PROLINE-CE

WORKPACKAGE T1, ACTIVITY T1.2

D.T1.2.2 Transnational best management practice report

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1. Introduction

The purpose of D.T1.2.2 “Transnational best management practice report” is to provide an overview of best management practices in drinking water supply areas, regarding different types of land use covering regional and national level, furthermore enhanced with EU level. Transnational best management practice report is developed within the scope of activity A.T1.2 “Review of best management practices for drinking water supply issues”, and it will provide a comprehensive structure for sustainable land-use practices regarding drinking water supply issues.

Best management practices in this report are derived either from past projects and studies (e.g. CC-WARE, Orientgate) or from existing national strategies, action plans, various country specific documents and several EU directives (Water Framework Directive, Floods Directive, Drinking Water Directive). Moreover, in D.T1.2.1 Country-specific reports, which are used as an input for this report, best management practices (also referred to as measures) are divided into three clusters according to the geographical scope that is predefined in WP T2 (Pilot actions) and contain a general description, advantages and challenges of the respective measure. Each measure is evaluated according to its water protection functionality, costs, duration of implementation and time interval of sustainability.

This transnational report is structured in such a way that each type of land use presents a separate chapter (forest, grassland, wetland, agriculture, special sites – dry areas and riparian strips and general). Best management practices are further divided into clusters depending on which geographical setting the measures is applied in (mountain sites, plain sites). At the start of each chapter, brief sectoral overview is provided on EU level (statistics, current situation and future challenges). At the end of each chapter a review is provided on a country level, highlighting similarities, discrepancies and gaps between practices in partner countries. Lastly, a well-known example of good practice is provided from the world for each type of land use, demonstrating how innovative or unconventional approach can produce excellent results in some areas.

Transnational best management practice report, supplemented by inputs from stakeholder’s workshops, aims to provide a comprehensive base for further deliverables of PROLINE-CE project, namely for the DT.1.3.4 Transnational catalogue of strategies and measures to be integrated into existing policy guidelines. Furthermore, this deliverable will directly contribute to PROLINE-CE output O.T1.2 “Strategy for the improvement of policy guidelines”.

2. Forests

2.1. Forests in general

The EU currently contains 5% of the world's forests and EU forests have continuously expanded for over 60 years, although recently at a lower rate. EU Forests and Other Wooded Land now cover 155 million ha and 21 million ha, respectively, altogether more than 42% of EU land area. 45% of European forests are predominantly coniferous, 36% are predominantly broadleaved and the remainder is mixed.

In regards to the Member States' national forest policies, they are formulated within a clearly defined framework of established ownership rights and with a long history of national and regional laws and regulations based on long term planning.

Although the Treaties for the European Union make no provision for a common forest policy, there is a long history of EU measures supporting certain forest-related activities, coordinated with Member States mainly through the Standing Forestry Committee.

The EU Forest Strategy, adopted in 1998 puts forward, as its overall principles, the application of sustainable forest management increasing the adaptive capacity to climate change and the multifunctional role of forests. The Strategy was amended in 2013, and the Commission presented an EU Forest Action Plan in 2006 (EC, 2016).

The most important effective forest policy mechanism at international level is Forest Europe (formerly: Ministerial Conference on the Protection of Forests in Europe, MCPFE), a pan-European forest policy process at ministerial level (of 47 Member States), conducted every 3 to 5 years (since 1990), that develops guidelines, criteria and indicators for the protection and sustainable management of forests. In 2007 the topic "Forests and Water" was discussed in Warsaw and a resolution was passed.

2.2. Best management practices – Forests – Mountain sites (MF)

Some of the best management practices are applicable in both plain and mountain sites. Unless indicated within the measure description, the applicability is shown in overview table at the end of the chapter.

- **BP MF1 Avoidance of the clear-cut technique**

Description of the measure

The clear-cut technique (CCT) as silvicultural measure for timber yield and subsequent artificial recruitment techniques does not conform to water protection requirements, as it can cause contaminations of the aquifer or streams with nutrients and solid matter mobilized from plant, humus and soil compartments. Additionally CCT creates topsoil drought conditions, which causes water repellency of the soil and humus layers. Water repellency of the topsoil increases surface

runoff processes and is in contradiction to flood mitigation, while also decreasing groundwater recharge.

