PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.2

IMPLEMENTATION OF BEST PRACTICES FOR WATER PROTECTION IN PILOT ACTIONS

D.T2.2.3 PILOT ACTION CLUSTER REPORT

PILOT ACTION CLUSTER 2

PLAIN AGRICULTURE/ GRASSLAND/ WETLAND SITES

Lead Institution	PP7 - OVF
Contributor/s	See next page
Lead Author/s	Tamás Belovai
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Contributors, name and surname	Institution
Slovenia	
Barbara Čenčur Curk	PP4 - University of Ljubljana, NTF
Jerca Praprotnik Kastelic	PP4 - University of Ljubljana, NTF
Anja Torkar	PP4 - University of Ljubljana, NTF
Primož Banovec	PP4 - University of Ljubljana, FGG
Ajda Cilenšek	PP4 - University of Ljubljana, FGG
Matej Cerk	PP4 - University of Ljubljana, FGG
Poland	
Joanna Czekaj	PP11 - GPW S.A.
Mirosława Skrzypczak	PP11 - GPW S.A.
Andrzej Siudy	PP11 - GPW S.A.
with contribution of	
Andrzej Pasierbiński	JARS sp. z o.o.
Agnieszka Kolada	IOŚ-PIB
Agnieszka Pasztaleniec	IOŚ-PIB
Damian Absalon	JARS sp. z o.o.
Eugeniusz Małkowski	JARS sp. z o.o.
Ewa Łupikasza	JARS sp. z o.o.
Mariola Krodkiewska	JARS sp. z o.o.
Hanna Rubin	JARS sp. z o.o.
Marek Sołtysiak	JARS sp. z o.o.
Jacek Francikowski	JARS sp. z o.o.
Krystyn Rubin	JARS sp. z o.o.
Piotr Siwek	JARS sp. z o.o.
Dominika Dąbrowska	JARS sp. z o.o.
Dorota Grabala	JARS sp. z o.o.
Ewa Kaczkowska	JARS sp. z o.o.
Jagoda Wąsowska	JARS sp. z o.o.

Rafał Ulańczyk	IOŚ – PIB
Krzysztof Skotak	IOŚ-PIB
Jacek Wróbel	JARS sp. z o.o.
Kinga Ślósarczyk	JARS sp. z o.o.
Tomasz Pecka	IOŚ-PIB
and support of:	
Andrzej J. Witkowski	AP19 - University of Silesia
Jacek Różkowski	AP19 - University of Silesia
Sabina Jakóbczyk - Karpierz	AP19 - University of Silesia
Sławomir Sitek	AP19 - University of Silesia
Bartosz Łozowski	AP19 - University of Silesia
Andrzej Woźnica	AP19 - University of Silesia
Hungary	
Magdolna Ambrus	PP7 - General Directorate of Water Management OVF
Orsolya Both	PP7 - General Directorate of Water Management OVF
Ágnes Tahy	PP7 - General Directorate of Water Management OVF
Róbert Hegyi	PP7 - General Directorate of Water Management OVF
Bence Kisgyörgy	KSzI Kft.
Márton Ganszky	KSzI Kft.
Janka Mezei	KSzI Kft.
Veronika Kiss	KSzI Kft.
Croatia	
Josip Terzić	PP8 - Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Ivana Boljat	PP8 - Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Matko Patekar	PP8 - Croatian Geological Survey, Department of Hydrogeology and Engineering Geology

Ivona Baničček	PP8 - Croatian Geological Survey, Department of Hydrogeology and Engineering Geology
Daria Čupić	AP17 - Croatian Waters
Germany	
Daniel Bittner	PP12 - Technical University of Munich
Gabriele Chiogna	PP12 - Technical University of Munich
Markus Disse	PP12 - Technical University of Munich

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1. Introduction

In this report best management practices (hereinafter: BMPs) examined in Pilot Actions (hereinafter: PA) are presented on the level of Pilot Action Clusters.

Pilot actions and pilot sites respectively were classified into three clusters (Table 1) concerning the geographic specification and natural site characteristics (aquifer type) and main land use:

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).

In this report following issues in PAs for **PAC2** are presented:

- an overview of conducted activities in PA;
- selected GAPs and BMPs in PAs with solutions/recommendations for adaptation of existing land use and flood management and improved policy guidelines;

Table 1: Pilot Actions and Pilot Sites respectively, classified into three 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**	

1.1. Pilot Action Cluster 2: 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)). Bank filtration has special characteristics; therefore, separate cluster (PAC3) was established for this case.

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

- 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 (PA 2.4.1: South Dalmatia: Prud, Klokun and Mandina spring; and PA 2.4.2: Imotsko polje springs),
- PA2.5: Neufahrn bei Freising, Germany.

Comparison of Pilot Action sites

The **Slovenian** pilot area (PA2.1) is 16.65 km2. The largest percentage of surface is covered with forest and semi natural areas (45.3 %), following with artificial surfaces (30.6 %); the least of the surface belongs to agricultural areas (24.1%) (*Fig. 1*). The **Polish** pilot area (PA2.2) is 193.93 km2. Its largest part is covered by forest areas – 47.8% of the land area, including forests – 46%. The remaining surface (1.8%) is covered by forest areas in the process of changes (forest nurseries, tree clearance). Agricultural lands cover the area of 82 km2. This constitutes 42.3% of the total sub-basin area. They include arable lands, areas occupied by permanent crops (orchards and plantations), meadows and pastures as well as areas of mixed farming. Due to the dominant nature of the communes making up the sub-basin, anthropogenic regions constitute a small percentage of this area, with merely 7% (*Fig. 2*). The total surface of the **Hungarian** Pilot Action area is 7614 km^2. The largest part of the PA is covered by non-irrigated arable lands (35.42%), discontinuous urban fabric (14.06%) and broad-leaved forest (17.36%). Also significant land uses are discontinuous urban fabric, pastures, grasslands and shrubs (*Fig. 3*). **Croatia** has two Pilot Action areas, PA2.4-1: South Dalmatia: Prud, Klokun and Mandina spring; and PA2.4-2: Imotsko polje springs. On PA2.4-1 broad-leaved forests (37919 ha) along with the transitional woodland-shrub areas (12125 ha) covers the majority of the area. Agricultural production composed of complex cultivation patterns, agricultural land with significant areas of natural vegetation, pastures, fruit trees and vineyards are concentrated in Rastok field, Vrgorac field and areas near Neretvariver. Water courses cover 256 ha, while 195 ha is covered with water bodies. Salt marshes (287 ha) and inland marshes (1693 ha) are present north of the Neretvariver (*Fig. 4*). Land use in Pilot Action Imotsko polje springs is Broad-leaved forests (6652 ha) along with land principally occupied by agriculture, with significant areas of natural vegetation (3715 ha) covers the majority of Pilot Action area. Agricultural production composed of complex cultivation patterns, agricultural land

