PROLINE-CE

WORKPACKAGE T2

PILOTS: IMPLEMENTATION AND FEEDBACK

O.T2.4 ACTION PLAN FOR ADAPTATION OF EXISTING LAND USE AND FLOOD/DROUGHT MANAGEMENT PRACTICES

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Date last release	11th March 2019

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Dictionary of abbreviations

BMP	Best Management Practice
DEWS	Drought Early Warning System
DWPZ	Drinking Water Protection Zone
FEWS	Flood Early Warning System
GAP	Gap in Land use Management or Water Management practice
GWP	**G**uideline for securing the **W**ater **P**rotection functionality of the forest ecosystems within the DWPZ
LULC	Land Use and Land Cover
PA	Pilot Action
PAC	Pilot Action Cluster
UWWTP	Urban Wastewater Treatment Plants

1. Introduction

Drinking water sources along rivers are vulnerable to floods, more distant areas to droughts. In the frame of work package T2 best practices for drinking water protection, flood and drought risk management were determined and tested concerning their contribution to improvement of drinking water safety and effectiveness including ecosystem services as well as economic efficiency, furthermore to achieve a function-oriented land-use based spatial management for water protection at the operational level, which is task of subsequent work packages T3 and T4.

The main goal of work package T2 is testing of Best management practices (hereinafter BMPs), which were developed in the frame of the work package T1 and were selected as relevant BMPs for Pilot Actions (hereinafter PAs). PAs were selected in each partner country in order to reflect conflicts (GAPs) of management & operation of water supply companies and land-use management in recharge/water protection areas. In PAs status of best management practices implementation was determined and in case of lacks identified, possibilities of improvement and implementation were assessed. In representative PAs, considering the different ecosystem services, implementation strategies of BMPs which are important for water protection were elaborated. PAs reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

The main goal of work package T2 is thus joint conceptualization of all PAs and perform necessary steps towards elaboration of optimal measures and actions to achieve flood protection and a sustainable drinking water level as an input to the CE Transnational Guide towards an Optimal WAter REgime (GOWARE), which is a tool, which will be developed in the work package T3 and is summarizing a common methodology and a vision for integrated water protection management in the participating regions, in order to provide a frame for the implementation of best practices regarding drinking water protection and flood mitigation.

2. Pilot Actions, Pilot Action Sites and Pilot Action Clusters

The key challenges of PROLINE-CE regarding land use and drinking water resources management are common to all EU countries and not only to the participating partners and are following:

- protection of drinking water sources,
- balancing conflicts of land-use, environmental needs & drinking water protection,
- mitigation of flood and drought impacts on water resources used for water supply,
- adaptation to climate change issues despite uncertain prognoses by means of adapted and target-oriented land-use activities.

Land-use planning, and flood protection measures are often in conflict with drinking water protection activities. Hence different land uses, such as agriculture, forestry, grasslands - pastures, urbanization, etc., and flood protection measures have impacts to drinking water quality and quantity. Moreover, due to changing world, also climate change and land-use changes have to be considered. PAs were selected in order to cover the broad range of possible conflicts regarding land use (forest practices, agriculture, urbanization, etc.) and flood management versus drinking water protection and drinking water management in different natural conditions (mountainous areas, plain areas, riparian strips).

Pilot actions (PAs) and pilot sites were selected according to geographic and natural site characteristics (aquifer type) and main land use. Selection of PAs was performed according to following criteria:

- each country has one PA,
- PAs have to present different natural characteristics of drinking water sources and land uses in their recharge areas,
- PAs have to present broad range of possible conflicts regarding land use and flood management versus drinking water protection.

Each partner has one PA, where common project results from work package T1 are tested and implemented. Outcome are also experiences of testing and implementation process in PAs, above all, how to involve broad range of stakeholders and moreover, how to communicate with policy makers.

The single PA is clustered concerning the geographic specification and natural site characteristics (type of drinking water source: surface water, groundwater, bank filtration) and main land use in three pilot action clusters (PAC): mountain sites, plain sites and special sites (riparian strips).

2.1. Pilot Action and Pilot Site

For the work within work package T2 definition of Pilot Action and Pilot Site is needed.

Pilot Action presents activities performed at Pilot Site, such as study of gaps and best management practices of land use and flood protection within sight of drinking water protection. In T2, Pilot Actions will be verified regarding implementation status of best management practices. In case of lacks identified, possibilities of improvement and implementation will be assessed. In representative pilot actions, considering the different ecosystem services, project partners will prepare implementation strategies of best practices which are important for drinking water protection. Thus, water supply management systems and best practices should be strategically implemented in the pilot actions, in order to achieve a function-oriented land-use based spatial management for water protection at the operational level. Measures and actions will be analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water management.

Pilot site is a physical environment – a recharge area of drinking water source, where Pilot Action is performed. A recharge area can be river basin in case of surface water sources; or porous, fractured or karts aquifer in case of groundwater sources; or riparian strip in case of bank filtration.

3. Clustering of Pilot Actions

Pilot actions and pilot sites respectively were classified into three pilot action clusters (hereinafter PAC) concerning the geographic specification and natural site characteristics (aquifer type) and main land use (Table 1), which are outlined for each PAC in Table 2:

- Pilot Action Cluster 1 (PAC1): Mountain forest and grassland sites,
- Pilot Action Cluster 2 (PAC2): Plain agriculture/ grassland/ wetland sites and
- Pilot Action Cluster 3 (PAC3): Special sites (riparian strips).

General classification was made already in the Application Form, but the final classification was done after discussions at the kick-off meeting in Munich in September 2016 and at the second project meeting in Parma in January 2017.

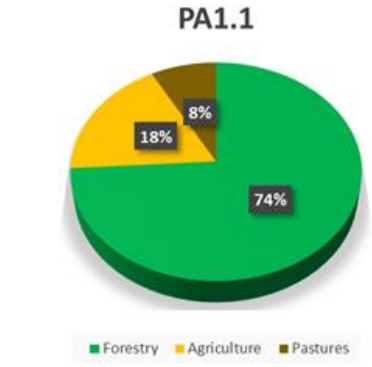
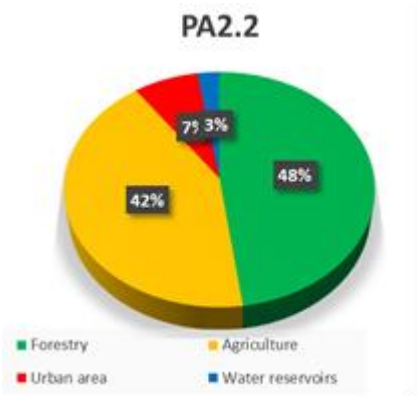
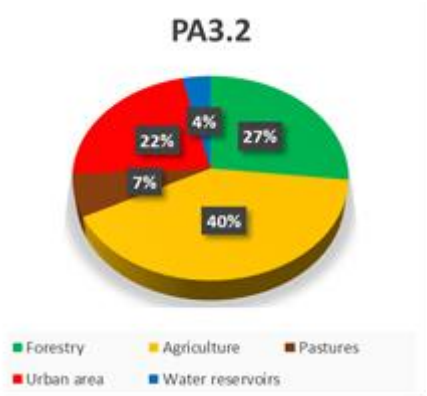
In the Application Form dry areas were selected to be part of Pilot Action Cluster 3. According to WHO, UNEP and deMartonne aridity index there are no dry areas in PROLINE-CE selected Pilot sites. On the other hand, during the discussion at the Parma meeting it was found out that several Pilot sites are facing water shortage in dry periods (each year or only in years with low precipitation); therefore it was decided that in all Pilot Actions impact of dry periods on drinking water resources will be studied, because in these periods there might be a problem regarding water quantity and quality and the competition for water. For that reason, the term “dry areas”

was excluded from the PAC3 title. Nevertheless, both Pilot Actions in the Pilot Action Cluster 3 have the least precipitation in comparison to other Pilot Actions.

Table 1: Pilot Actions and Pilot Sites respectively, classified into three pilot action clusters according to land uses and geographic scope.

PILOT ACTION CLUSTER 1 (PAC1) Mountain forest and grassland sites	PILOT ACTION CLUSTER 2 (PAC2) Plain agriculture/ grassland/ wetland sites	PILOT ACTION CLUSTER 3 (PAC3) Special sites (riparian strips)
PA1.1 Catchment area of the Vienna Water Supply, AT1 Drinking water source: Karst aquifer	**PA2.1 Well field Dravlje valley in Ljubljana, SI** Drinking water source: Porous aquifer	**PA3.1 Po river basin, IT** Drinking water source: Bank filtration
PA1.2 Catchment area of Waidhofen/Ybbs, AT2 Drinking water source: Fractured aquifer	**PA2.2 Water reservoir Kozłowa Góra, PL** Drinking water source: Surface water	**PA3.2 Along Danube Bend, HU2** Drinking water source: Bank filtration
	PA2.3 Tisza catchment area, HU1 Drinking water source: Surface water	
	P2.4 Groundwater protection in karst area, HR **2.4.1 - South Dalmatia: Prud, Klokun and Mandina spring** **2.4.2- Imotsko polje springs)** Drinking water source: Karst aquifer	
	PA2.5 Neufahrn bei Freising, DE Drinking water source: Porous aquifer	

Table 2: Main land use in particular Pilot Actions Cluster (PAC)

PILOT ACTION CLUSTER (PAC)	EXAMPLES OF DIAGRAMS OF DOMINATING LAND USE TYPE WITHIN THREE DIFFERENT CLUSTERS
PAC1 - Mountain forest and grassland sites In mountain forests and grassland sites best management practices for land use and drinking water management differ from those in plain sites. Therefore, this was selected as separate PAC. In mountainous areas drinking water sources are mainly originated from groundwater (fractured and karst aquifers). There are two PAs within this cluster and both are in karstic mountainous area and the major land use is forest, grassland and pastures. The major conflict regarding drinking water protection is timber production, gaming and cattle grazing.	 **Figure 1: Land use types within PA1.1. The dominating land use type within PA1.1 is forest.**
PAC2 - Plain agriculture/ grassland/ wetland sites In plain sites the main land uses are agriculture, grassland and urbanization. In plain sites drinking water sources can be surface water, bank filtered water or groundwater [mainly porous aquifer, but also karst aquifer (Croatian case)]. All PAs are in plain areas and the major land use is agriculture (with grasslands) and also urbanization (Table 1).	 **Figure 2: Land use types within PA2.2. The dominating land use types within PA2.2b are forest and agriculture.**
PAC3 - Special sites (riparian strips) Both Pilot Actions are riparian sites (Table 1). The main land uses are represented by agriculture and settlements. Both PAs face with issues related to water availability and water quality damage. Agricultural activities represent the main causes of contamination of water bodies and of the increase in water demand associated to irrigation practices. Furthermore, both PAs face with direct and direct impacts of flood and drought events.	 **Figure 3: Land use types within PA3.2. The dominating land use types within PA3.2 are forest and agriculture.**

Into the Pilot Action Cluster 1 (PAC1) two Pilot Actions from Austria were assigned (Table 1):

- PA1.1: Catchment area of the Vienna Water Supply, and
- PA1.2: Catchment area of Waidhofen/Ybbs.

Drinking water source in PA1.1 is karst aquifer, whereas drinking water source in PA1.2 is fractured aquifer (Table 1).

Into the Pilot Action Cluster 2 (PAC2) five Pilot Actions were assigned (Table 1):

- PA2.1: Well field Dravlje valley in Ljubljana, Slovenia,
- PA2.2: Water reservoir Kozłowa Góra, Poland,
- PA2.3: Tisza catchment area, Hungary,
- PA2.4: Groundwater protection in karst area, Croatia (PA2.4.1: South Dalmatia: Prud, Klokun and Mandina spring; and PA2.4.2: Imotsko polje springs);
- PA2.5: Neufahrn bei Freising, Germany.

Drinking water source in PA2.1 and PA2.5 is porous aquifer, whereas drinking water source in PA2.4 is karst aquifer. Surface water is drinking water source in PA2.2 and PA2.3.

Into the Pilot Action Cluster 3 (PAC3) two Pilot Actions were assigned (Table 1):

- PA3.1: Po river basin, Italy and
- PA3.2: Along Danube Bend, Hungary.

Drinking water source in both PAs is bank filtration or/and porous aquifer.

Objectives of the particular PA - geographic and thematic focus are presented in Table 3 and the main activities performed in particular PA are listed in Table 4.

Table 3: Objectives of the Pilot Actions: geographic and thematic focus of each Pilot Action.

Geographic focus	*Thematic focus*
PA1.1: Catchment area of the Vienna Water Supply	
The catchment area of Vienna Water Supply (pilot action 1.1 = PA1.1) is characterized by steep karstic mountain ranges with forest ecosystems, alpine pastures and rock areas. Focus of the broad study is the "Zeller Staritzen and Central Hochschwab area". Alpine pastures and hydrological modelling are analysed there.	The main objective is improved protection of drinking water resources through an integrated land use management approach, focusing on alpine pasture practices in mountainous areas (mountain grasslands) within the drinking water protection area of (DWPA) Vienna Water. Source water protection will be facilitated through the implementation of Best Management Practices (BMPs) for alpine pastures, specifically designed for the DWPA of Vienna Water.

	Hydrological Modelling will clarify the role of surface runoff and infiltration within the DWPA.
→ karstic mountains → alpine pastures → drinking water sources	→ alpine pastures (mountain grasslands) → modelling of infiltration and surface runoff → drinking water protection
PA1.2: Catchment area of Waidhofen/Ybbs	
Pilot action 1.2 (PA1.2) is situated in the Drinking Water Protection Area (DWPA) of Waidhofen/Ybbs, which is characterized by karstic mountains with steep slopes, where still semi-natural forest stands grow in a mosaic-mix with artificial conifer plantations. Forestry and hydrological modelling are analysed there.	Thematic focus is on forest management in a steep karstic alpine terrain with the overall purpose of drinking water protection. The karstic spring water with actual high quality should be protected so that the supply can be sustainably guaranteed on the present qualitative level. Source water protection will be facilitated through the implementation of Best Management Practices (BMPs) for forestry, specifically designed for the DWPA of Waidhofen/Ybbs. Hydrological Modelling will enlarge the protection focus in the thematic field of dolomite stone quarries.
→ karstic mountains → forest ecosystems → drinking water sources	→ forestry – silviculture → modelling of the hydrological impacts of dolomite quarries → drinking water protection
PA2.1: Well field Dravlje valley in Ljubljana, Slovenia	
Pilot action is a recharge area of a new (potential) well field in Dravlje valley (Glinščica river sub-basin) that is part of Ljubljana field porous aquifer. Glinščica river has recharge area in sandstones and claystones. → alluvial plain with surrounding hilly area → urban environment	The potential well field is in Glinščica river sub-basin and within urbanized area crossed by highway and with large open spaces (mainly agricultural areas), urban area and industry causing high pressure on land use. Dravlje valley is also a flood area with not properly regulated surface waters coming from hilly hinterland. Most of these waters are led to the urban sewage system, which in high waters cannot receive so much water and are flooded. The project focus is to harmonize land use and drinking water source protection and management, which is prerequisite for quality of life and drinking water in this area. → land use management

	→ urban surface water runoff → drinking water protection (spatial planning)
PA2.2: Water reservoir Kozłowa Góra, Poland	
Kozłowa Góra is a dam reservoir located at km 28+000 of Brynica River watercourse in the area of Silesian voivodship (Southern Poland). Kozłowa Góra reservoir is fed mainly by Brynica waters. According to the hydrological data from 2007-2016, the inflow rates, determined by the water balance method, range from 0.011 m3/s to 32.446 m3/s. Kozłowa Góra reservoir is classified as a shallow reservoir. In the pilot area, there are Lower and Upper Carboniferous formations. In its northern part, the Lower Carboniferous formations occur as alternate clayey-sandy shales and sandstones. A series of carbonate rocks, i.e. dolomites and limestones, was found over the clay-sandstone series (Wyczółkowski J., 1960 b). The higher-lying formations of the Upper Carboniferous have assumed the form of clayey shales, clayey-sandy shales and fine-crystalline sandstones. In the southern part of the area, within the reach of the Upper Silesian Coal Basin, the Lower Carboniferous formations are classified as Culm facies, while the Upper Carboniferous formations are represented by shales (classified as Paralic series), sandstones and coal of the Poręba, Grodziec and Flora beds. Their outcrops become exposed over small surfaces in the area of Kozłowa Góra. → shallow reservoir → lowland → mainly agricultural and woodland areas	Within a year in Kozłowa Góra reservoir water quality parameters changing is observed. Preliminary results of field and laboratory investigations indicate that pollution loads, supplied mainly through inlets, cause yearly phytoplankton bloom. In summer season, especially in June, sometimes July, algal bloom, causing decrease in quality parameters, is reported. This condition entails difficulties in water treatment and clogging of filters by diatoms and radiators, and, consequently, significant increase in treatment costs. For years the result has been closing the Water Treatment Plant until stabilization of parameters and algal bloom disappearance. The closure of water treatment technological line is associated with additional expenditure spends on for example filters perfusion, to keep their cleansing capacity. Main objectives of pilot action are: 1. Establishing multi-aspect water monitoring network 2. Setting up coupled models to predict water quality in the future to provide flexible fitting of water treatment technology due to current raw water quality 3. Community meeting and workshop organization to raise awareness and increase their knowledge 4. Preparation of proposal of DWPZ on the Kozłowa Góra reservoir → land use management → drinking water quality monitoring → drinking water protection (determination of DWPZ, spatial planning)
PA2.3: Tisza catchment area, Hungary	
The pilot area is located on the Middle Tisza area of the Hungarian Great Plain. The pilot area follows the line of the Tisza River in NE-SW direction. The eastern part of the pilot area extends long in the	On the Tisza pilot area, we are focusing on the surface drinking water abstractions located at Szolnok (River Tisza) and at Balmazújváros (Keleti Main Channel). The surface drinking water

direction of South by the Keleti Main Channel. Borders of the pilot area are the borders of direct catchment areas. The pilot area is a plain, with a very low altitude above sea level (avg. 85 – 150m) and a small average relative relief, i.e. 2 m/km2 on most parts. There is a more significant vertical relief in the area of Abádszalók which is covered by sand dunes, and the northern part of Hevesi Plains. → plain covered mainly with Quaternary sediments → pastures → agriculture	abstractions are more vulnerable because of the lack of natural protection layers. The travel time of the contamination is much shorter therefore prompt actions must be taken. Objectives of pilot action are (1) stakeholder involvement, (2) testing of BMPs in livestock farming and plant production through comparison of current state of the pilot area and an area in Hungary which has already been monitored for possible surface water contamination coming from agriculture, and (3) data gathering and evaluation (water stage levels, precipitation, water chemistry). → land use management (agriculture) → surface water quality
PA2.4: Groundwater protection in karst area, Croatia	
In the PROLINE-CE project, there are two pilot areas in South Dalmatia, which belong to the Adriatic Sea catchment area. These are typical karst fields with complex geological, lithological, hydrogeological and climatological processes. Karst fields are very specific, because karstic rock is covered by fine deposits (mostly plain area), whereas karstic rock in surroundings (mostly hilly areas) are bare karstic rocks with lack of vegetation. Climate is a mixture of Mediterranean and sub Mediterranean climate with very dry and warm summers. → Adriatic river basin → coastal karst polje → agriculture	The karst fields, due to their natural characteristics, represent a rare karst phenomenon with specific surface water flow and great suitability for agricultural activity. Given the fact that agricultural activity has a negative impact on both quality and quantity of water, karst fields represent a major challenge for drinking water protection and management. In addition, climate scenarios for this area for the period 2021 – 2050 show higher temperatures and lower recharge and therefore possible water shortages. Main focus in these pilot areas is to develop and implement measures for drinking water quality and quantity protection in relation to land use activities (above all agricultural activities) and climate change scenarios. → flood protection → land use → drinking water protection (determination of DWPZ, spatial planning)
PA2.5: Neufahrn bei Freising, Germany	
Neufahrn bei Freising is a community situated in the district of Freising (Landkreis Freising), which belongs to the administration district of Upper Bavaria (Regierungsbezirk Oberbayern). The community	The pilot area Neufahrn bei Freising represents the groundwater recharge zone that is related to the groundwater pumping wells of the local water supplier. Groundwater is used both for agricultural

covers an area of 45.51 km2 and has a population of 21.486 inhabitants. The pilot area relates to the Alpine foreland of Bavaria and thus accounts for the sedimentary basin of the Alpine orogeny. For the purposes of the activities related to PROLINE-CE, the important and thus considered lithostratigraphical units are related to the Quaternary and the Tertiary ages. Both units are characterized by loose sediments, i.e. mostly gravels, sands and clay (lenses), which originates from the Alps. Both units are separated by an extensive marl layer from the Miocene age with an average thickness of 15m. → Alpine foreland of Bavaria → mainly non-irrigated arable land, pastures, broad leaved forests	activities and as water supply for industrial usage (upper aquifer) and as drinking water supply (lower aquifer) in the area. Operational changes in agricultural practices are commonly related to economical driving forces, leading to the fact that agricultural land management is regulated by economic welfare. However, the supply of high-quality freshwater counts as one of the most important fundamental needs, although it is not always respected when adapting agricultural and industrial practices. The main objectives are 1) setting up a comprehensive data base including existing data and filling data gaps by installing new measuring points 2) set up of an integrated hydrological modelling framework, 3) integration of past land use changes and evaluation of the models' functionality and 4) testing, possible future land management scenarios and their impacts on the water resources. → land use management (agriculture, urban areas) → hydrological modelling for the recharge area of the Neufahrn wellfield → drinking water protection (spatial planning)
PA3.1: Po River Basin	
Po River Basin is mostly occupied by agricultural and forest/grasslands areas, which cover respectively 46% and 45% of the basin, while urban and industrial areas concern about 7%. The area includes 2155 surface water bodies, and 167 groundwater bodies. Hydrological and hydraulic modelling are considered for flood risk mitigation, hydrological and water balance modelling for water resources assessment including CC and LULC change. → riparian strips → complex landscape (agricultural areas prevailing) → drinking water availability	The main objective is improved protection of drinking water resource through an integrated land-use management approach, focusing on drought/flood planning, forecasting, early warning and management, also taking into account future climate change impacts. Water protection is carried out through the implementation of BMPs primarily designed for water availability, particularly during extreme events (drought and water scarcity/flood). Activities are focused on the improvement of hydrological modelling and related web tools, also considering CC and LULC and enhancement of planning processes, civil protection mechanisms and regulatory systems. → complex landscape (agricultural areas prevailing)

	→ drought, flood, climate change modelling → drinking water availability
PA3.2: Along Danube bend	
Danube bend area is mostly occupied by non-irrigated arable land (38.5%), discontinuous urban fabric (11.4%), broad-leaved forest (11%) and pasture (6.5%). The pilot area hosts the two most important bank-filtered drinking water resources of the Country. Water-quality monitoring systems and the implementation of proper land use practices are deeply investigated. → riparian strips → agricultural and urban → drinking water sources	The main objective is improved protection of drinking water resource through an integrated land-use management approach, focusing on the water quality protection and on the proper management of bank-filtered wells during flood events. Water protection is carried out through the implementation of BMPs primarily designed for reducing potential damages to water quality through sustainable agricultural practices and improved of municipal sewage treatments. Activities are focused on water quality monitoring systems in order to evaluate the effectiveness of BMPs implementation, also accounting for flood risk reduction. → agricultural and urban areas → groundwater quality damage mitigation → bank-filtered water/extraction wells protection (DWPZ and technical protection)

Table 4: Summary of activities performed in the Pilot Actions.

Activities in PA
PA1.1: Catchment area of the Vienna Water
In PROLINE-CE, Vienna Water aims to enlarge an already developed model (KAMPUS) for surface run-off, erosion and infiltration dynamics. We suppose that all addressed dynamics exert considerable pressures on the karstic groundwater resources. Vienna Water also combines this model with other outputs and results (snow model, climate model and measuring stations) from former – also partly EU-funded – projects. The validation of this model will be tested by model outputs compared to hydrological measurements at springs during strong precipitation events. The main pilot activities are situated in the area of "Zeller Staritzen and Central Hochschwab". In the field of alpine pastures (mountain grasslands) Vienna Water aims to communicate and implement Best Management Practices which support drinking water supply security. The most crucial BMPs in the field of alpine pastures were elaborated and defined as guidelines for the farmer's staff working in the mountainous areas. In the course of information transfer meetings and workshops with farmers, alpine pasture related authorities and water works staff, the thematic field of BMP on alpine pastures was opened and discussed. The information transfer activities can be regarded as crucial for the thematic field and persuasive efforts are integrated in order to ensure application of the

BMPs.

PA1.2: Catchment area of Waidhofen/Ybbs
Within the drinking water protection area (DWPA) it is necessary to convince the private and federal forest owners about the requirements of drinking water protection in relation to forestry. This is necessary as the overall purpose of drinking water protection in the field of forestry is new for the private and federal forest owners. Hence also the Best Practice Catalogue is new or unknown for them and as a result of this situation the activities focus on knowledge transfer to forest owners in the course of individual round table discussions about the requirements of drinking water protection within forested DWPA. Incentive payments (payments for ecosystem services) from the water supplier should motivate the stakeholders to apply Best Practices. The Best Practice catalogue of the project was written in short comprehensible style and translated into German language in order to be a potential tool for the stakeholders. The implementation of BMPs in PA1.2 Waidhofen/Ybbs was strategically planned through the elaboration of the "Guideline for securing the Water Protection functionality of the forest ecosystems within the DWPZ" (GWP) which defines all relevant BMPs for the watershed. As the implementation process in forest management needs time, GWP sets the foundation for a sustainable BMP application. GWP was resolved through the city council of Waidhofen/Ybbs and has now normative character. As part of the testing/demonstrating character of the PA, stakeholders will be invited to visit specific sites of the DWPA where results of already fulfilled or outstanding management activities will be showcased and discussed.
PA2.1: Well field Dravlje valley in Ljubljana, Slovenia
Inventory of possible polluters in the urban recharge area of potential well field Dravlje was made with assessment of their impact on drinking water source and elaboration of measures and best management practices for protection of drinking water source. Strong involvement of stakeholders for implementation of best management practices with several national meetings with particular stakeholder (one-to-one) and regular interactive workshops with local stakeholders. Distributed hydrological surface runoff model was established with full hydraulic propagation functions for surface waters, with evaluation of new flood measures (retention reservoir built in 2017) and climate change scenarios. Also, simulations of the groundwater pumping effects in the recharge area of planned well field Koseze were made, taking into account the impact of climate change. Several different pumping scenarios were modelled according to climate change and recharge conditions.
PA2.2: Water reservoir Kozłowa Góra, Poland
In June 2017 multiscale monitoring of the water resources was set up to investigate and assess water resources, sources of pollution and possible hazards. Based on the results mathematical models of hydrology and ecology of the Kozłowa Góra reservoir was established. Simulations run allowed to assess a.o. an impact of land use and water management to water quality and quantity and its ecology. A proposal for DWPZ was prepared and is being implemented. The proposal includes a.o. limitation in land use, wastewater management and fishery. The most important BMP is reaching the society and raise the awareness. In a situation where the guidelines, policies exist and are not enforced raising awareness among society, especially small, local ones

is crucial to implement.

PA2.3: Tisza catchment area, Hungary

Data evaluation and comparisons highlighted that current practices in livestock farming, plant production and flood mitigation are good enough to keep the raw surface water in an overall good quality. Data on chemical parameters (NO_3^-, NH_4-N, COD_{Mn}, NO_2^- and pH) measured at Szolnok *(Szolnok Waterworks)* were evaluated and showed very few momentary contamination events from the last six years. Although on most of the livestock farms open manure storages are still in use, the runoff coefficient is so small on the pilot area that the water originating from in situ precipitation is negligible. Overall low annual precipitation, high temperature and radiation contribute to the fact that contaminated rainwater rather evaporates back to the atmosphere or infiltrates into the soil. Water quality did not deteriorate considerably during the serious flooding in 2013 either.

PA2.4: Groundwater protection in karst area, Croatia

In situ measurements of physical-chemical parameters and sampling of spring, surface and rain waters, located in the area of explored karst fields and its catchment areas, will be carried out in monthly intervals. Physical-chemical and isotopic laboratory analyses of samples will enable assessing of land use impact on water quality.

Hydrological modelling of possible impacts of climate change on water resources will be carried out based on the established correlations between the precipitation and the air temperature during the historical period and their correlative discharges, for climate scenarios for the future (by 2050). Hydrological model will provide scenarios of average annual discharges and assessment of possible water shortages in terms of expected climatic conditions in the future.

In order to familiarize stakeholders, especially those in the pilot area, and locals with the results of this research, we will organize a workshop for stakeholders and inform local population through media and brochures.

PA2.5: Neufahrn bei Freising, Germany

In PROLINE-CE, a hydrological model was developed for the recharge area of the well field in Neufahrn bei Fresing. The model was set up using the One-Water Hydrologic Flow Model framework (OWHM), comprising several modules to simulate different hydrological processes in the area. The model integrates the current land use operations performed in Neufahrn, including different crops with different multi-annual crop rotations. This enables to simulate the impact of land use changes on the water quantity available for water extraction from the shallow wells in Neufahrn.

Using the present time series of nitrate from mandatory water quality analysis, we detected a general trend towards lower nitrate concentrations in the shallow aquifer. This points towards more sustainable application of fertilizers and more sound land use practices. This information will help future applications of transport models which can easily be coupled to the existing groundwater flow model.

Generally, we figured out that groundwater modelling and a more distributed monitoring of hydrochemical data with a higher temporal resolution is a timely challenge to continuously observe the relation between land use practices and groundwater properties.

During our 2nd stakeholder workshop, we informed people in Neufahrn about our activities and outcomes to

familiarize them with our identified BMPs and inform them about activities planned in the future.

PA3.1: Po River Basin

The activities carried out in PA3.1 mainly concern the drinking water protection in terms of water-quantity and flood risk mitigation.

The main gaps identified in PA3.1 account for the overexploitation of water resources, especially during drought events, and for the potential impacts of floods on drinking water resources, which are currently not fully considered in the integrated water management strategies. Furthermore, in PA3.1 strong attention is given to the evaluation of the potential impacts of climate change, which will directly and indirectly affect the drinking water supply.

In order to cope with these issues, suitable BMPs for the protection and management of drinking water have been selected and implemented. Specifically, in order to improve the flood forecast and water managing during droughts, respectively employed in FEWS and the DEWS systems, hydrological and hydraulic models have been configured and implemented at the basin scale.

Furthermore, current climate characterization and future variations in weather patterns have been evaluated by means of an integrated modelling chain that allows quantifying the impacts of climate change and land-use change, with a specific attention on their relation with freshwater ecosystem services.
Stakeholders have been the main actors in all phases of BMPs testing. They welcomed basic principles and methodologies for flood/drought operational management and for climate change simulation and projections. Meeting events highlighted that stakeholders involved in management of water shortage crisis should be not only professionals but also communities and non-experts.

PA3.2: Along Danube bend

In the Danube area, groundwater is particularly vulnerable to contamination induced by agricultural production, pollution by not adequate sewage systems or during floods. For this reason, activities proposed for PA3.2 concern the implementation of BMPs that are aimed at solving issues related to groundwater quality damage and its protection.

The issues associated to agriculture primarily affect bank-filtered water sources while poor quality water from urban areas arrive in water bodies after not adequate treatments. Furthermore, water quality is potentially affected by flood events because of river waters may reach the extraction structures and surface water can enter the wells.

In this context, selected BMPs account for the water quality monitoring, both in agricultural and in urban areas, the implementation of proper land-use practices and the construction of sewage systems and devices for wastewater treatment.

Activities are also focused on the evaluation of the BMPs effectiveness by clarifying the decrease in the groundwater chemical pollution due to the changes in agricultural activities and examining the increase in groundwater quality as consequence of the improvement of sewerage services and network connection.

In order to gain a good insight into the challenges of drinking water resources protection and in further developing of best land-use practices, stakeholders from various domains (Universities, scientific institutes, water management bodies, ministries, national parks, and NGOs concerned with environment and water protection) have been invited to participate in national meeting and workshops.

4. Climate change - general overview on the Central Europe domain

The following chapter is aimed to provide a frame about potential changes that Central Europe (CE) area could experience in weather, forcing recognized interest for water protection purposes, under the effect of Climate Changes (CC).

It should display and evaluate:

i) what are the climate conditions currently observed on Central Europe domain as returned by E-OBS gridded dataset;

ii) the potential variations that the domain could experience on short and long-time horizon under the effect of climate changes; In this regard, several weather variables are taken into account: seasonal temperature and cumulative precipitation values, consecutive dry and wet days and maximum daily precipitations;

Despite the considerable limitations associated with simplifications, they are assumed as proxy for expeditious evaluations about future changes in quantity and quality of water resources and occurrence and severity of hydrological/hydraulic hazards. In order to take into account, the high uncertainties currently associated to climate projections (increasingly larger for further future period of interest), the findings provided by an ensemble of different climate modelling chains included in EURO-CORDEX initiative are considered and characterized by very high horizontal resolution (0.11°, about 12 km over the Europe).

In the following, first, an overview about current conditions is reported using E-OBS dataset on reference period 1971-2000; after, the related climate zonation is shown recurring to widely used classification proposed by Koppen & Geiger (Koppen & Geiger, 1954; 1961). Furthermore, the main elements and approaches currently used to perform climate projections at regional scale are introduced and variations in different weather patterns are displayed on short (2021-2050) and long-time horizon (2071-2100) under two different scenarios of greenhouse gases and aerosols concentrations.

4.1. Selecting climate indicators

In recent years, several literature works provided exhaustive investigations about the expected impacts of CC on water resources and hydrological hazards at global (e.g. Hirayabashi et al., 2013), continental (e.g. Alfieri et al., 2015; Royas et al., 2012) or on areas included in CE domain (e.g. Vezzoli et al., 2015 for Po River Basin). Such studies usually adopt complex and time-consuming simulation chains in which hydrological and or hydraulic models use as inputs the data provided by climate simulations. They usually focus only on one of two topics covered by the project (drinking water protection or flood hazard) often adopting approaches and assumptions not easily managed by stakeholders and communities.

Then, in this work, an expeditious approach is preferred; it simply identifies a set of weather forcing that can be assumed as "proxies" to provide an assessment about the potential effects of Climate Changes on drinking water resources and hydrological hazard in Central Europe. They include seasonal cumulative rainfall and average temperature values respectively assumed as main drivers for water input and output (through evapotranspiration); moreover, three indices are selected among the 27 proposed by CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI) as recognized of higher interest for the topics covered by the Project; namely:

- Rx1day: yearly maximum 1-day precipitation;
- CDD (Consecutive Dry Days): Maximum length of dry spell, maximum number of consecutive days with precipitation (RR) < 1mm;
- CWD (Consecutive Wet Days): Maximum length of wet spell, maximum number of consecutive days with RR ≥ 1mm.

Such indicators are assumed related to events inducing hydrological hazards (according the geomorphological and land use features of affected areas) (Rx1d) and to precipitation pat-terns strongly affecting the effective amount of water entering the soil or recharging surface water bodies. Nevertheless, it is worth recalling that ETCCDI indicators are designed to detect "moderately extreme weather events" (Wehner, 2013) then characterized by return time periods usually less than 10 years. For much rarer (more severe) phenomena, it is necessary to recur to extreme value statistical theories. In last years, such techniques have been widely adopted to assess in steady conditions return periods of fixed Extreme Weather Events while, in recent times, numerous approaches have been proposed to account for non-stationary conditions potentially induced by climate changes.

