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 3

SPECIAL SITES (RIPARIAN STRIPS)

Lead Institution	PP13 - CMCC Foundation
Contributor/s	See next page
Lead Author/s	Guido Rianna & Angela Rizzo
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Contributors, name and surname	Institution
Hungary	
Robert Hegyi	PP7 - General Directorate of Water Management
Magdolna Ambrus	PP7 - General Directorate of Water Management
Peter Molnar	PP7 - General Directorate of Water Management
Tamas Belovai	PP7 - General Directorate of Water Management
Barbara Bezegh	PP14 - Herman Otto Institute Non-profit Ltd.
Matyas Prommer	PP14 - Herman Otto Institute Non-profit Ltd.
Mihaly Vegh	PP14 - Herman Otto Institute Non-profit Ltd
Orsolya Both	PP7 - General Directorate of Water Management
Ágnes Tahy	PP7 - General Directorate of Water Management
Antal Serfőző	Geogold Ltd.
István Waltner	PP14 - Herman Ottó Institute Non-profit Ltd.
Italy	
Silvano Pecora	PP9 - Arpae
Giuseppe Ricciardi	PP9 - Arpae
Cinzia Alessandrini	PP9 - Arpae
Francesco Puma	PP9 - Arpae (EU. WATERCENTER)
Paolo Leoni	PP9 - Arpae
Alberto Agnetti	PP9 - Arpae
Mauro Del Longo	PP9 - Arpae
Marco Brian	PP9 - Arpae
Valentina Dell'Aquila	PP9 - Arpae
Monica Branchi	PP9 - Arpae
Guido Rianna	PP13 - CMCC Foundation

Angela Rizzo	PP13 - CMCC Foundation
Sergio Noce	PP13 - CMCC Foundation
Monia Santini	PP13 - CMCC Foundation
Anna Sperotto	PP13 - CMCC Foundation
Silvia Torresan	PP13 - CMCC Foundation
Vuong Pham	PP13 - CMCC Foundation

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1. Introduction

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

Pilot actions and pilot sites are respectively classified into three clusters (Table 1) concerning the geographic specification and natural site characteristics (e.g. 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 from **PAC3** 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, GER **Drinking water source: Porous aquifer**	

1.1. Pilot Action Cluster 3: Special sites (riparian strips)

In the Pilot Action Cluster 3 (PAC3) two Pilot Actions were assigned, one located in Italy and the other one in Hungary:

- PA3.1: Po river basin;
- PA3.2: along Danube bend.

In the context of PROLINE-CE Project, for each pilot action the general practices for drinking water protection and water management at national level have been reviewed (in the framework of T1 activities), the main gaps related to the water management have been identified and relevant Best Management Practices (BMPs) have been selected and tested (in the framework of T2 activities). Furthermore, implementation status of BMPs has been also verified and in case of lacks, possibilities of improvement and implementation have been assessed.

In *D.T2.1.4 "Descriptive documentation of pilot actions and related issues"* a detailed description of geographic and social characteristics of Pilot Actions is reported. Specifically, the pilot areas included in Cluster 3 represent key territories for the respective countries not only for what concerns the water resources.

Po River Basin (PA3.1) has an area of 74.000 km^2, which encompass Italian, French and Swiss territory. This area represents the most developed part of the country, with an important role at environmental, economical, agricultural and industrial level. In addition, around 20 % of the country's population lives in this area.

The Hungarian case study (PA3.2) is located in the Northern part of Central Hungary, in section of Danube between Szob and Tass. It includes the municipality Budapest, the Szentendre Island, and the Csepel Island. On these islands are located the two most important bank-filtered drinking water resources of Hungary, which provide drinking water to the city of Budapest and to about 150 settlements. The main characteristics of PAs are briefly reported in Table 2.

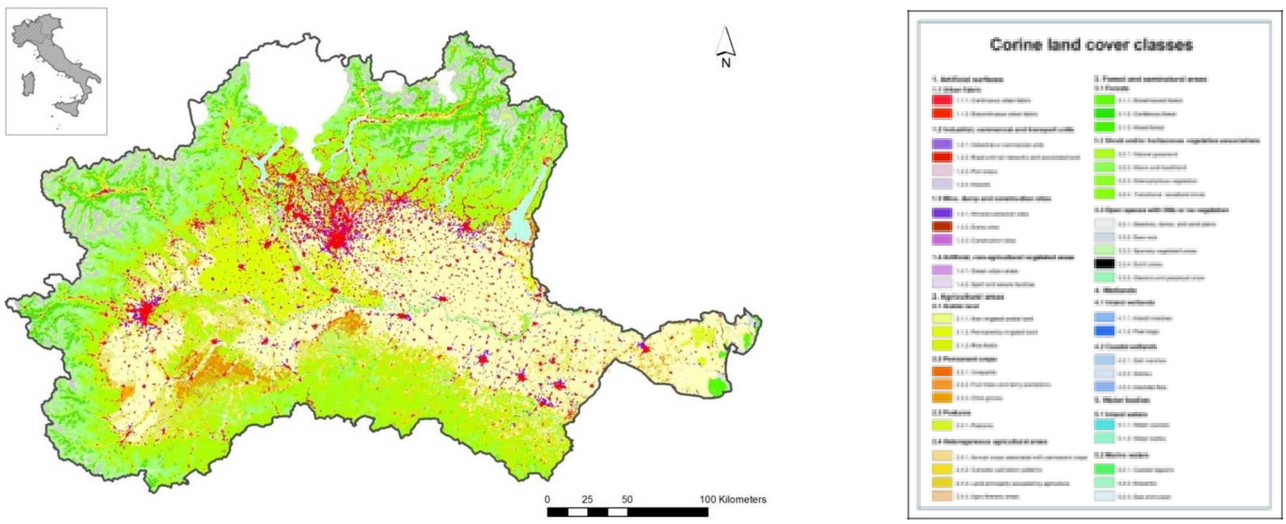

Figure 1: PA3.1 land use map.