with significant areas of natural vegetation, permanently irrigated land, non-irrigated arable land, pastures and vineyards is concentrated in Imotsko field and along settlements. Water bodies cover 313 ha, while around 62 ha is covered with inland marshes (*Fig. 5*). The **German** PA covers an area of about 48.8 km^2. The land use in the pilot area is dominated by (non-irrigated) arable land (44.86 %). Settlement structures (CORINE codes 112 and 121) take over 20.56 % of the pilot area. These include discontinuous urban fabrics as well as industrial and commercial units. With a considerably lower areal extent as compared to the arable land, forested areas and pastures take over 17.66 % and 13.05 % of the pilot area, respectively (*Fig. 6*).

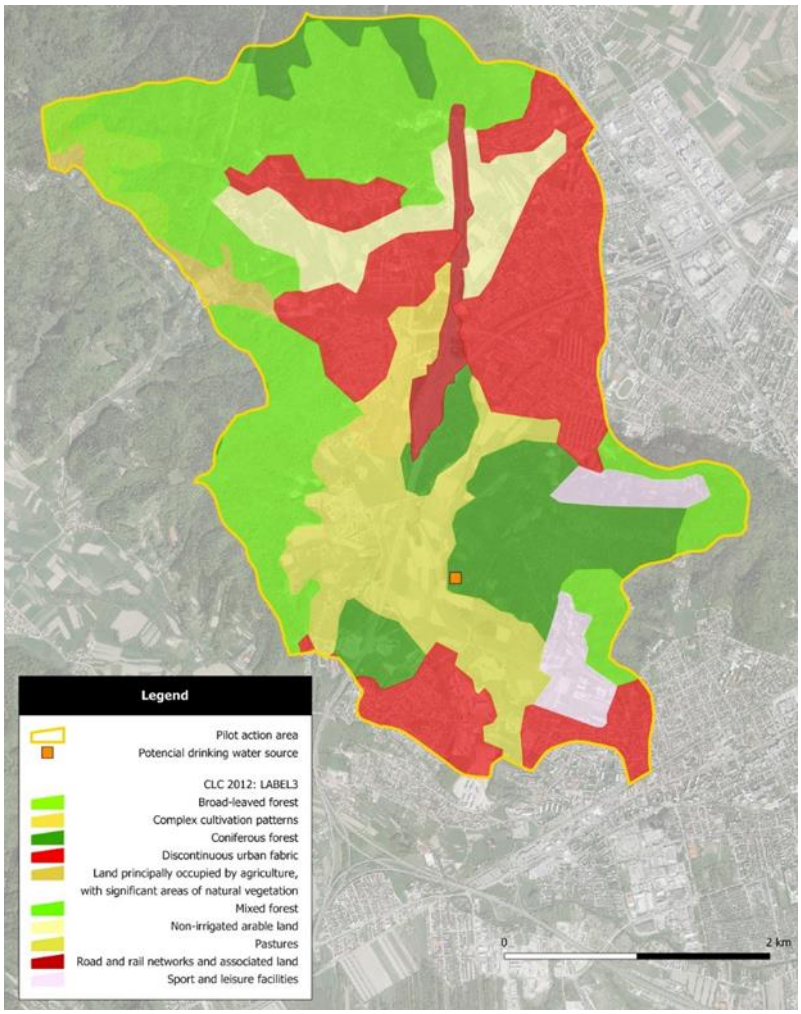

Figure 1: Land use in Dravlje valley pilot area, Slovenia (ARSO,2017).

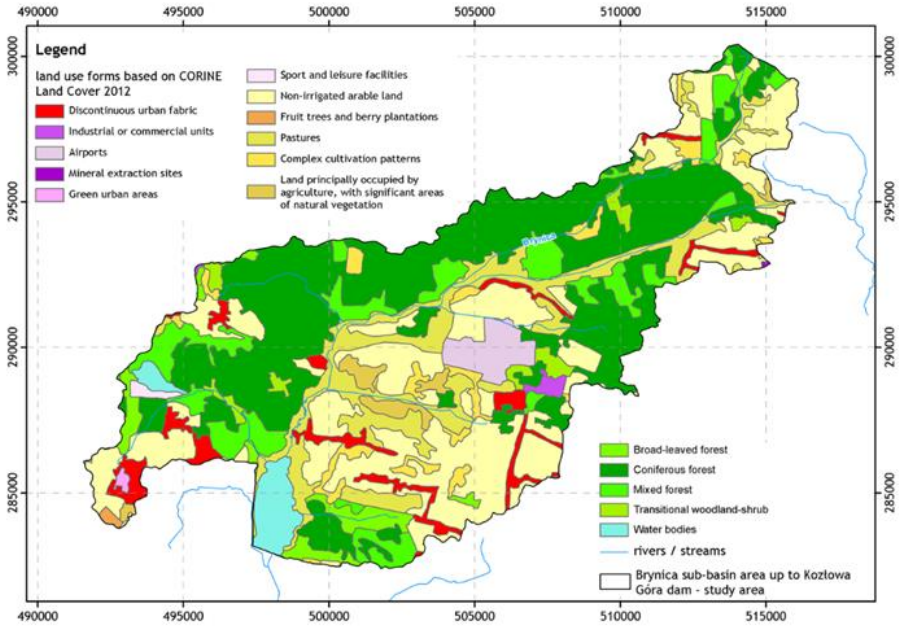

Figure 2: The land-use forms within the Brynica River sub-basin area, upstream the Kozłowa Góra dam, Poland.