4.2. Dataset

To provide an overview about current conditions, E-OBS dataset is used. E-OBS gridded data set (Haylock et al., 2008) contains daily maps of gridded data spanning the period from 1 January 1950 to the present, at four different grid resolutions for five weather variables (daily mean temperature TG, daily minimum temperature TN, daily maximum temperature TX, daily precipitation sum RR and daily averaged sea

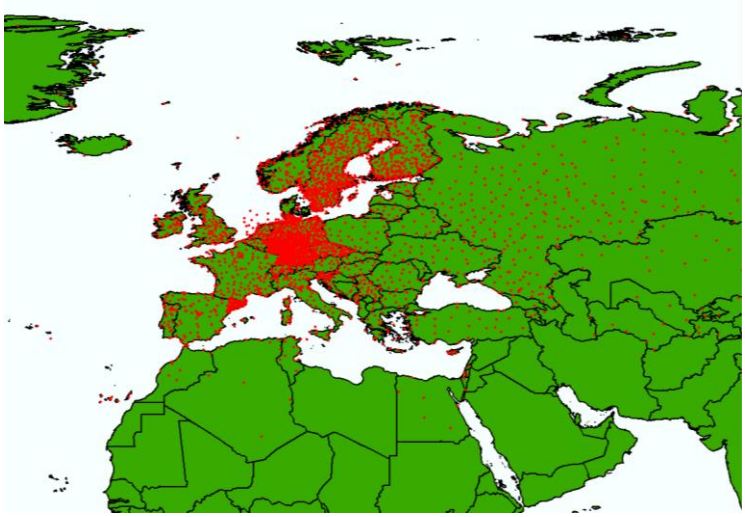


Figure 4: Distribution of weather stations providing data for E-OBS gridded dataset; focus on Europe area.

level pressure PP). It was developed within the European Union Framework 6 ENSEMBLES project (van der Linden and Mitchell, 2009) with the main goal to support validation of Regional Climate Models (RCMs) and improve understanding of climate change impacts. The data used are provided from the European Climate Assessment & Dataset (ECA&D), (Klein Tank et al., 2002; Klok and Klein Tank, 2008) with about 11,400 stations (update December 2017, Figure 4) and gradually expanding. Data are monthly updated thanks to National Meteorological and Hydrological Services (NMHSs), individual researchers affiliated with a university, global data centres like the National Climatic Data Centre (NOAA, Asheville, USA) or the synoptic messages from the Global Telecommunication System (van der Schrier et al., 2013). Specifically, in this work, version 16.0 is adopted with 0.25◦ × 0.25◦ regular longitude-latitude.

During recent years, several researches using the dataset attempted giving caveats about potential inaccuracies and constraints associated to it; for example, according van der Schrier et al. (2013) uncertainties due to urbanization, statistical interpolation, and the potential inhomogeneity drives the total uncertainty estimate. Hofstra et al. (2009) carry out an analysis about the homogeneity of the gridded data revealing that it is primarily induced by inhomogeneity in the underlying station data (e.g. break point detection); moreover, the comparison with much denser station return, on several areas, significant differences in precipitation (usually biased toward lower for E-OBS) while correlations overall are high. In this regard, Figure 4 show how the density of stations from which the gridded dataset is retrieved is highly variable across the Europe inducing larger uncertainties in areas less covered by observations (e.g. Southern Italy).

Finally, Turco et al. (2013), investigating Great Alpine Region and NW Italy, display how most E-OBS gridpoint series should to be shifted back by 1 day to have maximum overlap of the measurement period. Moreover, temporal and spatial similarities of most indices are higher adopting NWIOI (Ronchi et al., 2008; AAVV, 2011) and MAP (Frei and Schar, 1998) than between MAP or the NWIOI and EOBS.

In this work, the performed analysis considers Central Europe domain over 1971-2000 time span. The period is selected accounting for World Meteorological Organization (WMO) indications according which such length allowing properly taking into account interannual variability limiting, at the same time, the arising of statistically significant trend in weather pattern. Moreover, the same time span is used as reference for comparing climate simulations in Section 3 in D.T2.3.3.

In order to put in place effective and adequate adaptation counter measurements, the assessments about future evolutions of weather forcing and associated hydrologic variables have a crucial role. In this regard, the modelling chains usually carried out include three elements:

(1) Based on assumptions about future evolutions of economic development/growth and demographic changes at global and regional scale, Integrated Assessment Models (IAM) provide evaluations for future concentrations of greenhouse gases (GHG), aerosols, chemically active gases (greenhouse gases and aerosols) and changes in land use on next centuries. In this regard, Intergovernmental Panel on Climate Change (IPCC) has selected four reference standard pathways (commonly known as RCP Representative Concentration Pathways) allowing subsequent analysis by means of Climate models (CMs) following reference assumptions about

baselines and starting points and permitting the comparisons among climate projections. The four pathways respectively estimate an increase in radiative forcing levels of 8.5, 6, 4.5 and 2.6 W/m2, by the end of the century compared to pre-industrial era (1750). Of course, the first one is recognized as more pessimistic (but business as usual) and the last one more optimistic and feasible only assuming high mitigation counter-measurements (Figure 5).

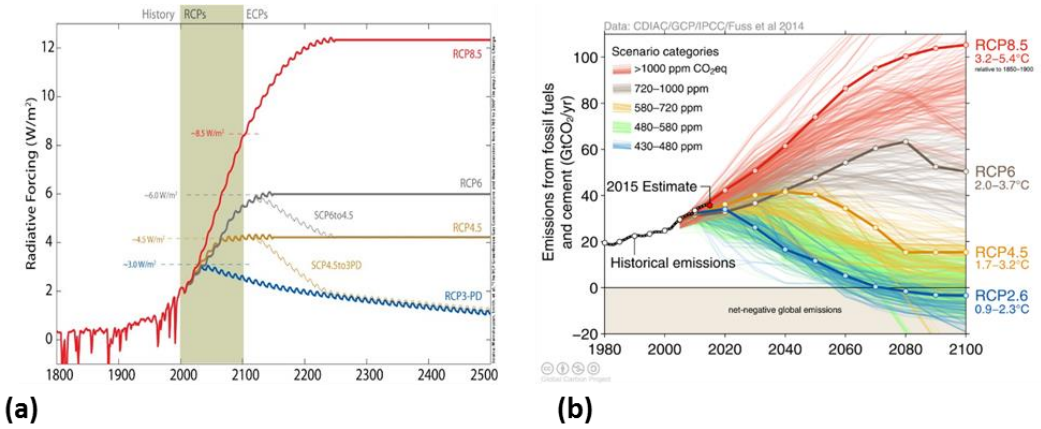


Figure 5: (a) expected trends in radiative forcing following the different RCPs (Meinshausen et al., 2011); (b) assessed increases in global temperature and emissions under the different concentration scenarios.

(2) Such assessments are used as forcing for Earth System Models (ESMs). They are numerical models aimed to assess the impacts on the climate system of variations of greenhouse gases. Nevertheless, due to their coarse horizontal resolution (at the moment, hardly exceeding 70-80km) they are able to simulate only large-scale atmospheric state (IPCC, 2014). Numerous studies (e.g. Breugem 2007; IPCC, 2014) show that they are able to reproduce the climate and the global response to the changes of GHG with higher reliability for some variables (temperature) and lower for others (precipitation). However, despite significant developments in recent years, because of the horizontal resolutions today permitted, these models are inadequate for estimates of trends and impacts at the local/regional level for which the features of the area (distance from the sea, topography) are crucial (even with respect of large-scale atmospheric circulation).

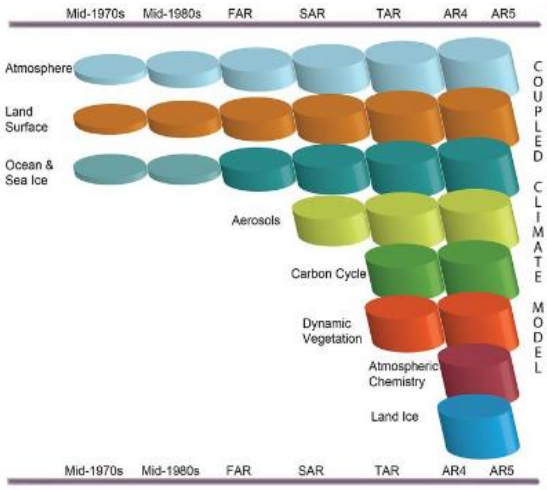


Figure 6: The evolution of Global models in terms of considered physical dynamics (from Wilby, 2017).

(3) For these reasons, several downscaling techniques were developed in last years; they largely differ for computational costs, prerequisites and limitations; they are classifiable as "statistical" and "dynamical" approaches. The first ones adopt frameworks based on empirical statistical relationships between "predictors" large-scale and “predictand” local climate variables, calibrated and validated on observed data and then applied to ESM variables. They require limited computational burden and also allow analysis at station scale but need long series of observed data for the definition of the statistical relationships. The latter ones involve the use of climate models at limited area and highest resolution (RCM Regional Climate Model) nested for the area of interest on the global model from which they draw the boundary conditions. Currently adopted resolutions, in the order of 10 km, on the one hand, allow a better resolution of the orography and, on the other one, solve a substantial fraction of the local atmospheric phenomena. Moreover, different experiments have proven their good capability in reproducing regional climate variability and changes (Feser, 2011). Even if this refinement makes it possible to accurately evaluate a remarkable fraction of weather patterns, dynamical approaches may misrepresent orography, land surface feedbacks and sub-grid processes, thus inducing biases preventing their direct use for impact analysis (Maraun, 2016; Maraun et al., 2015). To overcome this issue, different approaches, known as Bias Correction (BC) methods, have been proposed in recent years (Lafon et al., 2013; Teutschbein et al., 2012). They can be defined as statistical regression models calibrated for current periods in order to detect and correct biases, which are assumed to systematically affect the climate simulations. Although the advantages, limitations and warnings regarding their adoption are widely debated in recent literature (Ehret et al., 2012), they are currently recognized as a necessary stage in producing weather variables to use as inputs for impact-predictive tools. On the other side, in order to evaluate uncertainties associated to different realizations of climate experiments and favour the comparison among the simulations, in last years, several consortiums have promoted “ensemble” initiatives. Among these ones, in more recent years, the WCRP Coordinated Regional Downscaling Experiment (CORDEX) project (Giorgi et al. 2009) has been established; it provides a global coordination for Regional Climate Downscaling in order to improve climate change adaptation measurements and impact assessments. In this report, climate projections included in EURO-CORDEX ensemble at the highest available resolution (0.11°) are considered (Table 5).

Table 5: Available EURO-CORDEX simulations at a 0.11° resolution (~12km) over Europe (EURO-CORDEX ensemble); they are identified reporting providing institution, driving ESM model and adopted RCMs.

Code	Institution	Driving model	RCM
1	CLMcom	CNRM-CM5_r1i1p1	CCLM4-8-17_v1
2	CNRM	CNRM-CM5_r1i1p1	Aladin53
3	RMIB-Ugent	CNRM-CM5_r1i1p1	Alaro
4	SMHI	CNRM-CM5_r1i1p1	RCA4_v1
5	KNMI	EC-EARTH	RACMO22E_v1
6	DMI	EC-EARTH	HIRHAM5_v1
7	CLMcom	EC-EARTH	CCLM4-8-17_v1
8	KNMI	EC-EARTH	RACMO22E_v1

9	SMHI	EC-EARTH	RCA4_v1
10	IPSL-INERIS	IPSL-CM5A-MR_r1i1p1	WRF331F_v1
11	SMHI	IPSL-CM5A-MR_r1i1p1	RCA4_v1
12	CLMcom	HadGEM2-ES	CCLM4-8-17_v1
13	KNMI	HadGEM2-ES	RACMO22E_v1
14	SMHI	HadGEM2-ES	RCA4_v1
15	CLMcom	MPI-ESM-LR_r1i1p1	CCLM4-8-17_v1
16	MPI-CSC	MPI-ESM-LR_r1i1p1	REMO2009
17	SMHI	MPI-ESM-LR_r1i1p1	RCA4_v1
18	MPI-CSC	MPI-ESM-LR_r1i1p1	REMO2009
19	DMI	NorESM1-M	HIRHAM5

4.3. Current conditions

Figure 7a shows data concerning seasonal average temperature (in green, PASs are identified). The maps clearly highlight spatial patterns across the Region; during Winter (December-January-February, DJF) lower values are primarily observed in high altitude areas (values lower than -3°C) as Alps and Carpathian Mts while, on plain sites, the latitude tends to regulate values (higher for Mediterranean countries with values ranging between 3° and 10°C). During the Summer (June-July-August, JJA) large parts of the domain experience values crossing the 20°C while, in alpine areas values remain between 3° and 10°C. It worth stressing that reported values are main function of horizontal resolution of E-OBS datasets while locally they could result significantly different.

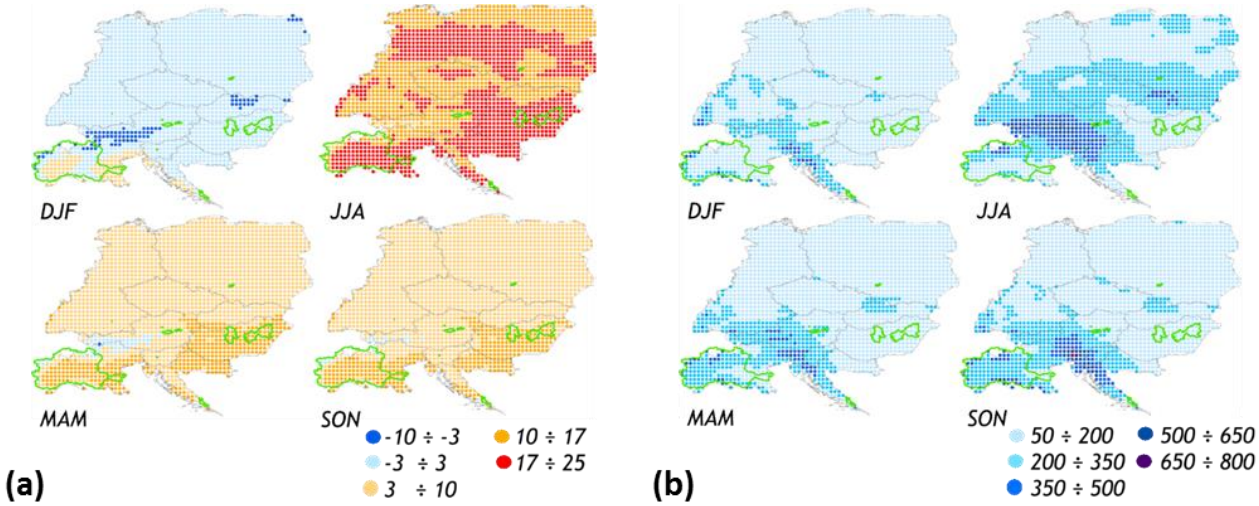


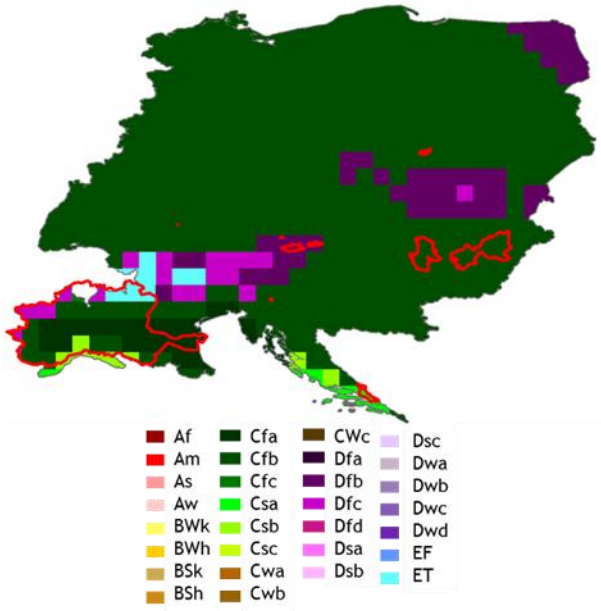
Figure 7: (a) seasonal temperature values on CE domain as reported in E-OBS gridded dataset (1971-2000 period, data reported in Celsius degrees); (b) seasonal cumulative precipitation values on CE domain as reported in E-OBS gridded dataset (1971-2000 period, data reported in millimetres/season).

During the intermediate seasons, Spring (March-April-May, MMA) and Autumn (September-October-November, SON) the Alpine Regions maintain values lower than 0°C (on wider area in MMA) while clear North-South growth gradients are detectable with northernmost areas characterized by values lower than 10°C, on average, and the Southernmost with higher values. Concerning PASs, the extension and the orography of PA3.1 entail that different thermometric regimes coexist (Alpine, Po Valley); on the other hand, the other PASs appear according E-OBS dataset characterized by a substantial homogeneity.

Figure 7b shows data concerning seasonal cumulative precipitation. Variations among the seasons appear less pronounced compared to what has been observed for temperature. During DJF, the higher values are monitored on Alpine, Apennine and High Adriatic areas (up to 600 mm/season) (PAS 3.1; 2.1) while on a large part of the domain, precipitation does not exceed 200 mm/season according E-OBS dataset; in such areas, several PASs are totally included (1.1; 1.2; 2.3; 3.2; 2.5).

During the summer, on a large part of CE, higher values are observed; in particular, in the NE part of alpine Region, seasonal precipitation may arrive at about 650 mm/season. In this case, the lower values are detected for Hungarian and Croatian PASs (3.2; 2.3; 2.4) while for Slovenian (2.1) and Austrian (1.1.1) PASs significant values are retrievable (up to 500mm/season). Again, Italian test case result characterized by large spatial variability while, for the remaining ones, seasonal values do not exceed 350mm/season.

For intermediate seasons, similar patterns arise with higher values observed, for SON, in NE part of Great Alpine Region and Liguria Apennines (up to 800mm/season). In this perspective, it is interesting to note how Hungarian test cases result characterized by moderate values during all the seasons.



1st	2nd	3rd	Description	Criteria*
A			Tropical	$T_{cold} \geq 18$
	f		- Rainforest	$P_{dry} \geq 60$
	m		- Monsoon	Not (Af) & $P_{dry} \geq 100-MAP/25$
	w		- Savannah	Not (Af) & $P_{dry} < 100-MAP/25$
B			Arid	$MAP < 10 \times P_{threshold}$
	W		- Desert	$MAP < 5 \times P_{threshold}$
	S		- Steppe	$MAP \geq 5 \times P_{threshold}$
		h	- Hot	$MAT \geq 18$
		k	- Cold	$MAT < 18$
C			Temperate	$T_{hot} > 10$ & $0 < T_{cold} < 18$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Cs) or (Cw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a or b) & $1 \leq T_{mon10} < 4$
D			Cold	$T_{hot} > 10$ & $T_{cold} \leq 0$
	s		- Dry Summer	$P_{sdry} < 40$ & $P_{sdry} < P_{wwet}/3$
	w		- Dry Winter	$P_{wdry} < P_{swet}/10$
	f		- Without dry season	Not (Ds) or (Dw)
		a	- Hot Summer	$T_{hot} \geq 22$
		b	- Warm Summer	Not (a) & $T_{mon10} \geq 4$
		c	- Cold Summer	Not (a, b or d)
		d	- Very Cold Winter	Not (a or b) & $T_{cold} < -38$
E			Polar	$T_{hot} < 10$
	T		- Tundra	$T_{hot} > 0$
	F		- Frost	$T_{hot} \leq 0$

Figure 8: Koppen-Geiger classification according Rubel & Kottek (2010); in legend, all the classes proposed by K-G are reported. PASs reported in red.

Legend: MAP = mean annual precipitation, MAT = mean annual temperature, Thot = temperature of the hottest month, Tcold = temperature of the coldest month, Tmon10 = number of months where the temperature is above 10, Pdry = precipitation of the driest month, Psdry = precipitation of the driest month in summer, Pwdry = precipitation of the driest month in winter, Pswet = precipitation of the wettest month in summer, Pwwet = precipitation of the wettest month in winter, Pthreshold = varies according to the following rules (if 70% of MAP occurs in winter then Pthreshold = 2 x MAT, if 70% of MAP occurs in summer then Pthreshold = 2 x MAT + 28, otherwise Pthreshold = 2 x MAT + 14). Summer (winter) is defined as the warmer (cooler) six month period of ONDJFM and AMJJAS.

In order to provide a synthetic characterization of climate features retrievable in the CE domain, the widely adopted climate classification proposed by Koppen (1900) and updated by Geiger (1961) is displayed (it is commonly known as Koppen-Geiger, K-G, classification). K-G is primarily based on five vegetation groups identified by the French botanist De Candolle: the equatorial zone (A), the arid zone (B), the warm temperate zone (C), the snow zone (D) and the polar zone (E). Furthermore, a second letter in the classification considers the precipitation (e.g. Dfc for snow and fully humid), a third letter the air temperature (e.g. Dfc for snow, fully humid with cool summer) (Kottek et al., 2006); in this perspective, the transition values among the classes are primarily determined through an expert judgment approach. Therefore, although more rigorous approaches have been argued and proposed in last years (Sanderson, 1999; Strahler, 1971; Peel et al., 2004), K-G continues to be broadly adopted in different application fields (Rubel & Kottek, 2011).

In this context, K-G classification proposed by Rubel & Kottek (2010) is adopted; they provided world maps for the observational period 1901-2002 adopting Climatic Research Unit (CRU) dataset of the University of East Anglia for the temperature (Mitchell and Jones, 2005) and the Global Precipitation Climatology Centre (GPCC) provided by the German Weather Service for the precipitation (Fuchs, 2008). Both are available on a regular 0.5-degree grid and monthly temporal resolution. Furthermore, the Rubel & Kottek (2010) analysis provides assessments about future shifts in classification (2003-2100), under the effect of climate changes, recurring to climate projections included in Tyndall Centre for Climate Change Research dataset, TYN SC 2.03 (Mitchell et al., 2004) including 20 global simulations under different emission scenarios. The results are provided for time spans 25 years long; for consistency with what previously reported, the findings for 1976-2000 are displayed in Figure 8 (in red, are reported PAS). Specifically, on CE domain, Rubel & Kottek (2010) identify seven classes:

- Cfb: temperate oceanic climate; in it, Hungarian (2.3; 3.2), Polish (2.2), Slovenian (2.1) and German (2.5) PASs fall,
- Dfb: warm-summer humid continental climate; in it, Austrian PASs fall (1.1; 1.2),
- Cfa: humid subtropical climate,
- Csb: warm-summer Mediterranean climate; in it, Croatian PASs fall (2.4),
- Csa: hot-summer Mediterranean climate,
- Dfc: subarctic climate,
- ET: Tundra.

In this sense, the large variability characterizing Italian PAS is confirmed; indeed, in it, five classes are included (ET, Dfc, Csb, Cfb, Cfa).

Figure 9 displays the spatial distribution of the three indicators above introduced (CDD, CWD, Rx1D) for CE domain (reference period 1971-2000). The first two should provide a characterization of the precipitation distribution (in terms of interarrival time and event length) while the third one is assumed as rough proxy for the occurrence of hydrological hazards.

Concerning CDD, the higher values are observed in the Southern part of CE domain (PAS 3.1 and 2.4) and Hungary (PAS 2.3 and 3.2) where they can reach

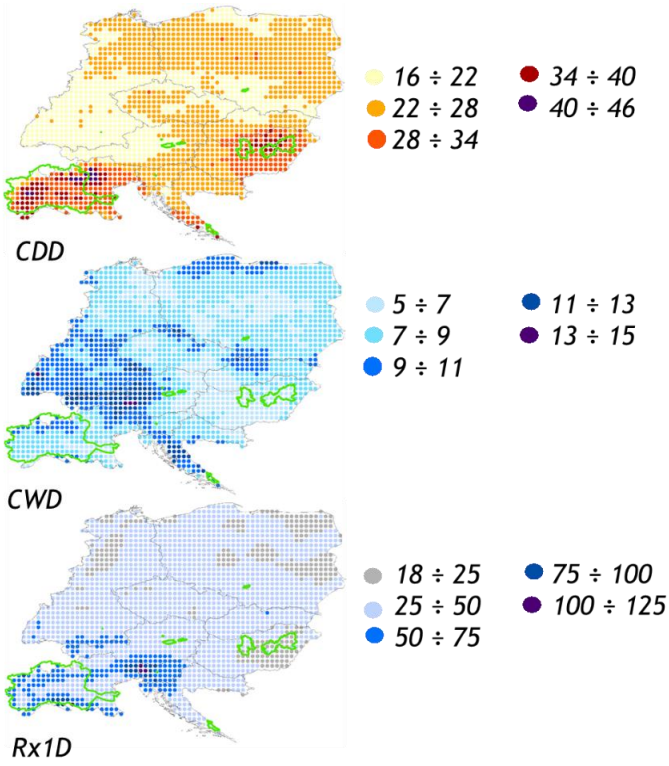


Figure 9: CDD (days, upper part), CWD (days, in the middle) and Rx1D (millimetres, in the bottom) values on CE domain as computed through E-OBS gridded dataset (1971-2000 period).

40-46 days with the resulting higher probability of water shortage issues. On the other hand, the areas in which Austrian, German and Polish PASs are included, result less affected with values hardly exceeding 20 days. Furthermore, the larger CWD values are registered in high elevation areas (e.g. NE part of Alpine region) where they may arrive at 15 days; on the other side, on plain areas, they are usually limited to 5-7 days.

Finally, considering Rx1d, the lowest values (not exceeding 25 mm/day) are registered in some areas of the northern part of CE domain and Hungary (PAS 3.2 and 2.3 partly lie in such areas). On the main part of the domain, the values do not go beyond 50 mm/day while the higher values are retrievable in high altitude areas of Alps, Apennines and South Bavaria. In the specific, the peak values are observed again in east part of Alpine Region where they reach 100-125 mm.

4.4. Future conditions

In the following, variations on short time horizon (2021-2050 vs 1971-2000) and long-time horizon (2071-2100 vs 1971-2000) are displayed under two RCPs, RCP4.5 and RCP8.5. Currently, to this aim, nineteen simulations are available (details reported in Table 5). The same weather forcing considered in Section 2 are analysed; for each one (for the two time spans and two RCPs), the variations are displayed in terms of 25th, 50th (median value) and 75th distribution percentiles according the scheme reported in Table 6.

Table 6: Layout displaying the arrangement of the variation maps concerning climate projections.

2021-2050 vs 1971-2000	*a) RCP4.5 25th percentile*	*g) RCP8.5 25th percentile*
	b) RCP4.5 50th percentile	*h) RCP8.5 50th percentile*
	c) RCP4.5 75th percentile	*i) RCP8.5 75th percentile*
2071-2100 vs 1971-2000	*d) RCP4.5 25th percentile*	*j) RCP8.5 25th percentile*
	e) RCP4.5 50th percentile	*k) RCP8.5 50th percentile*
	f) RCP4.5 75th percentile	*l) RCP8.5 75th percentile*

Variations in DJF temperature

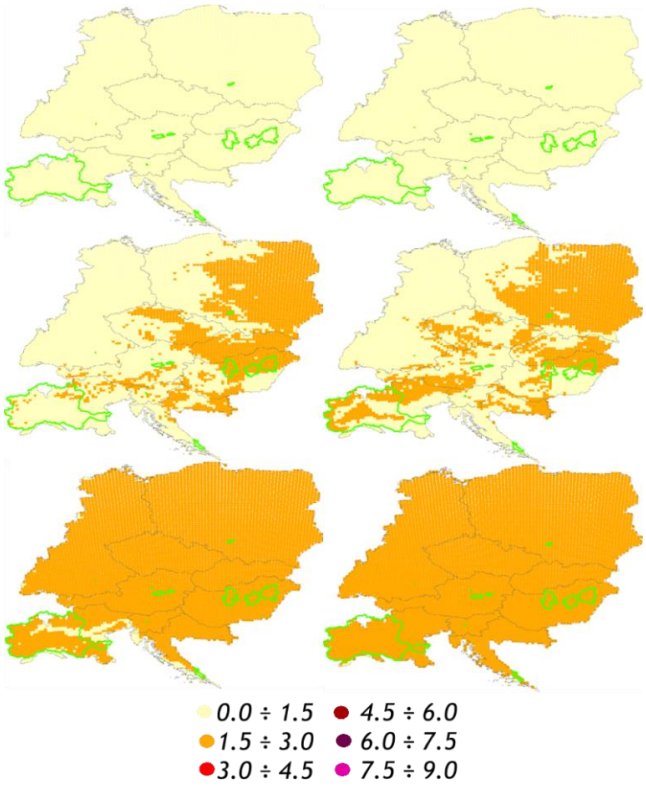


Figure 10: 2021-2050 vs 1971-2000. An increase in temperature is expected, for all seasons, under the two RCPs and the two-time horizons. For DJF, the increase returned as median value, is lower than 1.5°C on the western part of the domain while on the eastern part it could arrive at about 3°C. However, for 25th and 75th percentiles, increases appear quite homogeneous (up to 1.5°C and 3°C, respectively). Such findings show how, already on short term, snow precipitation and accumulation dynamics could be highly altered by expected warming. In this perspective, higher changes could occur in areas where, currently, average values are about 0°C.

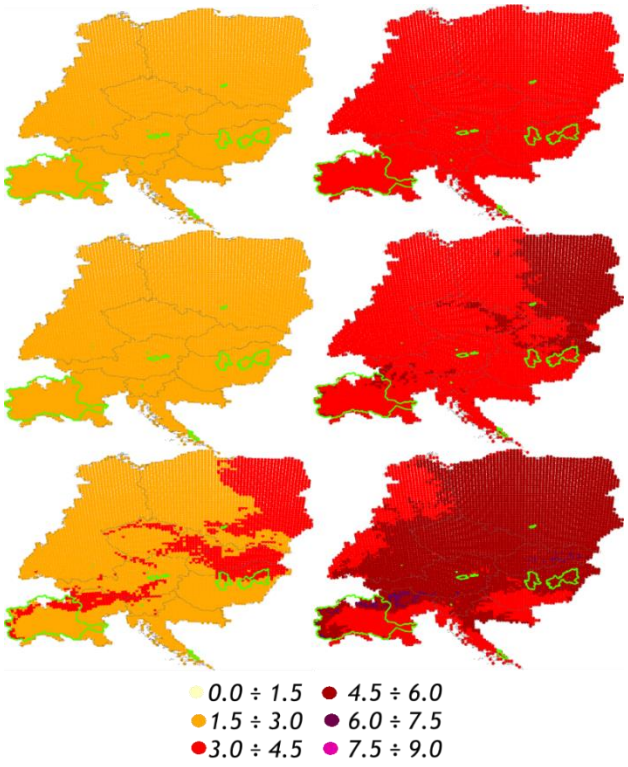


Figure 11: 2071-2100 vs 1971-2000. Two elements clearly arise by the findings on long time horizon; first, on average, much higher increases values are expected; furthermore, the severity of RCP strongly regulates the magnitude of variations. As median value, the increase does not exceed the 3°C under RCP4.5 while it could be about 4.5°C under RCP8.5 (larger values are detected in Eastern portion of the CE domain, up to 5-6°C). It is interesting noting how the variations returned by 25th-75th percentiles result quite close to values retrieved by the median one (higher increase expected on Alps with values, in Eastern part, ranging from 6 to 7.5°C). Under such results, snow dynamics could be totally upset by such increases.

Variations in JJA temperature

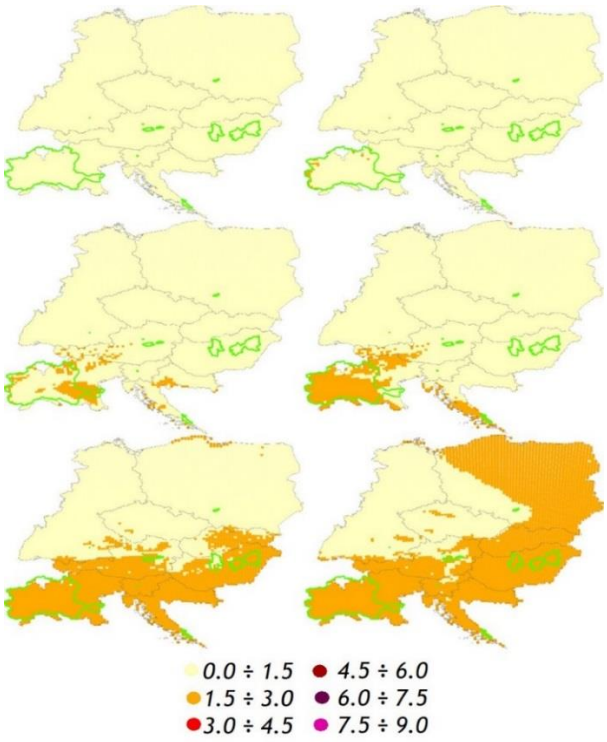


Figure 12: 2021-2050 vs 1971-2000. For JJA, on short time horizon, similar increase values are expected using EURO-CORDEX ensembles. However, significant variations characterize the spatial patterns: in general, higher values are constantly retrieved for the Southern part of the domain (Italy and Balkan countries); the two RCPs give similar findings also if the areas where the increases could exceed 1.5°C result quite larger under RCP8.5 (e.g., for 75th percentile, also the Eastern part of CE domain is expected to experience increases up to 3°C). Such variations in temperature could lead to substantial increase in atmospheric evapotranspiration demand driven also by higher humidity deficits.

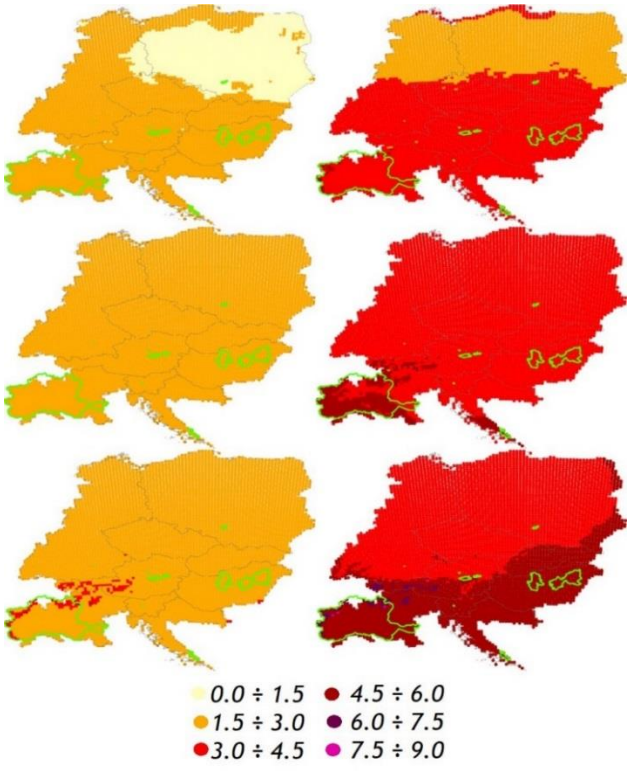


Figure 13: 2071-2100 vs 1971-2000. The two elements before stressed for DJF temperature are confirmed: the increases result main function of time horizon and RCP severity. Under RCP4.5 (RCP8.5), the increases are up to 3°C (6°C) with slight variations among the percentiles (with clear North-South increase gradient). Moreover, on the Alpine area, often larger values are returned with isolated peaks exceeding 8°C under RCP8.5; it could induce dramatic consequences also in current permafrost areas; concerning evapotranspiration, the increase in potential demand could significantly increase. Nevertheless, the actual evaporation should primarily account for the availability of soil water driven by rainfall cumulative values.