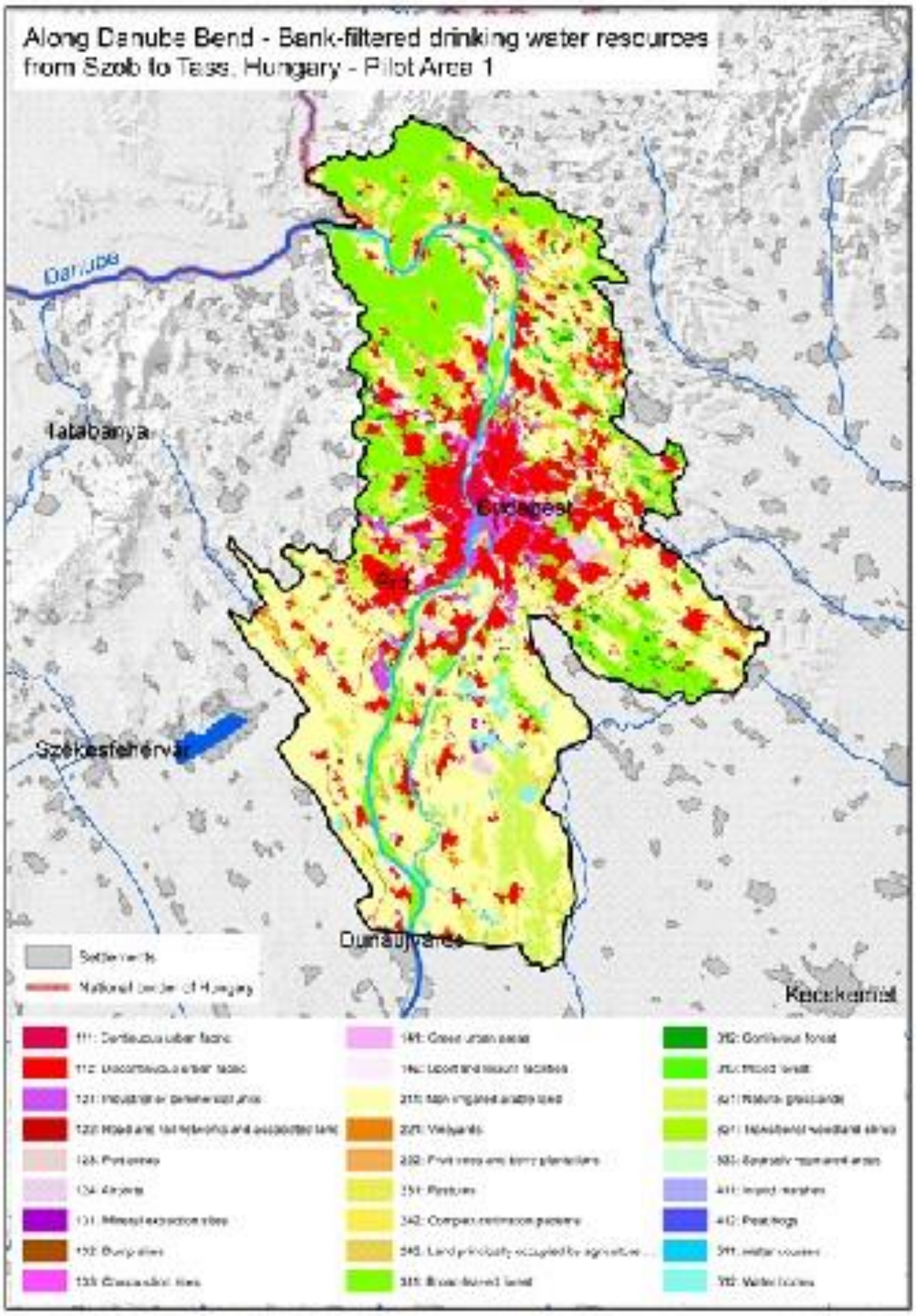

Figure 2: PA3.2 land use map.

Both PAs are characterized by prevalence of agriculture areas and, for this reason, the most relevant threats are associated to related activities, which affect both the quality and the quantity of the drinking water resources. Agricultural impacts include the contamination of water bodies with chemicals, pesticides, nitrates, the increase of water consumption and water demand associated to irrigation practices, the resultant decrease in water table height and land subsidence entailing, in turn, saltwater intrusion into aquifers. On the other hand, although urban areas cover proportionally small portions of PAs, they also produce relevant impacts on water resources. These impacts include: much larger water demand, contamination of water bodies with civil and industrial wastewater not properly treated, increase of runoff and erosion rates due to higher percentages of impervious surfaces, direct discharge of nutrient, organic matters and pathogens into surface waters and groundwater.

Based on the analysis of the local characteristics of the PAs, it is clear that the main issues to the drinking water resources are related to the water quality and water quantity protection and management. More specifically in the Po river basin area, the main issue results the relevant pressure on water resources demand and the associated crisis management, while in the Danube area drinking water resources are particularly vulnerable to contamination and, for this reason, the main issue is represented by the protection of the water quality. Specific gaps identified for the PAs are reported in Table 2.