Clear-cuttings and deforestations foster mineralization and nitrification processes by enhanced solar radiation acting on the unprotected surface. A further logical consequence of thinned forest stands is a decreased uptake of nutrients by the roots which increases the provision of different ions to be leached. BÄUMLER et al. (1999) described such an enhanced solution load in the discharge as a consequence of forest thinning in the Bavarian Alps. Enhanced mineralization processes as well as an increased nutrient provision in general can lead to an increased leaching of water pollutants into the receiving stream water or the groundwater (ROTHE et al., 2004; WEIS et al., 2008).

The water retention is substantially decreased on progressive clear-cutting and deforestation sites, which heightens transpiration losses and lowers interception of nutrients. Conversely, the increased impact of rainfall on the soil surface can favour the generation of surface runoff which additionally is enhanced through decreased macroporosity and soil compaction as a result of area-wide timber harvesting. MOHR et al. (2013) found out that clear-cutting areas can either be a sink or a source for runoff and erosion strongly depending on the soil microtopography and the rainfall intensity. Intense surface runoff and soil erosion processes thus can occur once a specific threshold of rainfall intensity (20 mm h^{-1} according to MOHR et al., 2013) has been reached and a connectivity of the soil microtopography has been generated. Moreover, MEGAHAN (1983) showed that clear-cuttings can significantly increase the peak snow water equivalent and snow melt rates in mountain areas leading to increased direct runoff, erosion and slope instability. As a consequence, areas located at a lower elevation can be affected adversely, e.g. in case of flash floods, and their ecosystem services can suffer substantial damages. Especially for convective storm events this fact is of primary importance.

While deforestations should generally be prohibited in drinking water protection zones (DWPZ), clear-cuttings should be avoided above a certain threshold (e.g. > 5000 m^2). By avoiding area-wide open spaces the forest maintains its protective function for its own system (tree stand, soil, soil ecosystem) as well as for all downhill located areas and hinders an enhanced discharge of nitrate as well as an enhanced runoff contribution of direct runoff resulting from overland flow or snow melt. In this way, erosion and soil degradation in general are limited and the topsoil of the forest maintains its ecosystem services in terms of water regulation and water purification. Moreover, downhill located areas also benefit from the protective function of the forest since the concerned land-use units and their ecosystem services are protected from upstream hazards. Especially in DWPZ the protection forest is of vital importance to maintain the water protective function of the whole area.

Measure advantages

Avoidance of CCT opens the path for a consistent water protection strategy. It assures the avoidance of the most threatening processes caused by forestry in terms of drinking water protection and flood prevention.

Challenges

The resistance of foresters towards the avoidance of CCT may be very strong, as CCT can be regarded as the most important silvicultural system applied in timber-yield forestry. A lot of knowledge transfer strategies will be needed to convince foresters about this step.

- **BP MF2 Establishment of a Continuous Cover Forest System**

Description of the measure

Continuous Cover Forest System (CCF) ensures a sustained provision of the forest functions for drinking water protection and flood prevention. The forest stands of CCF are multi-layered, uneven-aged and built up by the potential tree species diversity of the specific forest site. Forest management activities have to be applied on small spatial scales hence supporting a low disturbance regime. CCF forms an excellent basis for drinking water protection and flood prevention.

Measure advantages

CCF as true alternative to the clear cut technique provides the basis for a consistent strategy in forestry with the overall purpose of drinking water protection and/or flood prevention. It ensures the water protection functionality of forest ecosystems over space and time.

Challenges

The application of CCF requires in most of the cases specific training, as the majority of foresters are used to apply the clear cut technique. PROLINE-CE can provide such as first step in the course of the stakeholder workshops.

- **BP MF3 Defined Crown Cover Percentage of Forest Stands**

Description of the measure

The actual given crown cover percentage of forest stands has to range between 70% and 90% in colline to mountain areas and between 60% and 80% in subalpine areas. This guarantees a high degree of stability towards disturbances like wind storms and additionally provides enough space and light for a continuous regeneration process. Mobilization processes in soil and humus layers are kept on a low level and it can be regarded as basic requirement for the establishment of CCF and for the sustained provision of the water protection functionality of forest ecosystems.

Measure advantages

The defined crown cover percentage for forest stands provides a clear frame for forestry in DWPZ. It is a very important BP and helps to secure the water protection functionality of forest ecosystems (together with other BP's).