Variations in MAM temperature

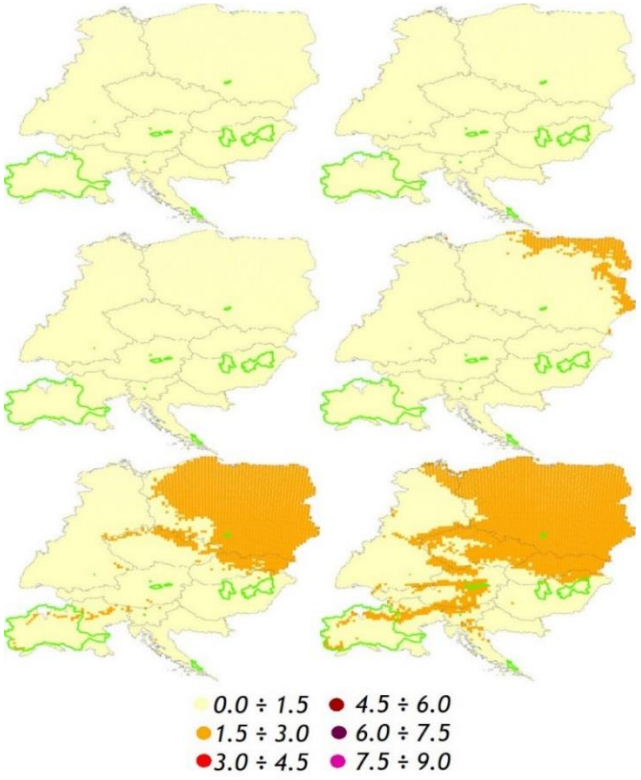


Figure 14: 2021-2050 vs 1971-2000. During MAM, on short-term horizon, the expected increases should not exceed, as median value, 1.5°C (in North-East part of the domain, under RCP8.5, higher increases are assessed). On the other hand, according 75th percentile, the part interested by larger increases result quite larger. Such increases could affect as snow persistency dynamics inducing significant variations in seasonal river discharge as, obviously, it could entail higher potential evaporation values.

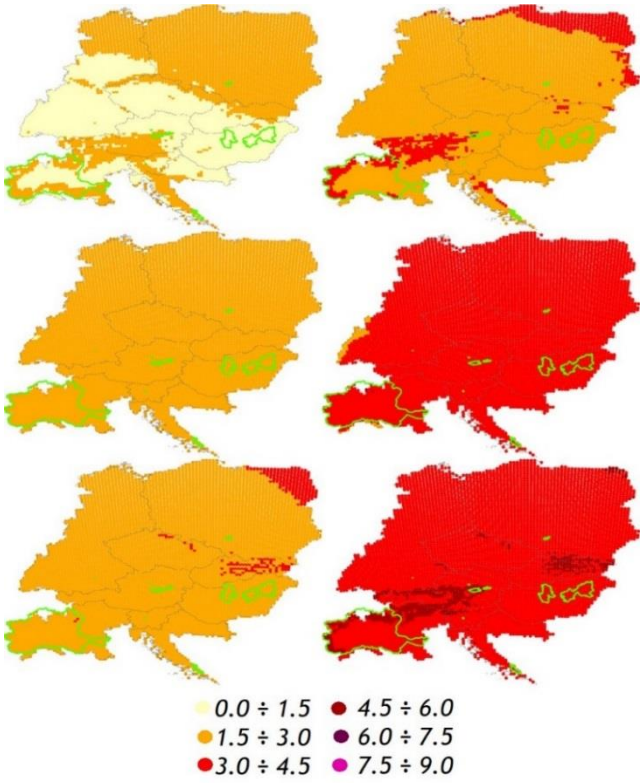


Figure 15: 2071-2100 vs 1971-2000. The increases expected on long term appear quite homogeneous over the domain (in special way, for 50th and 75th percentile). In general, the growth does not exceed 3°C under RCP4.5 and 4.5°C under RCP8.5; in this case, Alpine Region and some areas in Hungary could experience larger variations. As stressed before, the variations between RCPs result limited on short term and then the required adaptation measurements to face with such changes could be substantially equivalent while they could highly differ for long time targets in terms of interested areas, magnitude of variations and then required measures and costs.

Variations in SON temperature

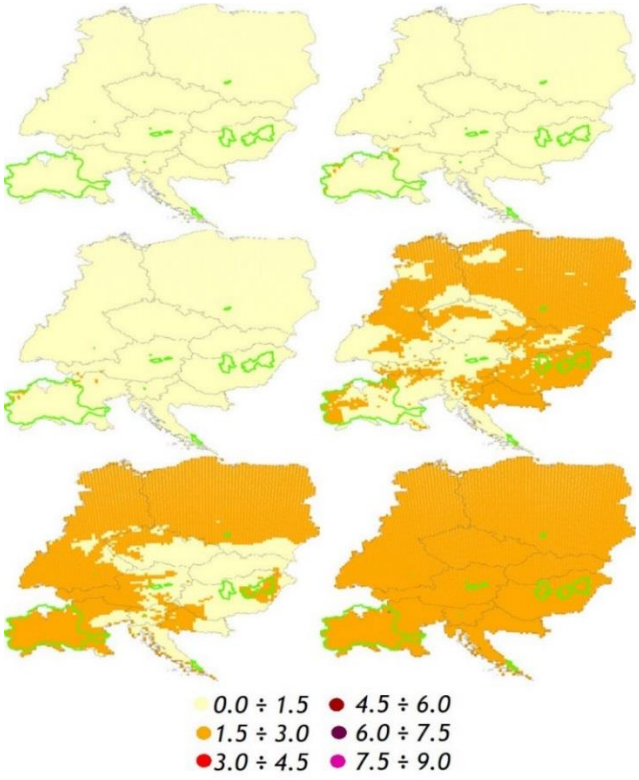


Figure 16: 2021-2050 vs 1971-2000.On short term, for SON, the median increases do not exceed 1.5°C under RCP4.5 while large values are expected under RCP8.5 (N-E domain, western Italy, Germany). The increases could maintain high the atmospheric demand after Summer season and delay the beginning of snow covering in high altitude areas. In general, the increases in air temperature are expected entailing substantial variations also in terms of rainfall patterns (see Figure 22-30, 32-33, D.T2.3.3). Indeed, it leads to increase in atmospheric moisture retention requiring the accumulation of higher water contents to trigger precipitation events (Clapeyron equation).

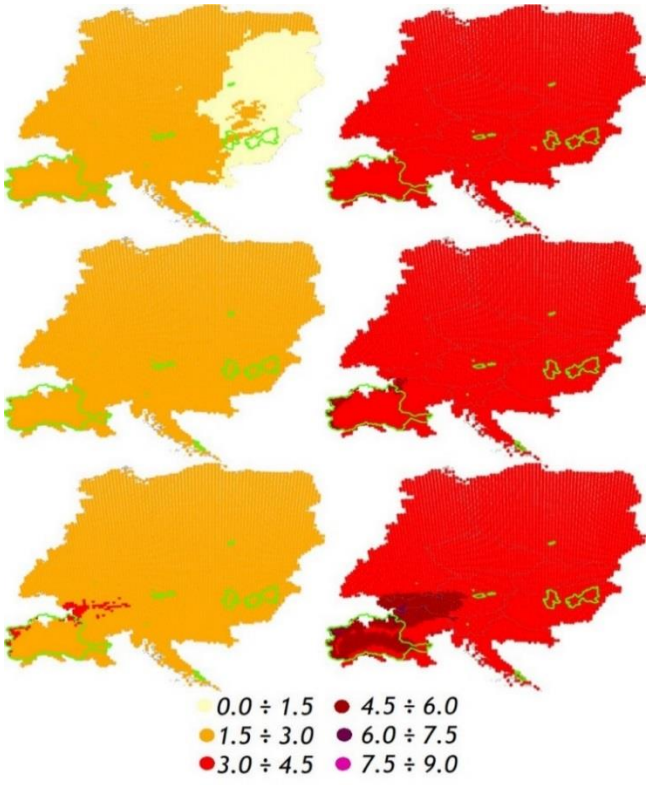


Figure 17: 2071-2100 vs 1971-2000. On farthest time horizon, the climate simulations forced by RCP4.5 reveal increases not exceeding 3°C while, under RCP8.5, it could arrive up to 4.5°C. It is interesting to note how, primarily for 75th percentile, the areas potentially affected by larger increases could correspond to Alpine Region (and Po Valley under RCP8.5). Such evaluations should be carefully taken into account by decision makers and water operators that, in last years, suffered the consequences of severe droughts led by increases in temperatures (during the entire year) and abrupt reductions in seasonal cumulative values.

Variations in DJF precipitation

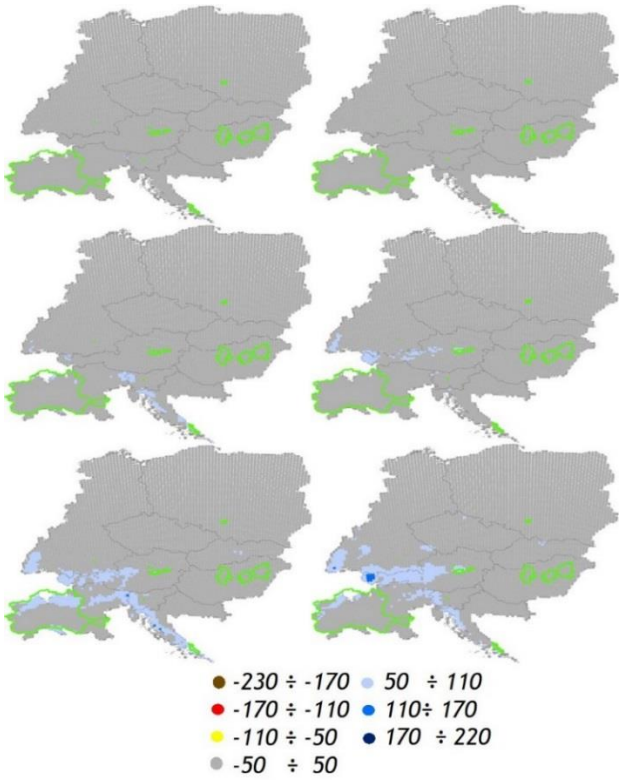


Figure 18: 2021-2050 vs 1971-2000.Concerning seasonal cumulative precipitation, in general, the tendencies revealed by climate simulations appear much less clear; the signals are contrasting for the different seasons and investigated areas. Moreover, findings displaying slight or no variations often result by "algebraic sum" of very different outputs provided by climate projections. For DJF, on short term, the variations appear quite limited. Only considering 75th percentile, on the Alpine arc, are estimated increases of about 50-100 mm/season; on the other side, no substantial decrease is estimated on the entire domain.

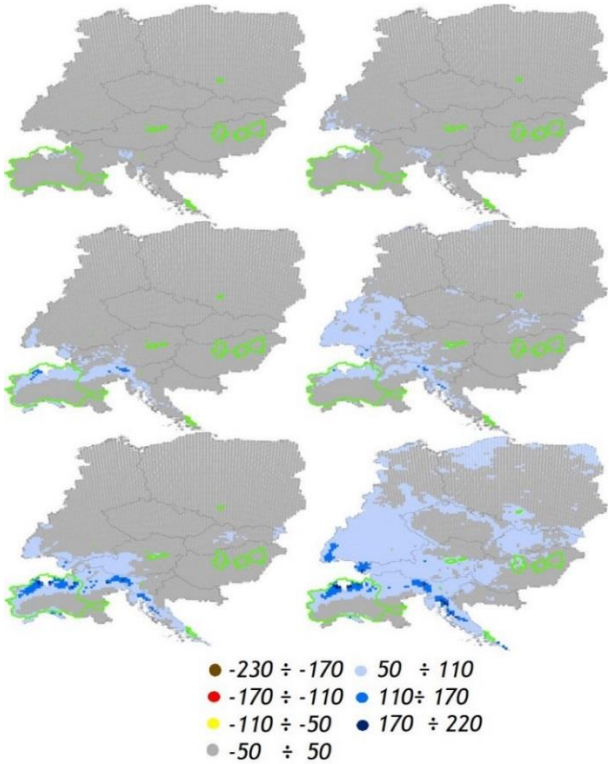


Figure 19: 2071-2100 vs 1971-2000. Concerning long time horizon, the climate simulations tend returning similar findings in terms of magnitude (higher increase on alpine region up to 220 mm/season) but not in extent of areas interested by increases: they are much larger under RCP8.5 (interesting primarily Germany, Austria and Balkan countries). On the other hand, Northeast part of the domain could result less interested by variations.

Variations in JJA precipitation

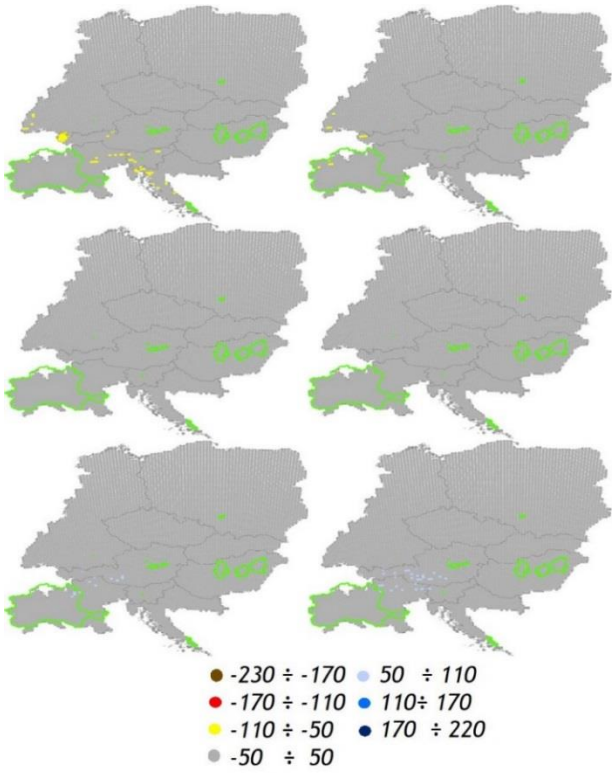


Figure 20: 2021-2050 vs 1971-2000. Concerning JJA, very slight variations could interest CE domain on short term horizon; then, the larger atmospheric demand driven by temperature increase (Figure 16) could entail a substantial reduction of soil water content with several consequences on different fields. For example, it could be necessary adopting more frequently irrigation practices (in special way, in south part of the domain where they are already widely utilized). On the other hand, in view of proper adaptation strategies, the selection of crops less water-demanding could be taken into consideration.

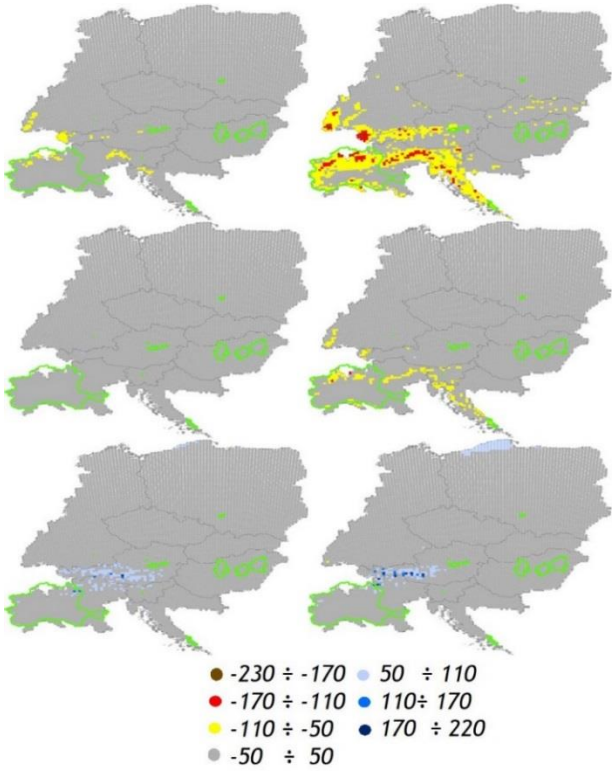


Figure 21: 2071-2100 vs 1971-2000. On long time horizon, the largest part of the domain appears slightly interested by variations in cumulative precipitations; however, contrasting findings characterize mainly the Alpine Region and Balkan countries under RCP8.5. They could experience substantial reductions according 25th and 50th percentile assessments while, on the other hand, mainly on Austrian Alps, moderate increases are assessed according 75th percentile. It confirms the great differences in output that currently could characterize climate projections.

Variations in MAM precipitation

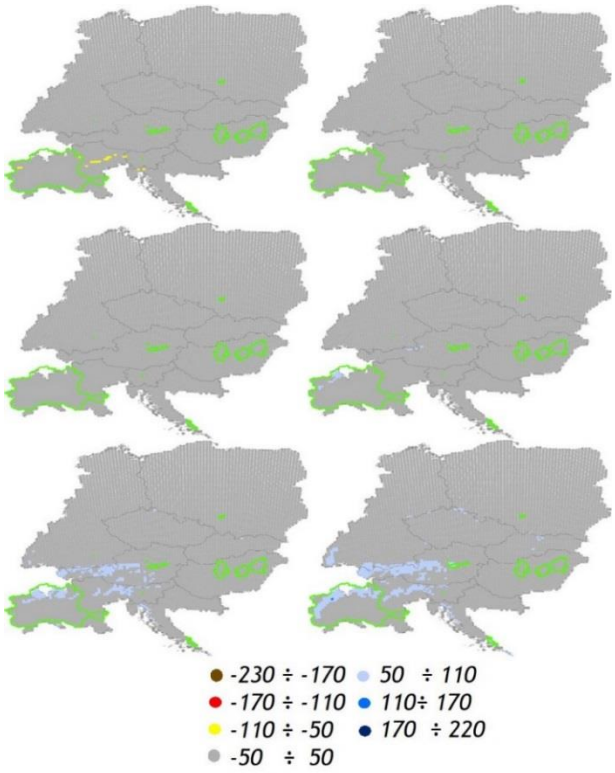


Figure 22: 2021-2050 vs 1971-2000. About MAM, on short term, moderate variations are returned only by 75th percentile assessments primarily on Alpine region and neighbouring areas. However, under both scenarios, the increases do not exceed 110 mm/season.

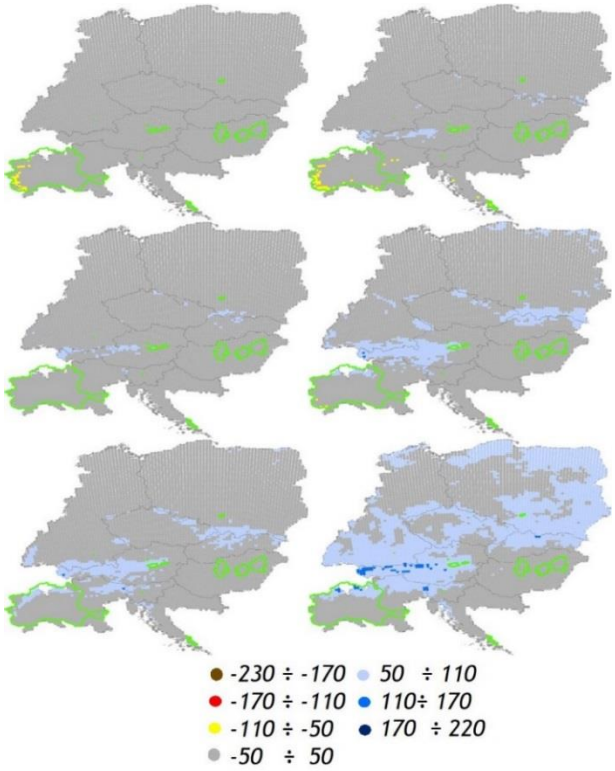


Figure 23: 2071-2100 vs 1971-2000. For MAM, on long time horizon, the larger part of the domain should be not affected by significant variations. In high altitude areas, however, variations up to 110 mm/season are evaluated as median values while they could interest larger parts according 75th percentile with peaks up to 170 mm/season. Again, in general terms, increasing signals are expected for the area.

Variations in SON precipitation

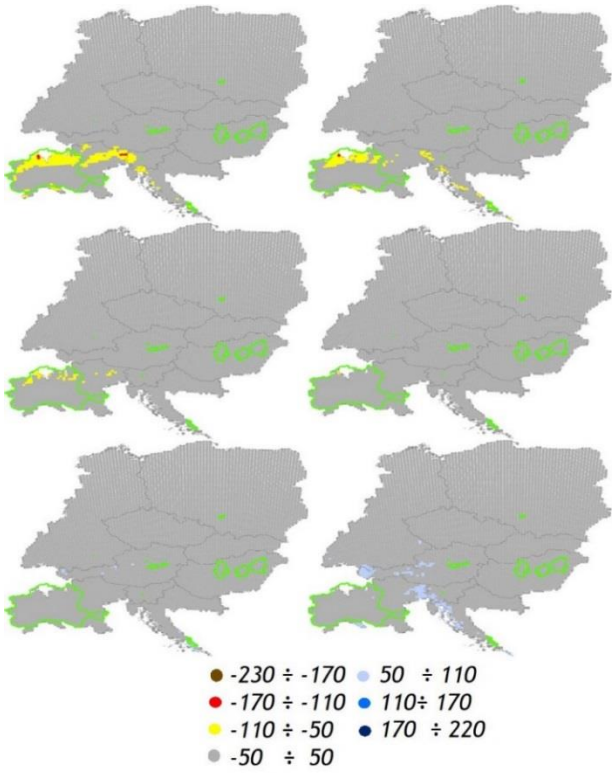


Figure 24: 2021-2050 vs 1971-2000. Concerning short term, for SON, contrasting findings already highlighted over the other seasons (in special way, Summer in Figure 24-25) are detectable. According 25th percentile evaluation, Alpine and Apennine regions could be interested by reductions, on average, about equal to 110 mm/season. The median values return very slight variations over all the domain under the two RCPs. Finally, very limited increases are retrieved considering RCP8.5 scenario in terms of 75th percentile.

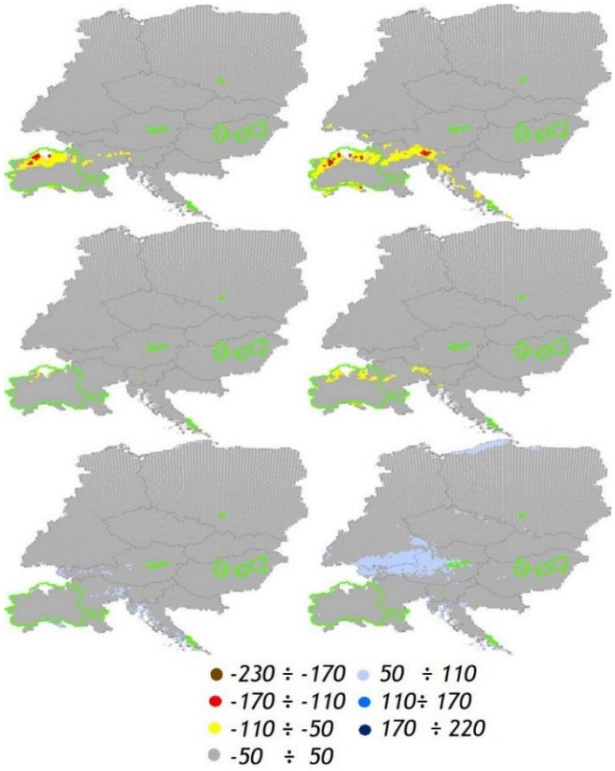


Figure 25: 2071-2100 vs 1971-2000. On long time horizon, the pattern before detected on short term more clearly arise: for 25th percentile, the reductions are expected affecting Alpine, Apennine and Balkan areas with reductions up to 170 mm/season. The median value returns very limited variations over all the domain while slight increases are assessed on borders among Germany, Austria and Italy and in extreme northern part of the domain (under RCP8.5 for 75th percentile).

Variations in CDD

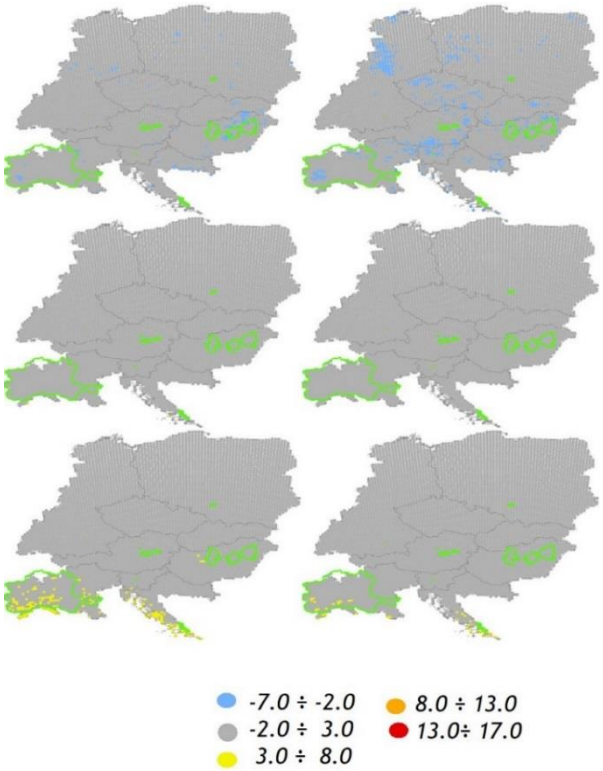


Figure 26: 2021-2050 vs 1971-2000. Concerning variations in CDD (Consecutive Dry Days), on short term, the median value returns limited variations over the entire domain. For 25th percentile, the areas interested by reductions result quite sparse over the CE domain (mainly under RCP8.5) while the increases returned by 75th percentile assessments are located in the Southern part of the domain (Italy and Balkan areas) with increases ranging, on average, between 3 and 8 days. In these areas, such result appears quite interesting considering the drought events recently affecting them and that could be exacerbated already on short time horizon according 75th percentile.

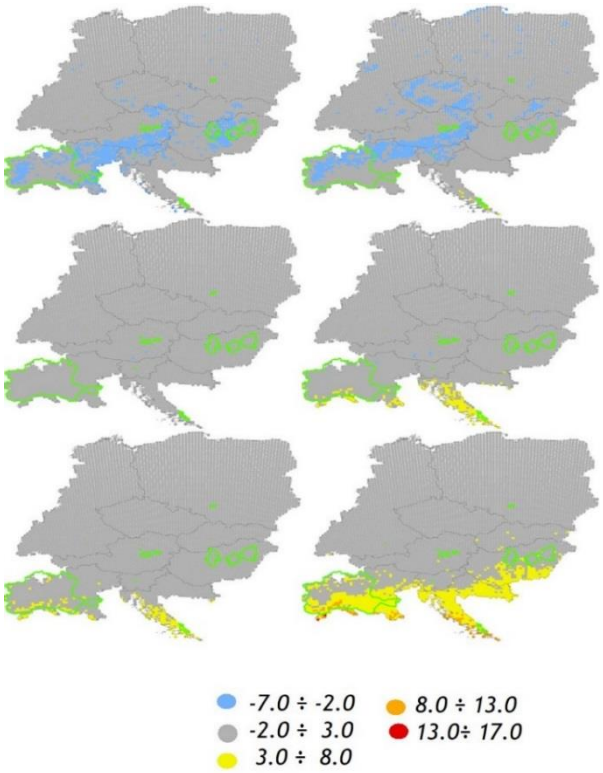


Figure 27: 2071-2100 vs 1971-2000. The spatial patterns already highlighted on short time horizon result substantially confirmed also on long time horizon; however, for 25th percentile, the areas interested by reductions result localized mainly on Alpine Region and Central part of the domain. For the median values, increases should interest only the areas located in the southern part of domain. Finally, larger areas are expected experiencing increases according 75th percentile with peaks also attaining 13 days.

Variations in CWD

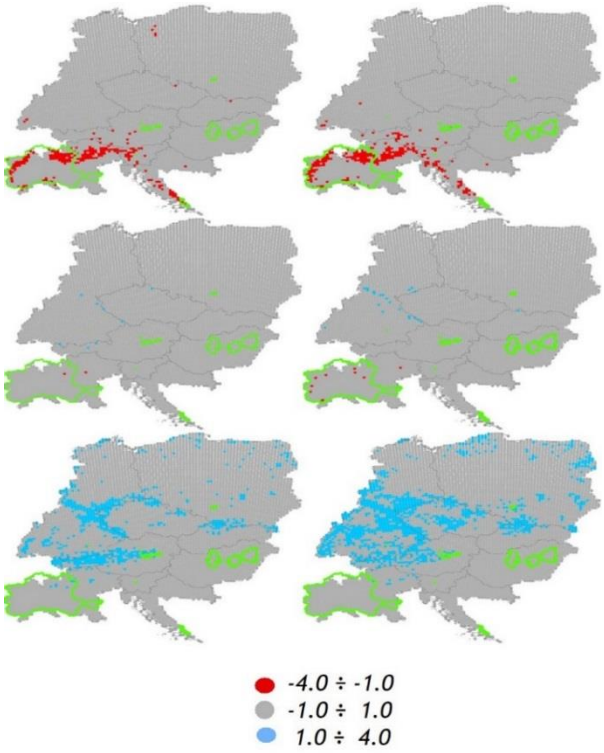


Figure 28: 2021-2050 vs 1971-2000. For what concern CWD (Consecutive Wet Days), the first element to stress is that expected variations stand in a range quite more limited than those considered for CDD (-4<CWD<4 vs -7<CDD<17). However, also for this indicator, not clear indications are retrievable: for 25th percentile, the reductions could primarily affect Alpine and Balkan regions. In terms of median value, significant variations appear very limited while, for 75th percentile, higher increases are assessed in special way in Northwestern part of the domain and high-altitude areas.

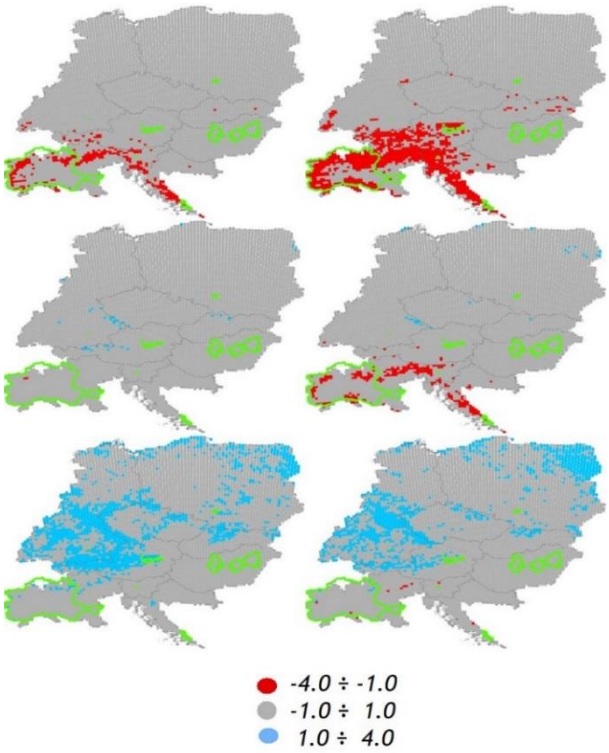


Figure 29: 2071-2100 vs 1971-2000. On long time horizon, similar patterns are retrieved. For 25th percentile, the areas potentially affected by reductions result quite larger than those expected on short time horizon. For median value, under RCP8.5, reductions are assessed over Italy and Balkan countries while increases are returned by 75th percentile over a large part of the domain.

Variations in RX1D

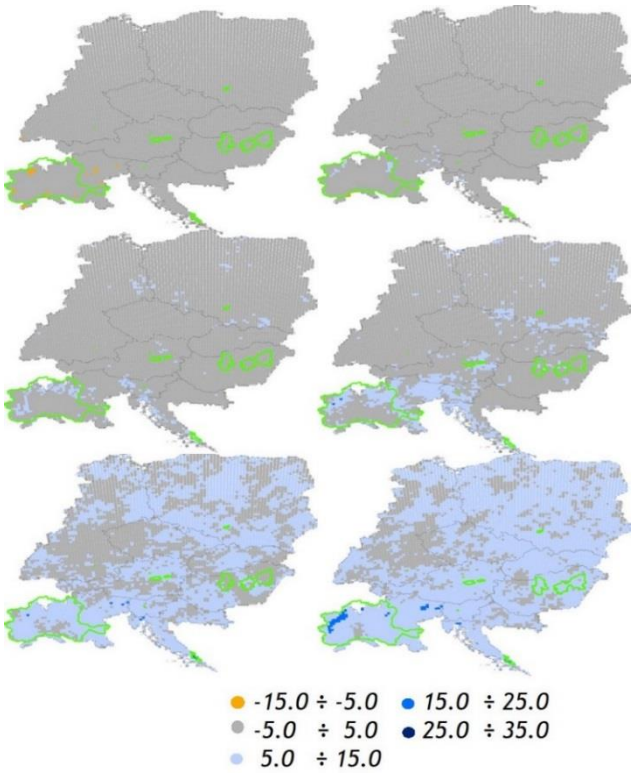


Figure 30: 2021-2050 vs 1971-2000. Concerning Rx1D, climate simulations provide clear increasing signals; on short time horizon, according median value, they primarily interest the southern part of the domain and high-altitude areas with values not exceeding 15 mm/day. For 75th percentile, the increases result quite generalized with limited part of the Alps that could experience growths up to 25 mm/day. It is worth recalling that Rx1D has been selected only as proxy for triggering of hydrological hazards. Their actual occurrence is strictly linked to geomorphological conditions of basins (extent, orography, land use/cover).

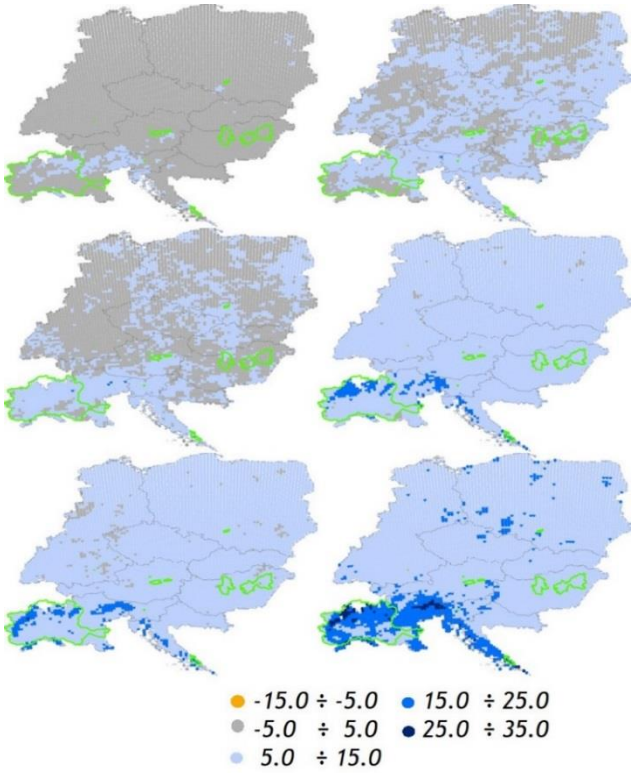


Figure 31: 2071-2100 vs 1971-2000. On long time horizon, the increasing before highlighted patterns result highly exacerbated over all the domain; in particular, over the Alps, generally the increase returned by median values assessments exceed 15 mm/day while, for 75th percentile, under RCP8.5, large part of Italian and Balkan territories could be interested by increases of about 15-25 mm/day with peaks attaining 25-35 mm/day on high altitude areas.

4.5. Application of climate change data in Pilot Actions

Climate change data were applied in Pilot Actions (PAs). In some PAs biased corrected EOROCORDEX climate data were applied, whereas in some PAs climate change data from previous projects were applied (see Table 7). More about national climate data is written in the D.T2.3.3 PA reports about climate change issues in pilots.

Table 7: Climate change data applied in Pilot Actions.