Project activities have allowed identifying the practices suitable for the management of the main issues affecting drinking water protection and hydraulic risk. Among these, some BMPs have been selected for each PA in relation to the specific identified gaps. In Table 2, the management practices identified for PAs in Cluster 3 are reported (referring to D.T2.1.2). In the following paragraphs, the gaps and the related BMPs identified for PA3.1 and PA3.2 to achieve a function-oriented land-use based spatial management are described; the main issues that remain to be solved are also indicated.

Table 2: Geographic and thematic focus of Pilot Actions in Cluster 3.

PA3.1: Po River Basin	*PA3.2: Along Danube bend*
Geographic focus	
Po River Basin is mostly occupied by agricultural and forest/grasslands areas, which cover respectively 46% and 45% of the basin, while urban and industrial areas concern about 7% (Fig.1). The area includes 2155 surface water bodies, and 167 groundwater bodies. Hydrological modelling for flood risk mitigation and water availability, also including CC and LULC change, are considered. → riparian strips → complex landscape (agricultural areas prevailing) → drinking water availability	Danube bend area is mostly occupied by non-irrigated arable land (38.5%), discontinuous urban fabric (11.4%), broad-leaved forest (11%) and pasture (6.5%) (Fig. 2). The pilot area hosts the two most important bank-filtered drinking water resources of the Country. Water-quality monitoring systems and the implementation of proper land use practices are deeply investigated. → riparian strips → agricultural and urban → drinking water sources

Thematic focus	
The main objective is improved protection of drinking water resource through an integrated land-use management approach, focusing on drought/flood events forecast and managing and accounting also for the future climate change impacts. Water protection is carried out through the implementation of BMPs primarily designed for water availability, particularly during extreme events (drought/flood). Activities are focused on the improvement of hydrological modelling, also accounting for CC and LUC and enhancement of civil protection mechanisms and regulatory systems. → complex landscape (agricultural areas prevailing) → drought, flood, climate change → drinking water availability	The main objective is improved protection of drinking water resource through an integrated land-use management approach, focusing on the water quality protection and on the proper management of bank-filtered wells during flood events. Water protection is carried out through the implementation of BMPs primarily designed for reducing potential damages to water quality through sustainable agricultural practices and improved of municipal sewage treatments. Activities are focused on water quality monitoring systems in order to evaluate the effectiveness of BMPs implementation, also accounting for flood risk reduction. → agricultural and urban areas → groundwater quality damage mitigation → bank-filtered water/extraction wells protection

2. Testing of BMPs in Pilot Action

2.1 Objective(s) of Pilot Actions in Cluster 3

Gaps identified in PAC3 affect drinking water in terms of both quality and quantity (D.T2.2.2). The assessment and the management of water scarcity events and the assessment of the main source of contamination represent therefore priority actions for the protection of the water resource system. Furthermore, due to the relevance of Po and Danube watercourses, impacts potentially induced by flood events also represent a key challenge and need to be taken into account. In this regard, although flood impact assessment methods primarily focus on direct damages due to inundation, indirect damages, such as the interruptions in services of water supply and the increase in water turbidity processes, can affect in substantial way the population and the assets located in the investigated areas. Nevertheless, the evaluation of indirect impacts of flood events on drinking water resources is not yet fully considered in the flood risk management cycle and represents, therefore, a gap in both PAs. Drinking water resources are also directly and indirectly affected by ongoing climate change and land use change, which can affect water quantity and water quality level but also can have cascading impacts on freshwater ecosystem services (FWES) and human well-being. This issue is particularly relevant in the PA3.1, where several prototypal studies have been carried out to assess future climate scenarios.

Based on these considerations, in PA3.1 the following three gaps have been identified and for each of them, BMPs have been selected:

- Pressures on water resources management -> the Drought Steering Committee and Drought Early Warning System (DEWS)
- Flood impact not fully implemented and considered-> The Flood Forecast Centre and Flood Early Warning System (FEWS)
- Climate change impacts on drinking water resources-> Analysis of the impacts of climate changes on drinking water resources.

In the case of PA3.2, the following three gaps have been identified and the related BMPs have been selected to solve these GAPs:

- Agricultural groundwater pollution-> Participation in Agro Environment Program
- Lack of sanitary coverage-> Municipal sewage disinfection
- Flood protection protocol on bank-filtered wells operations during high water and flood events-> Ensure the drinking water supply during high water or flood.

2.2 BMPs of Pilot Action

As recalled above, in PA3.1, pressures on water resources are mainly generated from the heavy exploitation of the water system and therefore the management of drought events is crucial for the evaluation of drinking water quantity. At national level, no drought risk assessment is periodically performed, while the Law R.D 1775/1933 requires the nomination of an emergency commissioner only in case of drought/water scarcity events. In 2007, responding to the drought emergency management, a Civil Protection Act established the Drought Steering Committee for the Po river basin, led by the Po River Basin Authority, with the Operational Support of the Emilia Romagna Environmental Agency. Since 2010, the activities related to drought prediction and simulations are supported by the DEWS System, designed and implemented on the basis of the above-mentioned agreement among Institutions and stakeholders.
Considering the flood management, in accordance with the National Civil Protection Department, the flood alerting system FEWS Po (Flood Early Warning System for the Po river basin) was drawn up in the 2000s. In 2013, the Po River Flood Forecast Centre was also established to provide flood forecasts, monitoring and evaluation.
The BMPs selected for the first two gaps are primarily devoted to improve (empower) these operational tools already working in the area. The enhancements are primarily related to management aspects in the first case and to modelling processes in the second case. Increasing awareness and enlarging the purposes of the tool including also proper assessments of exposure and vulnerability are taken into account for the second one. According to the third identified gap, the objective of Pilot Action is to propose strategies to increase the awareness of all the stakeholders (actors or users: administrators, decision-makers but also communities) about the potential impacts of climate changes and partly associated land use changes on drinking water resources. Specifically, a list of indicators to evaluate the effects of different climate, land use