Challenges

As timber production was and is the overall purpose for many forest regions, this BP can create discussions among foresters, as it requires a fundamental change in silvicultural concept and measure application.

- **BP MF4 Limitation of the Percentage of Timber Extraction**

Description of the measure

The limitation of the percentage of timber extraction with 10-25% of the forest stand volume during each silvicultural measure guarantees a low disturbance regime in forested DWPA. It helps to sustain stability of the forest stands and has to be applied together with the margins for crown cover percentage (BP MF3). The cutting frequency has to be integrated as well.

Measure advantages

The limitation of the percentage of timber extraction has the great advantage that together with the application of BP MF 3 the sustained stability and resiliency of the forest stands and forest ecosystems can be facilitated. This is a basic condition for flood mitigation and the protection of drinking water resources.

Challenges

Again the habitual management procedures in forestry will be an obstacle for the application of this BP, as it requires from the foresters a fundamental shift of timber yield patterns. Drinking water protection as an overall purpose is still rather new and unknown for most of the foresters.

- **BP MF5 Continuous Regeneration Dynamics**

Description of the measure

Forest stands in DWPZ have to host a continuous regeneration phase on minimum 10-20% of their spatial extension. This ensures the highest degree of resilience, as in case of disturbances the water protection functionality of the forest can be restored the fastest. Continuous regeneration is a basis condition for CCF, as it provides the basis for uneven-aged forest stands. In case of natural forest stands it also ensures the natural regeneration of autochthonous genetic material, which is of crucial importance for stability and resilience, especially under climate change.

Measure advantages

Continuous regeneration dynamics provide a basic condition for forest ecosystem stability and resiliency. Only when young trees can grow without hindrances in all forest stands and ecosystems, the system stability and also the water protection functionality are given on a high level.

Challenges

High wild ungulate densities are the greatest threat for a continuous regeneration dynamic. Browsing damages occur wide spread and also several DWPZ are affected. To solve this issue is a

true challenge, as the hunter organisations have a strong lobby and do not want to have significant changes, as those could affect their hunting habits.

- **BP MF6 Foster Stability, Vitality and Resilience of the Forest Ecosystems**

Description of the measure

In DWPZ stability, vitality and resilience of the forest ecosystems are the most important features. Stable forest ecosystems and forest stands can resist any given disturbance. In case of strong disturbances, resilient forest ecosystems can recover their water protection functionality rapidly. The vitality of the tree individuals and of the whole forest ecosystem is the basic condition for stability and resilience.

Measure advantages

Stability, vitality and resilience are the most important features of forest ecosystems in DWPZ. Hence any activities to foster those are important for drinking source water protection and flood prevention. The purpose in silviculture moves from high quality timber trees towards stable and vital trees, which makes a definite difference.

Challenges

This change in silviculture requires again a renunciation from habitual procedures in forest management. The foresters have to be trained towards perceiving the most stable and vital trees and also towards a consequent implementation of fostering stable and vital tree individuals.

- **BP MF7 Tree Species Diversity According to the Natural Forest Community**

Description of the measure

Tree species diversity according to the natural forest community guarantees the highest level of stability and resilience. Tree species diversity provides a high level of adaptability, also under climate change. Forest stands created by diverse tree species can utilize a broader scope of the forest soils, if deep-rooting and shallow-rooting trees are growing together. Knowledge about spatial distribution of the natural forest communities (forest hydrotopes) is required for the operational stratification of the DWPA and adaptive forest management. Man-made plantations with non-natural tree species should be transformed gradually to stands dominated by native species, depending on the local experience and legislation.

Measure advantages

In many forests tree species diversity according to the natural forest community is a definite advantage, as homogeneous conifer plantations are partially dominating the forests. Especially in times of climate change tree species diversity becomes mandatory for achieving forest ecosystem stability. Diversity has also positive side effects, e.g. for conservation purposes.

Challenges

In some forest areas there can be expected resistance against tree species diversity according to the natural forest community, if the habitual forestry practices had a strong focus on conifer plantations or other homogeneous timber yield focused plantations.

- **BP MF8 Improve the structural diversity of the forest stands**

Description of the measure

Forest stands in DWPZ should be structured vertically and horizontally. This involves tree species diversity as well as uneven-aged and multi-layered forest stands. Structural diverse forest stands are a basic requirement for continuous cover forest systems. Stability and resilience are improved in case of structural diverse forest stands.