Pilot Action	Climate change data	Application of climate data
PAC1.1 Catchment area of Vienna WS	CC-WaterS data	CC –WaterS climate change impact assessment study for PA1.1
PAC1.2 Catchment area of WS of Waidhofen/Ybbs	CC-WaterS data	CC –WaterS climate change impact assessment study for PA1.2
PAC2.1 Well field Dravlje valley in Ljubljana	EURO-CORDEX climate scenarios, bias-corrected by the Slovenian Environment Agency	- hydrological hydraulic model of Glinscica river - hydrogeological model of Dravlje aquifer
PAC2.2 Water reservoir Kozlowa gora	EURO-CORDEX climate scenarios, bias-corrected by Institute of Environmental Protection in Poland	Coupled hydrological-ecological model of Kozłowa Góra reservoir and its catchment
PAC2.3 Tisza catchment area	- CC predictions made by Eötvös Loránd University in the framework of CECILIA project - EURO-CORDEX climate scenarios	Evaluate the possible impact of CC on land use management, flood mitigation and drinking water protection
PAC2.4 Karst areas (South Dalmatia	Data from DHMZ (Croatian Meteorological and Hydrological Service),	Climate change modelling (changes in temperature, precipitation and specific

	climate models (Aladin, Promes, RegCM3) by external expert - hydrologist	discharge) for Imotsko polje and part of South Dalmatia (catchments of Prud, Klokun and Mandina mlinica springs)
PAC2.5 Neufahrn bei Freising	EUROCORDEX climate scenarios provided by CMCC	Time series analysis and hydrological model implementation
PAC3.1 Po river basin	Single climate simulation chain (CSC): CMCC-CM as GCM at about 80km, COSMO-CLM as RCM at 8km under RCP4.5 and RCP8.5 concentration scenarios	Data provided by climate projections are used as input for: • physically based models assessing water quantity and quality in Taro River Basin (tributary of Po River) • hydrological, water balance, numerical and stochastic models, drought indicators and indices assessing water quantity, drought and flood risk as also drought and flood characterization in Po River Basin
PAC3.2 Along Danube Bend	- CC predictions made by Eötvös Loránd University in the framework of CECILIA project - EURO-CORDEX climate scenarios	Evaluate the possible impact of CC on flood mitigation and drinking water protection

5. Best management practices for drinking water protection and mitigating floods

PROLINE-CE pilot actions reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes. In Pilot Actions demonstration of effectiveness of measures were performed, including ecosystem services and economic efficiency. The relevant Best Management practices (BMPs) selected for particular pilot action represent the management actions which were considered to solve the problems given through the existing GAPs. Their identification is the result of desk reviews, expert judgments and a deep stakeholder involvement.

BMPs selected within each Pilot Action were categorized in previous T1 and T2 reports according to Pilot Action Clusters (PAC1, PAC2 and PAC3). Each BMP was elaborated in detail addressing the following issues:

- Identified GAP provoking action,
- GAP short name,
- GAP short description,
- Best Management Practice / Management Action,
- Name of BMP,
- Type of land use regarded,
- Location,
- BMP description,
- Advantages of this BMP in PA,
- Challenges of this BMP in PA,
- Relevance,
- Limitations,
- Implementation of the BMP in PA,
- Comments,
- References / sources.

All these extensive descriptions of each GAP and corresponding BMP can be found in Annex 1 (BMPs for PAC1), Annex 2 (BMPs for PAC2) and Annex 3 (BMPs for PAC3) at the end of this report.

In this report however we classified GAPs/BMPs according to what kind of land use type/category each problem is related to: agricultural areas, urban areas, forest and alpine

pasture (Table 8). All GAPs/BMPs related to water management (general, drinking water and flood management) are actually related to all land uses. BMPs were classified in the same way as in the T1 BMP catalogue into following categories:

1) general water management (all land uses),
2) drinking water management (all land uses),
3) flood management (all land uses),
4) agricultural areas,
5) urban areas,
6) forest and
7) alpine pasture.

Table 8: Overview table of identified GAPs and related BMPs in Pilot Actions classified according to land use.

CATEGORY	GAP	BMP	COUNTRY	PAC
GENERAL WATER MANAGEMENT (all land uses)	No complex evaluation of water hazards	Complex catchment modelling and assessment of hazard	PL	2
	Small number of sampling locations and sampling campaigns (water monitoring)	Establishment of constant, multi-aspects water monitoring in the catchment scale	PL	2
	Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)	Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off – spring dynamic modelling)	AT	1
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	PL	2
	Pressures on water resources management	The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)	IT	3
	Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources	Joined and integrated management of drinking water resources (horizontal and vertical co-operation)	SI	2
	Lack of public engagement in development of action plans	Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach	DE	2

	Low level of ecological awareness of society	Raising awareness and increasing knowledge	PL	2
DRINKING WATER MANAGEMENT (all land uses)	Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)	Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)	HR	2
			IT	3
	Drinking water protection zones (DWPZs) do not exist	Determination (e.g. hydrogeological modelling) and establishment of DWPZs	SI	2
			PL	2
			HR	2
	Lack and not effective control over implementation restrictions for existing DWPZ	Strict implementation and inspection of DWPZ restrictions	SI	2
FLOOD MANAGEMENT (all land uses)	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	SI	2
	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	SI	2
	Water balance status and effective mitigation measures are not known (identified)	Water balance status will be determined with Hydrological / Hydraulical modelling	SI	2
	Increased contamination of surface drinking water resources during flood events	Reduction of flood effects at the surface drinking water resources	HU	2
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	HR	2
	Flood impact not fully implemented and considered	The Flood Forecast Centre and Flood Early Warning System (FEWS)	IT	3
	Improper flood protection of bank-filtered wells during high water and flood events	Ensure the drinking water supply during high water or flood	HU	3
	River banks vegetation is not maintained	Reducing river banks vegetation	SI	2
	Legalization of illegal construction on flood areas	To prevent legalization of construction on flood areas	SI	2
AGRICULTURAL AREAS	Improper manure storage	Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change	HU	2
	Agricultural surface water and groundwater pollution (e.g. improper or excessive use of pesticides and manure on plant production fields)	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	HU	2

	Inflexible time ban of fertilizers and manure application	Redefinition of time ban of fertilizers and manure application	SI	2
	Increased water demand	Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture	HR	2
	Continuous conversion of (permanent) grasslands	Continuous monitoring in both, surface water and groundwater	DE	2
URBAN AREAS	Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded	Natural wastewater treatment system	HR	2
	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (e.g. transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	SI	2
	Waste disposal which do not meet technical and environmental standards and illegal waste disposal	Educative brochure and awareness raising activities	HR	2
		Encourage and promote innovative solutions of sustainable waste management		
	Lack of sewage system and wastewater treatment	Appropriate collection and treatment of municipal waste water	HU	3
	Unarranged road rainwater discharge	Collection and treatment of road rainwater discharge, particularly within drinking water protection areas	SI	2
	No limitation of road runoff water salinity	Define limitation of salinity of road water run-off	SI	2
FOREST	Continued application of the clear-cut technique	Avoidance of the clear-cut technique	AT	1
	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages	Forest Ecologically Sustainable Wild Ungulate Densities	AT	1
	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests	SI	2
	Extensive construction of forest roads	Limitation of forest roads	AT	1
	Creation of conifer plantations, even within deciduous forest communities	Tree Species Diversity According to the Natural Forest Community	AT	1

	Cutting of old, huge and vital tree individuals	Foster old, huge and vital tree individuals	AT	1
ALPINE PASTURE	Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out of faeces	Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings	AT	1
	Grazing of cattle in or close to dolines and sinkholes	Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features	AT	1
	Unwanted cattle grazing (cattle density and grazing patterns)	Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)	AT	1

6. Action plan for achieving best functional patterns of land use

The main goal of the work package T2 activities is to set up an Action plan for adaptation of existing land use and flood/drought management practices for the purpose of drinking water protection. This Action Plan presents a road map towards integrated and sustainable drinking water protection.

In the first step the most relevant BMPs for particular PA from the work package T1 were selected (Figure 32). In PAs status of best management practices implementation was assessed and in case of lacks identified, possibilities of improvement (solutions and recommendations; Ch. 6.1) and implementation (Ch. 6.2) were assessed. Various activities were performed for the implementation of BMPs (Step 2 in Figure 32) and to find out stakeholder's opinion about selected BMPs (Step 3 in Figure 32; Ch. 6.3). In representative PAs, considering the different ecosystem services, implementation strategies of BMPs which are important for water protection were elaborated.

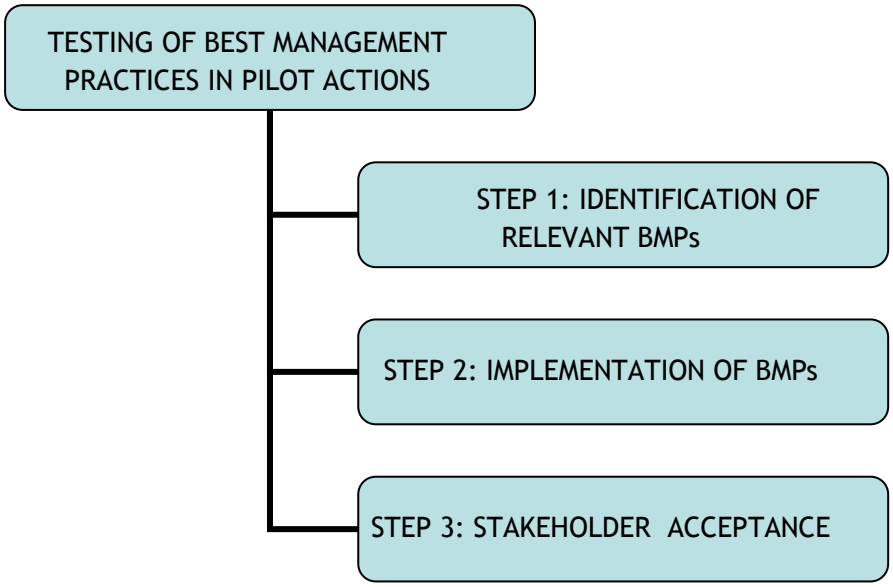


Figure 32: Testing of Best Management Practices (BMPs) in Pilot Actions.

6.1. Solutions and recommendations

In this chapter is summarized an analysis of examined/tested best management practices and related suitable solutions and recommendations for adaptation of existing land use and flood/drought management practices enabling drinking water protection. These solutions and recommendations thus may require:

- adaptation of existing land use management practices with the purpose of drinking water protection,
- adaptation of existing flood/drought management practices with relation to drinking water protection,
- adaptation of policy guidelines

Solutions and recommendations for adapting the existing best management practices are given in Table 9a, which is a combined table from all three PAC tables from the PAC reports (D.T2.2.3 and D.T2.3.4), which summarize all the GAPs/BMPs that were identified in PAs.

Remaining issues to be solved are listed in Table 9b.

Table 9a: Solutions and recommendations for adaptation of best management practices, which were selected as relevant BMPs for Pilot Actions (STEP 1: Identification of BMPs).

Category	Actual management practice (GAP)	Proposed BMP	Proposed recommendations and solutions			Country
			Adaptation of existing land use management practices towards the purpose of drinking water protection	Adaptation of existing flood/drought management practices with regard to drinking water protection	Adaptation of policy guidelines	
GENERAL WATER MANAGEMENT	No complex evaluation of water hazards	Complex catchment modelling and assessment of hazard	It is highly recommended that within preparation of local land use management plan procedure results of the catchment modelling should be taken into account.	It is highly recommended to use results of the catchment modelling simulation in flood/drought management.	Recommendation to include catchment modelling as a one of the tools using to improve water management.	PL
	Small number of sampling locations and sampling campaigns (water monitoring)	Establishment of constant, multi-aspects water monitoring in the catchment scale	/	Investment in monitoring system contains constant monitoring system.	Need of conducting proper, multi-aspect monitoring of water system should be emphasized in guidelines at local, regional and also national level.	PL
	Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)	Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off – spring dynamic modelling)	Using hydrological modelling to continuously evaluate the changes of spring discharge due to extending of quarry areas in the pilot area helps to support future decision-making. Through applying a rainfall/run-off model based on observed and defined processes as well as measured and mapped parameters the surface run-off and infiltration will be determined.	Using hydrological modelling to continuously evaluate the changes of spring discharge due to extending of quarry areas in the pilot area helps to support future decision-making. Through applying a rainfall/run-off model based on observed and defined processes as well as measured and mapped parameters the surface run-off and infiltration will be determined – relevant also for flood/drought protection.	/	AT
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	It is highly recommended that within preparation of local land use management plan procedure results of the ecological modelling, integrated with catchment models, should be taken into account.	It is highly recommended to use results of the ecological modelling simulation in flood/drought management.	Recommendation to include the ecological modelling, integrated with catchment models, as a one of the tools using to improve water management.	PL
	Pressures on water resources management	The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)	Improvement of knowledge on links between land use and water resources through: - Periodical updating of the assessment of land use (e.g. agricultural practices) impact on drinking water; - Increasing of number, spatial/temporal detail and type of data about land use and environment representation.	Increase the use and sharing of drought early warning system among stakeholders. Creation within the DEWS system of drought /water scarcity indicators and indices easier to understand for stakeholders. Investment in monitoring, simulation, and analysis. Increase weather, ice/snow cover and ground water information. Operational platforms maintenance, education, and training. Consider site-specific drought impacts on drinking water. Fix water shortage/drought thresholds.	Improvement of potential synergies among stakeholders on water demand and land use. Give more decisional power to the Permanent Observatory on water uses. Support to the implementation of the Water Management Plan.	IT
	Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources	Joined and integrated management of drinking water resources (horizontal and vertical co-operation)	Ministries, experts and public independently approach to common problematics, such as drinking water resources protection, instead of combining their knowledge and experiences to find unified and optimal solutions. Therefore, more communication and cooperation is needed horizontally (inside ministries, among ministries, among experts, etc.) and vertically	/	/	SI

			(panel discussions/round tables with experts and governmental bodies). More interactions (discussions, negotiations, finding solutions for sectors on which drinking water protection measures affect (trying to find win-win situations)) are needed for achieving the main goal – drinking water protection.			
	Lack of public engagement in development of action plans	Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach	No adaptation of existing land use management practices required.	The availability of a hydrological model can provide relevant information for the stakeholders in terms of water quantity and quality and support decision makers in the implementation of existing flood/drought management practices. The use of the proposed BMP has to be intended in a broader framework which can serve as decision support system for managers.	The value of an available hydrological model is not adequately reported in the current guidelines. This tool is of fundamental importance to find efficient site-specific solutions, to test the implementations of solutions proposed by the various relevant stakeholders and to communicate the decision-making process.	DE
	Low level of ecological awareness of society	Raising awareness and increasing knowledge	Participants are getting familiar with current land use management practises and proposal for BMP.	Participants are getting familiar with current flood / drought management practises and proposal for BMP.	/	PL
DRINKING WATER MANAGEMENT	Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)	Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)	Aim of measures is to mitigate negative effects of CC, therefore to prevent negative land use change and spreading of concrete surfaces. Instead, green retention and infiltration zones must be designated.	Flood management practices should include further construction of retention objects in flood prone areas. Agricultural production must adapt to upcoming CC scenarios and prolonged droughts by rationalizing water consumption and making it more effective.	CC Adaptation Strategy 2040-2070 and Action Plan 2019-2023 provide good guidelines for adaptation and resilience for CC. Local authorities should incorporate it in local plans and strategies.	HR
			The proposed solution is to carry out detailed studies about the potential impacts of climate changes and partly related land use change. The main goal is to provide probabilistic evaluations of impacts on drinking water resources accounting for multiple constraints. Furthermore, it could increase the awareness of all the stakeholders about the topic.	Investment in data collection, monitoring, model simulation and analysis, operational platform maintenance education and training. Promote synergic approaches between Disaster Risk Reduction and Climate Change Adaptation communities by considering the cross-dependence between droughts and floods periods. The assessments could support systemic evaluations about the management of extreme events (flood and droughts) achieving solutions effective also for preserving drinking water resources. Moreover, the approaches are straightly exploitable also for other test cases.	Test the implementation of proposed solution by relevant stakeholder's communication in the decision-making process. Improving the decision-making process increasing the awareness of all the stakeholders about the future challenges for effectively preserving drinking water resources.	IT
	Drinking water protection zones (DWPZs) do not exist	Determination (e.g. hydrogeological modelling) and establishment of DWPZs	DWPZ areas were determined with modelling and will be proposed to include in the Spatial plan of the Municipality of Ljubljana. In current Spatial plan there is only reserved are for planned Water field without surrounding protected areas with restrictions. The restrictions should already be applied, such as: construction of buildings is prohibited, no waste disposal, no storages of dangerous substances, prohibition of use of pesticides and fertilizers, salting undrained surfaces like yards and gravel roads, etc.	Glinščica stream is already regulated practically in its entire length. The riverbed is made from concrete and there are concrete panels on some parts of the bank. The planned water field is not endangered with flooding but the surrounding area is.	Adaptation of Spatial plan of the Municipality of Ljubljana with DWPZ determination and adoption of Decree on the water protection area for this aquifer.	SI
			Limitations and prohibitions are included within the proposal.	Limitations and prohibitions are included within the proposal.	Proposal considers current Water Law and policy guidelines;	PL

			If sanitary protection zones are proclaimed, land use management practices must definitely change. This is mostly related to agricultural practices, construction, spatial planning and waste management.	Adaptation is not necessary, Ordinance is already prescribed but implementation and inspection are lacking.	Policy guidelines are well developed concerning DWPZ, but implementation is lacking, inspections are inadequate, and penalties are rarely given.	HR
	Lack and not effective control over implementation restrictions for existing DWPZ	Strict implementation and inspection of DWPZ restrictions	It is prohibited to carry out activities in the catchment area that could endanger the ground water quality, such as: the disposal of waste, the storage of dangerous substances, the use of pesticides and fertilizers, salting undrained surfaces like yards and gravel roads, vehicle maintenance and parking of construction machinery, except in the case of activities for the public supply of drinking water. Hence well directed restrictions for DWPZ area there is no inspection and no control over its implementation.	In case of floods in the area of DWPZ surface waters and groundwater could cause pollution by transportation of pollutants.	Implementation should be supervised by inspectors of the Ministry of Agriculture, Forestry and Food.	SI
FLOOD MANAGEMENT	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	Some of the potential pollution sources are known (especially industrial establishments under Seveso Directive), but there is among others no registry of some other pollution sources (i.e. heating oil tanks in households), which are still quite common in Slovenia. Also, storage of large quantities of hazardous materials on flood prone zones is not regulated.	Some non-SEVESO and non – IED facilities are handling nevertheless significant amounts of polluting substances on flood prone areas. This includes also households storing small amount of chemicals, and especially heating oil tanks, that might leak during the flood event.	Potential pollution sources are exceeding current requirements of national legislation (Slovenia: Environmental protection act O.G. 39/2006) and EU requirements SEVESO Directive, IED Directive 2010, E-PRTR Register. Proposed amendment to existing Decree on conditions and limitations for constructions and activities on flood risk areas 89/08 – activities of storage activity on flood prone zones.	SI
	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	Wells heads should be constructed as sealed in a way to prevent the surface water intrusion in the well during the flood event.	Many water supply wells are on flood-prone plains, so the wells heads should be constructed as sealed.	Amendment to the data specification relative to standards of construction on flood prone zones (proposed amendment to existing Decree on conditions and limitations for constructions and activities on flood risk areas 89/08).	SI
	Water balance status and effective mitigation measures are not known (identified)	Water balance status will be determined with Hydrological / Hydraulical modelling	/	A Hydrologic model is a simplification of a real-world system (e.g., surface water, groundwater) that aids in understanding, predicting, and managing water resources. Hydrological/hydraulical models are developed to analyse, understand, and explore solutions for sustainable water management, in order to support decision makers and operational water managers. Hydrological models also allow us to do scenario analysis.	Flood risk map as an adaptation of evaluation of parcels included in Municipal spatial planning.	SI
	Increased contamination of surface drinking water resources during flood events	Reduction of flood effects at the surface drinking water resources	Change of agricultural practices in riparian areas.	Current flood management practices are good, but preparation for extreme flood events caused by CC seems to be necessary.	Guidelines for agricultural practices in riparian areas.	HU
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	Non-structural flood mitigation measures include prevention of land use change, establishment of protective forests and promotion of cultures resistant to floods (e.g. grapevines).	Proposed measures could enhance flood mitigation and management action.	Prevention of land use change should be included in designated sensitive areas (e.g. prevention of agricultural land spread on the account of Prološko Blato wetland areas).	HR
	Flood impact not fully implemented and considered	The Flood Forecast Centre and Flood Early Warning System	Strengthening role and requirements of flood management system in relation to the operational	Improvement of the monitoring and modelling system, also considering interactions with exposed elements	Integration in policy guidelines of predictability, uncertainty and communication improvement	IT

		(FEWS)	needs in all phases of disaster management (forecast, preparation, and response). Increase synergies among land use planning/management and emergency planning/management. Periodical updating of vulnerability and exposure evaluation.	and operational procedures. Investment in flood analysis, operational platform maintenance, education, and training. Consider flood, drought and water management as a unique operational process. Make flood information more understandable to citizens. Consider event related flood impact on drinking water.	concerning extreme events and related losses, including those for drinking water supply systems. Support to the implementation of the Flood Risk Management Plan.	
	Improper flood protection of bank-filtered wells during high water and flood events	Ensure the drinking water supply during high water or flood	/	Management practices could be applied for better protection of the wells during floods.	/	HU
	River banks vegetation is not maintained	Reducing river banks vegetation	Spreading of invasive plants cannot be limited. The most problematic plants are Ambrosia and Japanese Knotweed (Fallopia japonica). Ambrosia is declared to remove with a Decree while Japanese Knotweed is only advised to remove, both in the periods until blooming (August/September) to reduce the spreading. Ambrosia is prescribed to spray with applications to slower the spreading but only with cutting, it is still not sufficiently removed. Some of the stakeholders will try to remove Ambrosia with steam devices which is a new technic and more sufficient. Japanese knotweed is removed by cutting but the only adequate way to permanently remove the plant is to dig it out with its roots.	River banks vegetation prevents accessibility of rivers / streams and with it cleaning the stream bed. Fluidity of the streams is reduced with the residues after the logging, which presents a great issue in time of high water and floods.	Similar Decree as on Ambrosia (Ambrosia Decree on measures to suppress harmful plants of genus Ambrosia (Official Gazette No. 63/10)) should be accepted also on Japanesee Knotweed. The fees for not cutting river bank vegetation should increase.	SI
	Legalization of illegal construction on flood areas	To prevent legalization of construction on flood areas	Parcels evaluation of flood risk should not be taken only as a recommendation but for a regulation, never the less it is a mandatory requirement for buildings permit. Therefore, construction on such areas is illegal and should be penalized.	Illegal construction on areas evaluated with flood risk should not be legalized and should bear the consequences of floods or financial consequences of flood protection constructions.	Improvement of ineffective control or higher penalties from state authority on illegal construction (legislation implementation problem).	SI
AGRICULTURAL AREAS	Improper manure storage	Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change	Closed manure storage facilities, managing and collecting rainwater (better drainage systems on livestock farms).	Collecting rainwater could be advantageous in drought periods.	Guidelines for farmers about manure storage.	HU
	Agricultural surface water and groundwater pollution (e.g. improper or excessive use of pesticides and manure on plant production fields)	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	Existing practices can generally be adapted to employ better methods (e.g. ploughing parallel to the watercourse, usage of green products).	/	The availability of subsidies acts as a main driver for the implementation of such practices. Guidelines can be adapted to not only prohibit certain practices in sensitive areas but also to better encourage sound practices beyond the required minimum.	HU
	Inflexible time ban of fertilizers and manure application	Redefinition of time ban of fertilizers and manure application	Since vegetation activity depends on current weather conditions, the period of restrictions should be redefined according to the weather condition instead of	Inappropriate fertilization management affecting groundwater and surface waters could cause pollution by transportation of pollutants during floods.	The Slovenian Environment Agency yearly produces the agronomic prediction according to the weather forecast but is more as a recommendation and not as an	SI

			calendar date. If vegetation is not active, the N-compounds pass through soil directly into the groundwater.		obligation with determined exact date of fertilizing period.	
	Increased water demand	Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture	If BMP is implemented, more efficient use of water in agriculture could be achieved. On the basis of new findings, agricultural stress on groundwater could be quantified and if necessary, land use change could be prevented.	Groundwater monitoring network will reduce uncertainty and could enable better responses and management action in case of floods and droughts.	Relevant for water market: if necessary, revisions of payments, schemes and quotas.	HR
	Continuous conversion of (permanent) grasslands	Continuous monitoring in both, surface water and groundwater	/	Invest in infrastructure to increase the monitoring network in the pilot action, e.g. installation of river gauging stations, identification of piezometers usable to monitor groundwater level, installation of multi parametric probes that measures continuously relevant hydrogeochemical parameters (water level, water temperature, electrical conductivity, pH, Nitrate, dissolved oxygen).	The value of monitoring should be more emphasized in the policy guidelines and water suppliers as well as water authorities should receive incentives to better manage available data and to collect more frequently and with a better spatial resolution relevant hydrogeochemical data.	DE
	Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded	Natural wastewater treatment system	If measures are to be applied, land use and spatial planning documents and practices must be modified.	Natural WWTS must be flood-proof to avoid spreading of pollutants and degradation of water quality.	Plans for the extension of sewage and purification network must shift towards green and innovative methods.	HR
URBAN AREAS	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (e.g. transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	Development of small retention measures, with water retention for different users. Potential users: watering of green infrastructure, climate impact on the city level, water for biodiversity, water for animals in the city. Improved fire protection for more resilient city.	Development of small retention measures, with water retention for different users. Potential users: watering of green infrastructure, climate impact on the city level, water for biodiversity, water for animals in the city. Improved fire protection for more resilient city.	Existing policy and regulation measures do not address necessity for gradual multi-use improvements of existing drainage systems. Strategic development of new policy framework addressing complex climate change adaptation process is necessary.	SI
	Waste disposal which do not meet technical and environmental standards and illegal waste disposal	Educative brochure and awareness raising activities	Brochure aims to point out problematics related to landfills in karstic areas, which often do not meet minimum technical requirements. Brochure raises awareness on interaction of pollutants, groundwater and fast infiltration in karst terrains as well as remediation of improper landfills and adequate techniques of waste disposal in such vulnerable environment.	Landfill behaviour and associated emissions during flood events are not properly studied and evaluated. Worst case scenario includes heavy leaching of pollutants and potential erosion. Landfills must be floodproof and other hazards must be evaluated as well.	Policy guidelines are good, penalties are prescribed for illegal waste dumping, but inspections are poor, and misdemeanour is not punished.	HR
		Encourage and promote innovative solutions of sustainable waste management	These measures aim to encourage development of geographical software application with locations of illegal waste disposal sites (e.g. speleological objects – pits, caves). This is particularly important for drinking water protection zones. Such application could encourage general public and decision makers to tackle the persistent issue of illegal waste disposal.	In the last years, numerous actions with aim of cleaning speleological objects from waste have been done. This not only improves the quality of groundwater (less pollutant leach) but also improves the intake capacity of sinkholes, pits and ponors, therefore reducing flood peaks in some karstic areas.	Innovative solutions for waste management are not mandatory, but rather an option. However, positive management examples can serve as a catalyst to improve waste management guidelines.	
	Lack of sewage system and wastewater treatment	Appropriate collection and treatment of municipal waste water	/	/	Existing policy guidelines already establish required treatment. Unfortunately, in selected areas these guidelines are not yet implemented.	HU

	Unarranged road rainwater discharge	Collection and treatment of road rainwater discharge, particularly within drinking water protection areas	Road rainwater discharge (and main roads rainwater drainage and retention ponds with treatment) must be controlled and regularly maintained for all roads and motorways. Furthermore, road rainwater should not run through public sewage system.	Undesirable liquids such as mineral oils or other chemicals can be rinsed from the road into the groundwater and can consequently result in pollution of the drinking water source. Therefore, controlled and regularly maintained road rainwater discharge is necessary for all roads and motorways.	Adaptation of road management policy for road rainwater to run through separate system and not through public sewage system.	SI
	No limitation of road runoff water salinity	Define limitation of salinity of road water run-off	In the narrowest area of water protection zones regulations are prescribed. It is prohibited to carry out activities in the catchment area that could endanger the ground water quality; among others also salting of undrained surfaces like yards and gravel roads is prohibited. Salting of roads and motorway cannot be prohibited, but the salinity of road water discharge should be limited.	/	Upgrade on the Decree on the emission of substances in the discharge of meteoric water from public roads.	SI
FOREST	Continued application of the clear-cut technique	Avoidance of the clear-cut technique	Application of continuous cover forestry systems and all related BMPs, strategies and measures.	Application of continuous cover forestry systems and all related BMPs, strategies and measures.	Prohibition of clear-cut applications within DWPZ.	AT
	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages	Forest Ecologically Sustainable Wild Ungulate Densities	Regulation of the wild ungulate densities to a forest ecologically sustainable level, hence providing vital regeneration dynamics of all tree species.	Regulation of the wild ungulate densities to a forest ecologically sustainable level, hence providing vital regeneration dynamics of all tree species.	/	AT
	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests	Aging of Slovenian forests, due to unregularly maintenance can turn out problematical, since old growth forest ecosystems can be more vulnerable to extreme weather conditions and catastrophes if the natural regeneration dynamics do not take place.	Close to streams (brooks or rivers) logging residues should not be left in order to reduce the danger of driftwood formation during floods.	Most of the forest in the PA locates in two nature parks: Nature park Tivoli, Rožnik and Šišenski hill and also the natural park Polhograjski Dolomiti. In these parks activities are limited according to the Ordinance for each Nature park in order to protect nature but there are no directives for maintaining the safety of their visitors, even sanitary cutting needs authority's agreement. Despite that it has to be taken into account that natural forest ecosystems in general show the highest level of stability.	SI
	Extensive construction of forest roads	Limitation of forest roads	Application of skyline-cranes or other techniques for timber-yield.	Construction of forest roads only exceptionally if necessary for forest stabilisation.	Clear guidelines for forest management within DWPZ.	AT
	Creation of conifer plantations, even within deciduous forest communities	Tree Species Diversity According to the Natural Forest Community	Man-made plantations with non-natural tree species should be transformed gradually to stands dominated by native species. In Austria the project-DWPZ are represented through the Forest Hydrotope Map, defining the optimal tree species set for each forest site.	Man-made plantations with non-natural tree species should be transformed gradually to stands dominated by native species. In Austria the project-DWPZ are represented through the Forest Hydrotope Map, defining the optimal tree species set for each forest site.	The guidelines for DWPZ should define the creation of natural and stable forest stands with native tree species as necessary management practice.	AT
	Cutting of old, huge and vital tree individuals	Foster old, huge and vital tree individuals	Old, huge and vital trees provide a substantial contribution to forest stand stability. Hence, they have to be selected and protected, so that they can provide their services as long as possible.	Old, huge and vital trees provide a substantial contribution to forest stand stability. Hence, they have to be selected and protected, so that they can provide their services as long as possible.	Forest Policy in Austria should develop more awareness towards the need to protect old growth forests and tree species.	AT

ALPINE PASTURE	Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out faeces	Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings	In order to avoid the creation of erosion dynamics and concentrations of faeces, more troughs should be provided and distributed strategically over the whole alpine pasture. Construction of concrete basements for the troughs as erosion prevention.	In order to avoid the creation of erosion dynamics, more troughs should be provided and distributed strategically over the whole alpine pasture. Construction of concrete basements for the troughs as erosion prevention.	/	AT
	Grazing of cattle in or close to dolines and sinkholes	Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features	At active pastures the karstic features dolines and sinkholes have to be fenced out in order to minimize the risk of source water contamination with faeces stemming from cattle or other grazing livestock.	/	/	AT
	Unwanted cattle grazing (cattle density and grazing patterns)	Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)	Grazing management requires strategic planning, the placing of fences and the punctual change of the grazing cattle from one to the next fenced part of the alpine pasture. It helps to avoid erosion processes.	Grazing management requires strategic planning, the placing of fences and the punctual change of the grazing cattle from one to the next fenced part of the alpine pasture. It helps to avoid erosion processes.	/	AT

Table 9b: Remaining issues to be solved for best management practices, which were selected as relevant BMPs for Pilot Actions (STEP 1: Identification of BMPs).