scenarios and management practices on changes of ecosystem services involved in drinking water provisioning and management have been provided. In this context, REMHI Division of CMCC Foundation has deeply investigated the expected variations in hydrological regime of the area, providing data on temperature and precipitation variation for the period 2041-2070 and 2071-2100 vs 1982-2011. In details, the Global Climate Model, CMCC_CM (Scoccimarro et al., 2011) with a horizontal resolution of about 80 km has been dynamically downscaled using the RCM COSMO_CLM model at a horizontal resolution of 8 km, in the optimized suite on Italy carried out by Bucchignani et al. (2015).

In PA3.2, the impacts on water quality induced by flood, agricultural production, and sewage infiltration are recognized as the most relevant gaps and the protection of the extraction wells results fundamental to ensure the drinking water resources. In order to protect the drinking water resource, the Government Regulation 123/1997 on the protection of the actual and potential sources and water supply structures, defined criteria of water protection zones based on the implementation of safeguarding measures. Protection is intended to include the determination, designation, establishment, and maintenance of a protective block or area or zone. In this context, changes in water chemistry have been deeply examined, monitoring wells located in Szentendre Island, which represent the most complex area being characterized by agricultural production, recreational areas with no sewerage system connection, and high flood risk vulnerability.

In order to provide a comparative overview and to highlight the main characteristics/differences of BMPs selected in the Pilot Actions of Cluster 3, they have been merged in three groups, based on their relevance on the drinking water damage mitigation (in terms of quality, quantity and flood impacts). Climate change effects can affect both the quality and the quantity of the drinking water and can also have influence on the floods. Nevertheless, the gap related to this issue has been inserted in the “quantity group” even if it could overlap the gaps identified for the other two groups. Climate change has been selected as gap only in the case of PA 3.1, being this area particularly sensitive to the expected climate variations.

The proposed gaps/BMPs groups are:

Group 1 – Water Quality, which includes the following gaps of PA3.2: Agricultural groundwater pollution; Lack of sanitary coverage;

Group 2 – Water Quantity, which includes the following gap of PA3.1: Pressures on water resources management; Climate change impacts on drinking water resources;

Group 3 - Flood-protection, which includes the following GAP of PA3.1 and PA3.2: Flood impact not fully implemented and considered (PA3.1); Flood protection protocol on bank-filtered wells operations during high water and flood events (PA3.2).

2.2.1 GAP/BMP Group 1: Water Quality

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

Comments	
References / sources	

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

Relevance	Water protection functionality	high
	Cost of the measure	high

	Duration of implementation	long-term
	Time interval of sustainability	long-term
Limitations	Legislation on water resources stipulates that in the internal protection area of water resources only water supply facilities can be located. No residential or recreational park can be built on the external and “A” hydrological protection zone. Building of new residential or office buildings without drainage system on the external or “A” hydrological protection zone is prohibited.	
Comments		
References / sources		

2.2.2 GAP/BMP Group 2: Water Quantity

▪ **Identified GAP provoking action**	
GAP short name	**Pressures on water resources management**
GAP short description	Qualitative and quantitative over exploitation of water system and unbalanced exploitation rate between surface and ground water bodies; not yet fully implemented integration of needs and stakeholders’ priorities
▪ **Best management Practice / Management Action**	
Name of BMP	**The Drought Steering Committee and DEWS (Drought Early Warning System)**
Type of land use regarded	Agriculture, industry, urban areas
Location	Po river basin, Italy
BMP description	Drought Steering Committee is a Multisectoral partnership that consists in a forum of major water users in River Po basin, initiated and presided by the Po River Basin Authority (P-RBA). Since 2016, a permanent network of “Observatories on water uses” has been established among all public and private stakeholders of national relevance. According to this network, the Po Drought Steering Committee has the new role of Permanent Observatory on Water Uses in the P-RBD.
Advantages of this BMP in PA	Emergency planning and management; information and data sharing; updated knowledge of water resources and balance; agreed decisions among all the stakeholders involved, supported by an objective operational monitoring and modelling system; periodical meetings.
Challenges of this BMP in PA	Practicable, measurable and effective overcoming of Institutional fragmentation through an Authority with more decision-making power and more structured decision processes based on flow charts. Business continuity guarantee to maintain the operational system on water resources management (DEWS) in the Po River Basin District to support planning and integrated management processes. Integrated Water Resources Management supports Institutional change. The Po Observatory experience can be extended to the other established

	Observatories; opinions and activities about different approaches can be exchanged.	
Relevance	Water protection functionality	Medium/High
	Cost of the measure	Low
	Duration of implementation	Long-term
	Time interval of sustainability	Long-term
Limitations	Lack of imposition power (such a low could have); water scarcity emergency threshold planned not still implemented; high prediction uncertainties; need of nesting of higher resolution models, procedures and institutional tools (Land Reclamation Boards modelling); not all the information layers are already implemented (glaciers, ground water, evapotranspiration); cost benefits analysis implementation in the decision support tool; needs of completing the monitoring system for uptakes; web services for water scarcity information.	
Comments		
References / sources	Po river Basin District Water Balance Plan (2016)	

