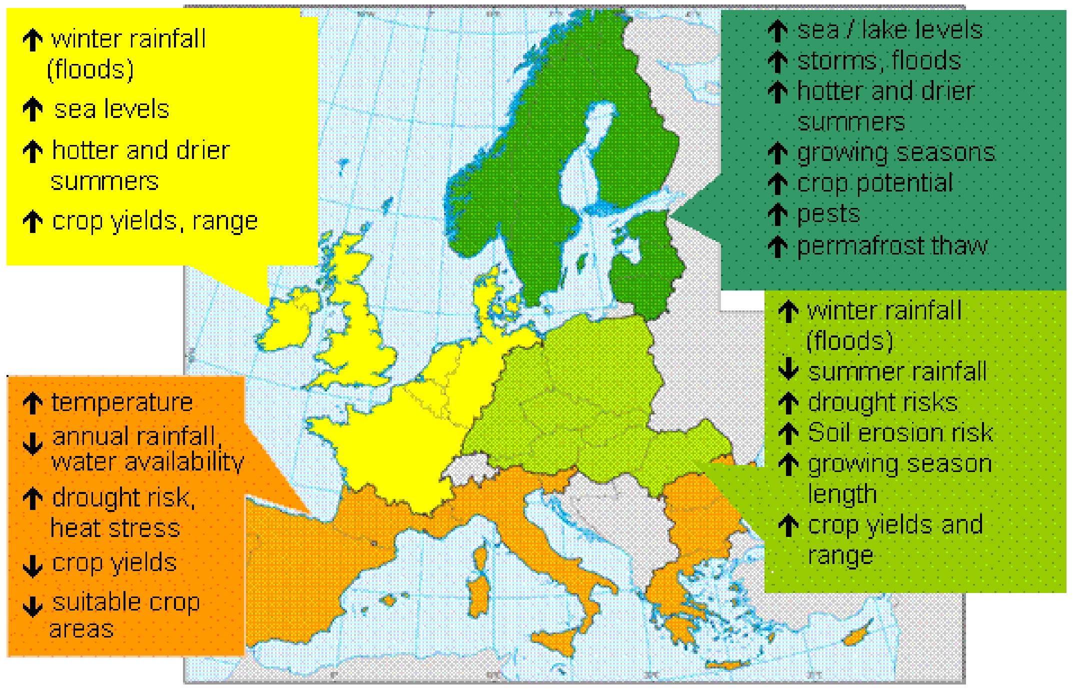


Figure 2. The forecasted influence of global climate changes on agriculture. Source: Federal Ministry for Environment. 2007

Because of climate change, water managers faces the problem of increasing temperatures, including the increased level of evaporation and water used by plants, increasing levels of carbon dioxide concentration, including variations in transpiration process, as well as temporal and spatial variability of precipitation, implying an increase of precipitation during winters and a decrease during vegetation periods (European Environment Agency, 2009; UNESCO, 2012).

Water resources show a significant spatial variation. Many different coefficients can be used to evaluate this (UNESCO, 2006; Rijsberman, 2006; UNEP, 2008; Cambridge University, 2012). Examples include:

Surface water resources coefficient: Measured as the capacity of surface water (sum of the annual river runoff) per capita;

Exploitation coefficient (water intake coefficient): defined as the ratio of the total water intake to the total sum of surface and groundwater resources per year;

Water poverty index: Measured through five indices: 1) water resources (amount and quality), 2) availability (the distance to water source, time of exploitation, existing conflicts), 3) ability to obtain water (ability to cover the costs of water purification, the kind of water management, existing water cooperatives), 4) use of water (rules of water management), 5) environment (evaluation of the dependency between water and the environment, the state of ecosystem, erosion) (Brown 2002; Chapagain and Hoekstra, 2004).

These three coefficients have been calculated for various European countries, and the results are presented in Figure 3. Because water resources significantly impact the human development in a country, the relationship between the water poverty index (WPI), and the human development index (HDI) is presented in Figure 4. In the present time, countries with a low HDI are also often experiencing a water deficit (Rijsberman, 2006; International Food Policy Research Institute, 2002).

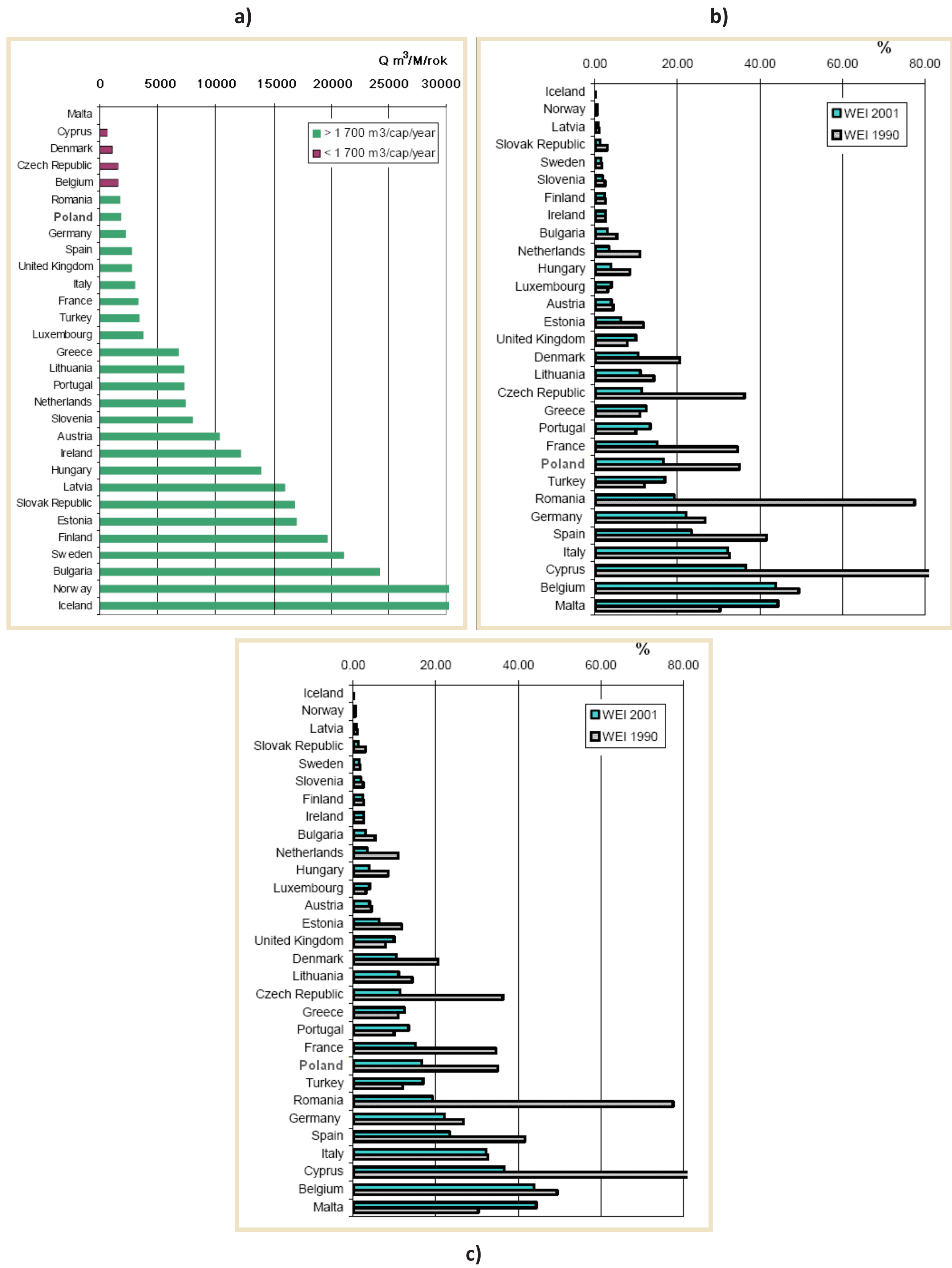


Figure 3. Coefficients for evaluation of water resources: a) surface water resources coefficient, b) water exploitation (intake) coefficient, c) water poverty index. Source: Derived from own calculations based on data from Brown 2002; Chapagain and Hoekstra, 2004; UNESCO, 2006; Rijsberman, 2006; Cambridge University, 2012,

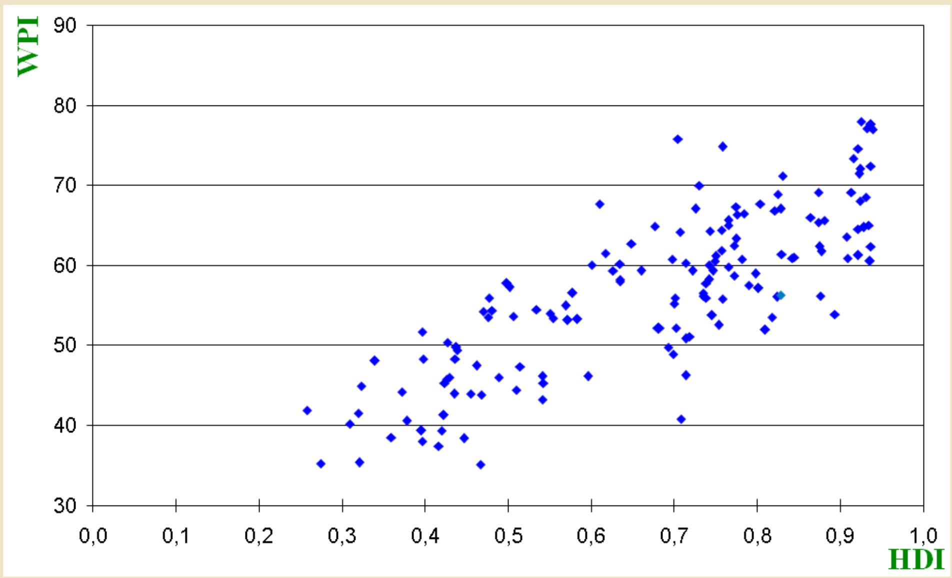


Figure 4. Relation between water poverty index (WPI) and human development index (HDI) for 147 countries of the world. Source: Derived from own calculation based on Chapagain and Hoekstra, 2004; UNESCO, 2006; Rijsberman, 2006

While considering water retention, it is plausible to think of it as storage of rain or snow melt water at the site of its origin, and taking measures to limit the rapid water runoff from the area, and from small water courses such as ditches and streams. It should be emphasised that rain water retention is free, whilst the use of surface and ground waters is charged with fees in most European countries (Figure 5).

Figure 5. Rainwater is free. In contrast to water extracted from groundwater aquifers or from rivers, any amount of it can be stored. Soon fees for use of extracted water will be introduced as "reimbursement of the costs of water services" as one of the aims of the Water Framework Directive. Source: poster of the Rain Water Harvesting Society.

Restoration of the natural retention capacity of river catchments is at the moment arguably the most eco-friendly method, and fulfilling conditions of the sustainable development of rural areas allowing the improvement of water balance of the river basin at the same time.

Photo 1. Significant amounts of water retained as snow cause floods when the water retention capacity of the catchment is low. Photo: W. Mioduszewski

Based on the discussion above, it is possible to pose the argument that a crucial measure for limiting the negative natural hydrologic phenomena such as floods and draughts is to ensure the retardation of water runoff from the catchment area after occurrence of an intensive rainfall. In other words, the implementation of small retention measures can significantly contribute to the restoration of the natural water capacity of a catchment as it was prior to human activity. The increase of water retention capacity of a catchment can significantly limit unfavourable impact of climate change, as well as the investments(water structures) accelerating water runoff from the catchment (Querner et al., 2012; UNEP, 2014).

2. Technical and non-technical measures to increase water retention

2.1. What is natural small water retention? Definitions

Despite a long history, the phrase "natural small water retention measures" (NSWRM) has not been clearly defined. In Poland, the term 'small retention' was used in the 1970s to denote small water reservoirs (Mioduszewski, 1997; Kowalewski, 2007). Nowadays, in very broad terms, it can be defined as technical and non-technical measures aiming at improving the water balance of a catchment (i.e. decreasing the variability of discharge) by increasing the catchments natural retention capacity.

It is possible to distinguish between many different forms of retention, for example, landscape (habitat), soil, surface (surface waters), and subsurface (groundwater) retention. Small retention differs from other forms of retention since it is uncontrollable, automatic, and its capacity is difficult to measure. The increase of landscape, soil, surface and subsurface retention influences the water cycle in the catchment, but humans cannot presently regulate the exact processes. Nevertheless, by implementing NSWRM, the potential water retention capacity of catchments can be increased in time of water excess and its prolonged occurrence in soil or, on the ground surface (Eotvos József College, 1997; Mioduszewski, 1997; Pierzgalski et al., 2002; Kowalewski, 2007; Palat et al., 2013). A summary of the measures that can be used for improvement of the water balance structure is presented in Table 1.