Measure advantages

Structural diversity in forest ecosystems provides an improvement of forest stand stability and additionally is necessary for the CCF (continuous cover forest systems). Hence it has to be followed as a guideline in forest management within DWPZ to achieve structural diversity.

Challenges

As many forest stands are based on the age-class system, structural diversity is actually not very common. Most of the forest stands are even-aged and only single-layered. The change of silvicultural practices towards structural diverse forest stands will have to involve both persuasive efforts and training of the foresters.

- **BP MF9 Forest Ecologically Sustainable Wild Ungulate Densities**

Description of the measure

High wild ungulate densities provoke severe browsing damages on tree seedlings and saplings, fraying damages and bark-peeling damages. Those inhibit the natural regeneration process of whole forest ecosystems or destabilize them. Natural regeneration is the crucial process in forest ecosystems, which has to be given on an optimal level for all present tree species, especially within DWPA. This can only be guaranteed, if the wild ungulate densities are regulated to a forest ecologically sustainable level, hence providing vital regeneration of all tree species.

Measure advantages

Ecologically sustainable wild ungulate densities provide a huge advantage, the forest ecosystems can evolve naturally, and they can grow according to their natural inner dynamics. This includes a vital regeneration layer within the forest stands, encompassing all tree species of the respective natural forest community. It is the most essential precondition for providing the water protection functionality of forest ecosystems.

Challenges

High level of wild ungulate densities is the greatest threat for a continuous regeneration dynamic. Browsing damages occur wide spread and also several DWPZ are affected. To solve this issue is a true challenge, as the hunter organisations have a strong lobby and do not want to have significant changes, as those could affect their hunting habits. To establish forest ecologically sustainable wild ungulate densities can be regarded as the main challenge in the forest sector.

- **BP MF10 Protection of the Gene Pool of the Autochthonous Tree Species**

Description of the measure

Autochthonous tree species have evolved since thousands of years in their specific forest regions. They carry the genetic information, which allowed them the survival of the past climate changes in those areas. They are the basis for the establishment of the natural forest communities (BP MF 7). Tree species diversity is dependent on them.

Measure advantages

Autochthonous tree species are the basic requirement for forest ecosystem stability. They carry a lot of genetic diversity and are the best in coping with the local climatic conditions. In times of climate change their value becomes priceless.

Challenges

In some regions it could already become difficult to find autochthonous tree species, especially in areas where only Norway spruce (*Picea abies*) was planted, always using only the varieties with the greatest increment levels. Again persistence can be expected, if the change from high-timber-yield species towards more stable autochthonous species is envisaged.

- **BP MF11 Foster old, huge and vital tree individuals**

Description of the measure

Old, huge and vital tree individuals carry excellent genetic information. They can supply younger and smaller tree individuals with nutrients via their common mycorrhizal network. Thereby they provide a substantial contribution to forest stand stability. Therefore they have to be selected and protected, so that they can provide their services as long as possible.

Measure advantages

The genetic information provided by old, huge and vital tree individuals have a high value for the sustainability of the forest ecosystem. Old and huge tree individuals can provide stability for the whole forest stand (in a quasi-mechanical way) and are also important for the nutrition of young trees (including the regeneration phase), who may receive nutrients from the old trees via the mycorrhiza-interconnected root system.

Challenges

The old, huge and vital tree individuals have to be selected for remaining in a forest stand. In recent times huge trees are in general selected for being cut. This change of behaviour has to be achieved through information and persuasive efforts.

- **BP MF12 Establishment of an adequate deadwood management**

Description of the measure

The presence and leaving of deadwood in forest ecosystems plays an important role for the biodiversity. Therefore it was proposed and has been accepted as an indicator for biodiversity on the pan-European level (GOVIL, 2002). In Bavaria, the establishment of an adequate deadwood management in state-owned forests is regulated by law, whereas this implementation is still voluntary in privately owned forests.

Deadwood provides a rich source of nutrients that is continuously released in the process of its decomposition. In particular carbon, calcium and magnesium are provided. In this way, on the one hand this management practice enhances the formation of humus and on the other hand improves the silvicultural productivity. Moreover, deadwood represents an important habitat and ecological niche for several micro- and macroorganisms, e.g. fungus-types, bacteria, different woodpecker species and owls, and thus enables a species-rich ecosystem.