▪ **Identified GAP provoking action**		
GAP short name	**Climate Change impacts on drinking water resources**	
GAP short description	The potential direct or indirect impacts of climate changes on drinking water resources require deep and complex analysis tools properly put into system allowing proper adaptation measures and improving community's awareness.	
▪ **Best management Practice / Management Action**		
Name of BMP	**Analysis of the impacts of climate changes on drinking water resources**	
Type of land use regarded	All type of land uses, including 14 classes aggregated from the third level of the CORINE Land Cover (CLC) classification. Nevertheless, LUC scenarios have been developed according projections for socio-economic, demographic and climate forcing.	
Location	The entire basin but primarily, focusing on a small river basin such as the Taro River basin to test the effectiveness of this BMP.	
BMP description	An attempt to perform an analysis aimed to assess the potential effects of climate changes and/or land use changes on drinking water resources; it will exploit different data sources and explicitly consider the view and needs of stakeholders.	
Advantages of this BMP in PA	It will permit arranging proper adaptation measurements with the aim of limiting negative consequences.	
Challenges of this BMP in PA	Future evolution of weather forcing under the effect of climate changes and associated feedbacks (f.e., in part, land use changes) are currently characterized by high uncertainties and low perception among all the stakeholders.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium
	Duration of implementation	High
	Time interval of sustainability	Medium

Limitations	Uncertainties have to be carefully evaluated and made clear to stakeholders; it requires the adoption of probabilistic approaches for all the different stages of modelling chain.
Comments	While the climate and land use projections are developed for the whole Po River basin, the application of InVEST model to assess the impacts of climate change on freshwater ecosystem services are developed for the Taro River basin, one of the tributaries of the Po river. It is due to efforts associated to data stocktaking and analysis currently associated to adoption of approaches for evaluating the cascading impacts on freshwater ecosystem services (FWES) and human well-being. Furthermore, climate projections are made available by past experiences under two RCPs up to 2100 and, yet, they are the data at the highest resolution available for Italian domain (Bucchignani et al., 2015). LUC simulations are carried out as novel result within the PROLINE-CE Project. The added value compared to previously proposed (e.g. Santini & Valentini, 2011) is represented by adoption of the above introduced climate projections. It permits properly understanding feedbacks of single and coupled effect of CC and LUC on drinking water resources.
References / sources	Bucchignani E., Montesarchio M., Zollo A.L., Mercogliano P. (2015). High-resolution climate simulations with COSMO-CLM over Italy: performance evaluation and climate projections for the XXI century. International Journal of Climatology DOI: 10.1002/joc.4379 – International Journal of Climatology DOI: 10.1002/joc.4559 Pham, H. V., Torresan, S., Critto, A., & Marcomini, A. (2018). Alteration of freshwater ecosystem services under global change – A review focusing on the Po River basin (Italy) and the Red River basin (Vietnam). Science of the Total Environment. (Under review) Santini M., Valentini, R. (2011) Predicting Hot-Spots of Land Use Changes in Italy by Ensemble Forecasting. Reg Environ Change, 11:483-502. DOI: 10.1007/s10113-010-0157-x. Vezzoli, R. et al. 2015. "Hydrological Simulation of Po River (North Italy) Discharge under Climate Change Scenarios Using the RCM COSMO-CLM." Science of the Total Environment 521-522: 346–58. Zollo A.L., Rillo V., Bucchignani E., Montesarchio M., Mercogliano P., 2015, "Extreme temperature and precipitation events over Italy: assessment of high-resolution simulations with COSMO-CLM and future scenarios", International Journal of Climatology, DOI: 10.1002/joc.4401.

2.2.3 GAP/BMP Group 3: Flood protection

▪ Identified GAP provoking action		
GAP short name	**Flood impact**	
GAP short description	Impacts of floods on water quality, especially on drinking water supply system and the whole environment is not yet fully considered in the flood risk management cycle.	
▪ **Best management Practice / Management Action**		
Name of BMP	The Flood Forecast Centre for the Po River and Flood Early Warning System (FEWS)	
Type of land use regarded	Infrastructures, industrial soil and contaminated sites, agriculture, urban areas	
Location	Po river basin, Italy	
BMP description	The Flood Forecast Centre for the Po river is in charge to the Interregional Agency for the Po river and is supported by the Hydrology Unit of Arpae. The Centre provides flood forecasts monitoring and evaluation supported by the FEWS system. Through FEWS it is possible to manage observed data (in situ and remote sensed), and forecasts obtained from meteorological-hydrological-hydraulic simulation in order to early detect floods, their occurrence, entity, and characteristics. The Flood Forecast Centre supports the Command and Control Unit within the Civil Protection System.	
Advantages of this BMP in PA	Emergency planning and management; information and data sharing; updated knowledge of flood exposure and vulnerability; supporting decisions through an objective operational monitoring and modelling system; opportunity, based on flood forecasts, to undertake mitigation actions protecting drinking water systems.	
Challenges of this BMP in PA	Managing the whole flood disaster cycle through a practicable, measurable and effective guide to support decisions, procedures, processes, and actions. Business continuity guarantee to maintain the operational system on flood management (FEWS) in Po river basin to support planning and integrated management processes. The Po River Flood Forecast Centre operational procedures and experiences can be shared and eventually extended to other River Basin Districts. Extension of the flood management operational tools to other aspects and sectors (climate change, water quality, sediment transport, ecology). Implementation of web services for flood warning.	
Relevance	Water protection functionality	Medium/High
	Cost of the measure	Medium
	Duration of implementation	Long-term
	Time interval of sustainability	Long-term
Limitations	During extreme events (intense, rapid or intense/rapid) it could be very difficult to supply information and to link all the stakeholders and actors in time to undertake flood mitigation actions; high prediction uncertainties; the actual consistency of the monitoring and forecasting network may be fully representative of the extension, heterogeneity, and complexity of the basin	

	and of the river network. The modelling and monitoring system may be periodically calibrated, updated and refined, mostly after extreme flood events.
Comments	
References / sources	Po River Basin District Flood Risk Management Plan (2016)