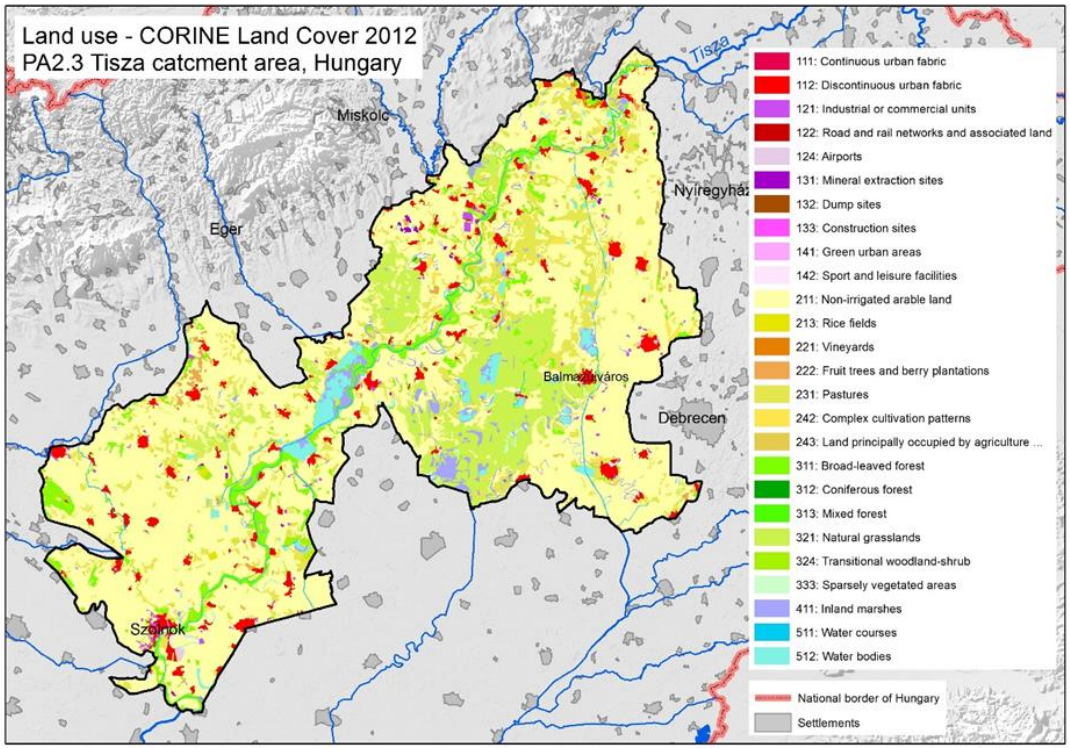

Figure 3: Land use in the Tisza catchment area, Hungary.

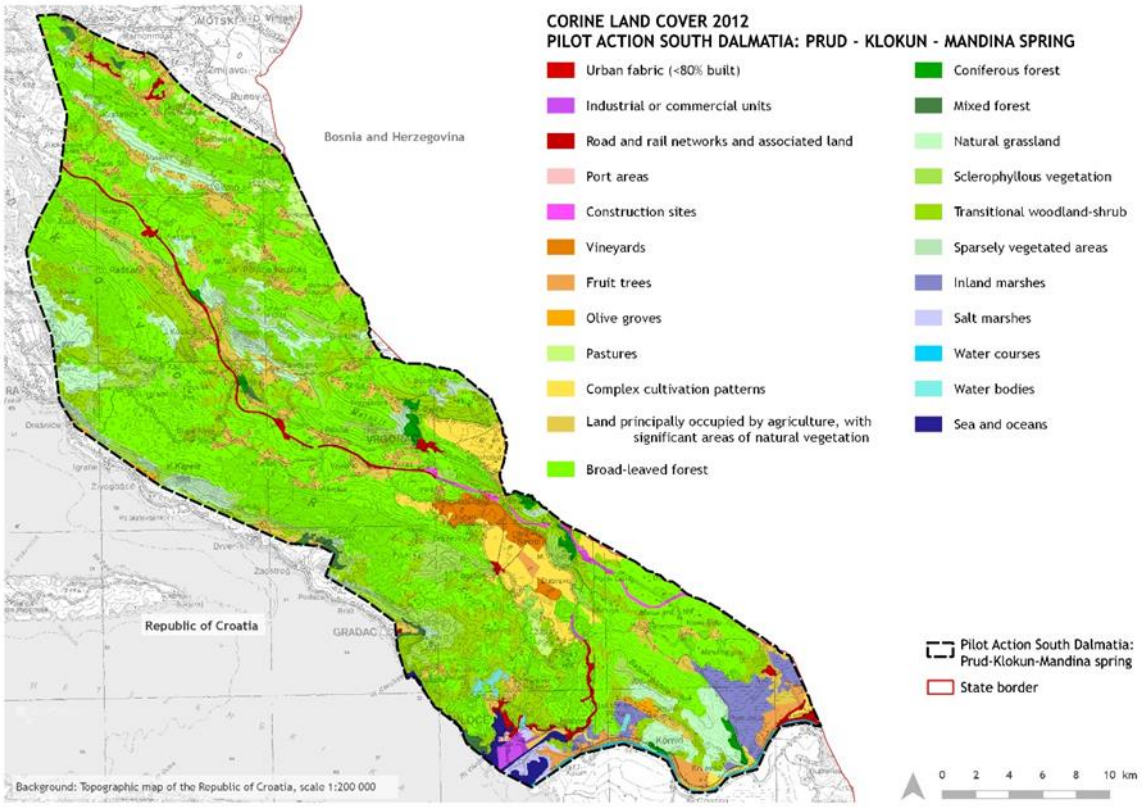

Figure 4: Land use in South Dalmatia, Croatia.