Deadwood is an integral part of the soil development process. While fostering the production of humus, deadwood directly helps to increase the water storage capacity of the uppermost soil layer. A thick humus-layer on the one hand enhances the purification of seepage water and on the other hand increases the water storage capacity of the soil. Hence, an adapted deadwood management enhances the ecosystem functions such as water provision, water regulation and water quality regulation. Moreover, deadwood locally regulates the microclimate and helps to keep the living conditions near the soil surface more constant (SCHIEGG PASINELLI et al., 2002). In terms of soil degradation, deadwood also locally hinders erosion processes and inhibits the outwash of nutrients and soil particles.

The Measure advantages of an adequate deadwood content go beyond its direct impacts on the water-related ecosystem functions. In fact, it also positively affects other forest management practices, e.g. natural regeneration. The natural regeneration of spruce, fir and Swiss stone pines has been proved to be very effective on deadwood (SCHIEGG PASINELLI et al., 2002). Additionally, deadwood helps to protect the young stands from browsing by game making the natural regeneration process more efficient.

The ecologically-valuable properties of adequate deadwood content are prerequisites to obtain a stable, vital and especially resilient forest which can fulfil its protective function.

This best practice is valid for both mountain and plain sites.

Measure advantages

- Positive impacts on the ecosystem services water regulation, water provision, water quality regulation;
- provision of nutrients and thus improvement of silvicultural productivity;

- protective function from browsing by game of young stands;
- coupling with other measures (e.g. natural forest regeneration of mixed-forests) can enhance the effect of an adequate deadwood management.

Challenges

- May hamper logging procedure;
- may increase the vulnerability to bark beetle infestations and forest fires.

- **BP MF13 Buffer Strips along Streams, Dolines and Sinkholes**

Description of the measure

Streams are sensitive sectors in many DWPZ and hence have to be protected with the highest priority. Buffer strips with dense and vital forest cover can protect the streams from direct infiltration of sediments or nutrient loads and from lateral erosion. Within buffer strips forest vegetation has to be stable and management operations have to be carried out in an extremely cautious manner. Dolines and sinkholes are karstic features and deserve the same attention like streams, buffer strips are also an adequate solution there.

Measure advantages

The protection of the stream-banks from lateral erosion processes through a vital forest cover can be regarded as the most crucial effect of buffer strips, as lateral erosion could mobilize huge amounts of soil-, gravel- and rock material, endangering both water supply facilities and human infrastructure in general. Also protection from nutrient loads and sediments is relevant. Buffer strips along streams are common Best Practices on a global scale. Additionally their shadowing effect on streams is relevant for keeping the waters relatively cool.

Challenges

A trend can be identified, where Buffer Strips along streams are clear-cut. This trend has to be reversed, as the protection from lateral erosion processes is more important. The balance between driftwood prevention and preservation of the forest cover along streams has to be found, what could lead to multi-dimensional discussions in some cases. The most important purpose within this context has to be the most efficient flood mitigation/prevention/protection functionality of the system Streams/Forest Ecosystems. A balance between lateral erosion and drift-wood prevention should be established. The huge threat-potential of lateral erosion processes has to be taken into account (see symbol picture lateral erosion processes, **Figure 1** & **Figure 2**). This situation is valid for both mountain and plain (flatland) stream systems.

Figure 1. Lateral erosion processes in a steep mountain stream system where a forested buffer-strip is totally lacking. The site is situated within the subalpine forest zone, where the potential natural forest community is Birch-Forest (*Betula litwinowii*), symbol picture, Georgia, Kazbegi-District.

Figure 2. The same stream system in downstream-view towards a scree-cone site area. Lateral erosion processes are present since centennials and have destroyed the close village Kazbegi through mudflow in the past (symbol picture).

- **BP MF14 Adaptive Forest Management under Climate Change**

Description of the measure

Climate change can alter the growth conditions for forest ecosystems significantly. For ensuring the provision of the ecosystem service (ES) "drinking water protection", adaptive forest management towards climate change has to be applied. This involves a strategic procedure, where the evaluation of both climate development regarding the climate change scenarios and of forest succession has to be carried before concept-design. The concept-design of adaptive management can demand various measures, for example the support of the migration of certain indigenous tree species.

Measure advantages

Adaptive forest management under climate change ensures the provision of the Ecosystem Service (ES) Drinking Water Protection over space and time. This is elementary for water protection issues.