Table 1. Systems and methods of water retention in rural areas (source: Mioduszewski, 2003)

Water resources	Systems and methods
Landscape (habitat) retention): landscape planning	Systems shaping the proper structure of land use through: • system of arable fields, grasslands, forests, ecological lands and ponds • forestation, creation of protective belts, woodlots shrubs, creation of bruises and terraces • increasing of the area of wetlands, peatlands and swamps, rewetting of peatland
Soil water retention: agriculture technology	Cultivation systems shaping water management in a soil profile: • improvement of soil structure (differential porosity), agricultural drainage, liming, the proper agro-techniques, proper crops rotation, increase of the organic matter content in soil
Groundwater: agriculture and landscape planning	Cultivation and drainage systems limiting surface runoff: • limiting of the surface runoff • increase of soil filtration capacity (deep-loosening) • anti-erosion measures, phyto-drainage and agricultural drainage measures • runoff regulation from the drainage system • ponds and infiltration wells for storage of precipitation runoff from sealed surfaces
Surface waters: water management, hydraulic structures	Hydro-technical systems of division and storage of water: • ponds and small water reservoirs • regulation of water runoff from ponds and small water reservoirs • water management – retention of water in drainage – irrigation systems and water governance • regulated outflow of water from ditches systems • increase of river valley retention including construction of polders

Another classification NSWRM is the distinction of technical and non-technical measures:

Technical measures. Most hydro-technical and drainage works, aiming at the retardation of surface water runoff can be included in this group. Technical measures include construction of small water reservoirs, damming of lakes, damming of water courses, construction of ditches and channels, the retention of drainage waters, the use of proper methods of water drainage from sealed surfaces (roofs, squares and streets) allowing water filtration on the adjacent unsealed areas, the restoration of small water courses, and flood valleys with use of technical measures (Lukáč et al., 1997; Mosný, 2001; Bahri, 2012; Meijer, 2012).

Non-Technical measures (planning methods). Proper spatial planning of the catchment can play an important role in water management. This measure focuses on the creation of spatial planning that can limit the accelerated runoff of rain and snow melting waters. The creation of proper structure of arable fields, grasslands and forests, creation of plants (shrubs, trees) protective belts, restoration of numerous natural and semi-natural habitats, including small ponds and wetlands, changing the arable lands into grassland, can be included in these measures (Kozák, 2012; Mioduszewski and Okruszko, 2012; Martinez- Martinez et al., 2014).

Non-Technical measures (agro-technical). These are the measures that depended on the way of land use, including the use of proper methods of arable field's cultivation in the river catchment. Basic measures within this group of measures are: the improvement of soil structure in forests and arable fields, anti-erosion measures on fields, preservation of proper forests habitats, prevention of formation of the primary water runoff tracks in forests, preservation of infiltration surfaces in urban areas, and regulations rain sewerage (Radczuk and Olearczyk, 2002; Angyán et al., 2003; Masih et al., 2011).

The measures included in this report are all categories under the general name NSWRM. The above-mentioned measures include agro-technical measures, small hydro-technical constructions, as well as measures aiming at improving water management in drainage facilities. Basic technical and natural measures are presented in Table 2. The name 'small retention' is a result from that the technical facilities used are commonly small, and have only a local meaning, sometimes less than hundred meters only.

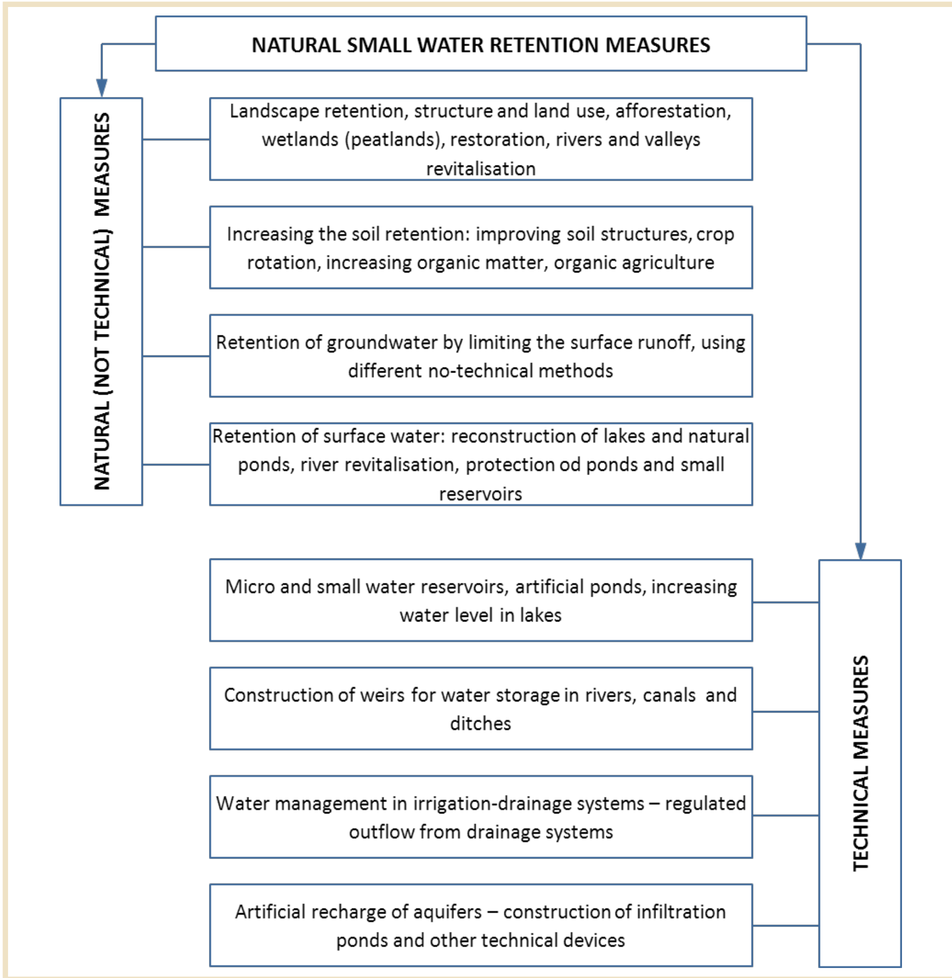


Table 2. The draft of natural small water retention measures (NSWRM), source: own analysis

Table 3. Illustrating the diversity of measures classified as NWRM (source: EU Commission, 2014)

Type	Class	Non-exhaustive list of examples
Direct modification in ecosystems	Hydro-morphology (Rivers, Lakes, Aquifers, connected wetlands)	Restoration and maintenance of rivers, lakes, aquifers and connected wetlands; Reconnection and restoration of floodplains and disconnected meanders, elimination of riverbank protection
Change & adaptation in land-use & water management practice	Agriculture	Restoration and maintenance of meadows, pastures, buffer strips and shelter belts; Soil conservation practices (crop rotation, intercropping, conservation tillage), green cover, mulching
	Forestry and Pastures	Afforestation of upstream catchments; targeted planting for “catching” precipitation; Continuous forestry cover; maintenance of riparian buffers; urban forests; Land-use conversion for water quality improvements
	Urban development	Green roofs, rainwater harvesting, permeable paving, swales, soakaways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration

There are no substantial differences between Tables 1 and 3, and the differences that exist mainly concern technical measures. Small water reservoirs, damming on watercourses and channels, as well as modernisation of water systems, mainly drainage and irrigation drainage systems, have been included in Table 1 (small retention).

Natural Water Retention Measures are defined as “measures that aim to safeguard and enhance the water storage potential of landscape, soil and aquifers by restoring ecosystems, natural features and characteristics of water courses and using natural processes” (EU Commission, 2014). Attention is drawn here to the restoration of natural, aquatic and water-dependent ecosystems, which has been damaged by anthropogenic activities, and which can cause an increase of potential retention capacity of a river catchment. The difference between NWRM and NSWRM lays mainly in the inclusion of technical measures for improvement of retention capacity of the catchment in NWRM. However, it should be emphasised that NWRM and NSWRM do not only contribute to improving the water balance (i.e. the decrease of discharge variability), but also that they are important elements of protection of biodiversity in rural and urban areas, as well as water quality protection, particularly from diffuse pollution.

In the next sections, the terms NSWRM and NWRM, as well as the phrase ‘small retention’ are all used to discuss retention measures.

2.2. Retention in agricultural areas

To utilise land for agriculture is usually not acknowledged as a form of retention measure, but through various agro-technical measures, the water balance of a catchment can significantly improve.

These various measures can all be categorised as small retention measures. An increase of the organic matter in soil, liquidation of the plough layer (i.e. the sealed layer created as a result of ploughing), and improvement of the structure of heavy soils, cause an increase in the water retention capacity of the soil. Even a small improvement in the water retention capacity can cause the retention of a significant amount of water. For example, an increase of water retention capacity by 10 mm (equal to 10 litres per 1 m2) can result in a total retention of 100 000 m3 per hectare. This is not a large amount if comparing it to the total demand of water of the agricultural sector, but if considering it from a catchment scale, retention of this amount can significantly limit the probability of flood occurrence.

Implementation of proper cultivation methods, for example limiting the frequency of ploughing, as well as ensuring that ploughing occurs along the contour lines, can be included in the non-technical measures. In other words, anti-erosion and agro-drainage measures cause the decrease of the water runoff and as a consequence, it causes an increase of water retention capacity of agricultural lands. Similar measures and results can be obtained by the implementation of phytoremediation tasks. Similarly, the creation of plants protective belts, the preservation of existing natural ecological enclaves in the landscape, such as ponds or enclaves of shrubs and trees, all serves to increase the water retention capacity.

However, reducing agricultural runoff can potentially also reduce erosion, combat productivity loss, lessen downstream pollution, and thus improve water quality. Thinking about the patchiness and connectivity of the agricultural landscape, buffer zones such as vegetation strips are also important from a spatial point of view since they may serve to provide the establishment of a more stable wildlife population. Therefore, the measures mentioned above may provide many other benefits beside water retention capacity due to their ability to perform multiple ecosystem services.

2.3. Landscape retention

All the measures taken to increase the retention capacity of a river catchment that are associated with changes in spatial planning or land use can be categorised as non-technical forms of small retention. These are measures that are most closely associated to natural water retention measures since they only change the capacity to store water by limiting the surface runoff, and increase the water retention capacity of soil.

To illustrate the value of landscape retention, the water retention capacity of wetlands and forests are presented in depth below.

Wetlands. When considering the water retention capacity of some forms of wetlands such as mires, swamps, marshes, and wet grasslands, it is crucial to particularly focus on:

- water retention capacity of the wetland soil, which means the ability to retain water in soil pores of the aeration zone;
- water retention capacity of the wetland (marsh and swamp), which is the ability to retain water on the surface of wetland areas;
- water retention capacity of the plateau in the adjacent area, which can occur as a result of the delay of groundwater outflow by the creation of peat in a fen or bog on the slope of the valley.

Rainwater can be retained in soil pores in the unsaturated zone, which is a zone between the ground level, and the groundwater table level (Figure 6). The higher the level of groundwater, the smaller the soil retention capacity, with the soil retention capacity being defined as the space that can be filled with inflowing water as a result of flood or excessive precipitation. In a natural wetland, if the groundwater table level is located on the surface of the ground, water retention capacity equals almost to zero. Therefore, every single drop that falls on the surface on such wetland can, theoretically, runoff to the river. The drainage of wetlands does not minimise the flood wave. Natural wetlands that are covered with some kind of swamp plants, for example shrubs, are characterised by significant hydraulic resistance. Moreover, small elevation differences of the terrain are typical for these areas. This is the reason why water in the form of snow melt, or flood water runoff from the area of wetlands slowly. Therefore, swampy river valleys can be treated as retention reservoirs. Water that flow into the area of the wetland can slowly run off back to the river, which decreases the flood wave on the river section situated below the wetland. This phenomenon is clearly visible in for example the wide (over 10 km width) Biebrza valley in Poland. Water can be retained on the surface of the valley for more than a few months. Therefore, the single drop of water mentioned above can freely, but slowly get back to the river.