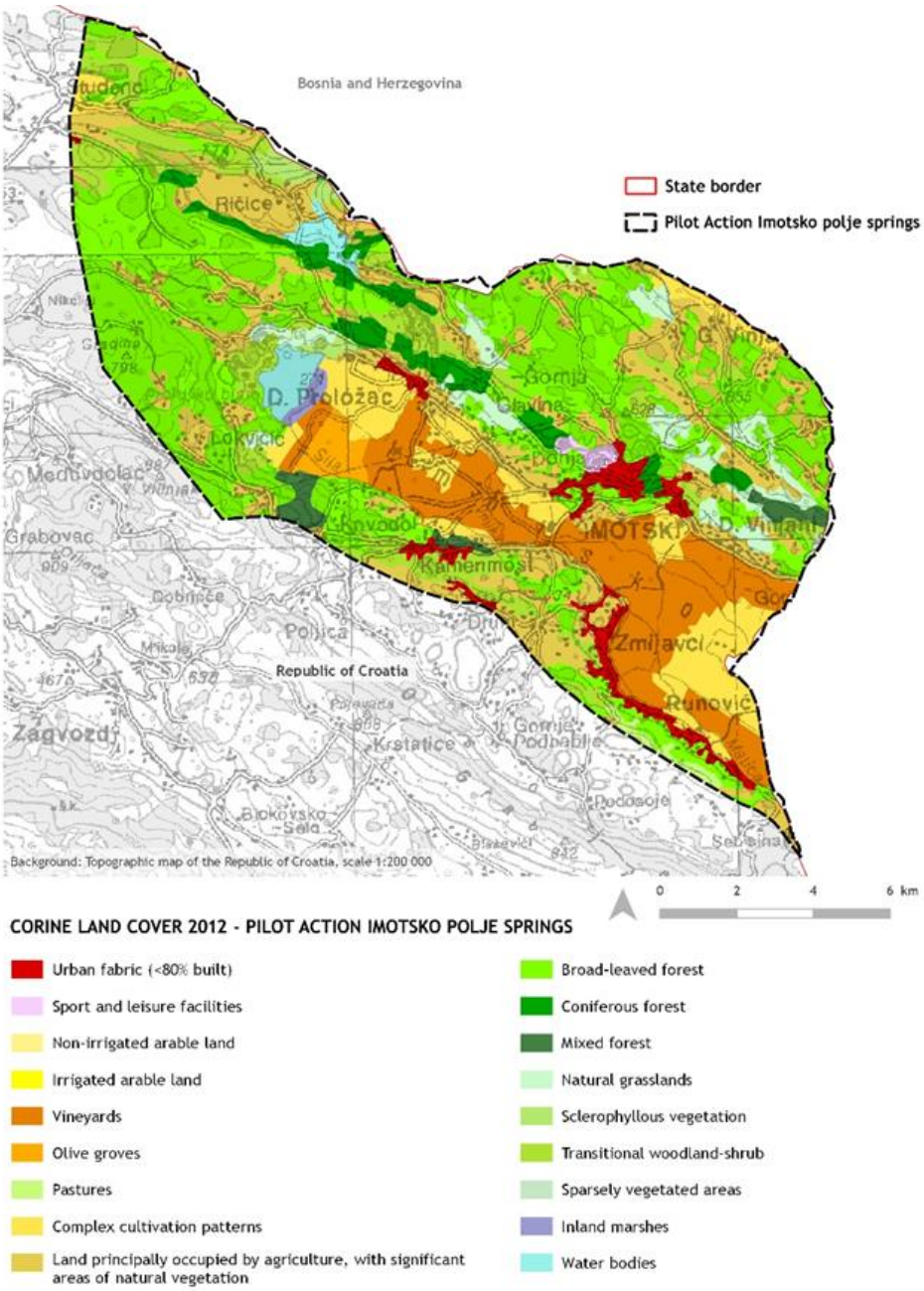

Figure 5: Land use in Imotsko polje springs, Croatia.

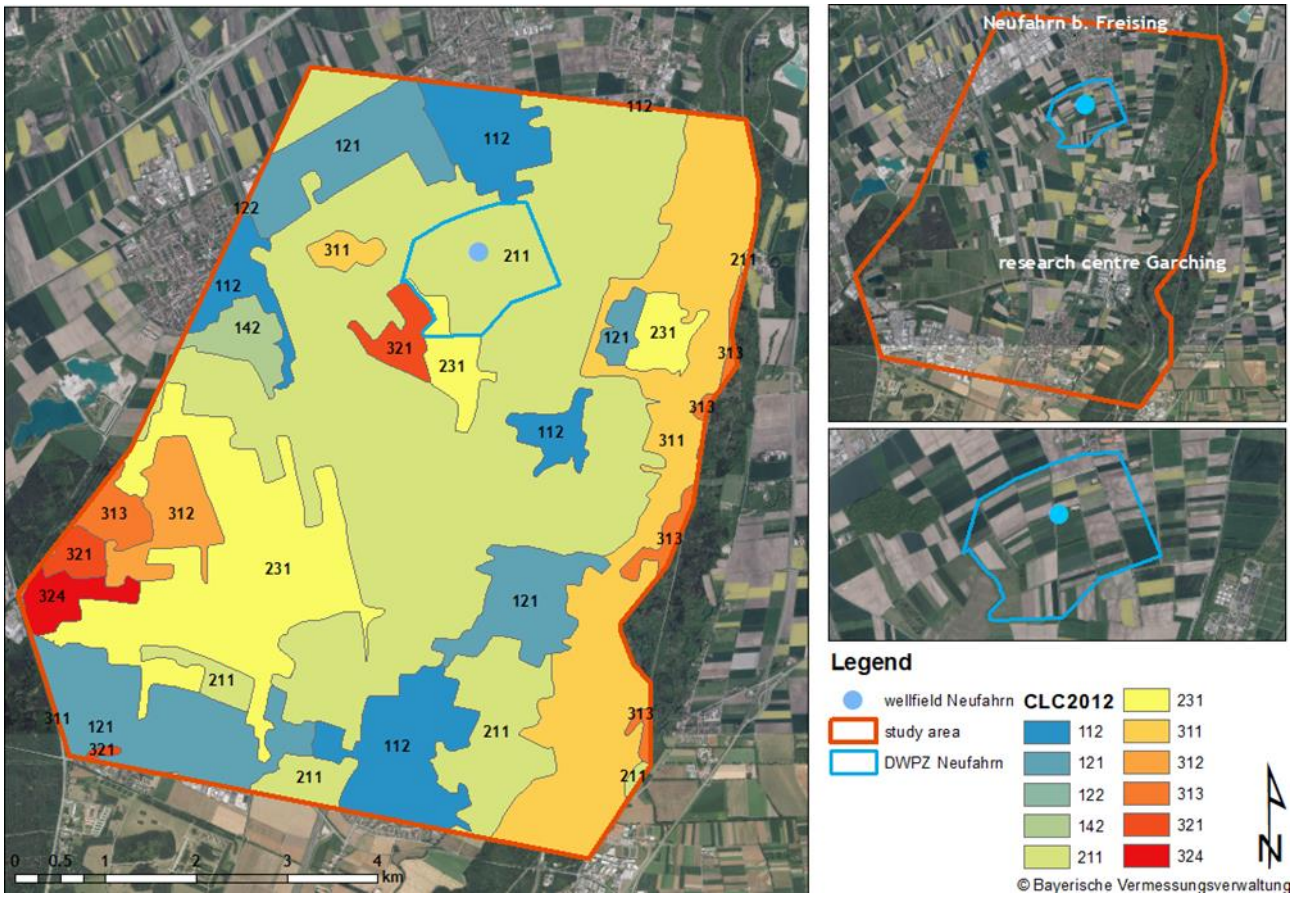

Figure 6: Land use in the Neufahrn pilot area, Germany.