Challenges

In some regions there actually can be identified various attempts to adapt forest ecosystems towards climate change. The most important fact in DWPZ is the use of indigenous tree species for reaching this goal, what could result in discussions in various cases, as there can be identified a tendency to use alien conifer or deciduous tree species for adaptation. This could be very dangerous as their stability in our climate is not proved. Hence the use of alien species for forestation or afforestation is not acceptable within the DWPZ. Again in some cases information transfer and persuasive efforts will have to be applied.

- **BP MF15 Natural Forest Succession in Case of Stable Forest Ecosystems**

Description of the measure

In some cases forest ecosystems already fulfil all criteria of an adequate drinking water protection forest. Tree species diversity and distribution, uneven-aged and multi-layered structure of the forests are given and stability, vitality and resilience have to be given on an optimal level. Wild ungulate densities are forest-ecologically balanced and the self-regulating force of such forest ecosystems is given on a high level. If all these criteria are fulfilled, forest management measures within those forest ecosystems can be suspended and natural succession can take place, until an urgent need for the implementation of management measures should arise.

Measure advantages

This measure assures a low disturbance regime for the included forest areas. This is of crucial interest for water protection. Also conservation targets can be achieved with this measure.

Challenges

It is not very common to let natural forest succession take place outside from national parks and natural forest reserves. Within DWPZ this measure could be a solution for achieving necessary goals, but again persuasive efforts will have to be applied.

- **BP MF16 Small-Scale Regeneration Techniques**

Description of the measure

Within DWPZ the applied regeneration techniques have to be carried out on small-scale areas. This is an essential contrast to the clear-cut technique and supports forest stand stability during the mostly natural regeneration phase. The adequate techniques are e.g. group selection cuts, single tree cuts or small-scale gap cuts. There has to be given the balance between light-provision for the regeneration of the forest trees and the stability of the remaining forest stand.

Measure advantages

Small-scale regeneration techniques like single tree cutting, small gap cutting or group selection system assure a low disturbance regime within the context of forest management measures and give advantage of the natural seed regeneration. This allows and supports the overall purpose of drinking water protection. The remaining forest stands can be kept in stable conditions and the conditions for natural or artificial regeneration dynamics are created.

Challenges

Small scale regeneration techniques are in “clear-cut countries” not very common, but in general well known. The need to apply them within DWPZ will have to encompass information transfer and persuasive efforts. In other countries the challenge is not given, as small-scale regeneration techniques represent state-of-the-art methods in normal forestry practices.

- **BP MF17 Structural Thinning Operations**

Description of the measure

In order to create uneven-aged and multi-layered forest stands, structural thinning can be applied. The focus is on the improvement of forest stand stability. Stable trees remain and unstable ones are removed. The structure of the forests is improved in terms of the creation of uneven-aged and multi-layered stands with a wide diameter-distribution. The spatial distribution of the thinning measures is determined by the improvement of structure and stability within the forest stands. The structure of the forest stands should be given on a horizontal and vertical level. Also the tree species diversity according to the forest hydrotope type (natural forest community) has to be given and thus is facilitated by structural thinning.

Measure advantages

Structural thinning can create more stable forest stands by widening the diameter-distribution, by the way of increasing the age-distribution and structural diversity. This supports forest stand

stability and resiliency and facilitates the establishment of the intended continuous cover forest system (CCF).

Challenges

Structural thinning is not very well known in forestry enterprises and will need to be taught to foresters.

- **BP MF18 Artificial Recruitment Techniques**

Description of the measure

Artificial recruitment techniques become necessary in cases, if the natural regeneration dynamics do not provide adequate results in terms of tree species composition and/or of quantity of tree seedlings and saplings. It is mandatory to use autochthonous plant material in order to maintain forest stand stability in a sustainable way. Artificial recruitment may also become necessary as a measure under climate change, if migrating tree species have to be supported.

Measure advantages

Artificial recruitment techniques are in some cases the only way to establish regeneration phases within forest ecosystems. Hence they are an indispensable factor for the facilitation of stable forest ecosystems. It never can be excluded that there arises the need for the application of artificial recruitment techniques. It is of crucial importance to use only indigenous tree species according to the forest hydrotope type (natural forest community) for planting.