Category	Actual management practice (GAP)	Proposed BMP	Remaining issues to be solved	Country
GENERAL WATER MANAGEMENT	No complex evaluation of water hazards	Complex catchment modelling and assessment of hazard	Good quality input and calibration data.	PL
	Small number of sampling locations and sampling campaigns (water monitoring)	Establishment of constant, multi-aspects water monitoring in the catchment scale	/	PL
	Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)	Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off – spring dynamic modelling)	/	AT
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	Good quality input and calibration data.	PL
	Pressures on water resources management	The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)	- Guarantee resources allocation for maintenance and improvement of existing platforms, procedures, expertise and activities. - Increase awareness on drinking water as a not renewable resource. - Guarantee methodologies for drought and water scarcity characterization. - Environmental and Economic Water accounting. Further developments in: - integration of climate, snow/ice water, reservoirs, surface water, and ground water observation, simulation, and management; - integration of in situ and remote sensing;	IT

			- coupling of water quality and water quantity observation and simulation; - scalable simulation tools considering different temporal and spatial scales (point, river, network, basin, district); - unification of flood, water shortage and drought observation and simulation platforms; - interactive, spatially based, web based, standardized and open architecture retrieving/ access services (data, metadata, and information); - harmonization among real-time and delayed time applications; - consideration of joint effects/impacts of strategies, guidelines, planning, design management, constraints, and practices; - standardization of tools methodologies, terminology, criteria, and procedures for water shortage damage assessment.	
	Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources	Joined and integrated management of drinking water resources (horizontal and vertical co-operation)	Actions for encouraging horizontal and vertical co-operation in drinking water management	SI
	Lack of public engagement in development of action plans	Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach	Not applicable	DE
	Low level of ecological awareness of society	Raising awareness and increasing knowledge	Limited channels of information flow in small communities.	PL
DRINKING WATER MANAGEMENT	Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)	Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)	First step is raising awareness on the climate change and adaptive management practices among relevant stakeholders. A timely reaction and development of CC adaptation plans benefits all ESS and population, therefore, it is a prerequisite for freshwater availability of future generations. Furthermore, adaptation plans, and strategies could save money in the long run due to prevention, instead of intervention.	HR
			- Enhance in understanding of physical behaviour and increasing in computational power to reduce remarkable uncertainties that characterized, at the moment, several elements of proposed modelling chain. - Adoption of probabilistic approaches or findings provided by ensemble initiatives to manage complex atmospheric processes and gaps about future paths in socio-economic and demographic trends. - Enhance the dissemination of the findings accounting for pros and cons in the modelling chain and permitting to have a clearer view about future state of drinking water resources that could be exploited by stakeholders. - Improve management and use of natural resources and ecosystem services to use and modify less the natural capital. - Encourage natural capital valorisation, circular economy and ecosystem optimal management through climate change simulation. - Implement complex, physically based, socially based and evidence related design, planning and governance tools linking environmental, economic and social resources, services and processes. - Promote the availability and practicality of climate projection ensembles to enable robust decision making thanks to a likelihood-based analysis.	IT
	Drinking water protection zones (DWPZs) do not exist	Determination (e.g. hydrogeological modelling) and establishment of DWPZs	Enabling adoption of decrees on the water protection areas for potential drinking water sources	SI
			Legal procedure for implementation.	PL
			Stakeholders and experts strongly support implementation of this measure, however, unwillingness of people to cooperate and since there are no legally binding obligations to abide pose a serious threat to the administration of the measure. Further education activities and awareness raising are needed to fully implement DWPZs.	HR
	Lack and not effective control over implementation restrictions for existing DWPZ	Strict implementation and inspection of DWPZ restrictions	More inspectors on field and more effective control.	SI

FLOOD MANAGEMENT	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	Establishing responsibilities and competence for setting up the register of point and diffuse sources of potential pollution on flood areas	SI
	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	Establishment of control.	SI
	Water balance status and effective mitigation measures are not known (identified)	Water balance status will be determined with Hydrological / Hydraulical modelling	/	SI
	Increased contamination of surface drinking water resources during flood events	Reduction of flood effects at the surface drinking water resources	Farmers and the water management sector should prepare for climate change.	HU
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	Measure is complex, as it faces resistance of local population, lots of financial compensation for losses, and generally, structural measures are still favoured.	HR
	Flood impact not fully implemented and considered	The Flood Forecast Centre and Flood Early Warning System (FEWS)	- Guarantee financial resources allocation for maintenance and improvement of existing platforms, procedures expertise and activities. - Increase awareness on heavy rain and flood as potential cause of not reversible damages. Further developments in: - integration of meteorological, snow water, reservoirs, water devices, surface water and ground water observation, simulation, and management; - coupling of water quality and water quantity observation and simulation; - coupling water and sediment cycles; - unification of flood, water shortage and drought observation and simulation processes and platforms; - interactive, spatially based, web-based, standardized and open architecture retrieving/ access services (data, metadata, models and information); - harmonization among real-time and delayed time applications; - consideration of joint effects/impacts of strategies, guidelines, planning, design management, constraints, and practices, (land use, water use, civil/environmental protection); - Standardization of tools methodologies, terminology, criteria, procedures for flood and heavy rain damage assessment.	IT
	Improper flood protection of bank-filtered wells during high water and flood events	Ensure the drinking water supply during high water or flood	- Further investigation of water chemistry measured in observation wells located on Szentendre Island. - Revising flood management in context of future climate conditions.	HU
	River banks vegetation is not maintained	Reducing river banks vegetation	Education of land owners.	SI
	Legalization of illegal construction on flood areas	To prevent legalization of construction on flood areas	Ban on legalization of constructions/buildings on flood areas must be incorporated into existing legislation.	SI

AGRICULTURAL AREAS	Improper manure storage	Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change	Solve the problem of frequent monitoring of livestock farms with or without involving the authorities, preparing for climate change.	HU
	Agricultural surface water and groundwater pollution (e.g. improper or excessive use of pesticides and manure on plant production fields)	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	Forecasting how plant production will change as climate changes could be advantageous.	HU
	Inflexible time ban of fertilizers and manure application	Redefinition of time ban of fertilizers and manure application	Enforcing cooperation among competent institutions (governmental, local), agricultural chamber, agricultural advisory services experts and farmers. Determination of rules concerning time ban on fertilizers and manure application.	SI
	Increased water demand	Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture	The measure is simple, but requires funding sources, which is unclear at the moment.	HR
	Continuous conversion of (permanent) grasslands	Continuous monitoring in both, surface water and groundwater	Not applicable	DE
URBAN AREAS	Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded	Natural wastewater treatment system	Challenges include high costs (which are also case with other purification methods) and extensive land surface is needed for the method (up to 5 m2 per PE, which is problematic for high scale systems).	HR
	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (e.g. transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	/	SI
	Waste disposal which do not meet technical and environmental standards and illegal waste disposal	Educative brochure and awareness raising activities	First step is raising awareness on the climate change and adaptive management practices among relevant stakeholders. A timely reaction and development of CC adaptation plans benefits all ESS and population, therefore, it is a prerequisite for freshwater availability of future generations. Furthermore, adaptation plans, and strategies could save money in the long run due to prevention, instead of intervention.	HR
		Encourage and promote innovative solutions of sustainable waste management	Stakeholders are a bit doubtful about the success of this measure. Although positive trends can be observed, the process is slow and requires persistence.	
	Lack of sewage system and wastewater treatment	Appropriate collection and treatment of municipal wastewater	- Development of sanitary coverage in Pócsmegyer and Szigetmonostor. - Identification of contamination source at Dunakeszi.	HU

	Unarranged road rainwater discharge	Collection and treatment of road rainwater discharge, particularly within drinking water protection areas	Enforcing more strict regulation for collection and treatment of road rainwater discharge, within drinking water protection areas	SI
	No limitation of road runoff water salinity	Define limitation of salinity of road water run-off	Enforcing cooperation among competent institutions (governmental) and experts for determination of salinity limitations for meteoric waters discharged from public roads.	SI
FOREST	Continued application of the clear-cut technique	Avoidance of the clear-cut technique	The avoidance of the clear-cut technique has to be applied within all DWPZ in Austria, what will be a challenge in many cases.	AT
	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages	Forest Ecologically Sustainable Wild Ungulate Densities	The regional and provincial forest authorities have to be forced to act according to the Provincial Hunting Acts.	AT
	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests	Establishing of subsidy system.	SI
	Extensive construction of forest roads	Limitation of forest roads	Limitation of forest road constructions within DWPZ will cause resistance of some forest owners.	AT
	Creation of conifer plantations, even within deciduous forest communities	Tree Species Diversity According to the Natural Forest Community	For DWPZ outside the PROLINE-CE project space it will be a challenge to establish the optimal native tree species set for each forest site.	AT
	Cutting of old, huge and vital tree individuals	Foster old, huge and vital tree individuals	The protection of old growth trees and forests in Austria is in general lacking, it has to be improved.	AT
ALPINE PASTURE	Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out faeces	Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings	Water trough spacing, and construction of concrete basements could be difficult on some alpine pastures.	AT
	Grazing of cattle in or close to dolines and sinkholes	Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features	Fences around dolines and sinkholes have to be maintained continuously for providing sustained functionality.	AT
	Unwanted cattle grazing (cattle density and grazing patterns)	Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)	The challenge of this BMP is the necessity of a strategic planning process which requires detailed knowledge about the pasture quality on the alpine pasture and the consequent implementation through the strategic placing and spacing of fences. To achieve this, training of the alpine staff and persuasive efforts will be necessary.	AT

6.2. Implementation possibilities of selected best management practices

There are many best management practices for drinking water protection and flood protection which is already existing but often actual implementation of these BMPs is slowed down or limited by economic, administrative, social acceptance or governance issues. Implementation possibilities were assessed for previous selected BMPs in all Pilot Actions of all three Pilot Action Clusters (PACs).

Testing of BMPs in PAs was done in three steps (Figure 32). In the first step the most important and relevant BMPs were selected. Various activities were performed for the implementation of BMPs (step 2) and the last step was to find out stakeholder's opinion about selected BMPs (step 3).

On the Pilot Action level some BMPs were already implemented in the frame of T2 activities. On the other hand, some BMPs are very complex and require system change or even policy change, which are long lasting procedures. Implementation of BMPs may require:

- adaptation of existing land use management practices with the purpose of drinking water protection,
- adaptation of existing flood/drought management practices with relation to drinking water protection,
- adaptation of policy guidelines.

For such BMPs possibilities of implementation were assessed and implementation strategies (procedures) were determined. Implementation possibilities of BMPs for drinking water protection and flood mitigation are presented in Table 10.

Table 10: Implementation possibilities of best management practices for drinking water protection and flood mitigation with implementation strategies (procedures) (STEP 2: Implementation of BMPs).

Category	Actual management practice (GAP)	Proposed BMP	Implementation of best management practices for drinking water protection and flood mitigation			Country
			Possibility of implementation YES/NO; in case of NO explanation is added	Proposal of procedure for implementation YES/NO; in case of NO explanation is added	Other	
GENERAL WATER MANAGEMENT	No complex evaluation of water hazards	Complex catchment modelling and assessment of hazard	Implemented			PL
	Small number of sampling locations and sampling campaigns (water monitoring)	Establishment of constant, multi-aspects water monitoring in the catchment scale	Implemented			PL
	Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)	Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off – spring dynamic modelling)	Implementation of Hydrological Modelling and Monitoring through the water works: Decision of the Municipality. Report about the modelling outcomes of the hydrological model KAMPUS.	Sustained implementation of Hydrological Monitoring, cooperation with experts. Presentation of the hydrological model KAMPUS applied within the pilot action "Zeller Staritzen" and its relevance for drinking water supply.	Analysis of modelling, application of management routines based on Modelling outcomes. Analysis of modelling, application of management routines based on Modelling outcomes.	AT
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	Implemented			PL
	Pressures on water resources management	The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)	Yes, but partially implemented. For the complete implementation, it is necessary to: - empower modelling system; - increase accessibility and availability of information; - further develop stakeholder's awareness and engagement; - assure incentives and investments to prevent, mitigate and better manage water scarcity events; - improve dialogue and communication.	- Confirm and intensify already started activities and projects; - implement economic and environmental methodologies for water resource.	Extend the number of stakeholders and stimulate attention to drinking water.	IT
	Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources	Joined and integrated management of drinking water resources (horizontal and vertical co-operation)	Realistically there are low possibilities of this drastic change in work organisation.	Water sectors should be reunited into one organisation and clearly separate their duties about drinking water resources protection issues.	/	SI
	Lack of public engagement in development of action plans	Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach	Implemented			DE
	Low level of ecological awareness of society	Raising awareness and increasing knowledge	Implemented			PL

DRINKING WATER MANAGEMENT	Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)	Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)	Some structural measures are in implementation process, such as construction of new irrigation system for Imotsko polje.	Local authorities should incorporate CC Adaptation Strategy 2040-2070 and Action Plan 2019-2023 provide good guidelines for adaptation and resilience for CC it in local plans and strategies	/	HR
			- The topic about implementation should be differentiated considering the implementation on test case simply requiring the stages above described; - in general, to properly account for CC in drinking water protection management, Acts as National Strategy for Adaptation (published in 2014) and next National Adaptation Plan represent key activities; - it should be integrated with analogue experiences at regional and urban scale. - integration of CC mitigation and adaptation issues as a cross cutting theme into sectoral and territorial Plans (agriculture, energy, water protection, protected areas, urban planning).	- Regional and Urban Adaptation Plans should be performed; - following EU Directive, the updates in Plans should explicitly account for CC issue (e.g. second implementation of actions required by flood Directive).	More quantitative evaluations activities could permit better driving decisions of Administrators also if carried out only on limited domains.	IT
	Drinking water protection zones (DWPZs) do not exist	Determination (e.g. hydrogeological modelling) and establishment of DWPZs	Possible with cooperation of Municipality of Ljubljana city and Ministry of the environment and spatial planning for acceptance of drinking water protection decree.	Municipality of Ljubljana city finance hydrogeological study for determination of DWPZ and submit to the Ministry of the environment and spatial planning for acceptance of drinking water protection decree.	/	SI
			Implemented		Proposal is currently under legal procedures.	PL
			DWPZ are determined for many springs captured for the purpose of water supply system, but tempo of determination and prescription of measures is highly variable and depends on geographical location.	Determination of drinking water protection zones (DWPZ), obligatory measures and limitations that are conducted in them as well as the deadlines for decisions on protection and the process of making these decisions are governed by The Ordinance on the conditions for the establishment of sanitary protection zones (Official Gazette No. 66/11 and 47/13).	/	HR
	Lack and not effective control over implementation restrictions for existing DWPZ	Strict implementation and inspection of DWPZ restrictions	With Ministries (of the environment and planning) support and guaranteed budget the proposal would be feasible.	Ministry of the environment and spatial planning should assign supervisors to control locals and local farmers and their acts in DWPZs.	Workshops and informational system about DWPZ areas restrictions should be upgraded among locals.	SI
FLOOD MANAGEMENT	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	Possibilities for implementation are medium. Information on some pollution /sources could originate from: a) Formalized procedures relative to chimney sweepers identifying the location and status of devices (and tanks) b) Identification of stores and storage facilities with hazardous substances.	To adopt and enforce legislation enabling access to data and reporting on the amount of stored hazardous substances on flood prone areas. Maintenance of the dataset. After the identification it is important to raise awareness and provide measures leading to improvements.	/	SI

	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	The information on the type of the well (sealed) should be emended to the data specification according to INSPIRE directive and reported in the national database of public service providers.	Recommendations on the level of strategic guidelines resulting from the PROLINE-CE project, implementation on the level of national legislation requesting obligatory sealed well heads for the water supply wells on flood prone areas.	/	SI
	Water balance status and effective mitigation measures are not known (identified)	Water balance status will be determined with Hydrological / Hydraulical modelling	The stakeholders generally fully accept the implementation of water balance model. The modelling to certain extent required by national legislation, but precise method is not defined.	Existing modelling approach – models developed by local communities and investors should be changed as they do not provide river basin scale models (they are usually limited by the municipal borders).	The scale and standardized approach to modelling is not defined different models are used (1D, 1D-2D, 2D for hydraulics), and different for hydrological modelling 1D, 2D, distributed, method for the integration of urban drainage is not defined.	SI
	Increased contamination of surface drinking water resources during flood events	Reduction of flood effects at the surface drinking water resources	This measure is partially implemented as the Szolnok Waterworks already has an effective flood action plan, but we would suggest reviewing the action plan with the consideration of a CC model. The realization of a full implementation depends on how many complications would waterworks face during trying to have access to a CC model. In addition, cost of measure is high.	Waterworks and the Hungarian Meteorological Service should orient their cooperation to this direction.	The Szolnok Surface Waterworks operates well during flood events, purification technology is suitable for the treatment of changing water quality – the operating system and the purification technologies must be reviewed in the context of climate change.	HU
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	Measure is complex, as it faces resistance of local population, lots of financial compensation for losses, and generally, structural measures are still favoured.	Expert community, service providers, decision makers and population must reach consensus in order to apply this measure.	/	HR
	Flood impact not fully implemented and considered	The Flood Forecast Centre and Flood Early Warning System (FEWS)	Yes, but partially implemented. For the complete implementation, it is necessary to: - empower modelling system; - improve operational procedures and activities considering the whole disaster cycle; - further develop citizen information and operation tools for alert dissemination; - assure incentives and investments to prevent, mitigate and better manage floods.	- Confirm and intensify already started activities and projects; - implement impact based economic evaluations of flood management.	Extend the number of stakeholders and stimulate attention to drinking water supply systems protection in case of floods.	IT
	Improper flood protection of bank-filtered wells during high water and flood events	Ensure the drinking water supply during high water or flood	Implemented			HU
	River banks vegetation is not maintained	Reducing river banks vegetation	Implemented – but it is not maintained as regularly as it should be.			SI
	Legalization of illegal construction on flood areas	To prevent legalization of construction on flood areas	Strict implementation of construction inhibition on floodplains considering flood hazard map is possible with Municipalities support.	After agreement with stakeholders (Ministry of the Environment and Spatial planning – Slovenian Environment & Slovenian water agency) this legislation proposal about flood risk evaluation of parcels included in municipal spatial planning will be discussed among departments how to implement this legislation and propose an approach of solving this problem.	Strict implementation of construction inhibition on floodplains considering flood hazard map.	SI

AGRICULTURAL AREAS	Improper manure storage	Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change	Possible. It depends on the relevant authorities who could inspect the operation of livestock farms (do authorities have enough capacity for the regular inspection?).	Authorities should be informed about GAP, as well as the imminence of climate change, so they can make the first step towards a regular monitoring/ inspection.	/	HU
	Agricultural surface water and groundwater pollution (e.g. improper or excessive use of pesticides and manure on plant production fields)	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	Possible. If farmers could be convinced that the Agrarian Environmental Program is beneficial for them, the implementation has a good possibility to be realized. To convince the farmers brochures have to be prepared or local events have to be organized to inform them about the consequences of improper use of pesticides and the benefit of participating in Agrarian Environmental Program.	Informative meetings for farmers about the Agrarian Environmental Program and climate change.	/	HU
	Inflexible time ban of fertilizers and manure application	Redefinition of time ban of fertilizers and manure application	With sufficient political will and farmers support implementation would be possible.	Increasing of environmental awareness of local farmers and to upgrade legislations with political consultant's advice.	/	
	Increased water demand	Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture	The measure is simple, but requires funding sources, which is unclear at the moment.	Water suppliers, municipality or county can seize the initiative or even finance it, but they can also file an official request to Croatian Waters.	/	HR
	Continuous conversion of (permanent) grasslands crop fields/lands	Continuous quantity and quality monitoring of agriculture pollution and water level in both, surface water and groundwater	Implemented			DE
URBAN AREAS	Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded	Natural wastewater treatment system	Hard to predict. Challenges include high costs (which is also case with other purification methods) and extensive land surface is needed for the method (up to 5 m2 per PE).	Local authorities or county starts the initiative and tries to find financial models.	/	HR
	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (e.g. transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	Currently low possibilities for implementation. There is no national discussion on sustainable drainage systems. Development of regulation and indicator system for the identification of objectives of water retention and reuse municipalities should achieve.	Development of regulation on water wise cities on national level as a part of climate change adaptation procedures. Integration of water wise concept on the level of city planning with overall water balance management as one of the components of spatial planning process.	/	SI
	Waste disposal which do not meet technical and environmental standards and illegal waste disposal	Educative brochure and awareness raising activities	Implemented			HR
		Encourage and promote innovative solutions of sustainable waste management	Main obstacle is unwillingness of the local community to adopt new environmentally friendly habits as a consequence of insufficient education on environmental issues and lack of government stimulations.	Small scale application must start in order to provide a positive example for the rest of community.	/	

	Lack of sewage system and wastewater treatment	Appropriate collection and treatment of municipal wastewater	Mostly Implemented, while sewage disinfection is not a general problem in the pilot area, there are specific locations that are still lacking.			HU
	Unarranged road rainwater discharge	Collection and treatment of road rainwater discharge, particularly within drinking water protection areas	Hopefully our political consultants will have good advice on its implementation to change construction legislations.	Separate drainage system should already be included into road planning.	/	SI
	No limitation of road runoff water salinity	Define limitation of salinity of road water run-off	Possible with strong stakeholder involvement.	Stakeholder involvement for adopting guidelines regarding roads salting or even updating existing Decree on the emission of substances in the discharge of meteoric water from public roads.	/	SI
FOREST	Continued application of the clear-cut technique	Avoidance of the clear-cut technique	Application of the GWP, hence facilitation of BMP implementation.	Setting up of the contract with the forest owners according to GWP, facilitated BMP application.	/	AT
	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages	Forest Ecologically Sustainable Wild Ungulate Densities	Application of the Hunting Law (Provincial Hunting Act of Lower Austria).	Information campaigns in local media (newspapers, radio or TV), persuasive efforts with regard to the implementation of ecological hunting practices.	In severe cases persecution of a trial in the specific court.	AT
	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests	Concessionaires (Snaga d.o.o.) are taking over management of the TRŠ park and therefore policies of the Park will be upgraded, and many actions will take place since the Parks budget will increase according to the Municipalities promises.	Snaga d.o.o. already started to inform and increase awareness of relevant stakeholders like local farmers and residents through meetings.	/	SI
	Extensive construction of forest roads	Limitation of forest roads	Application of the GWP, hence facilitation of BMP implementation.	Setting up of the contract with the forest owners according to GWP, facilitated BMP application.	/	AT
	Creation of conifer plantations, even within deciduous forest communities	Tree Species Diversity According to the Natural Forest Community	Application of the GWP, hence facilitation of BMP implementation.	Setting up of the contract with the forest owners according to GWP, facilitated BMP application.	/	AT
	Cutting of old, huge and vital tree individuals	Foster old, huge and vital tree individuals	Application of the GWP, hence facilitation of BMP implementation.	Setting up of the contract with the forest owners according to GWP, facilitated BMP application.	/	AT
ALPINE PASTURE	Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out faeces	Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings	Persuasive efforts with regard to the alpine pasture staff. Contracts with the alpine pasture staff.	After information campaigns for the own staff and the alpine pasture staff, the set-up of specific contracts can be carried out.	/	AT
	Grazing of cattle in or close to dolines and sinkholes	Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features	Persuasive efforts with regard to the alpine pasture staff. Contracts with the alpine pasture staff.	After information campaigns for the own staff and the alpine pasture staff, the set-up of specific contracts can be carried out.	/	AT
	Unwanted cattle grazing (cattle density and grazing patterns)	Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)	Persuasive efforts with regard to the alpine pasture staff. Contracts with the alpine pasture staff.	After information campaigns for the own staff and the alpine pasture staff, the set-up of specific contracts can be carried out.	/	AT

6.3. Acceptance of BMPs among stakeholders and experts

Implementation of best management practices at the local/regional level demands a transdisciplinary and participatory approach with dynamic interaction and feedbacks of stakeholders and experts. Therefore, an important part of implementation is acceptance of best management practices for drinking water protection and flood mitigation among stakeholders and experts, which was obtained through stakeholder workshops and individual discussion. The acceptance of BMPs among stakeholders and experts are presented in Table 11.

Table 11: Acceptance of best management practices for drinking water protection and flood mitigation among stakeholders and experts (STEP 3: Stakeholder acceptance).

Category	Actual management practice (GAP)	Proposed BMP	Acceptance of BMPs among stakeholders and experts			Country
			Possibility of implementation	Proposal of procedure for implementation	Other	
GENERAL WATER MANAGEMENT	No complex evaluation of water hazards	Complex catchment modelling and assessment of hazard	Stakeholders and experts recommend implementation of catchment modelling in water management as one of the tools to simulate water environment and impact of possible hazard on water.	Catchment modelling should be included in policy guidelines as important tool for water management.	/	PL
	Small number of sampling locations and sampling campaigns (water monitoring)	Establishment of constant, multi-aspects water monitoring in the catchment scale	Conducting a multi-aspect monitoring is an easy and sufficient solution for gathering information about water ecosystem	Implementation needs first carrying out screening monitoring to gather general spatial and seasonal information about water environmental components and water hazards. Next step is selecting representative monitoring points, which provide reliable information. Within selected monitoring point it is recommended to provide long-term multi-aspect monitoring to gather full knowledge of water environment and possible hazards.	/	PL
	Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)	Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off – spring dynamic modelling)	The main stakeholder, the water works of Waidhofen/Ybbs, is convinced from the necessity of this BMP and hence ensures its application. The main stakeholder, Vienna Water, is convinced from the necessity of this BMP and hence ensures its application in the course of the project.	The main tasks were already fulfilled during project life-time. The monitoring task will have to be sustained in future. The surface flow - spring dynamic modelling will be finalized during the project duration period.	/	AT
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	Stakeholders and experts recommend implementation of the ecological modelling, integrated with catchment models, in water management as one of the tools to simulate water environment and impact of possible hazard on water.	Ecological modelling, integrated with catchment models, should be included in policy guidelines as important tool for water management	/	PL
	Pressures on water resources management	The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)	Stakeholders are a bit doubtful about the success of this measure because their involvement is more recent with respect to flood issues. Although positive trends can be observed, the process is slow and requires persistence of efforts. Experts put in evidence the main implementation opportunities underlining the role of funding, multi-sectoral partnership, interdisciplinary qualitative-quantitative approaches, and innovation (ICT, humanities, applied research etc.), social awareness, training, and	- Insert easier and more accessible water information, especially drinking water, according to stakeholders needs; - increase the involvement of experts from different fields (communication, economy, environment, and social sciences) to test operational tools and share knowledge; - funding and implementation of interactive systems for hydrological simulation and application.	- Increase the knowledge of existing and potential problems and vulnerabilities linked to pressure on water resources; - increase the awareness on benefits of information and scenario (evidence-based) based decisions; - share with stakeholders and citizens the main steps and results.	IT

			stakeholder involvement.			
	Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources	Joined and integrated management of drinking water resources (horizontal and vertical co-operation)	Possible with strong stakeholder involvement and cooperation.	Persons (NGO or civil initiatives)/institution (national level) needed for coordination of different sectors.	/	SI
	Lack of public engagement in development of action plans	Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach	The proposed BMP is of difficult implementation. The support of an expert is fundamental for the stakeholder in setting up the model, running it and interpreting the results.	1. Perform a field survey to verify the accuracy of the available information 2. Analyse the quality of available data 3. Develop a conceptual model 4. Develop a mathematical model 5. Calibrate and validate the model 6. Use the model to test scenarios proposed by stakeholders 7. Support decision makers providing the model results in a comprehensible form	Bottlenecks that we identified in the implementation of the procedure are: - correct communication of the concept of model uncertainty, - correct communication of model results which may not be expected by the stakeholders.	DE
	Low level of ecological awareness of society	Raising awareness and increasing knowledge	High need to raise awareness and increase knowledge in society.	Organisation of meeting at local scale.	/	PL
DRINKING WATER MANAGEMENT	Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)	Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)	Stakeholders gave positive feedback, but realistic possibility is questionable (consensus of all involved groups is hard to reach).	This essential topic must be promoted to stakeholders and decision makers on all levels (from local to government). Results of CC modelling for Croatian pilot area was presented during 2nd national stakeholder workshop in Metković and discussion was held regarding potential loss of water resources in near future as well as adaptation of ecosystems to changes in temperature and precipitation trends. Higher level decision makers are harder to address, therefore, there is need for expert and scientific papers and publications.	/	HR
			Due to high complexity of investigated issue, several expertises are required to effectively address the topic; the starting point could be represented by Observatories proposed in other BMPs involving also expert in atmospheric sciences or adaptation processes. Moreover, awareness about the future potential issues for drinking water should be increased also in general public, making the results of research and institutional activities easier for all potential stakeholders (for example, stressing pros and cons or uncertainties in current estimations).	- Promote the development of participative processes and stakeholder engagement to promote bottom-up approaches; - integrate the activities about adaptation in Observatories, Technical panels and other decision-making bodies in which experts and communities are already involved; - replicate the experiences carried out on different contexts favouring the dissemination of the results.	/	IT
	Drinking water protection zones	Determination (e.g.	Implementation is feasible.	Municipality of Ljubljana city finance	/	SI

	(DWPZs) do not exist	hydrogeological modelling) and establishment of DWPZs		hydrogeological study for determination of DWPZ and submit to the Ministry of the environment and spatial planning for acceptance of drinking water protection decree.		
			High need of establishing DWPZ at Kozłowa Góra reservoir.	Procedure complies with legal acts.	/	PL
			The administration of these measures is expected to be more efficient in near future.	Further education activities and awareness raising are needed to fully implement DWPZs	/	HR
	Lack and not effective control over implementation restrictions for existing DWPZ	Strict implementation and inspection of DWPZ restrictions	Stakeholders identify lack of not effective inspection. Implementation itself is very complex and hard to realize.	Good effects on activities in the DWPZs are Agricultural Advisory Services encourage farmers to organic farming without pesticides and fertilizers. Because of smaller harvest, farmers get money compensations.	/	SI
FLOOD MANAGEMENT	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	Data collection, data validation and maintenance, legal framework for the data collection present a challenge.	Communication with the Slovenian Water Agency regarding the added information on potential storage of hazardous substances (as activity) in Water Management Information System.	Aggregated list of all potential point pollution sources (industry, heating oil tanks in households, etc.) is needed for efficient incident management in case of flood event.	SI
	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	Implementation is easily feasible with consideration of guidelines.	Guidelines have to be prepared and promoted by Ministry of environment and spatial planning.	Awareness rising and education process on this risk and potential measure as the number of stakeholders (only Water Utilities) is relatively limited.	SI
	Water balance status and effective mitigation measures are not known (identified)	Water balance status will be determined with Hydrological / Hydraulical modelling	Stakeholders agree on the importance of the harmonized river basin scale hydrological and hydraulic modelling providing good information on water balance. Nevertheless, existing legislation, but also specific bottlenecks (human resources, financial resources) do not provide easy solutions.	Change in legislation should define better the institution in charge of river basin scale models instead of municipality base models.	/	SI
	Increased contamination of surface drinking water resources during flood events	Reduction of flood effects at the surface drinking water resources	During the discussions with stakeholders, they gave positive feedback on the idea, however they seemed to find the predicted issues related to climate change less drastic.	Rising general awareness on CC.	The Szolnok Surface Waterworks operates well during flood events, purification technology is suitable for the treatment of changing water quality – the operating system and the purification technologies must be reviewed in the context of climate change.	HU
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	Stakeholders gave positive feedback, but realistic possibility is questionable (consensus of all involved groups is hard to reach)	Specific needs must be defined by local communities and service providers, while financing (for big infrastructural works) usually has to be supported by regional, national or EU funds.	/	HR
	Flood impact not fully implemented and considered	The Flood Forecast Centre and Flood Early Warning System (FEWS)	Stakeholders gave positive feedback, putting in evidence some difficulties and proposing ideas and solutions to complete the implementation. Experts put in evidence the main implementation strategies whose added value rely on funding opportunities, innovation (ICT, humanities, applied research etc.), social awareness, interdisciplinary applications, and stakeholder involvement.	- Insert easier and more accessible water information, especially drinking water, according to stakeholders needs; - increase the involvement of experts from different fields (communication, economy, environment, and social sciences) to test operational tools and share knowledge; - funding and implementation of interactive systems for hydrological simulation and	- Increase the knowledge of existing and potential problems and vulnerabilities linked to floods; - increase the awareness on benefits deriving from decisions based on full information and specific scenarios; - share with stakeholders and citizens the main steps and results.	IT

			application.			
	Improper flood protection of bank-filtered wells during high water and flood events	Ensure the drinking water supply during high water or flood	Location of individual wells is a critical factor, some are easier to protect than others.	Implementation can only be done at a local level.	/	HU
	River banks vegetation is not maintained	Reducing river banks vegetation	Implemented – but it is not maintained as regularly as it should be.			SI
	Legalization of illegal construction on flood areas	To prevent legalization of construction on flood areas	Despite strict legislations usually corruption at municipalities or at planning companies make such acts possible, therefore implementation and realisation present a challenge.	Stakeholders (Ministry of the Environment and Spatial planning – Slovenian Environment & Slovenian water agency) support us and will suggest how to approach solving this problem.	Flooding of constructions in floodplains due to noncompliance of the legislation and large material damage are now Municipalities problem.	SI
AGRICULTURAL AREAS	Improper manure storage	Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change	Experts from water sector agreed that the raised problems are very complex, and that although the situation might seem to be under control at the moment, the climate change could be a serious threat. It is also a common opinion that monitoring the water quality of River Tisza is enough, there is no need to monitor its tributaries.	- Educating farmers about proper manure storage; - Educating farmers about the disadvantages of improper manure storage.	/	HU
	Agricultural surface water and groundwater pollution (e.g. improper or excessive use of pesticides and manure on plant production fields)	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	Experts from water sector agreed that the raised problems are very complex, and that although the situation might seem to be under control at the moment, the climate change could be a serious threat. It is also a common opinion that monitoring the water quality of River Tisza is enough, there is no need to monitor its tributaries.	- Raising awareness; - Improving available subsidies and grants; - Educating farmers about the available methods.	/	HU
	Inflexible time ban of fertilizers and manure application	Redefinition of time ban of fertilizers and manure application	The Slovenian Environment Agency agronomic prediction according to the weather forecast but is more as a recommendation Expected limitations are lack of political will and resistance of local farmers.	Workshops and seminars for local farmers would improve awareness and perhaps reduce polluting their local groundwater source.	/	SI
	Increased water demand	Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture	Stakeholders gave positive feedback, but realistic possibility is questionable (mainly due to financing).	Monitoring of surface and groundwaters are responsibility of Croatian Waters. Research institution (such as Croatian Geological Survey) can propose locations for new monitoring sites on the basis of desk studies and field investigations	/	HR
	Continuous conversion of (permanent) grasslands	Continuous monitoring in both, surface water and groundwater	The proposed BMP is of relatively simple implementation. The support of an expert view can help the stakeholder in optimizing the monitoring network finding a good configuration in terms of cost/benefit ratio.	1. Perform a field survey to verify the accuracy of the available information. 2. Analysis of the institutional path to ask for the permission of the installation of additional monitoring point. 3. Design a monitoring network according to the necessity of the study site.	Bottlenecks that we identified in the implementation of the procedure are: - complex organizational structure to obtain the permit for the installation of new monitoring points, - resistance of some individuals in processing the requests for the installation of new monitoring points,	DE

				4. Find an optimal cost/benefit configuration of the monitoring network. 5. Collect the permission to install new monitoring points. 6. Share the data, maintain the database and proof the quality of collected data.	- lack of knowledge about the current situation (e.g., it was not possible to identify the owner of some existing monitoring points).	
URBAN AREAS	Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded	Natural wastewater treatment system	Unknown, mostly due to high costs.	A first step towards the implementation of this BMP will be the stakeholder involvement actions (authorities, local community, economic subjects etc.). Natural UWWTP possibilities will be included in educative brochure (see previous BMP).	/	HR
	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (e.g. transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	An initiative was launched and Ljubljana as Green Capital of Europe 2016 is considering it as one of the development potentials. No communication on higher (regulatory) level yet, due to the election procedure and re-organization of the ministries.	Communication with the stakeholders: state level – Ministry of Environment and Spatial Planning (general regulatory framework) and the City Municipality of Ljubljana (implementation framework).	Overall awareness rising as retention measures have significant spill-over effect, in order to motivate the communities towards its implementation. Retention measures should address the issue of IAS and mosquito control as well.	SI
	Waste disposal which do not meet technical and environmental standards and illegal waste disposal	Educative brochure and awareness raising activities	Stakeholders gave positive feedback and claim that foreseen activities will have positive impact on behaviour.	Details of optimal brochure dissemination and awareness raising activities will be discussed with local stakeholders.	/	HR
		Encourage and promote innovative solutions of sustainable waste management	Stakeholders are a bit doubtful about the success of this measure. Although positive trends can be observed, the process is slow and requires persistence.	Education of the local community to adopt new environmentally friendly habits.	/	
	Lack of sewage system and wastewater treatment	Appropriate collection and treatment of municipal wastewater	Sewage systems are continuously being improved in the region.	Increasing funding in critical regions in order to improve results.	/	HU
	Unarranged road rainwater discharge	Collection and treatment of road rainwater discharge, particularly within drinking water protection areas	Legislation for rain water discharge is very good but for many roads not implemented, moreover it should be stricter on DWPZ.	Inspection of all existing roads.	On motorways and main roads rainwater drainage and retention ponds with treatment are arranged but the infrastructure is not maintained.	SI
	No limitation of road runoff water salinity	Define limitation of salinity of road water run-off	Guidelines for road salting have to be determined (The dosing quantities of solvent should take into account the amount of solvent that it is already on the road).	Guidelines have to be prepared and promoted by Ministry of environment and spatial planning and Ministry of infrastructure.	/	SI
FOREST	Continued application of the clear-cut technique	Avoidance of the clear-cut technique	The acceptance of this BMP among stakeholders and experts is already given, what is due to information campaigns and persuasive efforts during the project pilot activities.	Application and execution of the GWP (Guideline for securing the Water Protection functionality of the forest ecosystems within the DWPZ)	If forest owners do not comply with GWP, persuasive efforts have to be carried out in order to convince them from contracting.	AT
	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-	Forest Ecologically Sustainable Wild Ungulate Densities	The acceptance of this BMP is still rather low among most of the stakeholders. The provincial Hunting Act will have to be stressed in some cases.	Some forest owners like the Austrian Federal Forests could act as example for all other stakeholders, as they have already the implementation of this BMP on their agenda.	Utilisation of interdependencies between forest owners, like the example of single forest enterprises. Stressing of the Hunting Act. Information campaigns for the general public in order to create a sphere of awareness for this	AT

	stripping damages				relevant issue. Forcing of the regional and local forest authorities through public awareness to conform with law.	
	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests	Implementation depends on the budget of the Park. The main problem is given through numerous private owners with relatively small parcels, hence constant conflicts among them.	The upgrade of the Park's policies in the direction of providing forest regeneration dynamics in sufficient quality and quantity and regularly maintaining the forest.	/	SI
	Extensive construction of forest roads	Limitation of forest roads	The acceptance of this BMP is still rather low among most of the stakeholders and experts.	Application and execution of the GWP. The specific situation for this BMP will have to be stressed specifically during the contracting process.	Further information of forest owners that the application of technical alternatives will result in higher PES.	AT
	Creation of conifer plantations, even within deciduous forest communities	Tree Species Diversity According to the Natural Forest Community	Forest owners have a higher understanding regarding this BMP, facilitated through the latest weather conditions.	Application and execution of the GWP. The fitting tree species were spatially explicitly defined through the Forest Hydrotope Model.	The implementation of tree species diversity based on native tree species still will need persuasive efforts, as Austrian foresters cling to the primacy of Norway spruce and recently also of Douglas fir.	AT
	Cutting of old, huge and vital tree individuals	Foster old, huge and vital tree individuals	Some stakeholders (forest owners) actually tend to cut all huge trees of forest stands. The understanding regarding this BMP will still need the application of persuasive efforts.	Application and execution of the GWP.	Persuasive efforts with regard to all forest owners and stakeholders who still did not sign the GWP contract.	AT
ALPINE PASTURE	Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out faeces	Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings	This BMP is accepted among stakeholders and experts. An adequate water supply for livestock together with fixed trough sites is seen as relevant from all stakeholders.	The implementation of this BMP could be hindered through lacking water resources in karstic terrain or lacking monetary resources for construction works. The latter obstacle could be overcome through contracts with alpine pasture staff.	/	AT
	Grazing of cattle in or close to dolines and sinkholes	Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features	Fences around dolines and sinkholes are potentially accepted through stakeholders, if those are informed accordingly. Hence persuasive efforts will have to be stressed.	Accurate maps with doline and sinkholes on the pasture areas improve the decision process where fencing is necessary. Knowledge transfer and discussion process with the stakeholders (alpine pasture staff).	/	AT
	Unwanted cattle grazing (cattle density and grazing patterns)	Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)	Grazing management is the BMP which actually will face the lowest degree of acceptance among stakeholders, as they will show resistance against changing their management habits. This BMP requires a high level of expertise and willingness to change.	Persuasive efforts in the course of information meetings with alpine pasture staff. The alpine pasture staff has to be convinced that both overgrazing and under-grazing is bad for the economic output of the alpine pasture and that grazing management is the adequate solution for this situation. Also, the positive side-effects on water protection and flood prevention should become aware.	/	AT

7. Conclusions

The main goal of work package T2 is testing of Best management practices (BMPs), which were developed in the frame of the work package T1 and were selected as relevant BMPs for Pilot Actions (PAs). PAs were selected in each partner country in order to reflect conflicts (GAPs) of management & operation of water supply companies and land-use management in recharge/water protection areas. PAs reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes.