Description of natural characteristics of Pilot Site is presented in *D.T.1.4 Descriptive documentation of pilot actions and related issues*. In continuation the main Pilot Action characteristics are presented in Table 2.

Table 2: Geographic and thematic focus of Pilot Actions in Cluster 2.

Pilot Action	*Geographic Focus*	*Thematic Focus*
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.	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

	→ alluvial plain with surrounding hilly area → urban environment	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	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 f.e. 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 and provide flexible fitting of water treatment technology due to current raw water quality

	Flora beds. Their outcrops become exposed over small surfaces in the area of Kozłowa Góra. → shallow reservoir → lowland → mainly agricultural and woodland areas	3. Community meeting and workshop organization to raise awareness and increase their knowledge 4. Preperation of proposal of DWPZ on the Kozłowa Góra reservoir
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 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 Holocene and Pleistocene sediments → pastures → agriculture	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) (Fig. 1). The surface drinking water 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 BMP's 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).
PA2.4: Groundwater protection in karst area, Croatia (PA 2.4.1: South Dalmatia: Prud, Klokun and Mandina spring; and PA 2.4.2: Imotsko polje springs)	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	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.

	Mediterranean and sub Mediterranean climate with very dry and warm summers. → Adriatic river basin → coastal karst polje → agriculture	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. → water and flood protection → land use
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 covers an area of 45.51 km2 and has a population of 21.486 inhabitants. (Neufahrn, 2017) 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	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 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.

2. Testing of BMPs in Pilot Action

2.1. Objective(s) of Pilot Actions in Cluster 2

Best management practices (hereinafter BMPs) for drinking water protection and management derived from T1 were reviewed and relevant BMPs were selected for particular pilot action. Implementation status of BMPs was verified in Pilot Actions (T2); in case of lacks identified, possibilities of improvement and implementation were also assessed. Drinking water protection and management and best practices are 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 were analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water level. 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; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

Review of main land use conflicts and BMPs on Pilot Action level has already been done in Pilot Action BMPs reports, which were a basis for *D.T2.1.2 Transnational case review of best management practices in pilot actions*.

On PAs within PAC2 in the *D.T2.2.2 Partner-specific pilot action documentations* a total of 19 GAPs were identified and 22 BMPs were proposed. In this report, we classified GAPs/BMPs according to what kind of land use type each problem is related to, or, if a problem is not related to any specific land use types, we grouped them according to water management subcategories. The groups are

- *general water management,*
- *drinking water management,*
- *flood management,*
- *all land uses,*
- *agricultural areas,*
- *urban areas.*

See description of the classification and an overview table of the grouped GAPs/BMPs in Ch. 2.2.

2.2. BMPs of Pilot Action

Five GAPs belong to *general water management*. These GAPs draw up some kind of shortage in measures, tools, or information, which would be necessary for ensuring a more efficient water management on the given PAs. The lack of DWPZs pose a problem on the Slovenian, Polish and Croatian Pilot Action sites, therefore we merged those GAPs into one but left the proposed BMPs separated to see how each country would/ could approach the problem. The other four GAPs in this group were identified on the Polish PA, where the inadequate monitoring system and the lack of information about water hazards and ecology of the water reservoir are causing the main issues.

We put one GAP in the group *drinking water management*, which is the pressure on water resources quantity caused by anthropogenic pressure, insufficiently working and weathered public water supply network, and climate change on the Croatian pilot action sites. Because of these factors there is a significant freshwater loss which could be mitigated by adaptation of CC models and reconstruction of public water supply network.

Issues related to flood events are the most common on PA2.1 in Slovenia. The GAPs are describing deterioration in both water quality and quantity, and the most important measure proposed is hydrological/ hydraulical modelling (see detailed description below in Ch. 2.2.1.). On the Hungarian PA Tisza Catchment area, the main problem is expected to be the unpredictability of flood events caused by climate change. To prevent unmanageable deterioration in water quality Hungarian partner proposed to revise the flood management operating system according to CC model. On Croatian PAs the flood events pose problem mainly because old/ weathered flood controlling infrastructure, but along with infrastructure maintenance the Croatian partner proposed non-structural mitigation methods as well.

In group *all land uses* we put one GAP/BMP identified on the German Pilot Action site, because the issue it describes cannot be approached with water management tools, but needs the collaboration of the public, the government and the experts as well.

We put four GAPs/BMPs in the group *agricultural areas*. Two of those were identified on Hungarian PA Tisza catchment area, where the main problem is improper use of pesticides and fertilizers and improper manure storage. These anthropogenic factors cause a quality deterioration in surface waters, while CC could worsen the problem. On Croatian PAs increased water demand is a serious problem and it will be worsened by the expansion of agricultural production areas in the future, the proposed solution is groundwater level monitoring. On the German PA continuous changes in agricultural land use pose a great issue for surface- and groundwater quality and quantity.

Finally, we put two GAPs/BMPs in the group *urban areas*, both identified on the Croatian PAs, both connect to waste management. The first issue is water quality deterioration caused by outdated waste water treatment system, and as a solution natural waste water treatment system was proposed. This solution costs three times lower price 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

- the illegal waste disposal, and the improper waste management. The proposed BMPs were raising its awareness and educate the public about sustainable waste management.

Table 3: Overview table for identified GAPs and related BMPs on Pilot Action sites in PAC2.

	GAP	BMP	
GENERAL WATER MANAGEMENT	No determination/ establishment of DWPZs	With hydrogeological modelling DWPZ areas will be determined	SI
		Proposal of DWPZ establishment	PL
		Defining and establishing sanitary protection zones in South Dalmatia	HR
	No complex evaluation of water hazards	Complex catchment modelling	PL
	Small scope of water monitoring	Establishment of constant, multi-aspects water monitoring in the catchment scale	PL
	Low level of ecological awareness of society	Raising awareness and increasing knowledge	PL
	No information about ecology of water reservoir	Establishment of an ecology model of water reservoir	PL
DRINKING WATER MANAGEMENT	Pressure on water resources quantity	Climate change adaptation and resilience / Reconstruction of public water supply network	HR
FLOOD MANAGEMENT	Pollution sources in flood prone areas are not known / identified	Register of potential point pollution sources on flood areas identified in PA	SI
	Surface water intrusion in the well	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	SI
	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants	Collecting torrential water in wider channels, small retention pond (transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model	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	HU
	Periodic field flooding	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures	HR