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

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 3: Summary of activities in the Pilot Actions in Pilot Action Cluster 3 (PAC3), Special sites (Riparian strips)

PA3.1: Po River Basin	*PA3.2: Along Danube bend*
Activities in PA	
The activities carried out in PA3.1 mainly concern the drinking water protection in terms of water-quantity and flood risk mitigation. The main gaps identified in PA3.1 account for the overexploitation of water resources, especially during drought events, and for the potential impacts of floods on drinking water resources, which are currently not fully considered in the integrated water management strategies. Furthermore, in PA3.1 strong attention is given to the evaluation of the potential impacts of climate change, which will directly and indirectly affect the drinking water supply. In order to cope with these issues, suitable BMPs for the protection and management of drinking water have been selected and implemented. Specifically, in order to improve the flood forecast and water managing during droughts, respectively employed in FEWS and the DEWS systems, hydrological and hydraulic models have been configured and implemented at the basin scale. Furthermore, current climate characterization and future variations in weather patterns have been evaluated by means of an integrated modelling chain that allows quantifying the impacts of climate change and land-use change, with a specific attention on their relation with freshwater ecosystem services. Stakeholders have been the main actors in all phases of BMPs testing. They welcomed basic principles and methodologies for flood/drought operational management and for climate change simulation and projections. Meeting events highlighted that stakeholders involved in management of water shortage crisis should be not only professionals but also communities and non-experts.	In the Danube area, groundwater is particularly vulnerable to contamination induced by agricultural production, pollution by not adequate sewage systems or during floods. For this reason, activities proposed for PA3.2 concern the implementation of BMPs that are aimed at solving issues related to groundwater quality damage and its protection. The issues associated to agriculture primarily affect bank-filtered water sources while poor quality water from urban areas arrive in water bodies after not adequate treatments. Furthermore, water quality is potentially affected by flood events because of river waters may reach the extraction structures and surface water can enter the wells. In this context, selected BMPs account for the water quality monitoring, both in agricultural and in urban areas, the implementation of proper land-use practices and the construction of sewage systems and devices for wastewater treatment. Activities are also focused on the evaluation of the BMPs effectiveness by clarifying the decrease in the groundwater chemical pollution due to the changes in agricultural activities and examining the increase in groundwater quality as consequence of the improvement of sewerage services and network connection. In order to gain a good insight into the challenges of drinking water resources protection and in further developing of best land-use practices, stakeholders from various domains (Universities, scientific institutes, water management bodies, ministries, national parks, and NGOs concerned with environment and water protection) have been invited to participate in national meeting and workshops.

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 flood/drought management practices and improved policy guidelines for both PAs. 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 4: Overview about the GAPs and related BMPs within PAC3.

Actual management practice (GAP)		GAP Group 1 **Water Quality** 1- Agricultural groundwater pollution 2- Lack of sanitary coverage	GAP Group 2 **Water quantity** 1- Pressures on water resources management 2- Climate change impacts on drinking water resources	GAP Group 3 **Flood protection** 1- Flood impact not fully implemented and considered 2- Flood protection protocol on bank-filtered wells operations during high water and flood events
Proposed BMP		BMP – 1 (PA3.2) Participation in Agro Environment Program	BMP – 1 (PA3.1) The Drought Observatory/ Steering Committee and DEWS (Drought Early Warning System)	BMP – 1 (PA3.1) The Flood Forecast Centre and FEWS (Flood Early Warning System)
Proposed solutions and recommendations	Adaptation of existing land use management practices	Such practices are already part of the program.	Improvement of knowledge on links between land use and water resources through: -Periodical updating of the	Strengthening role and requirements of flood management system in relation to the operational needs in all phases

			assessment of land use impact on drinking water; -Increase of number, spatial/temporal detail and type of data about land use and environment representation.	of disaster management (forecast, preparation, and response). Increase synergies among land use planning/management and emergency planning/management. Periodical updating of vulnerability and exposure evaluation.
	Adaptation of existing flood/drought management practices	Such practices are already part of the program.	Increase the use and sharing of drought early warning system among stakeholders. Creation within the DEWS system of drought /water scarcity indicators and indices easier to understand for stakeholders. Investment in monitoring, simulation, and analysis. Increase weather, ice/snow cover and ground water information. Operational platforms maintenance, education and training. Consider site-specific drought impacts on drinking water. Fix water shortage/drought	Improvement of the monitoring and modelling system, also considering interactions with exposed elements and operational procedures. Investment in flood analysis, operational platform maintenance, education, and training. Consider flood, drought and water management as a unique operational process. Make flood information more understandable to citizens. Consider flood impact on drinking water.