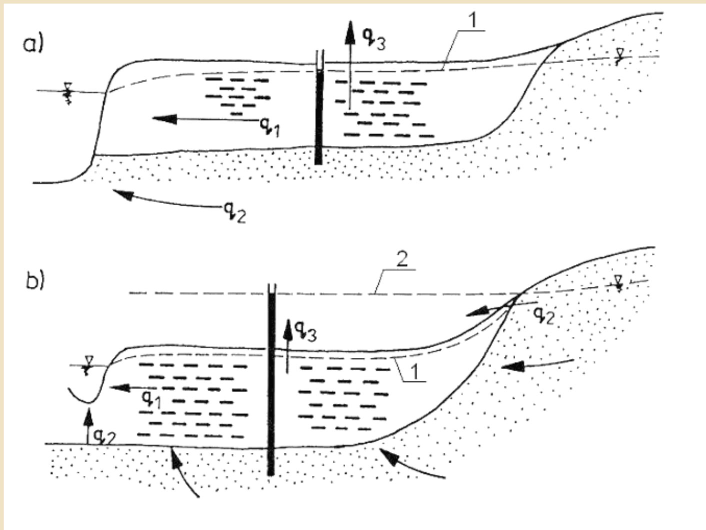


Figure 6. The scheme of water runoff from peatlands with different types of water alimentation: a) by surface waters, b) by groundwater, q1 – water runoff from the peat, q2 – water alimentation from the mineral layer, q3 – evapotranspiration, 1 – groundwater table level, 2 – water under pressure. Source: Mioduszewski, 2003

It has been estimated that the Biebrza valley in Poland can retain almost 50 000 000 m3 of water when the snow melts, which can reduce the flood in the downstream part of the river system (Okruszko, 2005).

The influence of the wetland on water flow in the watercourse depends more on the width, shape, and utilisation and slope of the valley, i.e. the so called valley retention area of the wetland, than on the water retention capacity of the soil in the aeration zone. During a flood episode, water fills in all soil pores and then it covers the surface of the area. After the decrease of water level in the river, it can runoff from the valley back to the river, but the flow rate is low, due to high hydraulic roughness coefficient (resulting from dense vegetation) and small terrain slopes towards the river. Water in various forms play a part in the creation of wetlands: surface, ground and rainwater. The general relation between these various forms of water, and the types of wetlands, as well as the influence of duration and the size of flood on the habitat has been presented in
Figure 7.

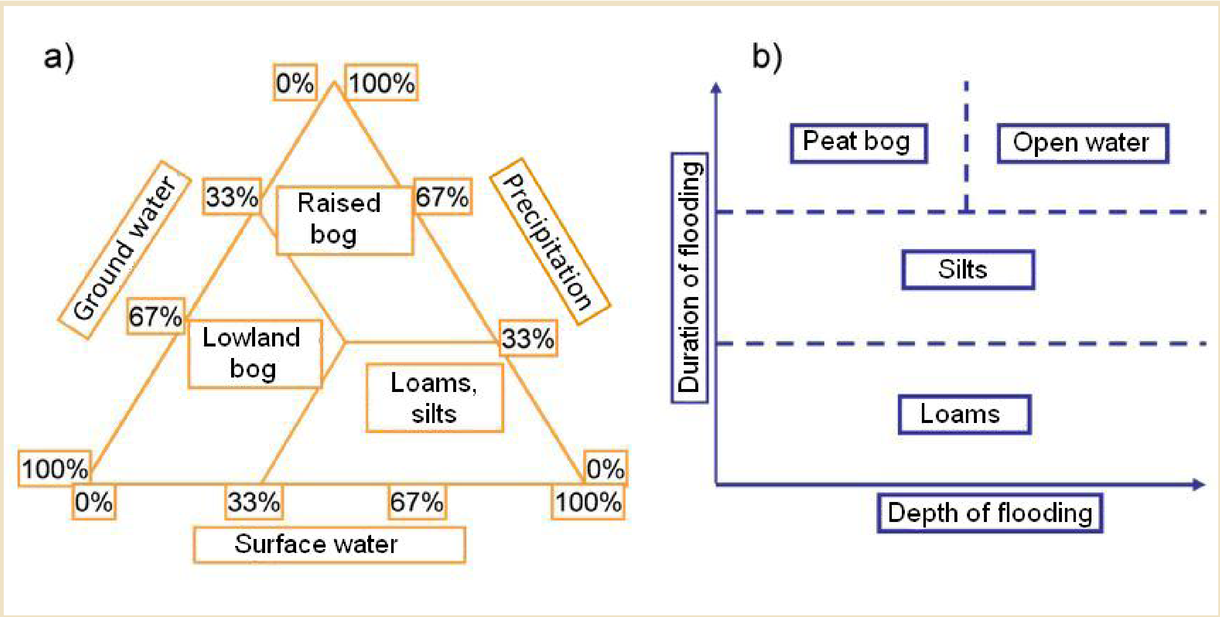


Figure 7. The relationship between different kinds of water alimenting the wetland, and type of wetland: a) kind of water, b) duration and water level during flood. Source: Okruszko, 2005

Some forms of peatlands, such as mires, that exist on the slopes of the valley and the outcrops of the aquifers play an important role in water circulation (Figure 6). Primarily, they delay water runoff from the aquifer, and cause the elevation of the groundwater table level on the plateau. Consequently, the water stored in these peatlands feed the valley with water during periods without precipitation.

Forests. Forests, like wetlands, are characterised by a significant potential water retention capacity. Forests regulate the water cycle by retaining water during times with precipitation, and by increasing the runoff to rivers during periods without precipitation (Chang, 2006; Gutry-Korycka, 2003; Pierzgalski et al., 2012).

The positive role of forests in limiting floods caused by heavy rains and snow melting on areas with significant denivelations in the terrain, combined with poorly permeable soils is unquestionable (Chang, 2006; Pierzgalski et al., 2002). However, it is difficult to prove its influence on the changes of the flow rate of the river. Forests play particularly important role in areas with diverse terrain, and poorly permeable soils. They limit the rapid water runoff from the surface by its retention in the ground.

The situation is different in sandy flat areas where the effective infiltration can be decreased, implying a decrease of the alimentation to the groundwater layer (Mioduszewski, 2003; Chang, 2006; Palat et al., 2013). The reason is that before afforestation, water originating from snow melting, or rains can infiltrate the soil. In such cases, water uptake by plants increase since the transpiration in forests is more significant than in other habitats.

2.4. Technical retention

All measures causing the increase of the amount of water retained in the catchment by any form of engineering solutions, such as for example the construction of particular water devices, are called technical measures of small retention.

Water reservoirs. Water reservoirs have always been an important element in the human environment. Traces of reservoirs used for irrigation constructed three to five thousand years BC can be found in India, Egypt and Greece. In Europe during the Middle Ages, as well as in modern times, water damming on rivers, as well as the construction of water mills, small power plants, and fish ponds, are all contributing to economic growth. Invention of the steam engine has limited the need to obtain energy from water and led to prompt decline in number of pond created by the water mils (Mioduszewski, 1997).

The phrase 'small water reservoirs' encompass a wide range of different kinds of reservoirs constructed by humans. These reservoirs are dug ponds, including fishponds and micro reservoirs, as well as small reservoirs in the form of a valve on a watercourse, or in a valley created during the construction of a larger dam. These reservoirs are usually supplied by water flowing in the watercourse. Reservoirs do not always have to be filled, they can also be dry, and filled with water only after heavy rains or snow melt, when flow rate increases. There are many different kinds of water supply systems, such as inflow of groundwater, surface runoffs, or drainage intakes.

A classification of the various forms of reservoirs is presented in Figure 8, including all the micro reservoirs and small reservoirs, which usually have a positive or minimal negative impact on the environment.

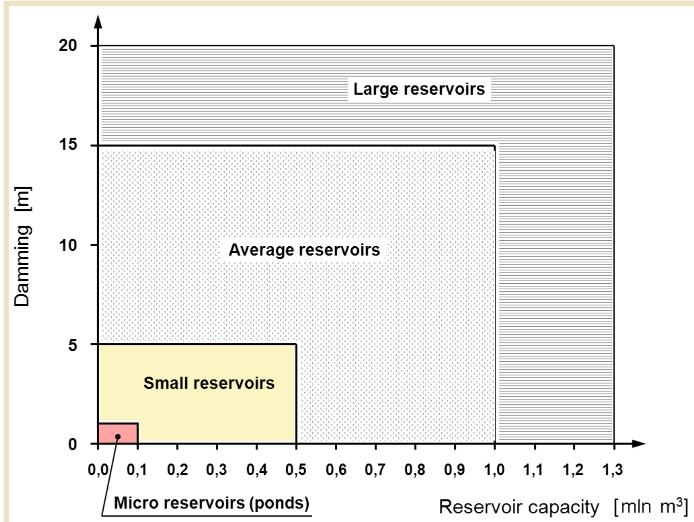


Figure 8. The classification of water reservoirs. Source: Mioduszewski, 2003

Water reservoirs play an important role in the human economy, as well as in the environment. Considering the various roles they play, they can be divided into the following categories:

- drought management – reservoirs storing water for economic purposes: water retention for irrigation in agriculture and forestry, human and agricultural water demands, fish-farming, power production (small water power plants);
- flood protection reservoirs – wet and dry reservoirs and polders;
- water reservoirs for recreation and aesthetic purposes: bathing resorts, aesthetic (park) sites, fishing ponds (non-economic fish farming);
- ecological reservoirs: aquatic flora and fauna enclaves, biofilters (constructed wetlands) or reservoirs serving as filtration site to purify water;

- water reservoirs used to improve water balance: alimentation of groundwater aquifers, limiting the erosion, retention of surface runoffs from sealed surfaces.

Reservoirs constructed only for the purpose to improve the water balance are very unusual. Instead, reservoirs are usually constructed to fulfil economic needs, or to serve as flood control. They are only occasionally constructed to fulfil environmental needs. However, almost every reservoir, regardless its designed purpose, also influences the water balance.

Drainage systems. With the global intensification of agricultural production, a large number of small watercourses are regulated and altered to meet the agricultural demand for water. In addition, so-called valley drainage systems are being constructed, resulting in the creation of a dense network of drainage ditches. Groundwater tables have also been lowered in vast areas of wetlands. In many cases, it is possible to restore the groundwater level through retention measures without restricting the agricultural sector, because the groundwater table is usually lowered more than is needed. Raising the groundwater table ought to be done by keeping a low water level during wintertime to stop reduction processes in the soil. The water level can then be raised during spring, after removing the excess water. Drainage systems such as drainage ditches, transport water to crop plants during times when water is in excess (Radczuk and Olearczyk, 2002; Holsten et al., 2011; Avery, 2012; Mioduszewski et al., 2014). In general, for the purpose of agricultural production, it is enough if the drainage system can guarantee six to eight percent of an unsaturated zone within the soil layer. There are technical solutions that can serve to restrict excessive water drainage from the drainage system. This can be done by using a regulated outflow from the drainage system (Figure 9) or by the construction of damming devices (damming constructions) on the drainage ditches. Devices that can be installed in a drainage well (Figure 9) to allow the regulation of water damming levels, and its adjustment to the current atmospheric conditions. Damming devices with the established (permanent) threshold are constructed on ditches. Construction of the weirs and water management depends on the climate, water discharge, soil and crop.

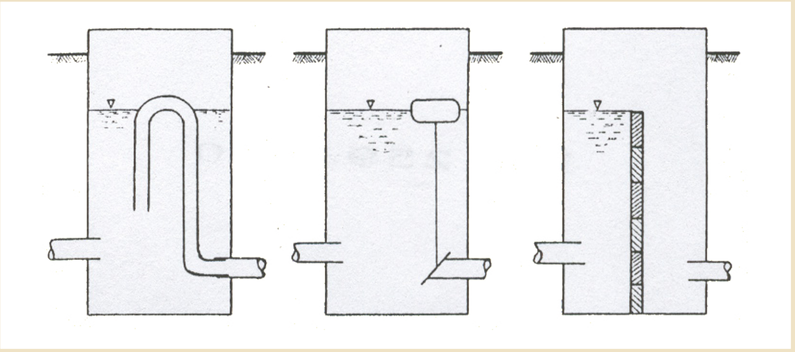


Figure 9. Scheme of the devices for regulation of the outflow from the drainage system (Mioduszewski, 2003)