ALL LAND USES	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
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
	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
	Increased water demand	Establishment of groundwater level monitoring network in Imotsko polje and South Dalmatia	HR
	Continuous conversion of (permanent) grasslands	Continuous monitoring in both, surface water and groundwater	DE
URBAN AREAS	Insufficiently effective waste water treatment system that needs to be reconstructed and expanded	Natural waste water treatment system	HR
	Unsanitary and illegal waste disposal	Educative brochure and awareness raising activities	HR
		Encourage and promote innovative solutions of sustainable waste management	

2.2.1. Water management

▪ Identified GAP provoking action	
GAP short name	**No determination/ establishment of DWPZs**
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/ establishment of DWPZs**
Type of land use regarded	All
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**: 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. **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	**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**

Type of land use regarded	Agriculture / forestry / urban	
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, waste water 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 scope of 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	Agriculture / partly forestry /
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	Agriculture / forestry / urban	
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	Agriculture / forestry / urban	
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	-

2.2.2. Drinking water management

▪ Identified GAP provoking action	
GAP short name	**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	**Climate change adaptation and resilience / Reconstruction of public water supply network**
Type of land use regarded	All
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/	

2.2.3. Flood management

▪ 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 prone areas
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 prone areas
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	**Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants**
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	Flood prone 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	**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 prone areas	
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	**Operation of surface drinking water facility at flood time**
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	Agriculture/ urban/ riparian forest
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	All
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	

2.2.4. All land uses

▪ 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	Agriculture

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)

2.2.5. Agricultural areas

▪ 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
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	**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
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 in Imotsko polje and South Dalmatia**
Type of land use regarded	Agriculture
Location	Croatia, Pilot action Imotsko polje springs and South Dalmatia: Prud, Klokun, Mandina springs

<table>
<tr><td>BMP description</td><td colspan="2">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</td></tr>
<tr><td>Advantages of this BMP in PA</td><td colspan="2">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.</td></tr>
<tr><td>Challenges of this BMP in PA</td><td colspan="2">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.</td></tr>
<tr><td rowspan="4">Relevance</td><td>Water protection functionality</td><td>Medium to high</td></tr>
<tr><td>Cost of the measure</td><td>Medium to high (site specific)</td></tr>
<tr><td>Duration of implementation</td><td>Short term</td></tr>
<tr><td>Time interval of sustainability</td><td>Long term</td></tr>
<tr><td>Limitations</td><td colspan="2">There are no technical limitations connected to this BMP, but financing could pose a problem.</td></tr>
<tr><td>Implementation of the BMP in PA</td><td colspan="2">This BMP has not yet been implemented in pilot area but will be suggested to stakeholders through meetings and consultation.</td></tr>
<tr><td>Comments</td><td colspan="2">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.</td></tr>
</table>

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
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	

2.2.6. Urban areas

▪ Identified GAP provoking action	
GAP short name	**Insufficiently effective waste water 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 waste water 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 waste water treatment facility. Such waste waters are disposed into surface waters, septic tanks and groundwaters, causing pollution (e.g. pathogens).
▪ Best management Practice / Management Action	
Name of BMP	**Natural waste water treatment system**
Type of land use regarded	Urban
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 waste water 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

<table>
<tr><td></td><td colspan="2">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.</td></tr>
<tr><td>Advantages of this BMP in PA</td><td colspan="2">Natural waste water treatment systems cost three times lower price than common 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 2: Example of natural waste water treatment system.</td></tr>
</table>

References / sources	Figure 2. https://greentumble.com/natural-wastewater-treatment-systems/

▪ Identified GAP provoking action	
GAP short name	**Unsanitary 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

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”.

3. Activities in the Pilot Action

The main activities carried out in the PROLINE-CE Project for the PAs are summarized in Table 3.

Table 4: Summary of activities in the Pilot Actions in Pilot Action Cluster 2 (PAC2).

Pilot Action	*Activities in PA*
PA2.1: Well field Dravlje valley in Ljubljana, Slovenia	- Inventory of possible polluters in the urban recharge area of potential well field Dravlje, assessment of their impact on drinking water source and elaboration of measures and best management practices for protection of drinking water source, - strong stakeholder involvement for implementation of best management practices with several national meetings with particular stakeholder (one-to-one) and regular interactive workshops with local stakeholders, - establishing of distributed hydrological surface runoff model with full hydraulic propagation functions for surface waters, with evaluation of new flood measures (retention reservoir built in 2017) and climate change scenarios, - simulations of the groundwater pumping effects in the recharge area of planned well field Koseze, taking into account impact of climate change in order to model pumping scenarios according to changed climate 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, waste water management, 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 few 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 (PA 2.4.1: South Dalmatia: Prud, Klokun and Mandina spring; and PA 2.4.2: Imotsko polje springs)	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	- Hydrological modelling with the One-Water Hydrologic Flow Model framework (OWHM), - water quality in the pilot area - according to main focus of PROLINE-CE we used the nitrate concentrations in the shallow groundwater as an indicator to trace the link between land use changes and groundwater quality in the Neufahrn pilot area.

3.1. Solutions for case specific adaptation of best management practices

In Table 4 an analysis of examined/tested best management practices is summarized and related suitable solutions and recommendations for adaptation of existing land use and water management practices and improved policy guidelines for PAs in PAC2. The overall purpose of all mentioned management practices is the sustainable protection of the drinking water resources. Testing the BMPs selected for the investigated PAs allowed identifying the remaining issues that need to be solved for their full implementation. In Table 4, recommendations and actions are also indicated for each BMP, following the classification in three groups previously proposed.

Table 5: Overview about the GAPs and related BMPs within PAC2.

GAP GROUP General water management			
Actual management practice (GAP)	NO determination/ establishment of DWPZs		
Proposed BMP	With hydrogeological modelling DWPZ areas will be determined.	Proposal of DWPZ establishment.	Defining and establishing sanitary protection zones in South Dalmatia.

Proposed solutions and recommendations	Adaptation of existing land use management practices	A Hydrogeological model is a mathematical model simulation for low and high groundwater level. DWPZs are defined according to mathematical model prediction of 50-day isochrone (DWPZ I) and 400-day isochrone (DWPZ II) according to how many days takes the water to inflow from vadose zone.	Limitations and prohibitions are included within the proposal.	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 of existing flood/drought management practices	Not relevant	Limitations and prohibitions are included within the proposal.	Not relevant
	Adaptation of policy guidelines	Adaptation of Spatial plan of the Municipality of Ljubljana with DWPZ determination.	Proposal considers current Water Law and policy guidelines;	Policy guidelines are well developed concerning DWPZ, but implementation is lacking, inspections are inadequate, and penalties are rarely given.
Remaining issues to be solved		/	Good quality input and calibration data.	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.