The main goal of the work package T2 activities is to set up an Action plan for adaptation of existing land use and flood/drought management practices for the purpose of drinking water protection. This Action Plan presents a road map towards integrated and sustainable drinking water protection:

- Step 1: selection of the most relevant BMPs for particular PA from the work package T1
- Step 2: assessment of status of BMPs in PAs; in case of lacks identified, possibilities of improvement (solutions and recommendations) and implementation were assessed.
- Step 3: various activities were performed for the implementation of BMPs and to find out stakeholder's opinion about selected BMPs.

In representative PAs implementation strategies of BMPs which are important for water protection were elaborated. The relevant Best Management Practices (BMPs) selected for particular pilot action represent the management actions which were considered to solve the problems given through the existing GAPs. Their identification is the result of desk reviews, expert judgments and a deep stakeholder involvement.

GAPs are basically the result/consequence of interactions or contradictions in the space, as the space is a product of its intrinsic characteristics and inputs of human activities/land use. Therefore, all selected GAPs and corresponding BMPs within the PAs of PROLINE-CE project were classified according to which land use type/category the identified problems/challenges are related to: agricultural areas, urban areas, forests and alpine pastures. All GAPs/BMPs related to water management (general, drinking water and flood management) are actually related to all land uses.

Eight GAPs were assigned to ***general water management***, which is related to ***all land uses***. These GAPs draw up shortage in measures, tools, or information, which would be necessary for ensuring a more efficient water management in the given PAs. The Italian partners have developed and currently maintain the Water scarcity and Drought Early Warning System (DEWS), supporting the Drought Observatory/Steering Committee of the Po River Basin and planning processes managed by the Po River Basin District Authority as well. Four GAPs in this group were identified in the Polish PA, where the inadequate monitoring system, lack of information about water hazards, lacking information about ecology of the water reservoir and low level of ecological awareness are presenting main issues. The Austrian and German partners stressed

importance of continuous hydrological monitoring and hydrological/hydrogeological modelling in order to assess groundwater recharge and possible impacts of land use on spring water quantity and quality. The German PA describes the need of collaboration of public, the government as well as experts in development in action plans. This cannot be approached with water management tools, but it regards general water management. Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources was set out in Slovenia as connecting different stakeholders (governmental institutions) and experts from different fields is of vital importance to achieve optimal results.

Three GAPs were classified in the group of ***drinking water management***, which is related to ***all land uses*** and present the pressure on water resources quantity caused by anthropogenic pressure, pipeline leakage, and climate change in the Italian and Croatian PAs. Because of these factors there is a significant freshwater loss which could be mitigated by reconstruction of public water supply network improving the understanding about the potential direct and indirect (e.g. for LUC) impacts of climate change permitting adequate adaptation strategies. In the Slovenian, Polish and Croatian PAs a need to establish drinking water protection zones (DWPZs) arises, therefore those GAPs were merged into one; however, in future steps each country proposed its own approach to solve the problem. Another GAP was identified in the Slovenian PA, which is insufficient inspection of limited/prohibited activities in existing DWPZs.

Issues related to ***flood management***, which is related to ***all land uses***, are the most common in Slovenia, then in Hungary but also noted in Italy and Croatia. The GAPs are describing deterioration in both water quality and quantity and the most important measure proposed is hydrological/ hydraulical modelling. For this flood forecast is very important and the Flood Early Warning System (FEWS), developed and currently maintained by the Italian partner, supporting the Flood Forecast Centre and planning processes managed by the Po River Basin District Authority, is a sample case. In both Hungarian PAs and in Slovenian PA the main problems are (1) potential rinsing of pollutants in flooded areas causing pollution of surface waters and with this linked drinking water sources and (2) interruption of drinking water supply due to flooding of drinking water supply infrastructure, for which registration of potential pollution sources in flood prone areas is needed and flood prevention measures (considering climate change) have to be implemented for ensuring drinking water supply during high waters/flood. The maintenance of river banks vegetation and legalization of illegal construction on flood areas are recognised as problem in Slovenia. In Croatian PAs the flood events pose problem mainly because of lack of maintenance of flood controlling infrastructure, but along with this the Croatian partner proposed non-structural mitigation methods as well.

Six GAPs/BMPs are recognised in ***agricultural areas***. Three of those were identified in Slovenia and Hungary, where the main problem is improper use of pesticides and/or fertilizers and improper manure storage. These anthropogenic factors cause quality deterioration in surface and groundwater, while climate change could worsen the problem. Solution is involving farmers to the Agrarian Environmental Program, frequent monitoring and education of farmers and emphasizing the importance of green products. In Croatian PA increased water demand for irrigation is becoming a serious problem and it will be worsened by the expansion of agricultural

production areas in the future and by climate change. The proposed solution is continuous monitoring of groundwater level and of irrigation water demand. In the German PA continuous changes in agricultural land use pose a great issue for surface- and groundwater quality and quantity.

Six GAPs/BMPs are identified in ***urban areas*** in the Croatian, Slovenian and Hungarian PAs. The main issue is water quality deterioration due to insufficiency or lack of sewage system and wastewater treatment, illegal waste disposal and waste disposal which do not meet environmental standards and unarranged road rainwater discharge. In case of wastewater management one solution is the establishment of wastewater systems (collection and treatment). For wastewater treatment a natural system was proposed, which costs three times less than common purification methods, it does not need any machinery or energy, and it is eco-friendly. The other issue is related to the public or illegal waste disposal, and the improper waste management. The proposed BMPs were raising awareness and educate the public about sustainable waste management. Concerning road rainwater, a collection and treatment of road rainwater discharge, particularly within drinking water protection areas are proposed. Moreover, limitation of salinity of road water run-off has to be determined. In the Slovenian PA also, urban runoff management was proposed as collection of torrential water in wider channels and/or small retention ponds which should be determined by hydrological/hydraulical model.

Six GAPs are assigned to land use ***forestry***. The majority were recognized in Austrian PAs, one in Slovenian PA. They mostly derive from (excessive) anthropogenic activities like clear-cutting, forest road construction, hunting, and conifer tree plantations and have as a consequence e.g. increased surface runoff and decrease of groundwater quality and quantity. Proposed BMPs are the avoidance of clear-cuts, limitation of forest road constructions, sustainable wild ungulate density, and plantation or natural regeneration of diverse autochthonous tree species.

Finally, three GAPs are classified in the group of ***alpine pastures***. They all address grazing management for cattle on karstic alpine pastures to prevent erosion processes and groundwater pollution.

In T2 many conflicts (GAPs) of management & operation of water supply companies and land-use management in recharge/water protection areas were identified. For most of them BMPs were proposed. For BMPs possibilities of implementation were assessed and implementation strategies (procedures) were determined. Implementation of BMPs for drinking water protection and flood mitigation may require:

- adaptation of existing land use management practices with the purpose of drinking water protection,
- adaptation of existing flood/drought management practices with relation to drinking water protection,
- adaptation of policy guidelines.

Additionally, stakeholder's opinion about selected BMPs was acquired. In most cases stakeholders are supporting the proposed BMPs, but mostly they are not in the position to achieve changes in the system.

Identified BMPs within PROLINE-CE project are on different levels, some of them are legislation and governmental oriented and the others are very operational and are based on practitioners (farmers, individuals…).

On the Pilot Action level some BMPs were already implemented in the frame of T2 activities. On the other hand, some BMPs are very complex and require system change or even change of policy guidelines, which are long lasting procedures and cannot be done during the project lifetime. Moreover, implementation of BMPs is limited by economic, administrative, social acceptance or governance issues. Therefore, it is crucial to continue with stakeholder dialogues for implementation of BMPs into daily practice and/or policy guidelines. Hence, further activities have to be focused on implementation of proposed BMPs on the national (guidelines issued by state agencies) and local level (e.g. BMP implemented by public water supplier, municipality). Hence it is crucial that BMPs for drinking water protection and flood mitigation are in concordance with all stakeholders (linked to all land use activities) in the recharge area of the drinking water source.

8. References

PROLINE-CE WORKPACKAGE T2, ACTIVITY T2.1 REPORTS:

- D.T2.1.2 Transnational case review of best management practices in pilot actions. Transnational report

PROLINE-CE WORKPACKAGE T2, ACTIVITY T2.2 REPORTS:

- D.T2.2.3 Pilot action cluster report: PILOT ACTION CLUSTER 1 – Mountain Forest and Grassland Sites
- D.T2.2.3 Pilot action cluster report: PILOT ACTION CLUSTER 2 - Plain Agriculture/ Grassland/ Wetland Sites
- D.T2.2.3 Pilot action cluster report: PILOT ACTION CLUSTER 3 - Special Sites (riparian strips)

PROLINE-CE WORKPACKAGE T2, ACTIVITY T2.3 REPORTS:

- D.T2.3.3 PA reports about climate change issues in pilots. Transnational report

PROLINE-CE WORKPACKAGE T2, OUTPUT REPORTS:

- O.T2.1 PA cluster 'mountain forests and grasslands' – implementation, showcasing best management practices. Output of Cluster 1.
- O.T2.2 PA cluster 'plains: agriculture, grass/wetland' – implementation, showcasing best management practices. Output of Cluster 2.
- O.T2.3 PA cluster 'riparian strips' – implementation, showcasing best management practices. Output of Cluster 3.

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ANNEX 1

- Descriptions of best Management Practices for Pilot Action Cluster 1

▪ Identified GAP provoking action	
GAP short name	**Continued application of the clear-cut technique**
GAP short description	Within PA1.2 there still can be identified the intent of forest owners to apply the clear-cut technique, which endangers water supply security as this silvicultural technique can impact water quality significantly.
▪ Best Management Practice / Management Action	
Name of BMP	**Avoidance of the clear-cut technique (BP MF1)**
Type of land use regarded	Forestry
Location	Inner water protection zone (e.g. extended protection zone of Hinterlug-spring) in PA1.2 and all other locations within PA1.2 where the clear-cut technique is intended to be applied.
BMP description	Avoidance of the clear-cut technique (CCT) at all locations of the PA. This involves the application of the BMP-alternatives, above all the overall strategy to apply continuous cover forestry systems (BP MF2) and all related BMPs, strategies and measures. The BMP is part of the overall *guideline for silviculture within the already decreed water protection zone (WPZ)* of Waidhofen/Ybbs. The guideline passed the municipal council of the city, which forms the basic condition to implement PES (payments for ecosystem services provision) for forest owners within the WPZ. Several knowledge transfer meetings and persuasive efforts were necessary to convince the members of the municipal council from the urgency of an integral drinking source water protection strategy, which is given with the "guideline".
Advantages of this BMP in PA	Avoidance of CCT opens the path for a consistent water protection strategy. It assures the avoidance of the most threatening processes caused by forestry in terms of drinking water protection and flood prevention. In PA1.2 it would open an era of consistent drinking water protection strategies, where the protection of the water resource moves into the centre of interests.
Challenges of this BMP in PA	Resistance of the respective forest owner(s), who wants to continue with the classical clear-cut technique and resistance of the district forest authority which is responsible for the authorisation of such forest management measures. The district forest authority would have to change the business-as-usual attitude and conform to the Federal Forest Act. There was set up a meeting between the respective forest owner, the regional forest authority, representatives of the municipality of Waidhofen/Ybbs and of the water works, scientists and representatives of the Federal Ministry of Sustainability and Tourism to discuss the issue of clear-cut application within the extended protection zone of Hinterlug spring. The meeting will have to solve the issue and avoid the clear-cut application. There were set up several preparation meetings in the course of which the issue was planned and strategic stakeholder interactions, including persuasive efforts, were implemented. Those yielded already first insights of involved persons.

Relevance	Water protection functionality	The BP MF1 is highly relevant for the water protection functionality (WPF) of the forest ecosystems. Through clear-cuts WPF is eradicated for several years (7-10 years or even more), and this within the extended protection zone of the second largest spring in PA Waidhofen/Ybbs.
	Cost of the measure	PES (payments for ecosystem services) provision, dependant on the amount assigned to the forest owner through the municipality. Medium cost level is expectable.
	Duration of implementation	Long term
	Time interval of sustainability	Continuous
Limitations	The most important limiting factor is the business-as-usual attitude of forestry players in Austria, who want to continue with the application of the forestry practice detrimental for water protection and flood prevention.	
Implementation of the BMP in PA	The implementation of the BP MF1 "Avoidance of the clear-cut technique" will be facilitated through PES schemes and talks with forest owners. Actually, some of the forest owners within PA1.2 already conform to this BMP. The others will have to be motivated (stakeholder involvement). Through the resolution of the "guideline" through the municipal council the implementation of the BMP will be facilitated.	
Comments	The resolution of the "guideline" through the municipal council can be regarded as milestone towards the implementation of integral drinking source water protection. The "guideline" is based on the BMPs defined in the course of PROLINE-CE.	
References / sources	Current process of land-use activities within PA1.2, communicated through PP3.	

▪ Identified GAP provoking action	
GAP short name	**Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages.**
GAP short description	Within PA1.2 elevated wild ungulate densities cause browsing, fraying and bark-stripping damages, which lead to instable forest ecosystems. Those cannot provide water protection functionality any more. Hence drinking water supply security can be endangered within a medium-term perspective.
▪ Best management Practice / Management Action	
Name of BMP	**Forest Ecologically Sustainable Wild Ungulate Densities (BP MF9)**
Type of land use regarded	Forestry

Location	The whole drinking water protection zone, hence the whole area of PA1.2.	
BMP description	High wild ungulate densities provoke severe browsing damages on tree seedlings and saplings, fraying damages and bark-stripping damages. Those inhibit the natural regeneration process of whole forest ecosystems or destabilize those. Natural regeneration is the crucial process in forest ecosystems, which has to be given on an optimal level for all present tree species, especially within DWPA. This can only be guaranteed, if the *wild ungulate densities are regulated to a forest ecologically sustainable level, hence providing vital regeneration of all tree species.*	
Advantages of this BMP in PA	Forest ecologically sustainable wild ungulate densities provide the huge advantage that the forest ecosystems can evolve naturally, can grow according to their natural inner dynamics. This includes a vital regeneration layer within the forest stands, encompassing all tree species of the respective natural forest community. It is the most essential precondition for providing the water protection functionality of forest ecosystems. Within PA1.2 the application of this BMP would open the path for a sustainable provision of water protection functionality of the forest ecosystems.	
Challenges of this BMP in PA	The main challenge is related to the actual practice of many forest owners within the PA, which is focusing on trophy-hunting activities and related high wild ungulate stocks. The hunters and forest owners within PA1.2 will have to conform with the regional Hunting Act of the province Lower Austria (Niederösterreich), where all necessary frame-conditions are defined.	
Relevance	Water protection functionality	The BP MF9 is highly relevant for the water protection functionality (WPF) of the forest ecosystems in PA1.2.
	Cost of the measure	Medium costs
	Duration of implementation	Long term
	Time interval of sustainability	Continuous
Limitations	Limitation within the context of BP MF9 is the missing willingness to change behaviour in the field of hunting/rearing “wild” ungulates. Related forest owners show in most of the cases inertia and want to continue their practices devastating for forest ecosystems.	
Implementation of the BMP in PA	The implementation of BP MF9 within PA1.2 can be described as truly challenging task, as it involves the change of management purposes for many forest owners. It can be regarded as success if some of the forest owners within PA1.2 show willingness for change. This could be achieved as one out of the forest players could show disposition for this fundamental change. The PES strategy could also motivate some forest owners to change their management purposes. Also, the regional Hunting Act of the province Lower Austria (Niederösterreich) has to be applied where all necessary frame-conditions are defined.	
Comments	The implementation of BP MF9 is not only within PA1.2 crucial as it is relevant for the whole Austrian forest area.	
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria.	

▪ Identified GAP provoking action		
GAP short name	**Extensive construction of forest roads**	
GAP short description	Within the PA1.2 forest roads are constructed according to the aims of the forest owners; the requirements of integral drinking water protection were not taken into account until now.	
▪ Best Management Practice / Management Action		
Name of BMP	**Limitation of forest roads (BP MF20)**	
Type of land use regarded	Forestry	
Location	The whole Pilot Action (PA1.2).	
BMP description	Forest Road construction and maintenance can cause several adverse impacts on water bodies and should hence be limited in DWPZ. The increase of surface runoff and of water storage loss is the main negative effect. Only in cases, if forest roads are necessary for the stabilization of forest areas, their construction could be considered. In those cases, their construction has to meet strict environmental restrictions.	
Advantages of this BMP in PA	For avoiding potential contaminations and hydrological adverse impacts caused by forest roads, the limitation of their construction within DWPZ is an indispensable need.	
Challenges of this BMP in PA	Forest owners within the PA1.2 have to be confronted with the potential negative effects of forest roads on the karst water bodies. Through information and motivation for BMP application through PES the change of the business-as-usual attitude could be achieved. Furthermore, the actual situation requires an authorization of each forest road construction project according to the Austrian Federal Water Act. This new situation is due to the fact that PA1.2 is now a legally decreed DWPZ (since June 2018). Specific legal frame-conditions are now in force for the whole PA1.2.	
Relevance	Water protection functionality (WPF)	For WPF it is of high relevance that forest roads do not occur in specific areas of the PA and that their overall proportion in DWPZ is rather low.
	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The BMP application is limited to forest owners who are willed to accept the change of management and also the amount of PES as motivating asset. But in the new situation with the legally decreed DWPZ (since June 2018) each forest road construction project will have to be passed and authorized according to the Austrian Federal Water Act. This will make it much more difficult to construct forest roads within the DWPZ (PA1.2).	

Implementation of the BMP in PA	The implementation of BMP MF20 will be dependent on the knowledge transfer process and the related negotiations with the forest owners. It is planned to provide a motivating aspect of PES for those forest areas which are kept free from forest roads. The necessary authorization of each forest road project according to the Austrian Federal Water Act will make it more difficult to construct forest roads within PA1.2.
Comments	Forest road construction is still seen as basic condition for the application of forest management in Austria. This basic condition in terms of willingness to change has to be overcome for DWPZ, especially in PA1.2.
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria. New legally decreed DWPZ in PA1.2.

▪ Identified GAP provoking action	
GAP short name	**Creation of conifer plantations, even within deciduous forest communities (forest hydrotopes)**
GAP short description	Plantation of Norway spruce (*Picea abies*) over all available forest sites within a region, in this case PA1.2.
▪ **Best management Practice / Management Action**	
Name of BMP	**Tree Species Diversity According to the Natural Forest Community (BP MF7)**
Type of land use regarded	Forestry
Location	The whole area of PA1.2
BMP description	Tree species diversity according to the natural forest community (to the forest hydrotope type) guarantees the highest level of stability and resilience. Tree species diversity provides a high level of adaptability, also under climate change. Forest stands created by diverse tree species can utilize a broader scope of the forest soils, if deep-rooting and shallow-rooting trees are growing together. Knowledge about spatial distribution of the natural forest communities (forest hydrotopes) is required for the operational stratification of the DWPA and adaptive forest management. Man-made plantations with non-natural tree species should be transformed gradually to stands dominated by native species, depending on the local experience and legislation. In PA1.2 the whole DWPZ is represented through the Forest Hydrotope Map, defining the optimal tree species set for each forest site.
Advantages of this BMP in PA	In many forest areas tree species diversity according to the natural forest community is a definite advantage, as homogeneous conifer plantations are partially dominating the forest sites in PA1.2. Especially in times of climate change tree species diversity becomes mandatory for achieving forest ecosystem stability. Diversity has also positive side effects, e.g. for conservation purposes. Within PA1.2 the implementation of the tree species diversity according to the Forest Hydrotope Model becomes mandatory. This will increase stability and resilience of the forest ecosystems and hence improve their water protection functionality.

Challenges of this BMP in PA	In some cases of forest owners there can be expected resistance against tree species diversity according to the natural forest community (forest hydrotope type), if the habitual forestry practices had put a strong focus on conifer plantations or other homogeneous timber yield focused plantations. It will be part of stakeholder talks and negotiations to overcome this hindrance and to convince the forest owners from the necessity to adapt tree species diversity to the site conditions. Through the resolution of the "guideline" by the municipal council the implementation of the BMP will be facilitated, as the PES scheme will now be available.	
Relevance	Water protection functionality	The application of this BMP is of crucial importance to improve the water protection functionality of the forest ecosystems within the PA1.2, as it will provide stability and resilience for the related forests.
	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The potential limitation for this BMP is, if forest owners are not willed to cooperate with the municipality. Almost all forest owners within the DWPZ will be cooperative within the context of PES schemes available, but also exceptions can be expected.	
Implementation of the BMP in PA	Some forest owners within PA1.2 actually are allowing the natural regeneration of the natural tree species set. Others still are planting Norway spruce on their forest sites. Those have to be convinced from the need for tree species diversity through knowledge transfer and the application of PES schemes. This process is facilitated through the resolution of the "guideline".	
Comments	The water protection functionality of the forest ecosystems within PA1.2 depends on the creation of diverse forest stands where the natural tree species set is implemented.	
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria.	

▪ Identified GAP provoking action	
GAP short name	**Cutting of old, huge and vital tree individuals**
GAP short description	Huge, old and vital tree individuals in most of the cases are cut for timber yield as those trees provide a considerable amount of biomass for any given purpose.
▪ Best management Practice / Management Action	
Name of BMP	**Foster old, huge and vital tree individuals (BP MF11)**
Type of land use	Forestry

regarded		
Location	The whole area of PA1.2.	
BMP description	Old, huge and vital tree individuals carry excellent genetic information. They can supply younger and smaller tree individuals with nutrients via their common mycorrhizal network. Thereby they provide a substantial contribution to forest stand stability. Hence, they have to be selected and protected, so that they can provide their services as long as possible. Especially within PA1.2 the application of this BMP could contribute significantly to improved forest ecosystem stability.	
Advantages of this BMP in PA	The genetic information provided by old, huge and vital tree individuals has a high value for the sustainability of forest ecosystems. Old and huge tree individuals can provide stability for the whole forest stand (in a quasi-mechanical way) and are also important for the nutrition of young trees (including the regeneration phase), who may receive nutrients from the old trees via the mycorrhiza-interconnected root system. In PA1.2 stability and resilience of the forest ecosystems could be improved through the implementation of this BMP.	
Challenges of this BMP in PA	Forest owners in general cut old and huge tree individuals for timber sale. Within PA1.2 forest owners will have to be informed about the advantages of this BMP and also will have to be motivated to implement it through the application of the PES scheme. Now the basic condition for the implementation of PES, the "guideline", was passing through the municipal council.	
Relevance	Water protection functionality	The application of this BMP is of crucial importance within PA1.2, as it will increase stability and resilience for the related forest ecosystems.
	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The potential limitation for this BMP is again given, if forest owners are not willed to cooperate.	
Implementation of the BMP in PA	The implementation of this BMP will need motivation, knowledge transfer, and training for the related stakeholders. Protection of those tree individuals requires specific silvicultural knowledge. This process is again facilitated through the resolution of the "guideline", as it will allow the implementation of the PES scheme.	
Comments	---	
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria. Koeck, R., Hochbichler, E. (2012). Das Wald-Hydrotop-Modell als WSMS-Werkzeug im Quellenschongebiet der Stadt Waidhofen/Ybbs. Report in the course of the CC-WaterS project: https://www.bmnt.gv.at - search for: "ccwaters"	

▪ Identified GAP provoking action		
GAP short name	**Land use activities causing changes in groundwater (GW) recharge and quality (e.g. quarries causing decrease of GW recharge; vulnerability of GW due to cattle grazing)**	
GAP short description	Occurrence of surface runoff and corresponding erosion processes can lead to input of solutes/contaminants into a karst system that may affect spring quality. The longer the flow paths the more likely erosion and solute input into the system occur. A spatially distributed hydrological model is needed to identify surface runoff patterns at different hydrological conditions, e.g., during summer storms, in a catchment.	
▪ Best management Practice / Management Action		
Name of BMP	**Continuous monitoring of relevant hydrological data and hydrological/hydrogeological modelling (surface run-off - spring dynamic modelling)**	
Type of land use regarded	General water management – the hazards. Pressures and impacts of various land use activities can be assessed	
Location	Zeller Staritzen and central Hochschwab	
BMP description	Applying a rainfall/run-off model based on observed and defined processes as well as measured and mapped parameters the spatial patterns of surface run-off and infiltration will be determined. The results are used for optimizing land use management and formulating water safety plans in a risk-based procedure by comparing the patterns with potential contamination loads, e.g. from cattle grazing.	
Advantages of this BMP in PA	Infiltration and surface run-off is important to assess the vulnerability of the groundwater	
Challenges of this BMP in PA	Implementation of different parameters in the model.	
Relevance	Water protection functionality	High
	Cost of the measure	Ãpp. €150.000,-
	Duration of implementation	til 2019/04
	Time interval of sustainability	Basic information for catchment management; sustainability not limited
Limitations	Can the simulations reproduce the observed spring dynamics	
Implementation of the BMP in PA	Implementation is in progress	
Comments		
References / sources	Report: modelling Hochschwab – spatial patterns of surface run-off	

■ Identified GAP provoking action		
GAP short name	**Erosion processes around water troughs for cattle due to open soils without vegetation cover, as well as washing out faeces.**	
GAP short description	Erosion takes place where water troughs for cattle are placed in concentrated manner. Cattle is frequently trampling the soils around the troughs, hence destroying the vegetation cover there. Erosion dynamics and concentrated amounts of faeces are the result of this situation.	
■ Best management Practice / Management Action		
Name of BMP	**Placing of water troughs for cattle more frequently, avoiding concentrations of cattle / Concrete basements for the troughs and their surroundings**	
Type of land use regarded	Subalpine and alpine pastures (mountain grasslands)	
Location	Zeller Staritzen and Central Hochschwab	
BMP description	Water troughs are an important tool for the subalpine and alpine pastures within karstic mountains, as water has to be provided there for grazing livestock (cattle). In order to avoid the creation of erosion dynamics and concentrations of faeces, more troughs should be provided and distributed strategically over the whole alpine pasture. This should ensure enough drinking water for the cattle, bring the cattle close to envisaged areas of the pastures and avoid erosion dynamics. The addition of concrete plates (concrete basements) for the troughs, also helps to avoid erosion dynamics.	
Advantages of this BMP in PA	Avoiding erosion dynamics within the context of alpine pastures is essential for drinking water supply security. Hence it is of interest to implement an alpine pasture strategy. Part of such a strategy is the spacing of the water troughs for cattle and also the construction of concrete basements in cases where this is possible. The avoidance of erosion and of concentrated cattle faeces around those troughs is the main advantage of this BMP.	
Challenges of this BMP in PA	Challenging is that the construction of concrete basements for the troughs is not easy at many locations of the alpine pastures. Another challenge is the lack of water within the karstic environment of the alpine pastures in PA1.1. Hence the sites where water troughs for cattle can be placed are naturally limited.	
Relevance	Water protection functionality	High
	Cost of the measure	Low-Medium
	Duration of implementation	Continuous
	Time interval of sustainability	Immediate until the time-span of the duration of implementation
Limitations	Water troughs for cattle can only be placed on sites where water is available.	
Implementation of the BMP in PA	The implementation of this BMP has been fulfilled for the major part of PA1.1, in some cases the implementation is on the way.	
Comments	Water for cattle is an essential question within karstic alpine pasture areas.	

	The lack of water in the higher elevations of these mountain ranges creates the need to solve the question of water provision. Within this decision-space also the issues of drinking water supply security have to be integrated. Hence a strategical spacing of the water troughs becomes a mandatory BMP.
References / sources	Gregory Egger 2018

■ **Identified GAP provoking action**		
GAP short name	**Grazing of cattle in or close to dolines and sinkholes**	
GAP short description	As dolines and sinkholes have direct connection to the karst aquifer, grazing of cattle within or close to those karstic features constitutes a high risk for source water contamination.	
■ **Best management Practice / Management Action**		
Name of BMP	**Fencing of dolines and sinkholes in order to keep cattle in distance from those karstic features**	
Type of land use regarded	Subalpine and alpine pastures (mountain grassland)	
Location	Zeller Staritzen and central Hochschwab	
BMP description	At all active pastures within the Hochschwab massif the karstic features dolines and sinkholes are fenced out in order to minimize the risk of source water contamination with faeces stemming from cattle or other grazing livestock. The fences have to be kept in functional condition and hence have to be checked through the mountain pasture staff.	
Advantages of this BMP in PA	The protection of the karstic aquifers from direct infiltration and percolation of faeces stemming from grazing livestock (above all cattle) is central part of the drinking water supply security strategy.	
Challenges of this BMP in PA	One challenge is that in case of strong precipitation events faeces of grazing livestock may be washed into dolines and sinkholes, despite the fact that the animals are fenced out from those features. This challenge can be faced through construction of derivation dams.	
Relevance	Water protection functionality	High
	Cost of the measure	Low
	Duration of implementation	Continuous
	Time interval of sustainability	Immediate until the time-span of the duration of implementation
Limitations	Only well-known karstic features can be fenced out from grazing livestock. If there should exist unknown karstic features, the BMP cannot be applied.	
Implementation of the BMP in PA	The implementation of this BMP has been fulfilled for the major part of PA1.1, in some cases the implementation is on the way.	
Comments	Despite the fact that alpine and subalpine pastures are in contradiction to drinking water supply security, the implementation of this BMP helps to reduce the risk of contamination of the source waters. The existence of	

	subalpine and alpine pastures is related to old servitude rights. Hence the BMP has to be highlighted as significant measure for water suppliers.
References / sources	Gregory Egger 2018

■ **Identified GAP provoking action**		
GAP short name	**Unwanted cattle grazing (cattle density and grazing patterns)**	
GAP short description	Most of the alpine pasture areas within PA1.1 do not have a strategic grazing management system at the moment. Overgrazing or undergrazing are the unwanted result of this situation. Potential erosion dynamics or degradation oft he pasture quality can be caused through this situation.	
■ **Best management Practice / Management Action**		
Name of BMP	**Grazing management for cattle on alpine pastures (temporally limited grazing on different locations)**	
Type of land use regarded	Subalpine and alpine pastures (mountain grassland)	
Location	Zeller Staritzen and central Hochschwab	
BMP description	Most of the alpine pasture areas within PA1.1 do not have a strategic grazing management system at the moment. Its implementation can be regarded as major land use management adaptation. Grazing management requires strategic planning, the placing of fences and the punctual change of the grazing cattle from one to the next fenced part of the alpine pasture.	
Advantages of this BMP in PA	This BMP provides the advantage that the alpine pasture area is used efficiently. Erosion processes can be diminished or avoided but also the degradation of the pasture quality through under-grazing is avoided.	
Challenges of this BMP in PA	The challenge of this BMP is the necessity of a strategic planning process which requires detailed knowledge about the pasture quality on the alpine pasture and the consequent implementation through the strategic placing and spacing of fences.	
Relevance	Water protection functionality	High
	Cost of the measure	Low
	Duration of implementation	Continuous
	Time interval of sustainability	Immediate until the time-span of the duration of implementation
Limitations	The BMP cannot be applied if the alpine pasture staff is not willed to learn and improve the management procedures.	
Implementation of the BMP in PA	The implementation of this BMP should be fulfilled for the whole area of PA1.1. At the moment the implementation is nowhere on the way.	
Comments	---	
References / sources	Gregory Egger 2018	

ANNEX 2

- Descriptions of best Management Practices for Pilot Action Cluster 2

▪ Identified GAP provoking action		
GAP short name	**No complex evaluation of water hazards**	
GAP short description	There are no methods for complex water hazard evaluation in the area of Kozłowa Góra reservoir catchment	
▪ Best management Practice / Management Action		
Name of BMP	**Complex catchment modelling and assessment of hazard**	
Type of land use regarded	General water management (all land uses)	
Location	Brynica River sub-basin	
BMP description	Catchment modelling, using Soil Water Assessment Tool, will provide complex information about possible water quality and quantity threats and make prediction of water quality through scenario's simulations included i.e. CC, wastewater discharges, using more fertilizers and so on.	
Advantages of this BMP in PA	Complex information about water resources, quick reaction on possible impact	
Challenges of this BMP in PA	Good quality input data	
Relevance	Water protection functionality	High
	Cost of the measure	Medium (depending on input data)
	Duration of implementation	Medium
	Time interval of sustainability	
Limitations	Low quality of input data – little possibility to calibrate model results.	
Implementation of the BMP in PA	SWAT model of Brynica catchment is prepared to simulate possible scenarios and quality water prediction.	
Comments		
References / sources		

▪ Identified GAP provoking action	
GAP short name	**Small number of sampling locations and sampling campaigns (water monitoring)**
GAP short description	In the catchment area there is only one water gauge, on the Brynica River, where the measurements are carried on. There is lack of additional measurements spots, located on inlet streams what cause gap in information about discharge water amount or loads of pollution.
▪ Best management Practice / Management Action	
Name of BMP	**Establishment of constant, multi-aspects water monitoring in the catchment**

	scale	
Type of land use regarded	General water management (all land uses)	
Location	Plain land (Brynica River sub-basin)	
BMP description	In the PA2.2 Kozłowa Góra area there is a lack in surface water monitoring (only one water gauge is located) there is a need to extend the surface water monitoring network for wider information about water quality and water discharge value concerns all tributaries to Brynica River.	
Advantages of this BMP in PA	• Complex information of surface water discharge and water quality • Data can be used as base for estimation of pollution loads to the drinking water reservoir. • Information will be used as model input and model calibration data.	
Challenges of this BMP in PA	Make the BMPs obligatory to implement and conducting in the future.	
Relevance	Water protection functionality	high
	Cost of the measure	Medium / high
	Duration of implementation	long
	Time interval of sustainability	long
Limitations	-	
Implementation of the BMP in PA	-	
Comments	-	
References / sources	-	

▪ **Identified GAP provoking action**	
GAP short name	**Low level of ecological awareness of society**
GAP short description	Actions, undertaken by the society, such as inappropriate water, wastewater and waste management, indicate a low level of ecological awareness within society.
▪ **Best management Practice / Management Action**	
Name of BMP	**Raising awareness and increasing knowledge**
Type of land use regarded	General water management (all land uses)
Location	Brynica River sub-basin
BMP description	Set of society and stakeholders' meetings to raise awareness and increase their knowledge.