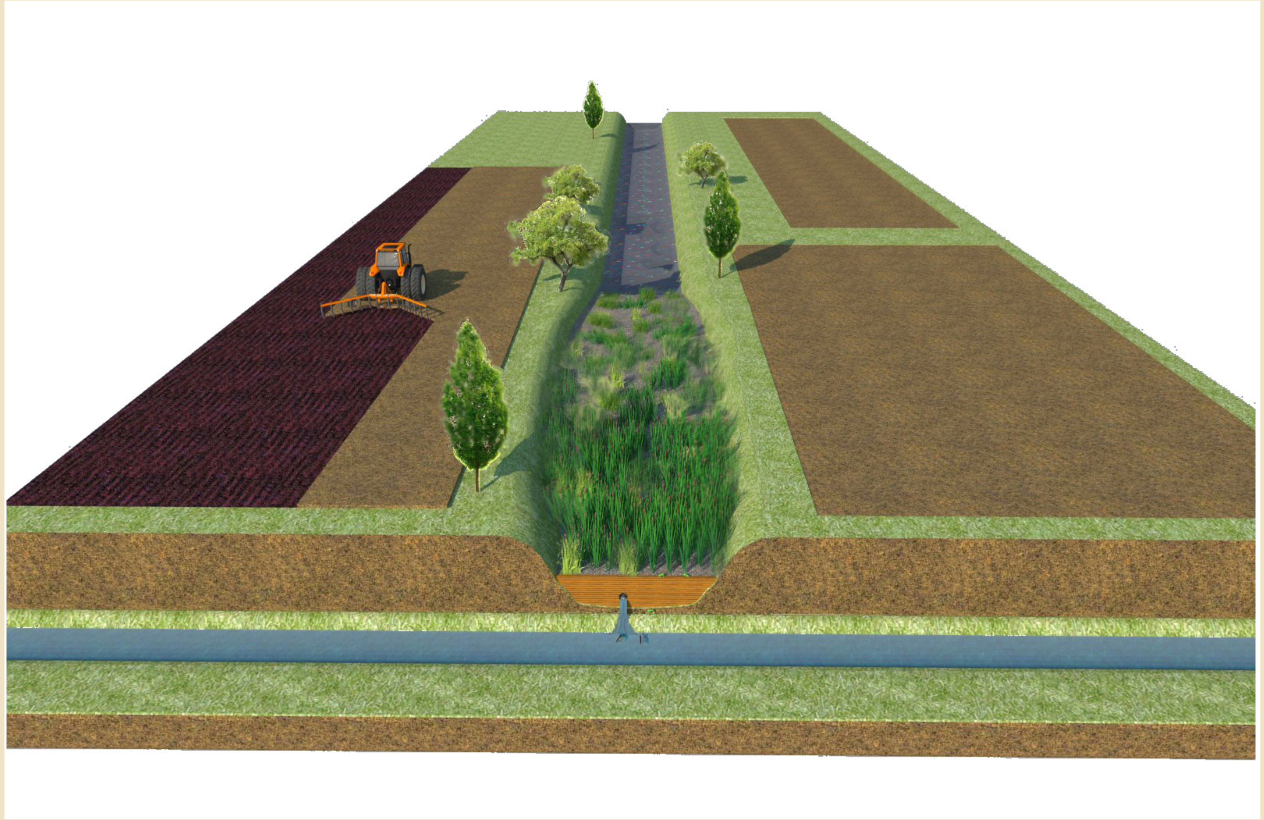
Research has illustrated that to regulate water outflow from the drainage system, or from the system of ditches, does not have a negative impact on agricultural production (Rozemeijer et al., 2010; Holsten et al., 2011; Avery, 2012; Mioduszewski et al., 2014). On the contrary, this type of water outflow regulation means that plants can use the stored water during the vegetation period. In general, water conditions can be improved for agricultural production. Moreover, water outflow from the regulated drainage system has lower loads of nitrogen and phosphorous. Therefore, the regulation of outflow can contribute to the improvement of water quality in rivers.

Regulated outflow drainage systems can be constructed in flat areas (Ángyán et al., 2003; Mioduszewski, 2009; Querner et al., 2012). When the landscape is more diverse, it is more effective to construct small retention reservoirs on the outflow of the drainage system. Water in such reservoirs can be cleaned and used for irrigation, or for other economic purposes. Similar solutions can be used in the system with drainage ditches.

Standard man-made drainage (melioration) ditches are usually built as a straight line without any significant vegetation and therefore, they cannot retain water, or provide a self-cleaning function which is essential in order to remove nutrients from agricultural run-off. The use of co-natural retention measures, such as allowing overgrow by water plants, can eliminate, or at least mitigate problems related to pollution of water bodies and groundwater, as well as erosion. Vegetated melioration ditches, wetlands, or more controlled systems such as reed bed filters and constructed wetlands, can be used to mitigate these kinds of problems (Melbourne Water, 2005; Heeb, 2011). While choosing the appropriate measures to address these problems, it is recommended to address the problems at the place of origin. Hydrology and hydraulic should be taken into account (Querner et al., 2012).

The figure below illustrates the treatment of agriculture run-off. The system can be placed at the end of melioration ditch, or inside the ditch.

Figure 10. An example of a co-natural system for agricultural run-off treatment.



Source: LIMNOS, Company for Applied Ecology, 2015

Reservoirs as flood protection measures are, after levees, the most popular solutions. Some examples are shown in the case study for Slovakia.

Water Management. Many valleys containing small rivers have been equipped with drainage systems, namely a network of open ditches. These areas are presently used as meadows and/or pastures with various degree of intensity of agriculture. Very often, the conceptual assumption is one of fast water runoff during springtime, and delivery of water for irrigation from other catchments, or dedicated retention reservoir during growing season. Very often, however, these assumptions are only realised to a limited degree. Commonly, the drainage network is constructed, but no water resources have been secured for irrigation. Such partial investment causes excessive water runoff, and drying of soil. Through proper water management, the excessive water runoff during spring can be limited, which ensures access to water for plants during growing season (Mioduszewski et al., 2014). A number of simulations and field observations show that proper water management allows effective use of the potential of retention capacity of drainage ditches. However, in most cases, the reconstruction of water system by the construction of damming facilities located on the small ditches is essential.

3. How to choose the catchment for the retention measures?

3.1. General remarks

The main aim of small retention is to improve the water conditions in the river basin. The other aim is to preserve biodiversity of habitats that are strongly related to water resources, including habitats and species of a great natural value. Measures categorised as small retention aims to cause a slowdown or restriction of surface water runoff, rainwater outflow, and subsurface flow. While planning for undertaking such measures, measures aiming at retention of water within the catchment by increasing soil retention, use of aquatic ecosystems, old meanders and ponds should be prioritised.

While developing a project, it is recommended to use natural conditions and features of the environment in a way that limits any potential negative impact. The use of natural conditions and features creates the best chances for success, and keeps costs to a minimum.

For example, in the Small Retention Programme developed for the Mazovian Voivoidship in Poland in 2008, apart from defining the possible solutions, a valorisation of needs and possibilities to retain water was prepared. The bases for the valorisation were natural factors such as climate, hydrology, hydrogeology, physiography, and economic conditions such as land use. The analysis of the realisation of small retention included 12 factors in 4 groups, including:

- climate conditions: climatic water balance and frequency of precipitation lower than 50% of the multiannual mean value;
- hydrological conditions: unit discharge rate of the multiannual low mean discharge, ration of high flow rates to the low ones, area of the land intensively used and situated within the flood terrace;
- hydrogeological conditions: soil water retention, groundwater renewable resources;
- land use: share of forests, share of the surface of lakes and artificial reservoirs, share of urbanised areas, share of orchards and vegetable production fields, share of arable lands within the unified water bodies.

These factors were chosen for the Mazovian Region, but they can be modified to the local context and used for other parts of CEE as well.

The performed analysis allowed for the development of a map of retention needs of the irrigated area, where each areas was categorised either as an area where an increase of retention is necessary, where development of retention would be beneficial, or where retention measures are not needed.

When planning for the location of for example a damming structure on a watercourse, the analysis should consider the water demand of other users situated within the reach of the planned investment, particularly those downstream. Furthermore, the analysis also has to consider wider biological flows, such as the conservation of the river ecosystem for the sake of for example migrating fish.

In regards to the economic analysis, it should include:

- costs of the development of technical documentation of the project;
- costs of land purchase;
- costs of materials and work;
- environmental costs connected with the implemented changes in the environment as a result of the construction originating during its exploitation (possible changes of the species composition of the biocenosis, threats to the migrating fish);
- external costs that can be the result of for example loss of users situated downstream the planned investment;
- benefits for water users and nature.

3.2. The methodology of catchment selection

Having identified a need to reduce water outflow, the next challenge is to identify the appropriate catchment to implement retention measures. In order to make this selection, it is necessary to utilise both hydrology data as well as GIS databases. Based on the aim, and on the availability of data, the selection of the catchment can be done through:

a) analysis of the water outflow from the catchment;

b) analysis of the water outflow and factors shaping the outflow (valorisation of need to increase retention);

c) use of mathematical model with spatially distributed parameters.

These approaches can be seen as a hierarchical ladder, where each step up will integrate the findings from the previous level to broaden the scope of the analysis.

Analysis of the water outflow. In this level of analysis, it is assumed that the watercourse is representative of the situation in the whole catchment. The analysis is usually based on the existing network of stream flow gauges, however, nowadays the number of records can be easily increased by using automatic water level monitoring. Additional research monitoring should be performed at least for a year to relate it to the already existing monitoring network. Following parameters should be considered to answer the question whether retention measures are truly needed in the catchment:

- length of low flow period;
- number of high water flow events;
- total amount of high water discharge (available resources).

Droughts caused by lack of precipitation can periodically occur quite often in the CEE countries. However, if the analysed watercourse experience the negative effects of the droughts more often than in other locations, it can be seen as evidence of a rapid exhaustion of groundwater resources caused by anthropogenic factors, like water intakes, or increase of sealed surfaces area. If the watercourse also has a large amount of disposable resources, this is a strong indication that measures that would inhibit surface runoff could be implemented. However, data that is solely based on a small number of water gauges in a vast area is not always satisfying. Therefore, this level of analysis ought to be complemented by other forms of analysis that are based on investigative monitoring, or spatial analysis.

Valorisation of needs to increase retention. Available hydrological and meteorological data, as well as maps at an appropriate scale should be used for this analysis. Its realisation can be summarised in the following steps (Pusłowska-Tyszewska et al., 2008):

I. Selection of the spatial planning unit (SPU), for example, a water body used in Europe for water level reporting or hydrological response unit (HRU) (Arnold et al., 1998)

II. Selection of available indices characterising disposable water resources and retention capacity of SPU

III. Spatial analysis based on:

- **a.** calculation of mean values of the factor for each SPU e.g. share of forests, mean unitary outflow;
- **b.** valorisation of the factors into three indices (0; 1; 2) where 2 means that implementation of measures for an increase of retention capacity in a SPU is needed, 1 means that increase of retention capacity in a SPU would be beneficial, and 0 means that there is no need to increase the retention capacity;
- **c.** creation of the aggregation map by summary of the indices for SPUs that spatially overlap each other;
- **d.** redistribution of the values on three needs of retention demand:
    - high – development of small retention is very desirable;
    - medium – development of small retention is beneficiary;
    - low – development of small retention is not needed.

For example, the indicators listed in Table 4 were defined for the Mazovian Region in Poland, but, similar calculations can be done for other regions. However, the site characteristics values (for example soil retention, hydrological indicators) will then differ (Pusłowska-Tyszewska et al., 2008).

Table 4. Characteristics used in the evaluation process and their threshold values (source: Puslowska-Tyszewska et al., 2008)

Name of the indicator	Unit	Site characteristics			Non-exhaustive list of examples	
		min	average	max	2 points	0 points
Climate indicators						
Climate water balance	mm	142	211	268	> 250	< 150
Frequency of precipitation lower than 50% of the mean multiannual value	%	16.4	19.8	22.8	> 21.0	< 19.0
Hydrological indicators						
Multiannual mean unitary outflow	l/s/km2	0.202	1.12	2.78	< 0.75	> 1.50
Ratio of the maximal flow (with probability of 1%) to the mean flow	-	6	169	700	> 200	< 100
Flood risk area	ha	0	0.002	0.012	> 0.010	< 0.005
Hydrological indicators						
Groundwater renewable resources module	m3/d/km2	79	177	390	< 150	> 250
Soil water retention	mm	74	135	182	< 125	> 175
Indicators related to land use						
Participation of forest	-	0	0.253	1.000	< 0.100	> 0.300
Participation of lakes	-	0	0.005	0.119	< 0.001	> 0.020
Participation orchards	-	0	0.071	0.570	> .250	< 0.125
Participation of urban areas	-	0	0.034	0.335	> 0.100	< 0.050
Participation arable land	-	0.126	0.478	0.791	> 0.500	< 0.300

The aim of this analysis is to increase the flexibility of the spatial planning, defined by the area, not the precise location, and evaluate the investments in the light of environmental needs.

In the **first stage** of the analysis, a water body was selected as a Spatial Planning Unit (SPU).

In the **second stage**, considering limitations in data availability, four groups of factors characterising disposable water resources were identified:

Climatic (meteorology and hydrology) indicators:

- climatic water balance (difference between precipitation (P) and reference evaporation (ETo))
- frequency of precipitation lower than 50% of the mean multiannual value

Hydrological conditions:

- multiannual mean unitary outflow
- ratio of the maximal flow (with probability of 1%) to the mean flow
- flood risk area

Hydrogeological indicators:

- groundwater renewable resources module for first aquifer
- soil water retention (for 1m layer depth and 2-4.2 pF)

Land use indicators from Corin Land Cover (participation in % in SPU):

- forests
- lakes and artificial water reservoirs
- urbanised areas
- orchards and vegetable cultivation
- arable lands

A map of the climatic indicators has been developed based on the interpolation of meteorological data that was obtained from the representative measuring sites (Figure 11a). A map of the hydrologic indicators has been generated by connecting the multiannual statistical data on water flow from water gauges with the respective catchments. A map of the soil retention has been developed by the Polish Institute of Soil Science and Plant Cultivation. Finally, a map of the module of renewable groundwater resources has been obtained from Polish Geological Institute.