GAP GROUP General water management				
Actual management practice (GAP)		No complex evaluation of water hazards	Small scope of water monitoring	Low level of ecological awareness of society
Proposed BMP		Complex catchment modelling	Establishment of constant, multi-aspects water monitoring in the catchment scale	Raising awareness and increasing knowledge
Proposed solutions and recommendations	Adaptation of existing land use management practices	It is highly recommended that within preparation of local land use management plan procedure results of the catchment modelling should be taken into account.	No adaptation required.	Participants are getting familiar with current land use management practises and proposal for BMP.
	Adaptation of existing flood/drought management practices	It is highly recommended to use results of the catchment modelling simulation in flood/drought management.	Investment in monitoring system contains constant monitoring system.	Participants are getting familiar with current management practises and proposal for BMP.
	Adaptation of policy guidelines	Recommendation to include catchment modelling as a one of the tool using to improve water management.	Need of conducting proper, multi-aspect monitoring of water system should be emphasized in guidelines at local, regional and also national level.	Participants are getting familiar with current policy

Remaining issues to be solved	-	-	Limited channels of information flow in small communities.

GAP GROUP General water management		
Actual management practice (GAP)		No information about ecology of water reservoir
Proposed BMP		Establishment of an ecology model of water reservoir
Proposed solutions and recommendations	Adaptation of existing land use management practices	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.
	Adaptation of existing flood/drought management practices	It is highly recommended to use results of the ecological modelling simulation in flood/drought management.
	Adaptation of policy guidelines	Recommendation to include the ecological modelling, integrated with catchment models, as a one of the tool using to improve water management.
Remaining issues to be solved		Good quality input and calibration data.

GAP GROUP Drinking water management		
Actual management practice (GAP)		Pressure on water resources quantity
Proposed BMP		Climate change adaptation and resilience / Reconstruction of public water supply network
Proposed solutions and recommendations	Adaptation of existing land use management practices	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.
	Adaptation of existing flood/drought management practices	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.
	Adaptation of policy guidelines	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.

Remaining issues to be solved	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.

GAP GROUP Flood management				
Actual management practice (GAP)		Pollution sources in flood prone areas are not known / identified	Surface water intrusion in the well	Torrential water flooding - excessive surface runoff, lack of water for animals and watering the plants
Proposed BMP		Register of potential point pollution sources on flood areas identified in PA	Sealed wells heads on flood areas evaluated according to Hydrological / Hydraulical model	Collecting torrential water in wider channels, small retention pond (transient marsh Mali Rožnik) managed according to Hydrological / Hydraulical model
Proposed solutions and recommendations	Adaptation of existing land use management practices	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.	Wells heads should be constructed as sealed in a way to prevent the surface water intrusion in the well during the flood event.	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.

	Adaptation of existing flood/drought management practices	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.	Many water supply wells are on flood-prone plains, so the wells heads should be constructed as sealed.	Aim of the improved retention measure: torrential waters running from the Rožnik hill are causing flooding and erosion problems
	Adaptation of policy guidelines	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.	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).	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.
Remaining issues to be solved				

GAP GROUP Flood management				
Actual management practice (GAP)		Water balance status and effective mitigation measures are not known (identified)	Increased contamination of surface drinking water resources during flood events	Periodic field flooding
Proposed BMP		Water balance status will be determined with Hydrological / Hydraulical modelling	Reducing flood effects on surface drinking water resources	Infrastructure maintenance and reconstruction / Non-structural flood mitigation measures
Proposed solutions and recommendations	adaptation of existing land use management practices	Not relevant	Change of agricultural practices in riparian areas	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).
	Adaptation of existing flood/drought management practices	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	Current flood management practices are good, but preparation for extreme flood events caused by CC seems to be necessary.	Proposed measures could enhance flood mitigation and management action.

		also allow us to do scenario analysis.		
	Adaptation of policy guidelines	Flood risk map as an adaptation of evaluation of parcels included in Municipal spatial planning.	Guidelines for agricultural practices in riparian areas.	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).
Remaining issues to be solved		-	Farmers and the water management sector should prepare for climate change	Measure is complex, as it faces resistance of local population, lots of financial compensation for losses, and generally, structural measures are still favoured.

GAP GROUP All land uses		
Actual management practice (GAP)		Lack of public engagement in development of action plans
Proposed BMP		Finding site-specific solutions by using a hydrologic model with a graphical user interface in a participative approach
Proposed solutions and recommendations	adaptation of existing land use management practices	No adaptation of existing land use management practices required.
	Adaptation of existing flood/drought management practices	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.
	Adaptation of policy guidelines	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.
Remaining issues to be solved		Not applicable

GAP GROUP Agricultural areas				
Actual management practice (GAP)		Improper manure storage	Improper or excessive use of pesticides and manure on plant production fields.	Increased water demand
Proposed BMP		Frequently monitoring livestock farms (authorities), providing information to the farmers about the environmental disadvantages of improper manure storage and about climate change.	Involving farmers to the Agrarian Environmental Program, emphasizing the importance of green products, providing information to the farmers about climate change.	Establishment of groundwater level monitoring network in Imotsko polje and South Dalmatia
Proposed solutions and recommendations	adaptation of existing land use management practices	Closed manure storage facilities, managing and collecting rainwater (better drainage systems on livestock farms).	Ploughing parallel to the watercourse, usage of green products.	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.
	Adaptation of existing flood/drought management practices	Collecting rainwater could be advantageous in drought periods.	Not relevant	Groundwater monitoring network will reduce uncertainty and could enable better responses and management action in case of floods and droughts

	Adaptation of policy guidelines	Guidelines for farmers about manure storage.	Not relevant	Relevant for water market: if necessary, revisions of payments, schemes and quotas.
Remaining issues to be solved		Solve the problem of frequent monitoring of livestock farms with or without involving the authorities, preparing for climate change.	Forecasting how plant production will change as climate changes could be advantageous.	The measure is simple, but requires funding sources, which is unclear at the moment.