Advantages of this BMP in PA	Direct contact with society to raise awareness and increase their knowledge.	
Challenges of this BMP in PA	Gathering and motivating the community for discussion and future actions.	
Relevance	Water protection functionality	High
	Cost of the measure	Low - medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Little public interest in the subject	
Implementation of the BMP in PA	Organisation of society discussion panels and stakeholders' workshop.	
Comments	Biggest challenge is to reach small, closed communities.	
References / sources	-	

▪ Identified GAP provoking action		
GAP short name	**No information about ecology of water reservoir**	
GAP short description	There is a lack in information about ecology of water reservoir Kozłowa Góra concerning whole ecosystem and possibility of the reservoir to i.e. self-cleaning.	
▪ **Best management Practice / Management Action**		
Name of BMP	**Establishment of an ecology model of water reservoir**	
Type of land use regarded	General water management (all land uses)	
Location	Kozłowa Góra reservoir	
BMP description	Establishment of ecology model of water reservoir gives a complex information on reservoir's ecosystem (including flora and fauna) and factors possibly have an influence on water quality and water quantity.	
Advantages of this BMP in PA	Complex information on water ecosystem	
Challenges of this BMP in PA	Collecting good quality data.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium (depending on input data)
	Duration of implementation	Medium
	Time interval of sustainability	
Limitations	Low quality data use to set up the model and to calibrate it.	

Implementation of the BMP in PA	Building ecological model of Kozłowa Góra reservoir for better understanding processes in the reservoir's water.
Comments	-
References / sources	-

▪ Identified GAP provoking action		
GAP short name	**Individualistic (Non-Sectoral) approach to common problematics regarding protection of drinking water resources**	
GAP short description	Ministries, agencies and experts do not jointly develop measures for drinking water protection, but each "fights their own battle" and for interests, which are not necessarily in favour of protection of drinking water resources. Lack of co-operation and willingness to negotiate in favour of protection of drinking water resources.	
▪ Best management Practice / Management Action		
Name of BMP	**Joined and integrated management of drinking water resources (horizontal and vertical co-operation)**	
Type of land use regarded	General water management (all land uses)	
Location	Slovenia	
BMP description	Ministries, experts and public independently approach to common problematics, such as drinking water resources protection, instead of combining their knowledge and experiences to find unified and optimal solutions. Therefore, more communication and cooperation are needed horizontally (inside ministries, among ministries, among experts, etc.) and vertically (panel discussions/round tables with experts and governmental bodies). More interactions (discussions, negotiations, finding solutions for sectors on which drinking water protection measures affect (trying to find win-win situations)) are needed for achieving the main goal – drinking water protection.	
Advantages of this BMP in PA	In brief this is a general problem and not only specifically for this problematic.	
Challenges of this BMP in PA	A challenge is to change organisation strategy of drinking water sources management, among all within governmental institutions.	
Relevance	Water protection functionality	Very High
	Cost of the measure	Low
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Expected limitations are lack of political will and also resistance to adaptation of many institutions.	

Implementation of the BMP in PA	Communication and cooperation horizontally (inside ministries, among ministries, among experts, etc.) and vertically (panel discussions/round tables with experts and governmental bodies) is absolutely necessary. This is a general problem and sadly we do not know the solution of solving this problem. It might be a good step forward if we would raise governmental awareness of the problem.
Comments	/
References / sources	The BMP derives from experiences.

▪ Identified GAP provoking action	
GAP short name	**Lack of public engagement in development of action plans**
GAP short description	Despite some approaches in the legal framework of how to engage the public in the development of action plans, more flexible and integrative concepts of how to involve public stakeholders in the decision-making procedure are missing.
▪ Best management Practice / Management Action	
Name of BMP	**Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach**
Type of land use regarded	General water management (all land uses)
Location	Plain area
BMP description	Public engagement should take place already at early steps of the decision process. The development of action plans for the implementation of protection plans should be carried out in close cooperation with land owners that are directly affected by future regulations in the delineated protection zones. Possible actions and measures should be elaborated based on land owner's possibilities to use existing structures/facilities/machinery. However, a tool is needed on which stakeholders can jointly elaborate site-specific action plans and which can be used to evaluate the effects of planned actions at the same time. Therefore, we propose hydrological models as BMP here; the model can be used as a participative approach given a graphical user interface (such as FREEWAT) and to test how any kind of changes (such as land use changes) affect the hydrological processes in the considered area. Moreover, a fully coupling between monitoring and model can provide a powerful tool for on-the-fly decision making. Modeling results can provide relevant information for stakeholders regarding water quantity and quality and support decision makers in the implementation procedure for final management plans. In close cooperation between land owners and decision-makers, site-specific solutions can be found which can reduce the trade-offs between all stakeholders.
Advantages of this BMP in PA	Engaging local stakeholders and affected land owners in the process of finding adequate, site-specific solutions can increase the acceptance of the finally proposed measures and potentially decrease the costs for compensation measures. Due to their daily business, land owners know best about potentials of how to restructure or manage their field operations. The hydrological model sets

	a joint framework all stakeholders may work with (given a short introduction) and helps to evaluate the impacts of a planned management practice. The proposed measure can significantly reduce the existing mistrust between authorities and land owners.	
Challenges of this BMP in PA	Little involvement generally leads to less acceptance of planned measures that could be decreased if site specific actions would be planned in cooperation with the affected land users. In this context, the stakeholders noticed that when their interests are affected by the implementation of a measure, then local stakeholders show a higher acceptance than those who just operate their business in the respective region (and live somewhere else). Local stakeholders feel more the problematic issues about planned measures and recognize the advantage of a solution, while stakeholders who are not so much connected to the territory do not feel the related danger/problem.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium
	Duration of implementation	MEDIUM-Short
	Time interval of sustainability	Long
Limitations	No	
Comments	----	
References / sources	Hanson et al. (2014), FREEWAT project (www.freewat.eu)	

▪ Identified GAP provoking action	
GAP short name	**Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)**
GAP short description	Climate change in form of droughts, floods, shorter winter season with reduced snow cover, in general change of the timing of seasonal events etc., will drastically affect freshwater resources. This problem is enhanced by high losses in water supply in Croatia – 42% national average, while pilot area is one of the worst supply areas in the country – with losses up to 80%.
▪ Best management Practice / Management Action	
Name of BMP	**Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)**
Type of land use regarded	Drinking water management
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	Croatia has recently developed drafts for CC Adaptation Strategy 2040-2070 and Action Plan 2019-2023 which serve as a basis for future mitigation action against CC. Roughly speaking, measures be divided into 2 categories (Rubinić, 2017):

	• Initial measure – to minimize the presence of negative anthropogenic pressures. • Administrative measures: rationalization of water consumption and water re-use wherever possible; promoting alternative sources of water; spatial planning measures for mitigation of flood effects in flood prone areas; monitoring and modelling projections; improvements in legal regulations. • Structural measures: reduction of losses from water supply network; construction and revitalization of accumulation structures; construction of thresholds in the basin to stabilize the water level in river/lake bed and the surrounding aquifer; construction of retention objects in flood prone areas; control of surface runoff in urban environment (construction of separate systems for meteoric water and sewage); construction of green retention and infiltration zones, green roofs, urban retention and accumulation.	
Advantages of this BMP in PA	A timely reaction and development of CC adaptation plans benefits all ESS and population, therefore, it is a prerequisite for freshwater availability of future generations. Furthermore, adaptation plans, and strategies could save money in the long run due to prevention, instead of intervention.	
Challenges of this BMP in PA	Raising awareness on the climate change and adaptive management practices among relevant stakeholders. Financial support in form of subsidies for adaptation.	
Relevance	Water protection functionality	High
	Cost of the measure	High
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Lack of funds, long implementation periods, low awareness of key stakeholders	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments	-	
References / sources	Ministry of Environment and Energy project - http://prilagodba-klimi.hr/ Drinkadria - http://www.drinkadria.eu/ CC Waters - http://www.ccwaters.eu/	

▪ Identified GAP provoking action	
GAP short name	**Drinking water protection zones (DWPZs) do not exist**
GAP short description	The lack of DWPZs pose serious problems in ensuring water quality on Pilot Action areas in Slovenia, Poland and Croatia (South Dalmatia).

	Slovenia: In current Spatial plan there is reserved area for planned Water field without surrounding protected areas with restrictions, which are of major importance for drinking water protection source. **Poland:** Kozłowa Góra reservoir is a drinking water source for the Upper Silesia region which has no Drinking Water Protection Zone established **Croatia**: The sanitary protection zones in the area of research have been proclaimed only for the Prud spring and for smaller springs of Grebica, Vrutak, Orašje and Izbitac located in the northwestern edge of the investigated area. For other springs used for water supply, sanitary protection zones have not yet been established. Although every spring/well in Croatia used for water supply should have defined sanitary protection zones, the existing Ordinance on determination of sanitary protection zones still does not have legal authority and it is impossible to initiate court proceedings in cases where no sanitary protection zones are established.
▪ **Best management Practice / Management Action**	
Name of BMP	**Determination (e.g. hydrogeological modelling) and establishment of DWPZs**
Type of land use regarded	Drinking water management
Location	Slovenia, Poland, Croatia
BMP description	**Slovenia**: DWPZ areas were determined with modelling and will be proposed to be included in the Spatial plan of the Municipality of Ljubljana. Drinking water protection zones include restrictions, such as: prohibition of buildings construction, no waste disposal, no storages of dangerous substances, prohibition of use of pesticides and fertilizers, salting undrained surfaces like yards and gravel roads, etc. DWPZs are of major importance for drinking water protection source, therefore restrictions should already be implemented. **Poland**: Proposal of establishment of DWPZ in the area of Kozłowa Góra reservoir. The proposal assumed the limitation in land use and land management in the area of established zone. **Croatia**: Determination of drinking water protection zones (DWPZ), obligatory measures and limitations that are conducted in them as well as the deadlines for decisions on protection and the process of making these decisions are governed by The Ordinance on the conditions for the establishment of sanitary protection zones (Official Gazette No. 66/11 and 47/13). Established sanitary protection zones are implemented into spatial planning documents (spatial plans of counties, cities or municipalities). Within recent studies, it has been established that the Vrgoračko polje, which is intensively farmed, belongs to the second zone of sanitary protection (according to the valid Ordinance). This fact should encourage the local population to turn to ecological farming because such production prohibits the use of most mineral fertilizers and almost all pesticides whose use is prohibited.
Advantages of this BMP in PA	SI: Protection of potential drinking water source for Ljubljana area. PL: Establishing limitation in land use will lead to decrease in pollution loads to

	water environment and, thus, improve reservoir water quality. HR: For the purpose of protection of surface and groundwater resource and unique and valuable ecosystems dependent on water, protected areas are established by the Water Act and other legislatives for the common good of the community. By protecting the drinking water sources, strategic natural resources are secured.	
Challenges of this BMP in PA	SI: The main challenge presents including DWPZs into Spatial plan of the Municipality of Ljubljana. PL: Main challenge will be raising awareness of the society since human activities is a main factor for water contamination. HR: Since the Ordinance on determination of sanitary protection zones does not have any legal authority, the greatest challenge would be to implement penalties.	
Relevance	Water protection functionality	High/ Very High
	Cost of the measure	Low (SI), (PL), Medium (HR)
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	SI: Expected limitations are lack of political will. PL: Possible long-lasting administration procedure after application HR: Unwillingness of people to cooperate and no legally binding obligations to abide by pose a serious threat to the administration of the measures.	
Implementation of the BMP in PA	SI: - PL: Implementation in the project lifetime based on raising awareness by discussion panels with residents, educational campaign. In near future the document will be applied for implementation at water management authority level. HR: It has not been implemented yet and for its success needs educational activities for the local community.	
Comments	/	
References / sources	The BMP derives from bad practice.	

▪ Identified GAP provoking action	
GAP short name	**Lack and not effective control over implementation restrictions for existing DWPZ**
GAP short description	There is lack of control over implementation of DWPZ restrictions, which is mostly not effective due to lack of co-operation among sectors (Environment, Health, etc) and due to low penalties (in case they are issued at all).
▪ Best management Practice / Management Action	
Name of BMP	**Strict implementation and inspection of DWPZ restrictions**

Type of land use regarded	Drinking water management	
Location	Slovenia, central part, PA area Dravlje valley in Ljubljana	
BMP description	In the narrowest area of water protection zones regulations governing the construction of buildings is prohibited, with the exception of construction intended for the public supply of drinking water. It is prohibited to carry out activities in the catchment area that could endanger the ground water quality, such as: the disposal of waste, the storage of dangerous substances, the use of pesticides and fertilizers, salting undrained surfaces like yards and gravel roads, vehicle maintenance and parking of construction machinery, except in the case of activities for the public supply of drinking water. Hence well directed restrictions for DWPZ area there is no inspection and no control over its implementation. Implementation should be supervised by inspectors of the Ministry of Agriculture, Forestry and Food.	
Advantages of this BMP in PA	With restrictions truly implemented, quality of drinking water supply would not be endangered. In the DWPZs Agricultural Advisory Services encourage farmers to organic farming without pesticides and fertilizers. Because of smaller harvest, farmers get money compensations.	
Challenges of this BMP in PA	Ministry of the environment and spatial planning should assign supervisors to control locals and local farmers and their acts in DWPZs.	
Relevance	Water protection functionality	Very High
	Cost of the measure	Medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	This limitation is a lack of supervising of implemented mechanisms.	
Implementation of the BMP in PA	Regular inspection and control should be performed over the restrictions for DWPZ area by the inspectors of the Ministry of Agriculture, Forestry and Food. How to implement this legislation will be discussed with the Chamber of Agriculture and Forestry of Slovenia on the future meeting. Also, informational system should be upgraded and some brochures about DWPZ areas restrictions spread among locals.	
Comments	/	
References / sources	BMP derives from bad practice. Decree on the water protection area for particular aquifer in Slovenia, which is based on Rules on criteria for the designation of a water protection zone.	

▪ Identified GAP provoking action	
GAP short name	**Pollution sources in flood prone areas are not known / identified**
GAP short description	Identification of the potential pollution sources locations in flood areas is a challenging task.

▪ Best management Practice / Management Action		
Name of BMP	**Register of potential point pollution sources on flood areas identified in PA**	
Type of land use regarded	Flood management	
Location	Slovenia	
BMP description	Aggregated list of all potential point pollution sources (industry, heating oil tanks in households, etc.) is needed for efficient incident management in case of flood event. Some of the potential pollution sources are known (especially industrial establishments under Seveso Directive), but there is among others no list of heating oil tanks in households, which are still quite common in Slovenia. Some non-SEVESO and non – IED facilities are handling nevertheless significant amounts of polluting substances on flood prone areas. This includes also households storing small amount of chemicals, and especially heating oil tanks, that might leak during the flood event. Potential pollution sources are exceeding current requirements of national legislation (Slovenia: Environmental protection act O.G. 39/2006) and EU requirements SEVESO Directive, IED Directive 2010, E-PRTR Register.	
Advantages of this BMP in PA	It is very important to know all the potential pollution locations to implement prevention measures in the case of floods (i.e. flood proofing) and improve response of intervention forces during the flood events.	
Challenges of this BMP in PA	Data collection, data validation and maintenance, legal framework for the data collection.	
Relevance	Water protection functionality	High
	Cost of the measure	Low
	Duration of implementation	Mid term
	Time interval of sustainability	Long term
Limitations	Household inventory and data privacy.	
Comments	Challenge is how to adopt and enforce legislation enabling access to data and reporting on the amount of stored pollution substances on flood prone areas. Maintenance of the dataset. After the identification it is important to raise awareness and provide measures leading to improvements.	
References / sources	Flood event in Ljubljana in 2010.	

▪ Identified GAP provoking action	
GAP short name	**Surface water intrusion in the well**
GAP short description	Exposure of wells during flood events

▪ Best management Practice / Management Action		
Name of BMP	**Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model**	
Type of land use regarded	Flood management	
Location	Slovenia in cases of wells in flood prone zones.	
BMP description	Many water supply wells are on flood-prone plains, so the wells heads should be constructed as sealed in a way to prevent the surface water intrusion in the well during the flood event.	
Advantages of this BMP in PA	Surface water cannot be mixed with groundwater, which is used for drinking water supply source, during floods. Water supply is not interrupted during the flood event.	
Challenges of this BMP in PA	No specific challenges are foreseen.	
Relevance	Water protection functionality	High
	Cost of the measure	Low
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	No limitations are foreseen.	
Comments	The information on the type of the well (sealed) should be emended to the data specification according to INSPIRE directive. Recommendations on the level of strategic guidelines resulting from the PROLINE-CE project, implementation on the level of national legislation requesting obligatory sealed well heads for the water supply wells on flood prone areas. Awareness rising and education process on this risk and potential measure.	
References / sources	Flood event in Celje in 1990 and flood event in Ljubljansko barje (Brest - Iški vršaj) in 2010.	

▪ Identified GAP provoking action	
GAP short name	**Water balance status and effective mitigation measures are not known (identified)**
GAP short description	Identification of problematic locations and possible solutions is done by modelling.
▪ Best management Practice / Management Action	
Name of BMP	**Water balance status will be determined with Hydrological / Hydraulical modelling**
Type of land use regarded	Flood management

Location	Slovenia	
BMP description	A hydrologic model is a simplification of a real-world system (e.g., surface water, groundwater) that aids in understanding, predicting, and managing water resources. Hydrological/hydraulical models are developed to analyze, understand, and explore solutions for sustainable water management, in order to support decision makers and operational water managers. Hydrological models also allow us to do scenario analysis.	
Advantages of this BMP in PA	Based upon the modelling results mitigation measures will be proposed for the improved protection of potential drinking water source.	
Challenges of this BMP in PA	To make as good as possible simplification of a real-world.	
Relevance	Water protection functionality	Medium
	Cost of the measure	Low
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	Availability and quality of data - there are no active measures of the river discharge.	
Comments	-	
References / sources	The BMP derives from experiences.	

▪ Identified GAP provoking action	
GAP short name	**Increased contamination of surface drinking water resources during flood events**
GAP short description	In case of high water, with increasing water level, the problems with the operation of the Szolnok surface waterworks are intensified
▪ Best management Practice / Management Action	
Name of BMP	**Reduction of flood effects at the surface drinking water resources**
Type of land use regarded	Flood management
Location	Tisza, Szolnok, Surface Drinking Water
BMP description	The Szolnok Surface Water Plant supplies 8 settlements besides Szolnok with drinking water, with a standard capacity of 60,000m^3/day. Tisza is a river with extreme water regime and its water quality varies widely. The surface water of the river Tisza is treated in a water purification plant, which is able to adapt to the changing raw water quality requirements with its versatile cleaning elements and grades. The security of water supply was also created in the case of emergency water pollution in Tisza, when the water of the Tisza is unsuitable for drinking water.

	Spare water base for Alcsi Holt-Tisza. The reserve water base can provide enough water for 2-3 weeks with the 50% capacity of the water purifier. The production of deep wells can also assist in the supply of drinking water if necessary. The Nagykunsági flood-reducing reservoir in the upper section of Tisza over Szolnok reduces the height of the flood level and makes the flood event more balanced. The Waterworks is prepared for operation under floods for which a flood management regulation is required.	
Advantages of this BMP in PA	Reducing flood peaks also reduces the operational risk of the surface drinking water resources. At the surface preparation is indispensable for floods and the management of water quality changes, especially at the extreme water regime of the Tisza. As a result of the preparedness and the established water purification technology, the supply of drinking water in case of bankfull is undisturbed. Flood reservoir makes water regime more equitable.	
Challenges of this BMP in PA	Extreme water regime and the resulting water quality effects pose challenges to the production of appropriate quality drinking water. Besides reducing the flood peaks, water supply facilitates more equitable water regime in the case of small waters.	
Relevance	Water protection functionality	high
	Cost of the measure	high
	Duration of implementation	long term
	Time interval of sustainability	long term
Limitations	High cost of measure	
Implementation of the BMP in PA	The operator of the Szolnok Surface Waterworks has developed the operating system for bankfull and small water, so Waterworks can supply its drinking water service in these extreme situations. The flood reservoirs along the Tisza River reduce the flood peaks, it affects the Szolnok Surface Waterworks. Water storage facilities will also available in the Nagykunság reservoir. The water purification technology is suitable for the treatment of changing water quality.	
Comments	Revising flood management in context of future climate conditions	
References / sources	-	

▪ Identified GAP provoking action	
GAP short name	**Periodic field flooding**
GAP short description	Large part of Imotsko polje is regarded as an area of potentially significant flood risk. Around 70% of area is exposed to periodic floods of variable intensity and duration. South-eastern part of Imotsko polje is exposed to flooding primarily due to the operation of HPP Peć-Mlini in neighbouring Bosnia and Herzegovina.

	Several facilities were built for flood mitigation (Prološko blato retention, Ričica accumulation, channels). Considering large catchment area (and Vrljika river as main recipient of all internal waters in Imotsko polje), non-structural flood defence measures (e.g. protective forests) could only have limited effect, especially during severe meteorological events (FAO and CIFOR, 2005). Despite structural flood defence measures, Vrgoračko polje is still exposed to significant flood risk. Tunnel which connects Rastok (upper polje) to Jezero (lower polje) is not in function, so floods occur frequently during rainy season. Lower polje (Jezero) drains excess waters towards Baćina lakes via Krotuša tunnel, and then the excess water from the lakes is drained towards the sea via another tunnel.
▪ **Best management Practice / Management Action**	
Name of BMP	**Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures**
Type of land use regarded	Flood management
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	In order to reduce property and agricultural damage caused by floods, it is necessary to reconstruct and regulate existing infrastructure. This is partly intended with project IM-BE Field (new irrigation system in Imotsko-Bekijsko polje). Focus should be put on reconstruction of Pećnik tunnel and downstream regulation (Trebižat/Tihaljina river). In order to achieve this, cross-border cooperation and joint action is necessary. Furthermore, all existing infrastructure needs cleaning, which hasn't been done since the infrastructure was constructed. A new tunnel is planned which would drain excess waters from Vrgoračko polje towards Birina lake. Such a tunnel would also improve ecological state of Birina lake. Concerning non-structural aspects of flood defense, focus should be laid on awareness raising and adaptive strategies. One way to achieve this is to encourage cultivation of annual plants or vineyards (and prevent land use changes). Flooding of well-drained soil types, where water disappears in one or two days, usually has no significant impact on vine growth. Vines are resilient and can return to production in the following season even if soil waterlogged and roots die due to lack of oxygen. Furthermore, establishment of protective forests could be beneficial on small scale application (e.g. some parts of Imotsko polje). According to FAO and CIPHER (2005), forest cover may influence small to moderate floods in small catchments (<10 km^2), but usually has little influence in large catchments (>10 km^2) or during severe meteorological events. From the point of land use, south-eastern part of Imotsko polje is characterized by vineyards, urban fabric and complex cultivation patterns. Increasing the portion of e.g. broad-leaved forests, could help mitigation floods by means of water use by trees and the “sponge effect”. Forest soils tend to have a more open structure resulting from greater amounts of organic matter, the action of tree roots and soil fauna. The presence of a network of macropores helps to transmit water quickly to depth, reducing the likelihood of

	surface saturation and rapid run-off (Nisbeth and Thomas).	
Advantages of this BMP in PA	Reduced damage to population, property and agriculture, increased cross-border cooperation and harmonized action in flood mitigation, long term effects on flood mitigation, financial savings (loss avoidance).	
Challenges of this BMP in PA	Main problem is downstream regulation and maintenance of infrastructure (Trebižat/Tihaljina river). Poor trans-border cooperation is a scenario that must not be disregarded. Non-structural measures are usually harder to implement because of indirect effects, and usually they require more time to be effective. Besides that, financial incentives are lacking so it is unclear at the moment who whould provide stimulus for afforestation or land use change in pilot area.	
Relevance	Water protection functionality	High
	Cost of the measure	High
	Duration of implementation	Short/ medium term
	Time interval of sustainability	Long term
Limitations	Lack of trans-border cooperation, lack of funds	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments	-	
References / sources	https://www.sttas.com.au/sites/default/files/media/documents/forestsprotectionfromfloodingroberts.pdf https://www.wineaustralia.com/getmedia/4ddeda8b-d142-4b01-8ead-5ef41ca55ed4/2012-flooded-vineyard-case-studies.pdf https://www.forestry.gov.uk/pdf/woodland_flood_control_iale_paper_2006.pdf/$FILE/woodland_flood_control_iale_paper_2006.pdf https://www.dalmacija.hr/Portals/0/docs/UOZastitaOkolisa/dokumenti/Rje%C5%A1enje/rje%C5%A1enje%20-%20hrvatske%20vode%20-%20vrgorsko%20polje0001.pdf https://www.wineaustralia.com/getmedia/4ddeda8b-d142-4b01-8ead-5ef41ca55ed4/2012-flooded-vineyard-case-studies.pdf https://www.forestry.gov.uk/pdf/woodland_flood_control_iale_paper_2006.pdf/$FILE/woodland_flood_control_iale_paper_2006.pdf	

▪ Identified GAP provoking action	
GAP short name	**Legalization of illegal construction on flood areas**
GAP short description	Despite prohibition of constructing buildings on flood areas, construction takes place and with time gets legalized. Ineffectiveness or lack of penalties from state authority on illegal construction (legislation implementation problem).

Best management Practice / Management Action		
Name of BMP	**To prevent legalization of construction on flood areas**	
Type of land use regarded	Flood management	
Location	Slovenia	
BMP description	Despite the fact that construction of buildings on flood areas is prohibited and is not safe, people insist on constructing on such areas in belief, the flood won't reach them. Institute for Water of the Republic of Slovenia has evaluated parcels with flood risk. Unfortunately, many take this document only for a recommendation and not for a regulation, although it is a mandatory requirement for building permit. Therefore, construction on such areas is illegal. Municipalities legalize such constructions due to tendency of keeping the spatial register up to date. If not sooner, constructions get legalized after flood when owners of parcels want a compensation from insurance companies, for which real estate has to be legal. Municipalities should not agree on such acts. With legalization of illegal construction on flood areas municipalities undertake responsibilities and must provide flood protection and included costs.	
Advantages of this BMP in PA	Strict implementation of construction inhibition on floodplains considering flood hazard map.	
Challenges of this BMP in PA	Usually corruption at municipalities or at planning companies make such acts possible and to avoid such cases is a big challenge.	
Relevance	Water protection functionality	Medium
	Cost of the measure	Low
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Expected limitations are lack of common sense of people which construct illegal buildings on flood area. Another limitation is corruption problem.	
Implementation of the BMP in PA	After agreement with stakeholders (Ministry of the Environment and Spatial planning – Slovenian Environment & Slovenian water agency) we will send this legislation proposal about flood risk evaluation of parcels included in municipal spatial planning, so they could discuss among departments how to implement this legislation and also suggest us how to approach solving this problem.	
Comments		
References / sources	BMP derives from past projects. Reports on flooding of constructions in floodplains due to noncompliance of the legislation and large material damage.	

Identified GAP provoking action

GAP short name	**Improper manure storage**	
GAP short description	The access of manure and liquid manure into watercourses near livestock farming areas could affect negatively the quality of the surface water resources.	
▪ **Best management Practice / Management Action**		
Name of BMP	**Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change**	
Type of land use regarded	Agriculture areas	
Location	Various sites along River Tisza on the pilot area	
BMP description	Inner and outer protective areas have been designated for the Szolnok surface drinking water abstraction, but riparian zone conditions outside of the protective areas still have significant impact on water quality. On the score of riparian livestock farms, it is important that no contaminants from manure shall be picked up by the natural runoff and transported directly into the watercourses. The formation of contaminated rainwater must be moderated. This can be done by harvesting, draining off and placing separately the rainwater from clean surfaces. The extent of manure contamination should be reduced. Good practise for harvesting and managing contaminated rainwater on livestock farms should be worked out. Contaminated rainwater could be treated by leachate on the manure holding sites or it can be placed on arable land considering the relevant legislation. Manure storage is related to this subject. Proper design and handling of closed manure storage facilities could keep manure from leaching and could stop water runoff contaminated by manure. Risk of leaching is directly proportional to the time unmanaged manure piles spend on the agricultural land sides, therefore the manure should be spread as soon as possible.	
Advantages of this BMP in PA	With these simple methods, manure and its valuable nutrients can be retained for agricultural utilization.	
Challenges of this BMP in PA	Increased monitoring of riparian livestock farms is necessary. Closed manure storage facilities were construct, although in many cases their design is not proper, and handling is incorrect. Setting up systems for draining off, utilizing and placing rainwater is not a general practise.	
Relevance	Water protection functionality	high
	Cost of the measure	moderate
	Duration of implementation	medium term
	Time interval of sustainability	sustainable with regular maintenance
Limitations	Livestock farming is not limited on the given area and can be managed in compliance with the law.	
Comments	-	

References / sources	Survey of livestock farms on the area of Ipoly and its tributaries.

▪ Identified GAP provoking action	
GAP short name	**Inflexible time ban of fertilizers and manure application**
GAP short description	Period of restriction of fertilizers and manure application is defined with exact date and does not adjust to current weather.
▪ Best management Practice / Management Action	
Name of BMP	**Redefinition of time ban of** fertilizers and **manure application**
Type of land use regarded	Agriculture areas: grassland, arable land
Location	Slovenia
BMP description	The restriction period of mineral fertilizers containing nitrogen use is defined from 15th November till 1st March and prohibition of manure and slurry use from 15th November (manure: 1st December) to 15th of February (according to Nitrate Directive and *Decree on the protection of waters against pollution caused by nitrates from agricultural sources*). Vegetation activity depends on current weather conditions which are unstable and yearly changing. If vegetation is not active, the N-compounds pass through soil directly into the groundwater. Consequently, the period of restrictions should be redefined according to the weather condition instead of calendar date. The Slovenian Environment Agency (meteorology section) monitors and predicts weather conditions should determine for each year date of fertilizing period. The storage of manure and slurry in the time of application restriction should be properly sealed to be safe from overflowing and consequently contamination of water sources. In order to spread environmental awareness among locals and local farmers, educational lectures should be frequently organized.
Advantages of this BMP in PA	Since some farmers must keep a fertilization plan (only those with fields within DWPZ and those included in sustainable farming program), supervision over fertilizing has improved. Farmers receiving subsidies are obligated to attend trainings for pesticide use, personalized expert advice and lectures every 5 years. In the first DWPZ fertilizing is forbidden for: mineral fertilizers containing nitrogen, manure and slurry, ploughing of permanent grassland and irrigation with water containing plant nutrients. On the narrowest DWPZ (VVO-I) farmers get money compensations because of fertilizer application limitation and consequently smaller harvest.
Challenges of this BMP in PA	Farmers are not satisfied with the prohibition and would like to repeal it, therefore main challenge present farmers' approval of implementation of widening the restriction period. A frequent supervision of manure and slurry storages In the period of

	prohibition would present a better control of the nitrate directive implementation, according to which, the manure and slurry should not be stored longer than two months on the farming area and should be located every year on a different place. The main challenge is to implement integral management of agricultural activities within recharge area of drinking water source (and in general in water body), which means that farmers have to be linked up with each other and share manure to farmers needing it etc. farming and cattle breeding.	
Relevance	Water protection functionality	Very High
	Cost of the measure	Medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Expected limitations are lack of political will and resistance of local farmers - conflicts of land use vs water management, lack of supervising / implementation mechanisms.	
Implementation of the BMP in PA	The Slovenian Environment Agency yearly produces the agronomic prediction according to the weather forecast but is more as a recommendation and not as an obligation with determined exact date of fertilizing period. In the future meeting with Chamber of Agriculture and Forestry of Slovenia we will discuss and try to find a way to implement The Slovenian Environmental Agency's agronomical prediction obligatory.	
Comments	/	
References / sources	BMP derives from bad practice causing deterioration of groundwater quality. REFERENCE: Nitrates directive and Slovenian Decree on the protection of waters against pollution caused by nitrates from agricultural sources.	

▪ Identified GAP provoking action	
GAP short name	**Improper or excessive use of pesticides and manure on plant production fields.**
GAP short description	The quality of surface drinking water resources can be significantly affected by riparian agricultural utilization.
▪ Best management Practice / Management Action	
Name of BMP	**Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change**
Type of land use regarded	Agriculture areas
Location	Section above Szolnok Intake Structures along River Tisza
BMP description	The most significant impact on the surface water quality is the access of contaminated grit into watercourses. This can happen through surface runoff transport. It follows that the effects can be mitigated by reducing surface runoff

	and stopping contaminated material transport on riparian areas. It is essential that the shoreline be accompanied by a lane of broader natural vegetation. The presence of contiguous lawn is favourable. Inner and outer protective areas have been designated for the Szolnok surface drinking water abstraction, but riparian zone conditions outside of the protective areas still have significant impact on water quality. In manure management the quantity does not make that much difference, but unmanaged manure piles should spend less time on the agricultural land sides, the manure should be spread as soon as possible. If ploughing runs parallel to the watercourse it could hinder surface runoff to access the watercourse. In the riparian areas, plant treatments should be precocious during weed control, given that it could increase the likelihood of the access of pesticides into the watercourse by surface runoff. Soil disinfection can be applied only in the most necessary cases in the riparian areas. Plant protection activities on riparian areas are regulated by the FVM Decree 43/2010 (IV.23) on plant protection activities, and, on the protection areas of drinking water resources, by Government Decree 123/1997 (VII.18) on the protection of water resources. In the case of sloping terrain towards a waterbody, the risk of runoff increases, so the use of defence equipment should be also increased. Surface runoff is significantly affected by cultivated plants. Growing wheat, especially autumn wheat, solve the problem of land coverage in most of the year. Wheat stocks are dense enough to decrease surface runoff. In case of root-crop stocks, where density is not that high, surface runoff can be decreased by applying proper ploughing orientation, in other words ploughing parallel to the near watercourse. In the case of short growing vegetation, the free soil surface increases the degree of erosion, which can be reduced by second planting methods. Land coverage can be ensured by planting species suitable for green manure. This technique could also improve the soil quality. Agri-environment packages include elements important to the quality of surface water, ensuring the longest possible soil cover, controlling the ratio of crops to crops, rules on fertilizer application, green fertilization, use of environmentally friendly pesticides, etc. The water erosion control practices program applies to areas with slopes greater than 12%. In this case, smaller sloping areas are also counted. Decree 10/2015. (III 13) FM is a guideline on the use of support for agricultural practices beneficial to the climate and the environment, on the conditions under which arable land, permanent grassland and land covered by permanent crops are fit for cultivation or grazing, and also promotes the proper maintenance and restoration of water protection zones.
Advantages of this BMP in PA	The methods proposed for use are not complicated, traditionally used in cultivation. Their application also represents an advantage in cultivation along with a favourable environmental protection and water protection effect. In case of participation in the Agrarian Environment Program, the lost income is compensated by the program.