In the **third stage**, the mean value of all indicators for each water body was calculated based on the spatial analysis. The exemplary results of the analysis have been presented in Figure 11a,b. In the next step, values of the indicators have been changed into indices: {0; 1; 2} (Figure 11c). The process demanded definition of two threshold values for each indicator. The threshold values defined the degree of needs of the area for development of small retention. The threshold values reflecting respective classes of needs and the scope of variation of the analysed indicators have been given in Table 4. These values should be evaluated individually, depending on the characteristics of the analysed area. In the next step, a summary evaluation of the needs of each water body was done. The evaluation was based on all analysed indicators. Based on the total value of all points (maximum number that was possible to obtain was 17), all Unified Water Bodies (UWB) were grouped into three categories:

- High need of small retention – water bodies with a sum of all points equal or higher than 12 points;
- Medium need of small retention – water bodies with a sum of all points between 7 and 11 points;
- No needs of small retention – water bodies with s sum of all points below 7.

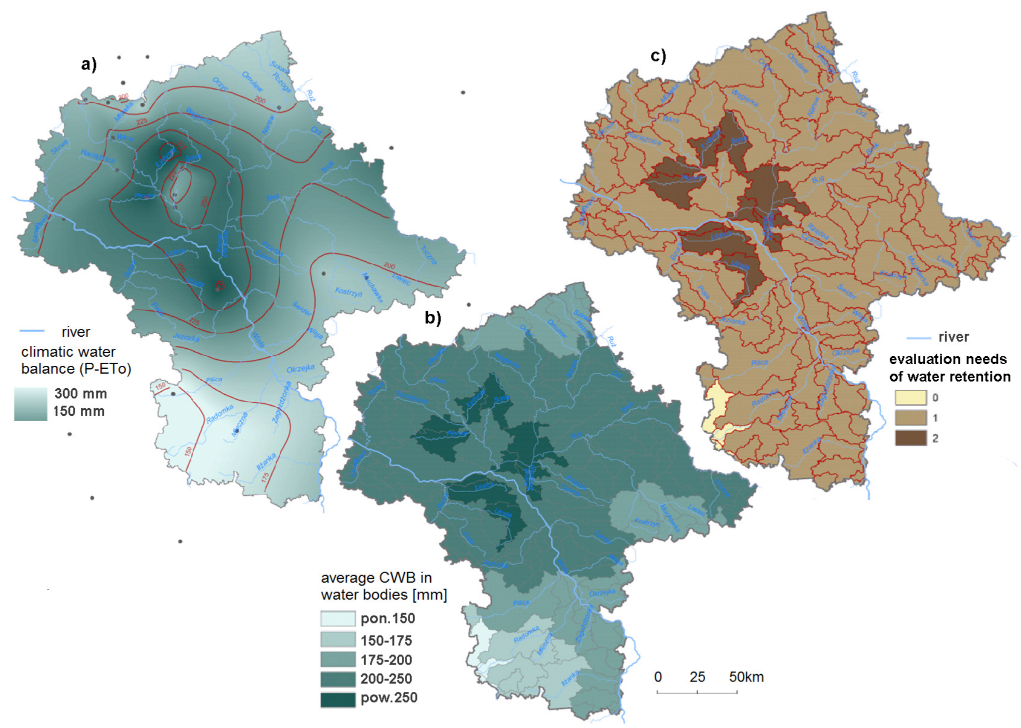


Figure 11. Example of indexing process for climatic water balance: a) isolines of climatic water balance (CWB), b) average CWB in water bodies, c) evaluation of water retention needs for water bodies. Source: Puslowska-Tyszewska at al., 2008

The summary values obtained within the process of valorisation for each water body, as well as the need of some small retention measures are presented in Figure 12.

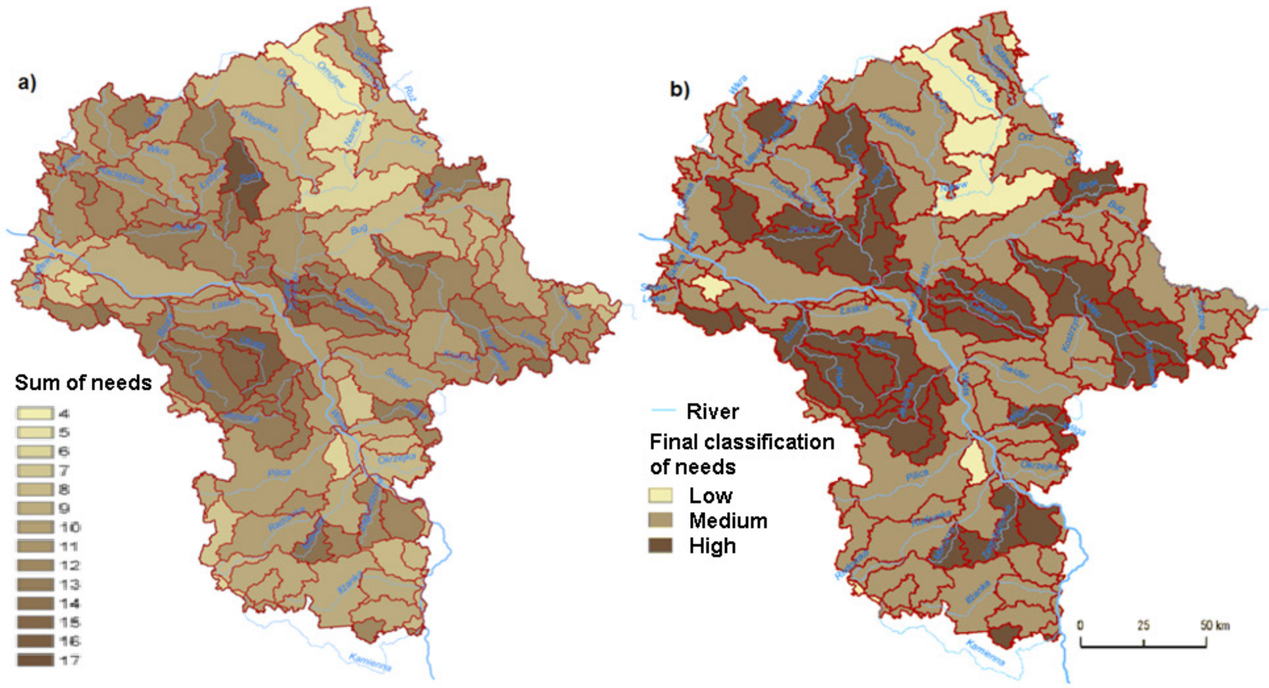


Figure 12. General evaluation of water retention needs in integrated water bodies; a) the results of evaluation (classes 1-17) of the Unified Water Body, b) the priority of small water retention measures. Source: Tyszewski et al. 2008

Use of mathematical model with spatially distributed parameters

To obtain a more precise analysis of the available water resources in each fragment of the catchment, it is possible to transfer information from a single water gauge by a mathematical model (precipitation – runoff type). Depending on the type of the selected model, it is possible to obtain a number of indicators that may be used for this method of valorisation of water retention needs. Outflow models such as the Soil and Water Assessment Tool (SWAT) can be used as well (Arnold et al., 1998). The defining feature of the model is that the catchment is divided into hydrologic response units (HRU) that combined covers land use, soil, and denivelations gradient of the catchment. Some examples of application of the SWAT model are given by Marcinkowski et al. (2013), and Giełczewski et al. (2013). There are other useful models as well, for example, it is possible to use SIMGRO to model water flow in unsaturated and saturated zones (Burek et al., 2012; Querner et al., 2012; Mioduszewski et al., 2014).

The proposed methods should always be appropriate to the analysed area in the catchment scale. Depending on the scale of the work, the level of accuracy will vary. Therefore, within the planning process, it is important to pay attention to the need of field recognition, i.e. that there is a need to carefully plan for the particular investment location. Moreover, the need for considering a number of tasks that potentially may not be implemented due to the local state of environment and local legislation should be kept in mind. These include:

- river continuity;
- existence of the protected areas;
- state of the environment e.g. water quality;
- consideration of needs of other users of water.

The mathematical model with spatially distributed parameters requires large quantities of data. Therefore, it is difficult to use it for all natural retention measures, and instead, this kind of numerical modelling is commonly only used for large-scale projects.

4. How can we evaluate the results of NSWRM in terms of flood protection, drought mitigation, and biodiversity increase?

4.1. Evaluation of natural small water retention measures

Due to the relatively small amount of the retained water, and small area of land where NSWRM measures are implemented, it is difficult to empirically illustrate its impact on protection against floods, and limiting droughts. However, numerical modelling shows that the above discussed measures are particularly useful for meeting the water demand of plants during droughts. Numerical modelling of scenarios, including drainage ditches networks with damming devices, show that the soil water conditions can be significantly improved if the proper water management is introduced (Arnold et al., 1998; Querner et al., 2012; Mioduszewski et al., 2014). The elevated groundwater table can contribute to the increase of water uptake by plants and, as a result, the increase of yields. In other words, the potential water retention ability of the drainage ditches can be used for improving the structure of water balance.

A number of research studies are concerned with the water balance of fishponds. Fishponds are reservoirs with clearly defined functions; the creation of the reservoir allows aquaculture with various levels of intensity. However like a number of other reservoirs, apart from their basic economic function, these reservoirs also serve other purposes such as recreation and environmental functions. As it is illustrated in Figure 13, fishponds also influence the water cycle in the catchment by creating a reduction of the maximal flow rate in the river. It occurs when the reservoir is filled during high water flow.

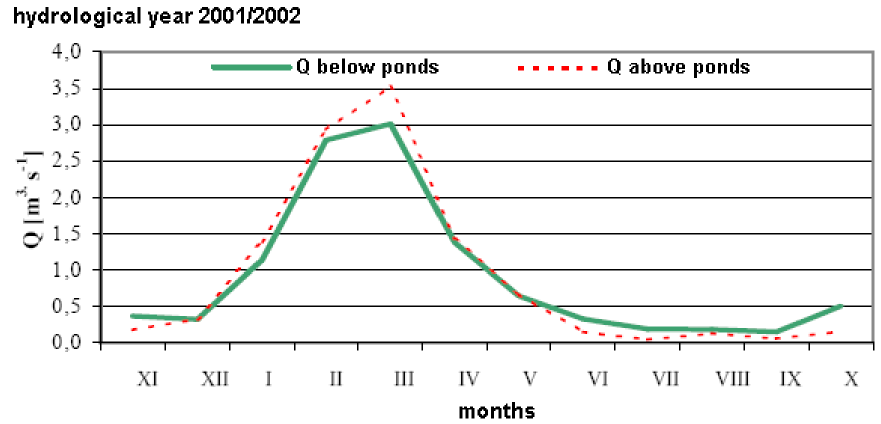


Figure 13. Mean monthly flow rate of Mała Wełna River on the sections upstream and downstream the group of fish ponds. Source: Murat-Błażejewska and Kanclerz, 2008

Under normal circumstances, NSWRM can significantly influence the water cycle in the catchment. However, it should be recalled that small retention measures is a form of so-called ‘uncontrollable retention’. In other words, although retention measures are implemented, leading to that the potential water storage capacity increases, actively controlled management is not possible. Consequently, the measures are limited in the sense that it is impossible to determine how and when water is to be discharged, and thus, its impact and effectiveness during catastrophic flood rates is limited.

Small water retention reservoirs can be more useful. Despite their low capacity, they can be an important part of the floods protection system, particularly on watercourses experiencing rapid (flash) floods. Such conditions exist where small watercourses flows through areas with significant slopes, and in cases where water is collected from urban areas. To fulfil their tasks, these reservoirs must be designed to have valves, allowing retention of the peak flow only (Mioduszewski, 2009).

Photo 2. Flood Valley of Biebrza River in Poland is a vast retention reservoir. Photo: W. Mioduszewski

Small retention plays an important role in limiting the negative effects of droughts. Sustaining high water table level in watercourses and reservoirs cause slower water runoff from the valley during springtime and, as a result, groundwater levels also rise, in the adjacent areas, both at the level of the valley and on the plateau. As a result of the elevated groundwater table, the water availability for plants – both natural vegetation and crops – is increased. This increases biomass production, and makes the agricultural system and the ecosystem more resilient in the event of a prolonged time without rain. Moreover, most small water retention measures are favourable to the natural environment. However, if poorly designed and planned, retention measures can also have a detrimental effect on the environment. For example, the construction of a new meander of a river channel, or the construction of a pond in an area can alter, or destroy the habitat in such a way that it poses a threat to the flora and fauna in the area. Furthermore, the construction of a dam on a river that is of importance for fish migration can have an adverse effect since it will prevent the fish to migrate. Therefore, even small-scale projects require careful planning and consideration of the environmental context before implementation.