			thresholds.	
	Adaptation of policy guidelines	The Agro-Environmental Program is already based on existing policy guidelines.	Improvement of potential synergies among stakeholders on water demand and land use. Give more decisional power to the Permanent Observatory on Water Uses.	Integration in policy guidelines of the fundamental role of predictability, uncertainty, and communication of extreme events in losses of lives and damages linked to heavy rain and floods, including losses in drinking water supply systems.
Remaining issues to be solved		- Data gathering on how many participants joined the National Agro-Environment Program since it was first launched.	- Guarantee resources allocation for maintenance and improvement of existing platforms, procedures expertise and activities. - Increase awareness on drinking water as a not renewable resource. - Drought and water scarcity characterization. - Environmental and Economic Water accounting. Further developments in: - integration of climate, snow/ice water, reservoirs, surface water and ground water observation, simulation and	- Guarantee resources allocation for maintenance and improvement of existing platforms, procedures expertise and activities. - Increase awareness on heavy rain and flood as potential cause of not reversible damages. Further developments in: - integration of meteorological, snow water, reservoirs, water devices, surface water and ground water observation, simulation and management; - coupling of water quality

		management; - integration of in situ and remote sensing - coupling of water quality and water quantity observation and simulation; - scalable simulation tools considering different temporal and spatial scales (point, river, network, basin, district); - unification of flood, water shortage and drought observation and simulation platforms. - interactive, spatially based, web based, standardized and open architecture retrieving/ access services (data, metadata and information); - harmonization among real time and delayed time applications; - consideration of joint effects/impacts of strategies, guidelines, planning, design management, constraints and	and water quantity observation and simulation; - coupling water and sediment cycles; - unification of flood, water shortage and drought observation and simulation processes and platforms; - interactive, spatially based, web based, standardized and open architecture retrieving/ access services (data, metadata and information); - harmonization among real time and delayed time applications; - consideration of joint effects/impacts of strategies, guidelines, planning, design management, constraints and practices, (land use, water use, civil/environmental protection); - standardization of tools methodologies, terminology, criteria,

			practices; - standardization of tools methodologies, terminology, criteria and procedures for water shortage damage assessment.	procedures for flood and heavy rain damage assessment.
Proposed BMP		BMP – 2 (PA3.2) Municipal sewage disinfection	BMP – 2 (PA3.1) Analysis of the impacts of climate changes on drinking water resources.	BMP – 2 (PA3.2) Ensure the drinking water supply during high water or flood.
Proposed solutions and recommendations	Adaptation of existing land use management practices	Not applicable	The proposed solution is to carry out detailed studies about the potential impacts of climate changes and partly related land use change. The main goal is to provide probabilistic evaluations of impacts on drinking water resources accounting for multiple constraints. Furthermore, it could increase the awareness of all the stakeholders about the topic.	Not applicable
	Adaptation of existing flood/drought management practices	Not applicable	Investment in data collection, monitoring, model simulation and analysis, operational	Management practices could be applied for better protection of the wells during floods

			platform maintenance education and training. Promote synergic approaches between Disaster Risk Reduction and Climate Change Adaptation communities by considering the cross-dependence between droughts and floods periods. The assessments could support systemic evaluations about the management of extreme events (flood and droughts) achieving solutions effective also for preserving drinking water resources. Moreover, the approaches are straightly exploitable also for other test cases.	
	Adaptation of policy guidelines	There are already relevant existing policy guidelines.	Test the implementation of proposed solution by relevant stakeholder's communication in the decision-making process. Improving the decision-making process increasing the awareness of all the stakeholders about	There are no clear recommendations at present.

			the future challenges for effectively preserving drinking water resources.	
Remaining issues to be solved		- Development of sanitary coverage in Pócsmegyer and Szigetmonostor; - Identification of contamination source at Dunakeszi	- Enhance in understanding of physical behaviour and increasing in computational power to reduce remarkable uncertainties that characterized, at the moment, several elements of proposed modelling chain. - Adoption of probabilistic approaches or findings provided by ensemble initiatives to manage complex atmospheric processes and gaps about future paths in socio-economic and demographic trends. - Enhance the dissemination of the findings accounting for pros and cons in the modelling chain and permitting to have a clearer view about future state of drinking water resources that could be exploited by stakeholders. - Improve	- Further investigation of water chemistry measured in observation wells located on Szentendre Island - Revise flood management in context of future climate conditions

		management and use of natural resources and ecosystem services to use and modify less the natural capital. - Encourage natural capital valorisation, circular economy and ecosystem optimal management through climate change simulation. - Implement complex, physically based, socially based and evidence related design, planning and governance tools linking environmental, economic and social resources, services and processes. - Promote the availability and practicality of climate projection ensembles to enable robust decision making thanks to a likelihood-based analysis.	

Considering the BMPs selected in PA3.1, during the PROLINE-CE Project, new datasets have been added to DEWS and new implementation of existing models have also been done. Nevertheless, management experience analysed during the project have highlighted potential further steps to improve the system, among which: i) giving more decisional power to the Permanent Observatory; ii) increasing weather, ice/snow cover, ground water and withdrawals information; iii) fixing water scarcity and drought thresholds; iv) increasing water resources awareness.

Regarding the second gap, the maintenance and the improvement with implementations of new tools in the Flood Forecast Centre and the Flood Early Warning System (FEWS) have been proposed as BMP. Also, in this case, the analysis highlighted some further steps to improve the system: i) promoting synergic approaches between Disaster Risk Reduction and Climate Change Adaptation; ii) enhancing predictive models enhancing parametrizations accounting for ice/snow cover, ground water state; iii) supporting vulnerability and exposure evaluation and then drinking water protection zones and water works; iv) increasing flood awareness among communities.

From the analysis of the BMPs selected in PA3.2 also emerged that the availability of subsidies acts as a main driver for the implementation of such practices and therefore improving the availability of subsidies and grants results a crucial point for fulfil the complete implementation of the activities. Furthermore, another important point is represented by the low awareness of the farmers about new available methods.