Challenges of this BMP in PA	On the riverbank, a natural vegetation band must be maintained or created. Farmers on riparian areas should be included in the use of environmentally friendly production methods, and in the participation in the agri-environment program. Enhanced monitoring is required to comply with existing general environmental, soil protection and pesticide use standards.	
Relevance	Water protection functionality	high
	Cost of the measure	moderate
	Duration of implementation	medium term
	Time interval of sustainability	
Limitations	The provisions of the legislation in the hydrogeological water basin protection area limit those highly polluting activities in agriculture, which are not part of the general cultivation practices.	
Implementation of the BMP in PA	Monitoring the land use along river Tisza between Szolnok Intake Structures and Kisköre	
Comments	-	
References / sources	Survey of agricultural lands along Ipoly and its tributaries, on the section above Komravölgyi Reservoir.	

▪ Identified GAP provoking action	
GAP short name	**Increased water demand**
GAP short description	Agricultural production that is purely conventional in this area presents the greatest negative impact both on the quality and quantity of the water resources. The main polluting agents (nitrates, phosphates, chemical residues and insoluble mineral particles) are generated by excessive application of fertilisers to crop fields, by use of fertilisers inadequate for crop cycles and by inappropriate tillage or irrigation practices. Water for the purpose of irrigation is used from watercourses (Neretva) or from mixed melioration systems for drainage and irrigation of closed karstic fields (Vrgoračko polje). Smaller part of the water used for irrigation comes from groundwater sources hence the need to monitor its quality. Agricultural production currently covers around 1,500 ha in Imotsko polje and is expected to increase to 3,330 ha after the construction on irrigation and melioration system (IM-BE Field project). Irrigation system will drastically change agricultural production, accompanied by intensification of production of fruits, vegetables and arable crops, hence increasing water demand.
▪ Best management Practice / Management Action	
Name of BMP	**Establishment of groundwater level monitoring network (e.g. Imotsko polje and South Dalmatia) for monitoring of irrigation water demand in order to assure efficient use of water in agriculture**

Type of land use regarded	Agriculture areas	
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs	
BMP description	Profitable agricultural production (of fruit and vegetables) causes increased pressure on water quantity, so it is necessary to establish groundwater level monitoring network. Proposed monitoring networks includes several stations (piezometers) located in: • Prološko blato – protected wetland area, floodplain karst field, which could be endangered due to drainage related to expansion of agricultural land. • Opačac – largest spring of Vrljika River, the largest watercourse and also the main recipient of Imotsko Polje. Opačac spring is captured by the water supply of Imotski and surrounding towns and villages. • Bosnia and Herzegovina – Imotsko polje stretches into neighbouring country (west Herzegovina, Bekijsko polje), therefore it is necessary to establish cross-border monitoring since transboundary catchment area size is not negligible and plays important role in water balance of Imotsko polje. • Upper part of the Vrgoračko polje (Butina spring) • Estavellas around Staševica • Sinkhole zone in the southeast part of the Vrgoračko polje	
Advantages of this BMP in PA	Since there is no monitoring of groundwater levels in pilot areas, this BMP will drastically reduce uncertainties, predict long term stresses on water balance in pilot area, support climate change data and evaluate impacts of new infrastructure on groundwater levels.	
Challenges of this BMP in PA	The main challenge is relatively high costs connected with establishment of monitoring systems, especially if it involves drilling of new boreholes. Decision makers and financiers (e.g. county, community) must be addressed adequately in order to realise the long-term importance of establishing a monitoring network.	
Relevance	Water protection functionality	Medium to high
	Cost of the measure	Medium to high (site specific)
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	There are no technical limitations connected to this BMP, but financing could pose a problem.	
Implementation of the BMP in PA	This BMP has not yet been implemented in pilot area but will be suggested to stakeholders through meetings and consultation.	
Comments	Related BMPs for further consideration: increase of irrigation efficiency (reduction of losses, efficient systems – sprinkles or drips), prevention of illegal connections to water systems, subsidies for efficient and good agricultural practices or	

	cultures that require low amount of water or vineyards which require no irrigation.
References / sources	-

▪ Identified GAP provoking action	
GAP short name	**Continuous conversion of (permanent) grasslands**
GAP short description	A spread conversion of, mostly permanent, pastures started due to socio-economic changes in the late 1980's to early 1990's. Since then, several agricultural land use changes occurred that are strongly related to socio-economic fluctuations in the pilot area.
▪ Best management Practice / Management Action	
Name of BMP	**Continuous monitoring in both, surface water and groundwater**
Type of land use regarded	Agriculture areas
Location	Plain area
BMP description	Enlarge the infrastructure of the existing monitoring network towards a higher temporal and spatial resolution of relevant water quality and quantity data. Therefore, in a first instance, an overview over existing data needs to be gathered to identify relevant, i.e. site-specific and question-related, data gaps. Once relevant gaps were identified, suitable installation points for new measuring devices have to be found and the temporal resolution at which each measuring device should operate have to be set. Finally, the enhanced monitoring program can start. Generally, the value of a continuous monitoring of water-related data should be more emphasized in existing policy guidelines. Water suppliers as well as water authorities should receive incentives to better manage available data and to collect hydrological data more frequently and with a higher spatial resolution.
Advantages of this BMP in PA	A comprehensive monitoring of relevant hydrological data provides valuable insights into the functioning of a regarded catchment or study area. Well-managed and highly temporally and spatially resolved data form the base for an in-depth understanding of the ongoing hydrological processes as well as for understanding the effects of external impacts, such as land use and climate change, on the natural system. No adaptation of existing land use management practices required.
Challenges of this BMP in PA	The greatest challenge, in our opinion, is to implement a better structure for data management between and in different responsible authorities. Moreover, data transfer from privately owned measuring devices should be made more interesting for the owners to share their data. Generally, we found complex organizational structures while trying to obtain the permit for the installation of new monitoring points as well as a resistance of some individuals in processing the requests for the installation of new monitoring points.

Relevance	Water protection functionality	High
	Cost of the measure	Low
	Duration of implementation	Short
	Time interval of sustainability	Long
Limitations	No	
Comments	----	
References / sources	World Health Organization & United Nations Environment Programme. (1996). Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programs / edited by Jamie Bartram and Richard Ballance. London : E & FN Spon. http://www.who.int/iris/handle/10665/41851	

▪ Identified GAP provoking action	
GAP short name	**Insufficiently effective wastewater treatment system that needs to be reconstructed and expanded**
GAP short description	Currently, sewage system exists only in the area of Imotski and settlement Donja Glavina. The system is outdated, and only 25-30% of population is connected to it. Urban wastewater treatment facility, located in Donja Glavina, was built during 1980's (II. level of purification, capacity 10.000 PE). Surrounding settlements and villages do not have adequate sewage network nor the connection to wastewater treatment facility. Such wastewaters are disposed into surface waters, septic tanks and groundwaters, causing pollution (e.g. pathogens).
▪ Best management Practice / Management Action	
Name of BMP	**Natural wastewater treatment system**
Type of land use regarded	Urban areas
Location	Croatia, Pilot action Imotsko polje springs
BMP description	Plant purification systems have been in use for the past 50 years and have proven their efficiency in comparison to other treatment methods. They represent artificial swamps that simulate natural purification processes. The wastewater is completely purified via biological, chemical and physical processes (aerobic and anaerobic decomposition, evaporation, sedimentation and plant incorporation). Almost all organic and mineral components are removed, as well as toxic compounds and bacteria of various origin. Swamp plants such as common reed (*Phragmites australis*), broadleaf cattail (*Typhia latifolia*), yellow flag iris (*Iris pseudacorus*) etc. are grown on the substrate whose roots penetrate the soil and further stabilize the substrate. The roots offer an expanded surface for the development of microorganisms, the plants partly embed the toxic components (phosphorous and nitrogen) and the dead vegetation offers heat isolation during the winter that disables the freezing of water in the substrate.
Advantages of this	Natural wastewater treatment systems cost three times lower price than common

<table>
<tr><td>BMP in PA</td><td colspan="2">purification methods, and they are also easy to maintain. High degree of purification (in summer 90-99%, winter 70-80%) is accomplished with no energy or machinery required. These systems adapt well to the environment and they produce no foul smells. Sludge produced from these systems can be used in compost production.</td></tr>
<tr><td>Challenges of this BMP in PA</td><td colspan="2">Extensive land surface needed for the method (up to 5 m^2 per PE), favourable terrain incline, system sensitivity to oxygen levels, weed control in the early stages.</td></tr>
<tr><td rowspan="4">Relevance</td><td>Water protection functionality</td><td>High</td></tr>
<tr><td>Cost of the measure</td><td>Medium to high (depending on the size)</td></tr>
<tr><td>Duration of implementation</td><td>Medium</td></tr>
<tr><td>Time interval of sustainability</td><td>Short term</td></tr>
<tr><td>Limitations</td><td colspan="2">Relatively high price (which is also case with other purification methods)</td></tr>
<tr><td>Implementation of the BMP in PA</td><td colspan="2">A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.</td></tr>
<tr><td>Comments</td><td colspan="2">The first system in Croatia was built on the island of Cres for 330 PE in 2001 and has high purification success rate.
Another successful implementation example is city of Vrlika, Croatia.
 
Figure 1: Example of natural waste water treatment system.</td></tr>
<tr><td>References / sources</td><td colspan="2">Figure 1.
https://greentumble.com/natural-wastewater-treatment-systems/</td></tr>
</table>

<table>
<tr><td colspan="2">▪ Identified GAP provoking action</td></tr>
<tr><td>GAP short name</td><td>Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants</td></tr>
</table>

GAP short description	Torrential water running from hill Rožnik's banks along the ZOO is causing clogging of the runoff channels and flooding. Simultaneously there is lack of water for animals and watering the plants.	
▪ Best management Practice / Management Action		
Name of BMP	**Collecting torrential water in wider channels, small retention pond (transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model**	
Type of land use regarded	Urban areas	
Location	Slovenia	
BMP description	With torrential water management running from hill Rožnik's banks through the channels along the ZOO would stop causing clogging of the runoff channels and flooding. Torrental water would be collected in wider channels or ponds. The water runaway with a charging reservoir or a pond for drinking water for the animals would be arranged with previous calculations with a hydrological model.	
Advantages of this BMP in PA	Based upon the modelling results mitigation measures will be proposed for the improved torrential water management and flood protection of the ZOO area.	
Challenges of this BMP in PA	Financial input for planning and management of the water management construction.	
Relevance	Water protection functionality	Medium
	Cost of the measure	Low
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	Availability and quality of data - there are no active measures of the river discharge.	
Comments	-	
References / sources	The BMP derives from experiences.	

▪ Identified GAP provoking action	
GAP short name	**Waste disposal which do not meet technical and environmental standards and illegal waste disposal**
GAP short description	Split-Dalmatia County is on a second place concerning the total produced quantity of municipal waste (246,396 t) in The Republic of Croatia, right after the City of Zagreb. It is also one of the worst counties in Croatia concerning municipal waste recovery, with a rate of only 11.3%. Due to inappropriate waste management such as unsanitary waste disposal and numerous illegal disposal sites in the wider Pilot Action area, not only that are soil, surface water and groundwater endangered, but the potential pollution poses a grave threat to human health. Even though waste management plans on country and county level envisaged various measures of waste reducing, recycling and separate collecting, their

	implementation in practice is still lacking, especially due to inefficient allocation of tasks and insufficient coordination between different administrative levels. According to the initiative "Čisto podzemlje (Clean underground)" of Croatian speleologists there is at least one location within pilot action Imotsko polje and eight confirmed locations within pilot action South Dalmatia where municipal waste was illegally dumped into speleological objects such as karstic pits and caves, but also in swallow holes and springs. In Krčevac spring, which is a documented habitat of an endemic species *Proteus anguinus,* around 3 m^3 of waste (car tyres, oil canisters etc.) was illegally disposed. Furthermore, Kozjačić the main landfill of wider Imotsko polje area is actually an unsanitary dump without proper barrier liner system, gas venting and leachate collection systems. The landfill remediation process is in preparation stage. Ajdanovac and Lovornik landfills in South Dalmatia are actually unsanitary dumps without proper barrier liner and cover systems, gas venting and leachate collection systems. The remediation process of both mentioned landfills is in preparation stage. The case of Lovornik landfill is an example of insufficient coordination and cooperation among different administrative levels (ministry-city-municipality level). The remediation process of this landfill was prolonged due to issues with property rights which dated back to 2008 according to the official City of Ploče news (2017).
▪ **Best management Practice / Management Action**	
Name of BMP	1) **Educative brochure and awareness raising activities** 2) **Encourage and promote innovative solutions of sustainable waste management**
Type of land use regarded	Urban areas
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs
BMP description	1) An increase of environmental awareness through educative brochure and local community and economic subjects' involvement actions are a prerequisite for the sustainable waste management. It should be emphasized how illegal waste disposal in karstic pits, swallow holes and springs directly affects the groundwater, its vulnerable ecosystems and consequently human health. A clear and easy to understand illustrations of these negative impacts should be primarily given to economic subjects who deal with waste materials but also to local communities which should be promptly informed on all relevant waste management activities. To ensure long-term benefits from an environmental, economic and social perspective, the engagement in recycling, reusing and reducing waste activities ought to be encouraged on a consumer level. 2) Encouragement and promotion of innovative solutions for sustainable waste management such as: applications for smartphones which educate and help citizens with separate waste disposal and recycling or allow them to report

	illegally disposed waste, damaged waste infrastructure etc.; online databases with all relevant info on waste management activities (active or closed landfills, landfills in remediation process, dump sites etc.).	
Advantages of this BMP in PA	1) Raising awareness among local communities, opens up the possibility of positive change in their behaviour and current habits and by doing so increases the likelihood of environmentally friendly activities which could indirectly reduce negative impacts on water resources. 2) Innovative solutions are vital for the future of waste management and its synergy with the environment. Innovative app-based technology could help to increase community involvement in a sustainable waste management process.	
Challenges of this BMP in PA	Selecting a suitable and effective approach to initiate stakeholder's involvement and motivate them to apply environmentally safe practices.	
Relevance	Water protection functionality	Medium
	Cost of the measure	Low-medium (depending on the scope of activities)
	Duration of implementation	Short term
	Time interval of sustainability	Long term
Limitations	Unwillingness of the local community to adopt new environmentally friendly habits as a consequence of insufficient education on environmental issues and lack of government stimulations.	
Implementation of the BMP in PA	A first step towards the implementation of this BMP, will be the stakeholder involvement actions (authorities, local community, economic subjects etc.) through which an educative brochure encompassing all relevant gaps and proposed solutions/measures will be disseminated.	
Comments	1) Programme of educative-informative activities on sustainable waste management prescribe educative flyers and brochures, educative workshops, TV and radio broadcast on sustainable waste management (recycling, separate collecting, reuse etc.) as the activities which local self-government units are bound to conduct. 2) Programme of educative-informative activities on sustainable waste management prescribes the making of a smartphone application for sustainable waste management as one of the activities which local self-government units are bound to conduct.	
References / sources	2) An online web page on the activities for waste reduction by Croatian Agency for the Environment and Nature: http://sprjecavanjeotpada.azo.hr/ Free online application for waste sorting and proper disposal: https://www.razvrstaj.me/hr/ e-ONTO or Register on waste generation and its cycle (from the producer to disposal site) by Croatian Agency for the Environment and Nature: http://eonto.azo.hr/#/Ulaz Online map viewer of speleological object with illegally disposed waste: http://www.cistopodzemlje.info/?q=map	

	Some examples of smartphone applications for separate waste collecting and reporting on illegally disposed waste locations, developed on city level: "ZelenKO" and "E-otpadnici".

▪ Identified GAP provoking action		
GAP short name	**Unarranged road rainwater discharge**	
GAP short description	Road rainwater discharge of roads in DWPZ is not led to the road rainwater colleting system and it is not treated.	
▪ Best management Practice / Management Action		
Name of BMP	**Collection and treatment of road rainwater discharge, particularly within drinking water protection areas**	
Type of land use regarded	Urban areas	
Location	Slovenia	
BMP description	Roads in the DWPZ should have arranged road rainwater discharge. In order to control and to collect rainwater which rinses sediments, waste and waste oil from the road, impermeable rain water drains along roads have to be arranged, with collection of rain water in storm water management pond (retention basins with variety of grasses, shrubs and/or wetland plants) for sedimentation of suspended material and for treatment of polluted water with oil-grit separators (OGS) or oil-sediment separators (OSS). However, on motorways and main roads rainwater drainage and retention ponds with treatment are arranged but the infrastructure is not maintained.	
Advantages of this BMP in PA	Undesirable liquids such as mineral oils or other chemicals can be rinsed from the road into the groundwater and can consequently result in pollution of the drinking water source. Therefore, controlled and regularly maintained road rainwater discharge is necessary for all roads and motorways. Furthermore, road rainwater should not run through public sewage system.	
Challenges of this BMP in PA	Regulations are hard to change.	
Relevance	Water protection functionality	Very High
	Cost of the measure	Medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Expected limitation is a lack of political will to change regulation and/or municipalities to implement the measure in spatial plans.	
Implementation of the BMP in PA	Road rainwater discharge (and main roads rainwater drainage and retention ponds with treatment) must be controlled and regularly maintained for all roads and motorways. Furthermore, road rainwater should not run through public sewage system. SMERNICE, ZAKONODAJA	

Comments	
References / sources	BMP derives from bad practice. References: Slovenian legislation: Rules on road design. Decree on the emission of substances in the discharge of meteoric water from public roads. Decree on the emission of substances and heat when discharging wastewater into waters and the public sewage system.

▪ Identified GAP provoking action		
GAP short name	**Abandonment of forest areas**	
GAP short description	Abandonment of private forests, resulting aging of the forests and through it elevated vulnerability of the forests towards natural disasters	
▪ Best management Practice / Management Action		
Name of BMP	**Forestry subsidies and encouraging foresters to facilitate regeneration dynamics within their forests**	
Type of land use regarded	Forest	
Location	Slovenia	
BMP description	Aging of Slovenian forests, due to unregularly maintenance can turn out problematical, since old growth forest ecosystems can be more vulnerable to extreme weather conditions and catastrophes if the natural regeneration dynamics do not take place. Small-scale forest owners should become more motivated to manage their forests in order to increase resilience of their forests to natural disasters. This can only be achieved if the natural regeneration dynamics of the forest ecosystems are facilitated. Incentives for more active forest management and provision of ecosystem services will be proposed, including - among others - subsidies, free advisory services for forest management, or the support of cooperative management.	
Advantages of this BMP in PA	This BMP has the advantage of increasing stability and resilience of forest ecosystems. Only if regeneration dynamics are taking place continuously, the desired stability can be achieved. In PA private small-scale forest properties are prevailing, however, only few private forest owners are actively managing their forests and following the forest management plans, prepared by Slovenian Forest Service. Incentives for more active forest management will be proposed in order to increase the resilience of these forests to natural disasters and enhance the provisioning of forest ecosystem services.	
Challenges of this BMP in PA	So far, incentive mechanisms are often only partially successful due to limited man power in public forest service and deficits in implementation of forest management plans. In addition, the evaluation of provisioning of forest ecosystem services is still remaining a challenge on regional, national and EU level.	
Relevance	Water protection functionality	High

	Cost of the measure	Low
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Limited man power in public forest service and low interest in forest management by private small-scale forest owners.	
Comments		
References / sources	Bončina A ED. (2013) Razvoj večnamenskega gospodarjenja z gozdovi: funkcije gozda, ekosistemske storitve in prednostna območja. Razvoj večnamenskega gospodarjenja z gozdovi: funkcije gozda, ekosistemske storitve in prednostna območja. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Zavod za gozdove Slovenije, Ljubljana. pp. 31-36 Golobič M (2010) Gozd v prostorskem načrtovanju. Gozdni prostor: načrtovanje, raba, nasprotja: zbornik prispevkov. A Bončina, D Matijašić. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Zavod za gozdove Slovenije, Ljubljana: 7-11 p. Kadunc A ED. (2015) Zakonodaja o gozdovih: odprta vprašanja in predlogi rešitev. XXXII. Gozdarski študijski dnevi. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Dolenjske Toplice. pp. 209 Krušec T (2010) Socialne in ekološke funkcije gozdnih površin na Jarškem in Tomačevskem produ. Diplomska naloga. Graduation thesis. Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire. Univerza v Ljubljani. University of Ljubljana, Ljubljana Kumer P (2017) Vpliv družbenogeografskih dejavnikov na gospodarjenje z majhnimi zasebnimi gozdnimi posestmi. Filozofska fakulteta, Oddelek za geografijo. Univerza v Ljubljani, Ljubljana Marinšek A, Celarc B, Grah A, Kokalj Ž, Nagel T A, Ogris N, Oštir K, Planinšek Š, Roženbergar D, Veljanovski T, Vochl S, Železnik P, Kobler A (2015) Žledolom in njegove posledice na razvoj gozdov - pregled dosedanjih znanj. Impacts of ice storms on forest development - a review. Gozdarski vestnik 73. 392-405 Medved M, Bajc M, Božič G, Čas M, Čater M, Ferreira A, Grebenc T, Kobal M, Kraigher H, Kutnar L, Mali B, Planinšek Š, Simončič P, Urbančič M, Vilhar U, Westergren M, Krajnc N, Kušar G, Levanič T, Poljanšek S, Jurc D, Jurc M, Ogris N, Klun J, Premrl T, Robek R, Železnik P, Gričar J, Piškur M (2011) Gospodarjenje z gozdom za lastnike gozdov. Kmečki glas, Ljubljana Ohnjec Ž (2007) Analiza razmer za spravilo lesa in transport lesa v krajinskem parku Tivoli, Rožnik in Šišenski hrib. Diplomska naloga. Graduation thesis. Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire. Univerza v Ljubljani. University of Ljubljana, Ljubljana Simončič T, Matijašić D (2013) Zelena knjiga o plačevanju ekosistemskih storitev iz sredozemskih gozdov. Green book on payments for environmental	

	services from Mediterranean forests. Zavod za gozdove Slovenije, Ljubljana Vilhar U, Kraigher H, Kutnar L, Simončič P, Grecs Z (2013) Načrtovanje obnove gozda po velikih poškodbah. Planning Forest Restoration after Large-Scale Disturbances. Gozdarski vestnik 71. 3-17 Vilhar U, Planinšek Š, Ferreira A (2010) Vpliv gozdov na kakovost virov pitne vode Mestne občine Ljubljana. Influence of forests on drinking water resources quality in the Municipality of Ljubljana. Gozdarski vestnik 68. 310-320

ANNEX 3

- Descriptions of best Management Practices for Pilot Action Cluster 3

▪ Identified GAP provoking action		
GAP short name	**Pressures on water resources management**	
GAP short description	Qualitative and quantitative over exploitation of water system and unbalanced exploitation rate between surface and ground water bodies; not yet fully implemented integration of needs and stakeholders' priorities	
▪ Best management Practice / Management Action		
Name of BMP	**The Drought Observatory/ Steering Committee and Drought Early Warning System (DEWS)**	
Type of land use regarded	General water management	
Location	Po river basin, Italy	
BMP description	Drought Steering Committee is a Multisectoral partnership that consists in a forum of major water users in River Po basin, initiated and presided by the Po River Basin Authority (P-RBA). Since 2016, a permanent network of "Observatories on water uses", supported by the Hydrologic Service of Arpae, has been established among all public and private stakeholders of national relevance. According to this network, the Po Drought Steering Committee has the new role of Permanent Observatory on Water Uses in the P-RBD.	
Advantages of this BMP in PA	Emergency planning and management; information and data sharing; updated knowledge of water resources and balance; agreed decisions among all the stakeholders involved, supported by an objective operational monitoring and modelling system; periodical meetings.	
Challenges of this BMP in PA	Practicable, measurable and effective overcoming of Institutional fragmentation through an Authority with more decision-making power and more structured decision processes based on flow charts. Business continuity guarantee to maintain the operational system on water resources management (DEWS) in the Po River Basin District to support planning and integrated management processes. Integrated Water Resources Management supports Institutional change. The Po Observatory experience can be extended to the other established Observatories; opinions and activities about different approaches can be exchanged.	
Relevance	Water protection functionality	Medium/High
	Cost of the measure	Low
	Duration of implementation	Long-term
	Time interval of sustainability	Long-term
Limitations	Lack of imposition power (such a low could have); water scarcity emergency threshold planned not still implemented; high prediction uncertainties; need of nesting of higher resolution models, procedures and institutional tools (Land Reclamation Boards modelling); not all the information layers are already implemented (glaciers, ground water, evapotranspiration); cost benefits analysis implementation in the decision support tool; needs of completing the monitoring system for uptakes; web services for water scarcity information.	
Comments		
References / sources	Po river Basin District Water Balance Plan (2016)	

▪ Identified GAP provoking action		
GAP short name	**Climate change impacts on drinking water resources (e.g. pressure on water resources quantity)**	
GAP short description	The potential direct or indirect impacts of climate changes on drinking water resources require deep and complex analysis tools properly put into system allowing proper adaptation measures and improving community's awareness.	
▪ Best management Practice / Management Action		
Name of BMP	**Assessment of climate change impact on drinking water resources and determination of adaptation and resilience of public water supply (e.g. reducing pipeline leakage and water reuse)**	
Type of land use regarded	Drinking water management	
Location	The entire basin but primarily, focusing on a small river basin such as the Taro River basin to test the effectiveness of this BMP.	
BMP description	An attempt to perform an analysis aimed to assess the potential effects of climate changes and/or land use changes on drinking water resources; it will exploit different data sources and explicitly consider the view and needs of stakeholders.	
Advantages of this BMP in PA	It will permit arranging proper adaptation measurements with the aim of limiting negative consequences.	
Challenges of this BMP in PA	Future evolution of weather forcing under the effect of climate changes and associated feedbacks (f.e., in part, land use changes) are currently characterized by high uncertainties and low perception among all the stakeholders.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium
	Duration of implementation	High
	Time interval of sustainability	Medium
Limitations	Uncertainties have to be carefully evaluated and made clear to stakeholders; it requires the adoption of probabilistic approaches for all the different stages of modelling chain.	
Comments	While the climate and land use projections are developed for the whole Po River basin, the application of InVEST model to assess the impacts of climate change on freshwater ecosystem services are developed for the Taro River basin, one of the tributaries of the Po river. It is due to efforts associated to data stocktaking and analysis currently associated to adoption of approaches for evaluating the cascading impacts on freshwater ecosystem services (FWES) and human well-being. Furthermore, climate projections are made available by past experiences under two RCPs up to 2100 and, yet, they are the data at the highest resolution available for Italian domain (Bucchignani et al., 2015). LUC simulations are carried out as novel result within the PROLINE-CE Project. The added value compared to previously proposed (e.g. Santini & Valentini, 2011) is represented by adoption of the above introduced climate projections. It permits properly understanding feedbacks of single and coupled effect of CC and LUC on drinking water resources.	
References / sources	Bucchignani E., Montesarchio M., Zollo A.L., Mercogliano P. (2015). High-resolution climate simulations with COSMO-CLM over Italy: performance	

	evaluation and climate projections for the XXI century. International Journal of Climatology DOI: 10.1002/joc.4379 – International Journal of Climatology DOI: 10.1002/joc.4559 • Pham, H. V., Torresan, S., Critto, A., & Marcomini, A. (2018). Alteration of freshwater ecosystem services under global change – A review focusing on the Po River basin (Italy) and the Red River basin (Vietnam). Science of the Total Environment. (Under review) • Santini M., Valentini, R. (2011) Predicting Hot-Spots of Land Use Changes in Italy by Ensemble Forecasting. Reg Environ Change, 11:483–502. DOI: 10.1007/s10113-010-0157-x. Vezzoli, R. et al. 2015. "Hydrological Simulation of Po River (North Italy) Discharge under Climate Change Scenarios Using the RCM COSMO-CLM." Science of the Total Environment 521-522: 346–58. Zollo A.L., Rillo V., Bucchignani E., Montesarchio M., Mercogliano P., 2015, "Extreme temperature and precipitation events over Italy: assessment of high-resolution simulations with COSMO-CLM and future scenarios", International Journal of Climatology, DOI: 10.1002/joc.4401.

▪ Identified GAP provoking action	
GAP short name	**Flood impact not fully implemented and considered**
GAP short description	Impacts of floods on water quality, especially on drinking water supply system and the whole environment is not yet fully considered in the flood risk management cycle.
▪ **Best management Practice / Management Action**	
Name of BMP	**The Flood Forecast Centre and Flood Early Warning System (FEWS)**
Type of land use regarded	Flood management
Location	Po river basin, Italy
BMP description	The Flood Forecast Centre for the Po river is in charge to the Interregional Agency for the Po river and is supported by the Hydrologic Service of Arpae. The Centre provides flood forecasts monitoring and evaluation supported by the FEWS system. Through FEWS it is possible to manage observed data (in situ and remote sensed), and forecasts obtained from meteorological-hydrological-hydraulic simulation in order to early detect floods, their occurrence, entity, and characteristics. The Flood Forecast Centre supports the Command and Control Unit within the Civil Protection System.
Advantages of this BMP in PA	Emergency planning and management; information and data sharing; updated knowledge of flood exposure and vulnerability; supporting decisions through an objective operational monitoring and modelling system; opportunity, based on flood forecasts, to undertake mitigation actions protecting drinking water systems.
Challenges of this BMP in PA	Managing the whole flood disaster cycle through a practicable, measurable and effective guide to support decisions, procedures, processes, and actions. Business continuity guarantee to maintain the operational system on flood management (FEWS) in Po river basin to support planning and integrated management processes.

	The Po River Flood Forecast Centre operational procedures and experiences can be shared and eventually extended to other River Basin Districts. Extension of the flood management operational tools to other aspects and sectors (climate change, water quality, sediment transport, ecology). Implementation of web services for flood warning.	
Relevance	Water protection functionality	Medium/High
	Cost of the measure	Medium
	Duration of implementation	Long-term
	Time interval of sustainability	Long-term
Limitations	During extreme events (intense, rapid or intense/rapid) it could be very difficult to supply information and to link all the stakeholders and actors in time to undertake flood mitigation actions; high prediction uncertainties; the actual consistency of the monitoring and forecasting network may be fully representative of the extension, heterogeneity, and complexity of the basin and of the river network. The modelling and monitoring system may be periodically calibrated, updated and refined, mostly after extreme flood events.	
Comments		
References / sources	Po River Basin District Flood Risk Management Plan (2016)	

▪ Identified GAP provoking action		
GAP short name	**Flood protection protocol on bank-filtered wells operations during high water and flood events**	
GAP short description	When flood occurs, the river may flood the well structures, or surface water can enter the wells.	
▪ Best management Practice / Management Action		
Name of BMP	**Ensure the drinking water supply during high water or flood.**	
Type of land use regarded	Flood management	
Location	Budapest Waterworks, Szentendre Island bank-filtered system	
BMP description	The Budapest Waterworks Szentendre Island bank-filtered wells are gradually being built, some of them is beyond the age of 100, so their structure is different. The old wells have been renovated several times, equipped with modern technical equipment, facilities, remote control. The well structures are above the standard flood level at the time of their construction. The Budapest Waterworks is prepared for operation during flood events with flood management orders.	
Advantages of this BMP in PA	The Budapest Waterworks has set up a flood operating order based on its great deal of practice and experience in operating during flood events.	
Challenges of this BMP in PA	Ensure water supply during protracted high water and flood events.	
Relevance	Water protection functionality	high

	Cost of the measure	high
	Duration of implementation	long-term
	Time interval of sustainability	long-term
Limitations		
Comments		
References / sources		

▪ Identified GAP provoking action		
GAP short name	**Agricultural groundwater pollution**	
GAP short description	Nutrients used in agricultural production infiltrate into the soil causing groundwater contamination	
▪ Best management Practice / Management Action		
Name of BMP	**Participation in Agro Environment Program**	
Type of land use regarded	Agriculture areas	
Location	Bank filtered water resources systems at Vác, Leányfalu, and on Szentendre Island	
BMP description	Water quality of bank filtered water resources can be significantly affected by agricultural production and water dissipation techniques for wastewater treatment in settlements. On Szentendre Island, arable crop production is significant, intensive, irrigated strawberry farming is conducted in relatively large areas. The island became a sensitive nature area in 1999 under the National Agro Environment Program. Since 1999 it results an environmentally friendly.	
Advantages of this BMP in PA	The environmentally friendly cultivation methods of the National Agro Environment Program (NAP) are fully in line with water protection requirements. If on the hydrographic protection areas of "A" and "B" water resources farmers connect with NAPs with a significant area of land, the groundwater load can be reduced from the top soil layer to the groundwater.	
Challenges of this BMP in PA	Convincing the widest possible range of farmers to participate in the Program. The Water Resources Protection Law contains rules and restrictions on agricultural production in "A" and "B" hydrological protection areas of water resources. However, controlling every activity on those areas is very difficult due to the lack of monitoring. The NAP's professional architecture and rules form a unified system, with which better results can be achieved, the environmentally-friendly effect is more significant. The program control system has been built.	
Relevance	Water protection functionality	high
	Cost of the measure	medium

	Duration of implementation	medium-term
	Time interval of sustainability	medium-term
Limitations	The Water Resources Protection Laws contains rules and restrictions on agricultural production on "A" and "B" hydrological protection areas of water resources.	
Comments		
References / sources		

▪ Identified GAP provoking action	
GAP short name	**Lack of sewage system and wastewater treatment**
GAP short description	In water resources protection areas, the wastewater disposal was unresolved for a long time. After the drainage and sewage treatment, the quality of the ground water changes slowly.
▪ Best management Practice / Management Action	
Name of BMP	**Appropriate collection and treatment of municipal wastewater**
Type of land use regarded	Urban areas
Location	Bank filtered water resources systems at Dunakeszi, Vác, Leányfalu, and on Szentendre Island
BMP description	Quality of bank-filtered water can be significantly affected by background impacts. Major background impacts are coming from sewage handling practices and agricultural production. As a result of decades of sewage infiltration on urban land areas, high concentration of nitrate (100-200 mg / l) is present in the groundwater below and around these areas. In the non-drained areas, the preparation and use of sealed wastewater was obligatory in the water protection zone. Keeping under control the transportation or infiltration of the sewage from storage vessels is difficult and still unresolved. From the evolution of groundwater quality and other information, it appeared that in most cases sewage infiltration occurs. The construction of sewage systems in urban areas has resulted in solutions. Sewerage services has been progressively implemented, households have gradually joined the network. If a house is being built on the external "A" and "B" hydrological protection areas for water resources where a sewerage network is available, it is mandatory to connect to the network. Thus, groundwater is getting less and less stressed, but the nitrate content that has been already added is only slowly being eliminated. This process has been going on for several decades in some locations. At the test sites, it is monitored how nitrate content in groundwater varies over time.
Advantages of this BMP in PA	Sewage infiltration decreases
Challenges of this	It is difficult to separate the effects of urban land sewage infiltration from

BMP in PA	other activities which can cause nitrate pollution.	
Relevance	Water protection functionality	high
	Cost of the measure	high
	Duration of implementation	long-term
	Time interval of sustainability	long-term
Limitations	Legislation on water resources stipulates that in the internal protection area of water resources only water supply facilities can be located. No residential or recreational park can be built on the external and "A" hydrological protection zone. Building of new residential or office buildings without drainage system on the external or "A" hydrological protection zone is prohibited.	
Comments		
References / sources		