Photo 3. Small pond filled with water from the drainage system. Photo: Z. Kowalewski

The construction of a dam, which inhibits water outflow, or the creation of meanders are measures that not only increase the water level in a stream, but also increase the groundwater table in the valley. In most cases, these measures are favourable to the environment since they improve the conditions of water dependent ecosystems by improving the biodiversity of the valley, and the hydromorphology of the riverbed. However, in areas used for agriculture, such measures can have negative effects on crops.

Moreover, the construction of a dam in a forest environment can increase the soil moisture too much for some trees species. Therefore, succession of trees and species that have higher demand for water should be considered (higher humidity habitats). This is commonly a positive development, seeing the high value of forests. Forests with higher soil humidity are characterised by higher biodiversity.

Photo 4. Plants development (succession) in the pond decreases its retention capacity. Photo: W. Mioduszewski

Natural and man-made water reservoirs are valuable elements of the agricultural landscape. The construction of small retention reservoirs could to some degree be seen as the restoration of reservoirs that have existed before. Moreover, through research conducted during this project, it has become clear that within a few months after a reservoir is constructed, it usually becomes a habitat for aquatic species and avifauna, which are valuable for the environment.

All measures to increase water retention capacity usually contribute to the improvement of surface and groundwater qualities. Due to slowdown of water outflow from the catchment, plants and crops can use nutrients during the vegetation period.

Small dug ponds, despite their small sizes, can enrich the biodiversity of the agricultural landscape, as they can be sites of amphibians' reproduction, for example frogs. In sub-mountain areas, a small reservoir can be reproduction site for four species of newts' population, which can have hundreds of individuals. In lowlands, for example in Mazury and Wielkopolska in Poland, cranes can populate midfield small reservoirs

In extensively used fishponds, similar changes to the ones seen in eutrophic lakes can develop. The occurrence of rare plants species, like Salvinia natans, Nymphoides peltata or Trapa natans is also possible. The occurrence of avifauna in fishponds is also quite frequent. Islands existing on the reservoirs enrich species diversity and the number of birds, and they are usually used as habitats for ducks. The attractiveness of such islands can be increased by the occurrence of black-headed gull, the presence of which can ensure a protective umbrella from predators (e.g. hooded crow) and produce suitable conditions for the development of a population of other species, like black-necked grebes. For example, black-headed gulls and five different species of ducks currently inhabit the ponds located on the river Barycz in Poland. Ponds can also serve as an important breeding ground for amphibians like the fire-bellied toad, a toad that is quite common in Poland, although rare in Western Europe.

Water reservoirs that are constructed as a result of the excavation of gravel or sand can also enrich biodiversity. Such reservoirs can become reproduction sites for amphibians and birds (e.g. river terns), especially if there is an island. The construction of islands as floating platforms has become an effective method of increasing the population of terns.

4.2. Analytical methods

To conduct an assessment is crucial since the empirical evidence can assist in formulating lessons learned, and thus, it is valuable information for when designing a new project.

Assessment of NSWRM can be conducted directly or indirectly with the use of available measuring techniques and calculation tools. A direct assessment can be conducted by monitoring the site before and after the measure has been implemented. The scope of the monitoring will depend on the expected results. In case a quantitative assessment will be conducted, the monitoring should cover the components of the water balance, for example water level, temperature of surface and groundwater, as well as meteorological conditions. In case a qualitative assessment will be conducted, biochemical indicators should be monitored, for example water quality or population of vertebrates and invertebrates.

A quantitative assessment conducted with the use of a precipitation-outflow mathematical model, and which seeks to measure the impact of NSWRM, follows the following steps: (1) calibration and validation of the model for selected catchment and period, (2) scenario modelling, (3) analysis of results.

In regards to the first step, i.e. the selection of a catchment, the period and profile of the model calibration is crucial since they influence the sensitivity of the model to even small investments. The selection of a period when intensive changes in the catchment took place should be avoided, particularly instances of hydro-technical constructions, and periods with limited precipitation. Moving on to the second step, the construction of a scenario is important since it allows the researcher to create a realistic exemplary of the retention measure, whilst experimenting with various variables. To make it realistic, it is important to draw up a scenario that is reasonable, and only implement measures that are suitable for the environment that it signifies.

The variables that are most frequently changed when drawing up a scenario are:

- change of size;
- change of location;
- change of size and location of retention measures.

A quantitative analysis can be conducted by assessing yields, groundwater resources or surface runoff. It is also possible to do a comparative study by examining for example a multiannual period, years with large/limited precipitation, periods of high water flow, or only the vegetation period. Assessment can be performed by comparing different scenarios within the same calculation period, or by analysing NSWRM in years rich in precipitation and years poor in precipitation.

Two of the most common assessment models are the SIMGRO model, and the SWAT model, previously discussed in this report. The SIMGRO model (Querner at al., 2012) has been used to study the effect of small water retention, particularly regulated outflow from ditches, on water resources in the catchment (Mioduszewski et al., 2014).

A number of publications connected to the SWAT model present the results of modelling that aim at evaluating SRM on flood protection and drought mitigation. These can be found by accessing https://www.card.iastate.edu/swat_articles/. For example, it includes analysis of impact on:

- Wetland restoration on downstream flood peaks (Martinez-Martinez et al., 2014);
- Agriculture management on groundwater (Dourte et al., 2013);
- Tillage and irrigation on downstream flow (Masih et al., 2011).

Based on these publications, it is difficult to draw conclusions regarding the influence of NSWRM in another catchment located in different climate. Due to significant factors influencing the outflow process, mathematical assessment of small retention should be conducted on a defined catchment and in the adequate scale.

4.3. The benefits of natural small water retention measures

All the small retention measures have positive social, economic and environmental effects. The most important benefits are:

- changes in water outflow structure in the river, decrease of the flood wave and, in some cases, improvement of low flow conditions;
- satisfying the needs of water dependent forest and swamp ecosystems, as well as the improvement of the state of environment as a result of elevation of groundwater tables;
- increase of groundwater aquifers alimentation, which causes the increase of groundwater resources;
- fulfilling some of economic demands, for example, water reservoirs can be used as water intakes for fire-fighters, bathing resorts, fish ponds, water intakes for irrigation or watering holes for wild animals;
- improvement of natural values of environment, improvement of biodiversity of agricultural landscape by the restoration of wetlands, small ponds, creation of natural aquatic fauna and flora enclaves, creation of human friendly micro climate;
- protection of surface water quality, retention of suspended matter, cleaning of rainwater from nutrients (nitrogen and phosphorous).

5. How can we incorporate the natural water retention measures in the RBMP, FPMP and DMP?

A vision for EU water policy is set out in the Water Framework Directive. The Directive advocates development and implementation of River Basin Management Plans (RBMP), Flood Protection Management Plans (FPMP) and Drought Management Plans (DMP).

Natural Small Water Retention Measures (NSWRM), as well as Natural Water Retention Measures (NWRM) share many characteristics with other methods aiming to protect of water resources and natural capital.

The correlation between water retention measures and the EU Directive and its associated strategies is presented in Figure 14.

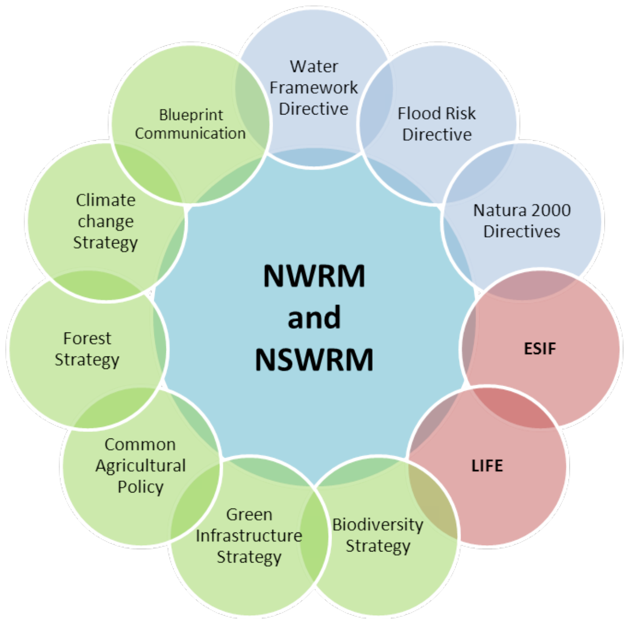


Figure 14. Aim and scope of Natural Water Retention Measures (NWRM) and Natural Small Water Retention Measures (NSWRM). Source: Borchers T., 2014.

Although acknowledging the importance of all the strategies identified in Figure 14, this report will only discuss the different strategies directly related to water management and water resources protection.

All these strategies published as official EU guidelines, recommend implementation of measures that aim to improve the potential water retention capacity in catchments. Therefore, although they might not always promote NSWRM or NWRM specifically, they indirectly recommend the implementation of small water retention measures.

For example, the policy document The EU policy document on Natural Water Retention Measures (EU Commission, 2014) produced by the Water Framework Directive CIS Working Group Programme of Measures (WGPoM) states that "NWRM are multi-functional measures that aim to protect and manage water resources using natural means and processes". Based on this, they claim that NWRM can contribute to achieving other explicitly stated goals.

In a Report (EU Commission, 2012d) written by the Commission to the European Parliament and the Council on the Implementation of the Water Framework Directive, member states are recommended to: "continue consolidation of integrated multidisciplinary water management, look for solutions that balance environmental protection and sustainable economic development"(European Commission, Framework Water Directive, 2000/60/EC)

The necessity to integrate water management with other sectors is stressed in the various strategies. Land management, agricultural practices, urban development, small water power plants, shipping, and flood protection, all have a major impact on water resources. It has been stressed that agriculture significantly influences water resources due to its sheer water demand, and diffuse pollution. However, examining the River Basin Management Plan, it neither emphasises agricultural measures to a sufficient extent, nor does it advocate that farmers comply with, and work towards implementing the WFD. Moreover, there is lack of detailed information about the potential to use funds from Rural Development Programs for implementation of measures in rural areas. The EU Commission has proposed to integrate the Water Framework Directive into the first pillar of the Common Agricultural Policy (CAP). Effective use of water as well as water management should be a priority of Rural Development Programs (RDP).

Another important document outlining the current implementation of EU water policy is the Report on the Review of the European Water Scarcity and Droughts Policy (Commission, 2012b). This report stresses that there is a need to promote technologies and practices allowing efficient use of water, also in agriculture. The basis for long-term sustainable management is to ensure consistency between new economic uses, and water availability. Special attention should be paid to land use.

Justification of measures contributing to the increase of natural water retention in the catchment can be found in A Blueprint to Safeguard Europe`s Water Resources (EU Commission, 2012a), distributed from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.

The state of the water resources in the EU is not satisfactory. Protection measures to improve this have been based on an in-depth analysis of current water policy measures, and a goal to simplify the process. Because the European aquatic environment is diverse, an emphasis has been placed on solutions adapted to the local context and environment.

It is believed that the most prominent reasons for a deteriorating quality of water resources are all interrelated. These include climate change, land use, economic activity (economy, agriculture, tourism etc.), urban development and demographic changes.

As the water quality in the EU is deteriorating, many countries face the risk of water shortages, and the threat of aquatic ecosystems becoming less resilient, and thus more sensitive to extreme events like floods and droughts. To ensure economic and environmental stability and recovery, climate change adaptation measures should focus on green growth. Through the development of green infrastructure, resilience can be improved. One example would be the establishment of buffer zones that ensure a biological continuity between rivers and their shores. Wetlands and flood valleys should also be restored to increase water retention and to protect biodiversity and improve soil fertility. These measures represent a valuable alternative to the typical 'grey infrastructure', which includes, among other things, levees and the construction of dykes and dams. The Commission notes that special attention should be paid to preventing the degradation of the sources of rivers. These are small water bodies, which often serve as a spawning sites for many fish species, and which are often vulnerable to the effects of agricultural works such as drainage and backfill, and drying. As discussed above, it is also important to recall that fishponds play an important role in the retention and maintenance of water in the landscape, and the prevention of floods and erosion.

Analysing these demands set out by the European Commission, it is clear that actions such as increasing the potential capacity of the catchment reservoirs, i.e. implementing NSWRM or NWRM, fit well within the wider framework of European water policy. Technical and non-technical infrastructure underpinning small water retention measures is covered in the Commission`s recommendations as green infrastructure.