4. Conclusions

Pilot Action Cluster 3 (PAC3) encompasses Pilot Action 3.1 (PA3.1 – Po River Basin) and Pilot Action 3.2 (PA3.2 – Danube Basin). As emerged from the PAs analysis, PA3.1 and PA3.2 represent key territories for the respective countries not only for what concern the local water resources. Po River Basin District (PA3.1) is the largest one in Italy and represents an exceptionally varied reality besides being one of the main national economic forces. The Hungarian case (PA3.2) is focused on the most important water supply area in the country, the bank-filtered water resources on the right and left bank of the Danube, on the Szentendre and Csepel Islands. The bank-filtered water resources located on the pilot area supply with drinking water about 2.5 million inhabitants.

Within the PROLINE-CE Project, the whole water governance process has been investigated for the PAs: BMPs for drinking water protection and management derived from T1 have been reviewed and relevant BMPs selected for each 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. Furthermore, the main problems, pressures and gaps and the related heterogeneous measures and practices for land management and drinking water protection have been reviewed. Drinking water management and best practices have been 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.

Regarding the PAC3, in PA3.1 the increase of water consumption and climate change impacts represent important issues, affecting the drinking water availability especially in terms of water scarcity. On the other hand, in PAC 3.2, preventing the quality deterioration of drinking water sources and ensuring an adequate standard for the drinking water supply during floods represent the main issues. In order to cope with these criticalities, several BMPs have been identified. In each PA, main gaps and proposed BMPs to promote optimal land use and water resources protection have been selected. Specifically, in PA3.1 the following gaps have been identified:

- Pressures on water resources management;
- Flood impact not fully implemented and considered;
- Climate change impacts on drinking water resources.

For each of them, the following BMPs have been selected:

- The Drought Steering Committee and Drought Early Warning System (DEWS)
- The Flood Forecast Center and Flood Early Warning System (FEWS)
- Analysis of the impacts of climate changes on drinking water resources

In the case of PA3.2, the following GAPs have been identified:

- Agricultural groundwater pollution;
- Lack of sanitary coverage;
- Flood protection protocol on bank-filtered wells operations during high water and flood events.

For each of them, the following BMPs have been selected:

- Participation in Agro Environment Program;
- Municipal sewage disinfection;
- Ensure the drinking water supply during high water or flood.

The comparison of the GAP and related BMPs in PA3.1 and PA3.2 allows stating that regarding the Italian case study (PA3.1), more attention is required for the management of the drinking water supply even considering the climate change effects on water resources. Managers expressed a strong interest in flood and drought modelling (FEWS and DEWS) for their possible application in the operational daily management, whilst the climate change simulated scenarios could be useful to address strategic planning and investment options assessment on new supply resources. National meeting has highlighted that the proposed practices are well accepted among the stakeholders, which realize the potential benefits coming from integrated water management, appropriate modelling and simulation, projected climate change and land use change, opening the way to new methodologies and tools for transactions, cooperation and sharing of information.

In the Hungarian case study PA3.2, the drinking water quality is the major challenge and the proposed BMPs aim to the assessment of strategies and practices for the protection of the water quality and flood impacts mitigations. Proposed investigations for the future include continuous monitoring of water chemistry and flooding on Szentendre Island, the collection of numerical data on how many participants joined the National Agro-Environmental Program on the PA, and the identification of pollution source at Dunakeszi and Vác and, if necessary, other settlements on the left side of the Danube.

In both investigated cases, direct and indirect impacts of flood events need to be better investigated and, in this case, stakeholders proposed detailed mapping and planning of areas prone to be impacted, especially of most vulnerable elements in terms of both drinking water resources and potential sources of pollution (such as areas of storage and deposit of contaminants). In this contest, an adequate territorial and land use planning results useful for limiting risk of potential contamination.

Finally, in both PAs of Cluster 3, future climate change could affect the water resources, affecting both water availability and water quality. For both pilot actions, future climatic variations have been evaluated by means of modelling chains, including climate simulations and hydrological modules (T2.3.3). Nevertheless, climate change impacts are recognized as a main threat only in PA3.1, where the expected variations in temperature and precipitation will cause a strong increase in water demand.

5. References

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PROLINE-CE WORKPACKAGE T1, ACTIVITY T1.1 REPORTS:

- D.T1.1.1 Country reports about the implementation of sustainable land use in drinking water recharge areas
- D.T1.1.3 First review of status quo report
- PROLINE-CE WORKPACKAGE T1, ACTIVITY T1.2 REPORTS:
- D.T1.2.1 Country-specific best management (Italy)
- D.T1.2.1 Country-specific best management (Hungary)

PROLINE-CE WORKPACKAGE T1, ACTIVITY T1.3 REPORTS:

- D.T1.3.2 Start-up stakeholder workshops implemented plus related documentation (Italy)
- D.T1.3.2 Start-up stakeholder workshops implemented plus related documentation (Hungary)

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

- D.T2.1.2 Best management practices report. PILOT ACTION: PA3.1 Po River Basin
- D.T2.1.2 Best management practices report. PILOT ACTION: PA3.2 Along Danube bend
- D.T2.1.4 Descriptive documentation of pilot actions and related issues. PILOT ACTION: PA3.1 Po River Basin
- D.T2.1.4 Descriptive documentation of pilot actions and related issues. PILOT ACTION: PA3.2 Along Danube bend

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

- D.T2.2.2 Partner-specific pilot action documentations. PILOT ACTION: PA3.1 Po River Basin
- D.T2.2.2 Partner-specific pilot action documentations. PILOT ACTION: PA3.2 Along Danube bend