GAP GROUP Agricultural areas		
Actual management practice (GAP)		Continuous conversion of (permanent) grasslands
Proposed BMP		Continuous monitoring in both, surface water and groundwater
Proposed solutions and recommendations	adaptation of existing land use management practices	No adaptation of existing land use management practices required.
	Adaptation of existing flood/drought management practices	Invest in infrastructure to increase the monitoring network in the pilot action. Installation of gauging stations on the Isar river, identification of piezometers usable to monitor groundwater level, installation of multi parametric probe that measures continuously relevant hydrogeochemical parameters (water level, water temperature, electrical conductivity, pH, Nitrate, dissolved oxygen)
	Adaptation of policy guidelines	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.
Remaining issues to be solved		Not applicable

GAP GROUP Urban areas		
Actual management practice (GAP)	Insufficiently effective waste water treatment system that needs to be	Unsanitary and illegal waste disposal

		reconstructed and expanded		
Proposed BMP		Natural waste water treatment system	Educative brochure and awareness raising activities	Encourage and promote innovative solutions of sustainable waste management
Proposed solutions and recommendations	adaptation of existing land use management practices	If measures are to be applied, land use and spatial planning documents and practices must be modified	Not relevant	Not relevant
	Adaptation of existing flood/drought management practices	Natural WWTS must be flood-proof to avoid spreading of pollutants and degradation of water quality	Not relevant	Not relevant
	Adaptation of policy guidelines	Plans for the extension of sewage and purification network must shift towards green and innovative methods	Policy guidelines are good, penalties are prescribed for illegal waste dumping, but inspections are poor, and misdemeanour is not punished	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.
Remaining issues to be solved		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)	As above	Stakeholders are a bit doubtful about the success of this measure. Although positive trends can be observed, the process is slow and requires persistence.

4. Conclusions

Six Pilot Action belong in PAC2: *PA2.1 Well field Dravlje valley in Ljubljana*, SI; *PA2.2 Water reservoir Kozłowa Góra*, PL; *PA2.3 Tisza catchment area*, HU1; *P2.4 Groundwater protection in karst area, 2.4.1 - South Dalmatia: Prud, Klokun and Mandina spring* and *2.4.2- Imotsko polje springs*, HR; *PA2.5 Neufahrn bei Freising*, DE.

PA2.1 is a potential well field in the Glinščica river sub-basin (Dravlje valley in Slovenia). It lies within urbanized area crossed by Ljubljana's ring-road. Large open spaces (mainly agricultural areas), urban area and industry causing high pressure on land use. This is also a flood prone area without efficient surface water regulation. This is a problem mostly because non-regulated surface water coming from the hilly hinterland can enter the urban sewage system, which in high waters cannot receive that much water and are flooded. Most of the issues are flood related and causing problems both in qualitative and quantitative aspects. Four out of the five BMPs describe a solution based on hydrological/ hidraulical models.

Within **PA2.2** Kozłowa Góra several GAPs were identified included Small scope of water monitoring, No DWPZ established, No complex evaluation of water hazards, No information about ecology of water reservoir and Low level of ecological awareness of society. During PA activities GPW actions responded the identified GAPs. 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 runned 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, waste water management, 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.

On **PA2.3** Tisza catchment area 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 few 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.

The above shows that the situation is satisfying at the moment. The problem lies in climate change and how it is going to affect the efficiency of the current practices. For instance, open manure storages may not pose a big threat in the current climate conditions, but an extremely intensive rainfall could possibly trigger a surface runoff, even on a flatter land, which could contaminate the nearby watercourses. As it was mentioned by BRUNETTI et al. (2001) and BATES et al. (2008)

(and many more) for countries in the temperate zone, climate change will decrease the number of rainy days but increase the average volume of each rainfall event.

Current practices should be evaluated in context of future climate conditions.

On **PA2.4** (PA 2.4.1 and PA 2.4.2**)** the main issues are increased water demand (due to rise in agricultural production), periodical field flooding, poor condition of water supply network, illegal waste dumps, inadequate waste water treatment and non-compliance with regulations and restrictions set out by DWPZ ordinance. BMPs are expected to promote topics such as water protection, pollution and climate changes, resulting in an increased awareness among the whole community and water users. Intensive stakeholder involvement is the first step towards the implementation of any BMP. Perhaps the hardest thing to change is the human consciousness and this is where further efforts must be directed – this refers both to decision makers and population. Decision makers must directly stimulate good practices, and vice-versa, the population should adapt and generally change their attitude towards changes in actual management practices (which often include negative financial repercussions). Although PROLINE-CE duration is too short to test the BMPs in pilot areas, indications towards positive changes in practices could be observable within project timeline. Croatian geological survey is a research institution, and therefore is not competent to directly implement measures and BMPs, but could only push such incentives via brochures, consultation with decision makers, education and further research.

On **PA2.5** proposed BMPs are *continuous monitoring program of hydrological data* with a high resolution in time and space as well as *hydrological modelling*. In the light of continuous changes in management practices as well as strongly economic-driven land use changes, a monitoring of relevant parameters in surface water and groundwater, such as water level, electrical conductivity, temperature, pH, nitrate among others, sets an appropriate frame to detect impacts of ongoing changes in the hydrological system. Given the enhanced database, a hydrologic model serves to relate any kind of changes to particular changes in the management system. Moreover, the hydrologic model allows to pre-evaluate the impacts of a planned action and, thus, supports the decision-making process from the beginning to the end of an implementation process. Moreover, a comprehensive, understandable and applicable modelling framework can serve as a common tool for all stakeholders, from land owner to decision maker, to jointly elaborate action plans, making decision-making more participatory. An enhanced public engagement further helps to reduce the mistrust between the engaged parties.

SUMMARY

In this report, we highlighted the relevance of previously identified GAPs/BMPs on Pilot Actions encompassed by PAC2. Classifying the GAPs/BMPs showed that most of the issue find on the pilot sites are related to flood events, the lack of measures, tools, or information in water management, or the negative effects coming from agricultural production. All of these factors cause a deterioration in both drinking water quality and quantity. The implementation of proposed solutions (BMPs) are limited by

- in general, and drinking water management: lack of political will, long lasting administrations, little public interest, low quality data;
- in flood management: not available or law quality data, high cost of measures (lack of funds), lack of trans-border cooperation;
- in agriculture: financing, lack of willingness of farmers to cooperate (a change to green production is expensive);
- in urban areas: 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.

In many cases the lack of public awareness worsens the situation, therefore excessive educational programs would be necessary even if the first approach of the problem is related to experts or the government.

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