To develop green infrastructure, the Commission recommends member states to increase efforts on integration policies at the national level. Member states should take full advantage of RBMP plans that require an integrated approach to water resource management in various policy areas, such as agriculture, aquaculture, energy, transportation and integrated management of natural disasters. The Commission proposes to develop guidelines under the Common Implementation Strategy, dealing with the measures in the field of natural water retention. The guidelines should facilitate the implementation of such an integrated approach. It will be crucial to develop guidelines that ensures proper water level in reservoirs where crustaceans, molluscs and other aquatic invertebrates live. This will require the development of the first pillar of CAP to support measures to improve natural water retention.

Plans that aim to protect water resources in Europe repeatedly emphasise that one of the solutions that can significantly help to reduce the adverse effects of drought and floods is green infrastructure, particularly measures that increase the natural water retention. These include the restoration of the valley floodplains and wetlands, which can store water during periods of heavy or excessive rainfall, that can be used in times of scarcity. The impact of green infrastructure on the water balance depends on many different parameters such as infiltration capacity, land cover, the season of the year etc.

According to the EU Biodiversity Strategy, green infrastructure can support ecosystem services. This strategy also emphasises that an important part of reducing the risk of flooding is correct agro-technology, especially measures for improving the structure of soil which allow increased infiltration of water into the aquifers. This is a form of a small retention measure. It is recommended that these activities are included in the RBMP and FPMP.

In the following section, small retention is discussed with specific reference to four countries: Poland, Slovakia, Slovenia and Hungary.

Small retention in Polish planning documents. The issue of natural small water retention measures is briefly discussed in Polish planning documents. Although only discussed to a limited degree, small retention measures are included in River Basin Management Plans (RBMP), in Flood Protection Management Plans (FPMP), and in Drought Management Plans (DMP). However, in all Plans, there is lack of a clear connection between the problem and small retention. NSWRM or NWRM is not explicitly mentioned but some elements are discussed. In Water – Environmental Program, which is an appendix to the RBMPs, most measures are connected with water quality protection. However, measures to prevent erosion, support ecological and sustainable agriculture, and creation of buffer zones along watercourses, and measures to increase forest areas are also mentioned.

During the implementation of the Water Framework Directive, a number of planning documents were developed in Poland:

- Water management plans for the river basins, KZGW 2008- separate plans for the Vistula and the Odra and 8 other river basin districts of international basins which only partially (small areas) are located on Polish territory;
- Water- Environmental Program, KZGW Warsaw 2008- it is an attachment to the water management plans containing list of measures, including new investments;
- Separate Master Plans for the basins of the Vistula and the Odra rivers, KZGW Warsaw 2014;
- The program of flood protection in the Upper Vistula basin, KZGW Kraków 2010;
- The program of flood safety in the Water Region of the Central Vistula, Masovian Governor Warsaw 2012 (Draft for public consultation)- the work has been suspended;
- The Program of countermeasures for droughts effects – the project is in the development phase, no information about its planned content is available.

The water management plans developed in 2008 have not been approved by the European Commission, mainly due to the lack of explicit reference to environmental issues. These plans represent the existing state of water management and have been supplemented with a detailed statement of the expected investments in different water bodies.

In most cases, these plans only contain very general statements when referring to non-investment activities. There is, however, a lack of proposals for measures in the field of small retention. In 2014, the Master Plans, which are temporary documents replacing the water management plans, were developed. These documents do not take the non-technical measures to retain water into account. The document focuses mainly on the investment activities such as construction and reconstruction and modernisation of water facilities.

More detailed flood protection plans have been developed for the basin of the Upper and Middle Vistula. The Plan for the Upper Vistula takes into account the construction of small reservoirs in mountainous areas. However, the European Commission has not yet approved it. In contrast, work on the Middle Vistula flood plan has been on hold pending the completion and approval of the Master Plan. A lot of space has been devoted to small retention in the general description of the activities in the program of flood safety. This indicates its importance. Theoretical analysis of the hydrological consequences of the liquidation of the levees or construction of polders (flooding valleys used for agriculture) has been carried out. The possibility of using agricultural drainage systems to reduce floods has also been analysed. There is, however, a lack of clear indications on how small retention activities will be implemented in practice. This program provides an overview of several thousand objects and devices that should be implemented in the coming years- there are proposals for small reservoirs with a capacity of hundred thousand to two million m3. It also highlights some organic soil drainage facilities that ought to be modernised and adapted to the retention of snow melting waters.

The only planning documents dedicated to the issues of small retention are the Provincial Development Programmes of small retention. They have been implemented, to some extent, but they mainly focus on investments such as small water bodies, including fishponds, water damming (impoundments) on lakes, and the construction of dams on streams. However, these are the programmes with a relatively low status. Nonetheless, they can be regarded as the beginning of a path towards implementation of the idea of natural water retention.

Small retention in Slovakia. The experience in Slovakia in regards to implementing small water retention is rather marginal. Guidelines at the national level have been drawn, but realisation has not yet occurred. Yet, it is possible to make some provisional remarks.

- Water management problems does not only exist in agriculture, but in all basins, where water runoff conditions in the last 20 years have been altered, and where, as a result, accelerated drainage, and increased variability of the flow rate of in basin has occurred.
- Local climate changes are due to global climate change. Although also being an issue in the past, these challenges now urgently require financial investments.
- The main problem associated with water retention is to comply with legislation, and apply the appropriate technical parameters. This demands a broad knowledge, especially in the areas of hydrology, water management and environmental sciences. Currently there are a number of examples where implementation has not had the desired effect, because appropriate knowledge has been lacking. For example, the implementation of a green area does not automatically mean that the water flow will be uniform in rivers throughout the year, and that an active development of natural fauna in water reservoirs will occur.
- Political and social forces drive water management, which in turn has an impact on the landscape. However, the actors involved all have different interests, creating potential conflicts.

The Hungarian Experience. Small water retention was dealt with in the 1st version of the River Basin Management Plan (RBMP) in the chapter on Programme of Measures. However, more extensive use of natural water retention measures is foreseen in the 2nd RBMP. NSWRM and NWRM have been included in these programmes as a response to the Ministry of Interior Affairs, which is responsible for water management on the national level.

In order to expand natural water retention measures, the traditional runoff management system had to be changed. This led to the creation of National Water Strategy (NWS). The NWS emphasises water retention measures to mitigate water management problems under conditions of climate change. Within the framework of the operational program of the NWS, a number of actions and measures are planned with specific reference to the integrated management of extreme hydrological events, by storing the flood water in order to have a better access to water during periods of draughts.

The purpose of the National Water Strategy is not only to meet agricultural water demand (e.g. irrigation), but also for other uses, including maintenance of ecological services. The main focus will on:

• encouraging natural water retention measures by building new reservoirs;

• keeping back the water in the river bed (river bed-retention);

• increasing the water retention capacity of soils;

• encouraging introduction of suitable agro-technical interventions;

• modifying regional- and land use systems.

These measures will be taken into account in the 2nd HU 1000 RBMP.

Water structures in Slovenia. Almost a hundred investments connected to water retention, and improvements to the structure of water balance have been implemented in Slovenia in the past ten years. The basic economic aim of these investments is to limit the undesired effects of droughts and floods. Due to climatic conditions, and the character of the landscape, attention has been given to investments connected with flood protection.

The term “small retention” is not used in Slovenia. Small water retention measures were not part of the 1st SLO RBMP. So far, only a relatively small number of non-technical measures aiming to limit the negative droughts or flood effect are undertaken. Nonetheless, a number of investments include measures that can be defined as small retention.

European countries all face similar problems with implementing NSWRM. Documents related to water policy, both at the European and national levels, accept small water retention as the most appropriate method of increasing natural retention of river catchments, that could lead to the improvement of the water balance reducing the risk of flood and drought. In addition, these measures increase the biological diversity of ecosystems in rural and urban areas. To a large extent, they limit the spread of pollution, especially from agricultural production. Despite this, implementation of these principles faces resistance. This resistance is not only caused by a lack of awareness, but mainly due to that these measures have to be implemented simultaneously across various sectors. However, although this is a cross-sectoral policy, agricultural areas are of significant importance for the reasons outlined above. Furthermore, spatial management plans play a significant role, by for example limiting the urban development within the river valleys.

It is crucial that in documents such as the RBMP, FPMP and DMP, clear statements backed up by empirical evidence outlining the need to implement specific retention measures should be made. However, these documents are on their own not sufficient. The introduction of a legal framework, as well as raising public awareness through training is crucial. Activities to raise awareness, preferably co-organised by the public and the private sector, should be linked with the World Water Day (March 22).

However, the most important action should be to incentivise landowners to implement retention measures. Implementation of measures should be encouraged through financial and legal assistance. For instance, a farmer who plans to build a small water reservoir to catch contaminated drainage water flowing from the field should not face complex procedures for obtaining building or environmental permits. In the present times, many farmers restrain from taking actions due to the complex rules.

6. Lessons learnt from implemented projects in Poland, Slovakia, Hungary, and Slovenia including best examples of combined effects and involvement of stakeholders

Small retention measures are not a novel invention. Retention projects are planned to improve the water balance, or it is a project with a different objective that indirectly improves the water balance as a side effect. For example, farmers who improve the soil structure in order to obtain higher yields, often contribute to the increase in water supplies for the plants, whilst also reducing the risk for flooding. Similarly, wetland restoration projects may have positive impact on the water resources in the area, although the explicit aim of the project is to protect the wetland ecosystem.

Integrated approach to water management is, however, a combination of many different measures for economic and environmental purposes. As a result, their widespread use significantly affects water resources and their distribution.

A strength of small retention measures is the wide range of methods encompassed within the policy; ranging from planning, to agricultural activities, to the construction of small hydro-technical facilities.

Another strength of small retention is its positive impact on environmental conditions. These measures increase the biological diversity of both the rural and urban landscape, and limit the spread of pollution.

In this report, case studies demonstrating the implementation of small retention measures from the four cooperating countries are presented. In most of the cases, the implementation of measures was a consequence of the need to protect the natural environment rather than to restore water. Very often, the phrases “small retention” or “natural water retention measures” were not even used. A summary of these case studies is presented here, but all examples are described in more detail in the appendix “Case Studies- Small Water Retention Measures”.

It should be emphasised that the examples of retention measures mentioned and discussed here does not cover all forms of retention measures. The examples discussed in this report mainly illustrate technical measures.

A summary of the discussed case studies, including its objectives and results is given in Table 5.

Table 5. Summary of the case studies

No	Name	Work characteristics
	POLAND	
1	Natural small water retention program	The program is implemented throughout the country. It included the construction of small reservoirs, damming streams, water damming on lakes, construction of fishponds, and an upgrade of drainage systems in river valleys. It is estimated that the average annual increase of retention is approximately 15 million m3.
2	Small water retention in Garwolin forest	Within the Garwolin Forestry, 50 small water reservoirs have been built and 32 ha of drained wetlands have been restored. Estimated increase of water retention is ca. 0.5 million m3. The measure contributed to the increase of biological diversity.
3	Water reservoir Czyżew	Flood and recreational reservoir of the area of 2.45 hectares and a capacity of 40 thousand m3 was built in 2014. Increase in the number of birds is visible.

No	Name	Work characteristics
4	Water reservoir Zgorzała in urban areas	Restoration of dried small lake. The reservoir takes water from impermeable areas and relieves water runoff into the river. The reservoir device for increasing the efficiency of purification of rainwater has been constructed.
	SLOVENIA	
5	Karst pond in village Goce	Reconstruction of a dried pond in the project "1001 karst ponds 1001 stories of life". An increase of biodiversity has been observed.
6	Rehabilitation of clay pit in village Rence	Reconstruction of the reservoir formed after clay extraction. The reservoir is very valuable as a habitat for many bird species.
7	Multifunctional phytoremediation system	Systems consist of artificially meandered stream segment in a function of retention and treatment of incoming inflows and improvement of ecosystem services.
	SLOVAKIA	
8	Reconstruction of the mountain weir HB Klauzy	Reconstruction of damming facility in the National Park, which was destroyed in 2010. The goal of reconstruction is protection against flood and improvement of water conditions for the local fauna and flora.
9	Flood protection area- the polder Klatova Nova Ves	The construction of the polder is designed to reduce the risk of flooding. It limits the maximum flow rate by 85%.
10	The Podspady-Protected area Bor –The natural water retention by beaver weirs	Beavers build dams, damming water within environmentally valuable areas. These activities improve the water balance for the local fauna and flora. There is a clear increase in biological diversity.
11	Small water retention measures in Haluzice Gorge	Technical and no-technical measures. The main purpose is protection against erosion and floods.
	HUNGARY	
12	Marsh protection in Egyek-Pusztakócs	The measure covers large areas of marsh in the Hortobágy National Park (approx. 4000 ha), which were previously dehydrated. Work is expected to reduce the occurrence of periodical flooding.
13	Water infrastructure including small water retention supports land and water management	Many investments to improve water management in the valley of the Tisza River. Works include flood protection, reduction of the flood wave by 1m. Monitoring system will be built and there will be a change of land use.
14	Complex water retention at the Nagyszéksós Lake system	Wetland restoration was combined with utilisation of treated waste water applying some structural measures.

The described case studies can be divided into the following groups:

I. Nation-wide activities. Only one project- the National Program of Small Retention in Poland – is included in this group. This project included mainly technical measures like the construction of water reservoirs, water damming on rivers, and water damming on lakes. The weakness of this project was the lack of consideration for non-technical measures. In some provincial programs, associated with the nation-wide framework, this issue was raised, but it was not addressed in practice. Moreover, the program lacked overarching financial support. Hence, funding rather than need determined which projects were implemented. It is estimated that only about 30% of the programme plans have been realised.

II. Regional activities. This group includes two Hungarian examples, covering the protection of large wetlands, and improvement of water management, including flood protection in the catchment of the river Tisza. A variety of activities have been planned to cause periodic flooding of land (Marsh Egyek-Pusztakócs), and restore and protect previously present water relations, as well as to improve water management on a large catchment area of the Tisza river.

Spatial activities include the example of the development of small retention in the Garwolin Forest. Fifty small water reservoirs were constructed in one Forest Division. Small retention in forest areas was also carried out in other Polish regions. Larger works were undertaken in for example the Piska Forests in the Bialowieża Forest. The work consisted mainly of construction of weirs on small streams and ditches, and restoration of drained peat lands. Evaluation shows large changes in vegetation, including the loss of certain tree species (e.g. pine) and its replacement by wetland vegetation. Attempts to assess the volume of retained water have been made. It has been estimated that on average, retention increase was in the range of 5-10 mm, as calculated for the water catchment area, while the hydrometric measurements carried out on the larger streams showed no significant changes in the intensity of secondary flows. If the flow changes occur, they are insignificant in comparison to natural fluctuations in flow rates.

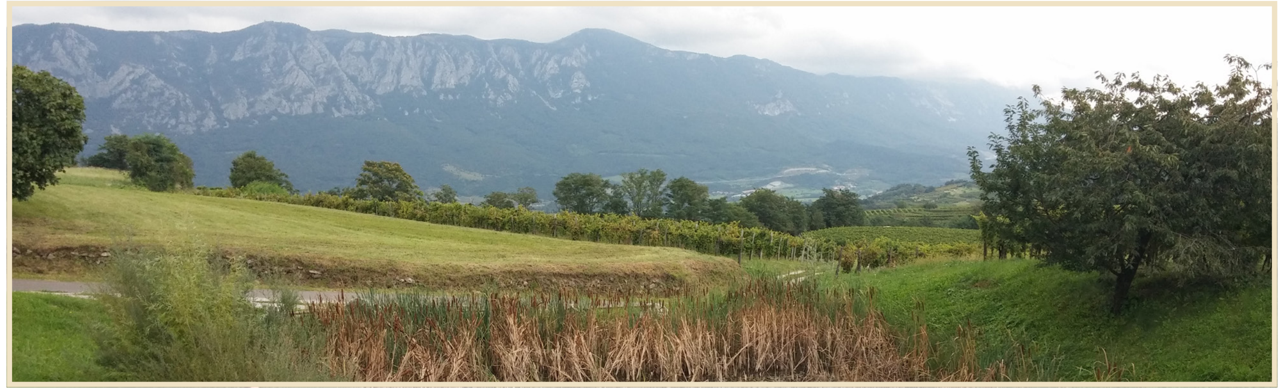
Technical structures include water reservoirs (Czyżew and Zgorzała in Poland). Other examples from Poland, as well as the karst pond and clay pit from Slovenia, and the reconstruction of a mountain (Klauzy) weir from Slovakia can be categorised as point objects. In each country, there are many structures of these types. These are mostly small reservoirs built for the abstraction of water for irrigation as well as recreational reservoirs. Each of the reservoirs serves as a flood reservoir. However, due to the relatively small total volume and the desire to maintain a constant water level in summer (recreational use), it is difficult to separate the volume for flood protection from the total volume of the reservoir.

III. Other activities. In addition to the national and regional projects, there are three more unconventional case studies. The first one is the construction of polder Klatov Nova Ves in Slovakia. It is an example of combining the agricultural use of the valley, whilst utilising the valley as a flood reserve. The method of creating water storage capacity for the reduction of flood risk from the agricultural use of the valley is, according to many, considered to be the optimal method from an environmental point of view. To some extent, dry reservoirs act as so-called polders.

In Slovenia, river meandering was performed. The aim of that project was to protect water quality, increase biological diversity and water retention.

Finally, in Slovakia, a water management project was developed that utilised beavers. Although beaver activity could have damaging effects in some locations due to that they create natural damming structures, in areas that are not used, the impact of beaver activity can be regarded as positive. However, it should be kept in mind that this is not a long-term solution since the beavers inevitably eventually leave the habitat and search for new locations.

To sum up, it should be emphasised that the explored cases improved conditions for the natural flora and fauna, as well as increased biological diversity of terrestrial and aquatic ecosystems. To some extent, the implemented measures contributed to the reduction of the adverse effects of floods and droughts, although it is difficult to numerically demonstrate the magnitude of this impact. The effects on the water cycle will be visible after implementation of more small water retention measures.



7. Conclusions – what is the best action plan

Human activity, such as the construction of drainage systems, the sealing of surfaces as a result of urbanisation, and the regulation of rivers and changes of land use, have contributed to altering the water cycle, which has resulted in an increased frequency of extreme events, such as floods and droughts. Besides being harmful to humans, these events also negatively effect the natural environment, and increase pollution to surface and groundwater. In addition to the human impact, it should also be noted that climate change might further exacerbate the issue.

Considering this, it is clear that water management should aim to increase the natural retention capacity of river basins, creating the conditions for storage (retention) of rainwater and snow in the catchment, and slowing down the water runoff into surface watercourses. A number of technical as well as non-technical measures can be used to obtain this goal. These activities are called "natural small water retention measures" or "small retention" – as opposed to hydraulic engineering activities involving the construction of for example large reservoirs, canals, and embankments. Small retention involves proper planning of agricultural and forestry areas, including the restoration of wetlands and river valleys, implementation of suitable agricultural technology, creation of objects for water retention in rural and urban areas, and modernisation of existing drainage systems.

It has been argued that all these measures have a positive impact on water resources by limiting the effects of droughts and floods, and moreover, that they create favourable conditions for the natural environment and for biodiversity. Furthermore, it has been suggested that they contribute to limiting the spread of pollution, particularly originating as a result of agricultural activity.

Based on previously published literature (Juszczak et al., 2007; Burek et al., 2012; Acreman and Holden, 2013; Marcinkowski et al., 2013; Mioduszewski et al., 2014) as well as expert advice, the authors have tried to evaluate the impact of a number of selected small retention measures (Table 6). The impact of the selected case studies on surface and groundwater, and on potential soil retention has been evaluated. Moreover, the impact of the selected case studies on landscape, biodiversity and water quality protection has been assessed. Although all the projects examined are small in scope, and mainly have positive outcomes, it should be acknowledged that they also have some occasional negative side effects.

An assessment of the impact of the various case studies on water resources and the environment has been made according to a four-point scale as it is shown in table 6.

Table 6. Evaluation of the impact of small retention measures on water resources and environment

Name of the indicator	Impact on water resources			Impact on			Threats
	Surface water	Soil retention	Groundwater	Landscape	Biodiversity	Water quality	
Afforestation of agricultural lands (poorly permeable soils, hummocky area, presence of snow melting floods)	++	+/–	+/–	+++	+++	++	Disappearance of certain plants (weeds)
Afforestation of agricultural lands (permeable soils – sands, presence of snow melting floods)	+	+/–	+/–	++	+++	++	Decrease of alimentation of groundwater aquifers
Mid-field afforestation (intensive agriculture, lack of forests, problems resulting from eolian erosion)	+	++	+	+++	+++	+	Implementation of foreign species
Agrotechnics (soil structure improvement) – poorly permeable soils	++	+++	++	+	+	++	Excessive intensification of agriculture
Agrotechnics (soil structure improvement) – permeable soils	+++	+++	++	+	+	++	Decrease of alimentation of groundwater
Agrotechnics-field water harvesting (small dikes around field edges)	+++	+++	+++	+/-	++	+++	large impact on the loss of deposits on the floodplain valley
Buffer zones along water courses and reservoirs lands (poorly permeable soils, hummocky area)	+	+	+	++	++	+++	Decrease of the area of grasslands and arable lands
Regulated outflow from drainage systems	+	++	+++	+	+	+++	Excessive humidity of arable lands, soil degradation (reduction processes)
Active water management on a drainage system (river valleys)	+++	+++	+	+	+	+	Intensification of agriculture
Construction of micro reservoirs on ditches	+++	++	++	++	+++	++	Excessive humidity of arable lands
Infiltration reservoirs and ditches	+	+	+++	+	+	++	Pollution of groundwater
Dry reservoirs/flood polders (river valleys used for agricultural purposes)	+++	++	+	+	++	+	Periodic destruction of crops yields, excessive humidity/drying
Construction of reservoirs on outflows from drainage systems	++	+	+	++	++	+++	Loss of the area for agricultural production
Old meanders/side reservoirs on rivers (retaining water during high spring flow)	++	+	++	++	++	+	
Construction of small reservoirs on rivers (dammed reservoirs)	+++	++	++	+	++	++	Destruction of valuable ecosystem, problems with fish migration
Dug ponds in local terrain denivelations	+	++	+	+	++	+	Destruction of valuable ecosystems
Small ponds (restoration)	++	++	+	++	+++	+++	Conversion of the ecosystem into less valuable
Water course restoration (meandering)	+++	++	+	+++	+++	++	Flooding of agricultural lands
Swamps restoration (peatlands)	+++	+++	++	+++	+++	++	Excessive limitation of water courses alimentation
Anti-erosion measures (various)	++	+	++	++	++	++	Changes in ecosystems

Scale: +++ meaningful impact, ++ medium impact, + small impact, +/– negative or no impact

The large variety of small measures, all relating to different public offices (agriculture, municipal economy, natural environment, transportation) make implementation very challenging. There are examples of plans that are developed but that have not been implemented. However, there are also numerous examples of projects that have had a different aim, but that has yet increased the retention capacity of a catchment area.

Small retention development programs must be included in the wider strategies for development. Among other things, small retention measures should be considered for:

- spatial development plans, both local and general;
- River Basin Management Plans (RBMP), the implementation of the Water Framework Directive, Flood Protection Management Plans (FPMP) and the Drought Management Plans (DMP);
- plans for the Common Agricultural Policy (CAP), particularly in agro-environmental programs;
- strategies for environmental protection, including Natura 2000 protected areas, with particular emphasis on wetlands;
- plans for modernisation of irrigation-drainage systems (if such are developed) in scope of its use of for snowmelt water retention.

Considering the great diversity of small retention measures, plans for small retention measures should be kept flexible, and should be adapted to the local context. However, an overarching framework ought to be developed. This should include:

- proposals for legislative changes to facilitate the small retention field works (e.g. the simplification of procedures for obtaining permits for the construction of small water reservoirs that capture drainage water);
- necessary range of state aid (technical and organisational) for small investors (farmers), e.g. the development of projects;
- proposals for legislation requiring the inclusion of certain small retention issues in investment projects;
- the size and scope of financial assistance and the conditions for granting depending on the type of measure;
- identification of the institutions responsible for conducting training and information on issues of small retention- this refers mainly to the inclusion of water issues in the responsibilities of the institutions responsible for agricultural advisory, or organisations responsible for water management for agriculture use.

Based on this overarching framework, small retention measures should be implemented. The strategy of implementation should include mainly stimulating activities that will be undertaken by different individuals or legal entities. The course of action should include:

- political decisions concerning the needs and scope of the activities that will be supported by government entities and public administrations;
- allocation of financial resources and the appointment of a coordinator responsible for implementation of the program;
- preparation and dissemination of information materials about the advantages of small retention and the expected range of support that may be provided (essential, legal and financial support);
- announcement of the call for proposals, receiving proposals for the implementation of small retention, evaluation of the merits of applications in terms of the feasibility of the program, and the assessment of the significance of proposals for water resources;
- technical and substantive assistance in the design and implementation of investment (tasks, program legislative support).

It should be noted that the financial support for Natural Small Water Retention implementation is needed. Furthermore, legal assistance should be provided in order to help small investors obtain the necessary permits to undertake the planned work.

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