Challenges

Artificial recruitment techniques are very well established in forestry hence their application should be easy. The use of indigenous tree species will only provoke in some cases discussions – these have to be lead with the purpose of transporting the cornerstones of source water protection through adaptive forest management.

- **BP MF19 Forest Fire Prevention**

Description of the measure

Forest fire prevention is of a vital interest for the integrity of forest ecosystems, especially if they are providing a continuous protection of drinking water supply. Climate change and other challenges threaten forests and their protection and production functionality. According to climate change simulations forest fires could increase in future. For this reason it is necessary that forest management practices address principles that ensure fire prevention. Fire prevention measures require attention from all authorities, especially from those responsible for forest management. Forest fire prevention does not only protect life, environment and natural heritage, but in most cases it is the most effective strategy to reduce damages. Forest fire prevention includes:

- Technical measures – maps (fire hazard maps); video surveillance and detection system; observation and reporting system; intervention system;
- silvicultural and preventive measures – forest stands care, timely thinning of the stands, removal of dry wood, construction and maintenance of fire paths, keeping the water springs clean;
- other measures – restriction, prohibitions and other regulations related to camping, tourism, burning (grass, shrubs, weeds).

Measure advantages

As the effects and impacts of forest fires are disastrous for the water protection functionality of forest ecosystems (both for drinking water protection and for flood prevention), forest fire prevention becomes crucial for DWPZ. Especially in countries with a high risk of forest fires this is of prior importance, but also other countries have to be aware about the threat of forest fires and should have prevention and mitigation concepts available.

Challenges

In quite humid countries, the forest fire prevention concepts are not that wide spread like e.g. in Mediterranean countries. Despite this fact forest fire prevention concepts and strategies have to be elaborated for DWPZ.

- **BP MF20 Limitation of Forest Roads**

Description of the measure

Forest Road construction and maintenance can cause several adverse impacts on water bodies and should hence be limited in DWPZ. The increase of surface runoff and of water storage loss is the main negative effect. Only in cases, if forest roads are necessary for the stabilization of forest areas, their construction could be considered. In those cases their construction has to meet strict environmental restrictions.

Measure advantages

For avoiding potential contaminations and hydrological adverse impacts caused by forest roads, the limitation of their construction within DWPZ is an indispensable need.

Challenges

In many countries forest roads and their construction are a cornerstone of “normal management situations”. Foresters tend to over-construct forest roads. Hence it is very difficult to convince them to abstain from constructing them. Focused information transfer and persuasive efforts will have to be applied.

- **BP MF21 Adequate Timber Yield Techniques**

Description of the measure

The intensive use of heavy machinery for timber harvesting has harmful impacts on the forest soils. Especially in mountain areas, the vulnerability of forest sites to anthropogenic impacts is increased due to low depths of the groundwater table and too small catchment areas (LfU, 2014). Depending on the soil texture and antecedent moisture conditions, the soil may suffer surface compaction or even ground seepage. Surfaces that experienced such disturbances by intensive forest operations are not likely to recover on the short or mid-term scale. Klaes et al. (2016) showed that the textual and structural soil disturbances as a result of timber harvesting with heavy equipment are still significant after ten years of recovery on fine-textured forest soils.

Soil compaction substantially reduces the infiltration capacity. As a consequence, surface run-off and erosion processes increase while the water recharge decreases. Moreover, the transfer and the storage of nutrients may be hindered as a result of physico-chemical disturbances of the mineral properties (SCHEFFER et al., 2010).

Generally, any kind of interferences in the soil system should be avoided in drinking water protection zones (DWPZ), therefore adequate timber yield techniques should prevent the damaging of the soil- and humus layers. In the case of mountainous forest sites the application of the cable-crane system or animal-traction systems is recommended. The tractor-skidding method should only be applied in exceptional cases and the soils must then be frozen or dry. With the cable-crane system the assortment-technique (cut to the length method) has to be applied and the whole-tree harvesting method has to be avoided. In flat areas the tractor-skidder method has to be applied in times when the soils are frozen.

The rock material for the road network should correspond to the local geology. In this context, any kind of contamination with geogenic substrates has to be avoided. Skid trails should be arranged in a predefined distance. To further protect the skid trails from ground seepage a maximum wheel load of the harvest machinery should be considered, e.g. max. 4t (LfU, 2014).

Measure advantages

The application of adequate timber yield techniques has the advantage that the soil and humus layers are kept in desirable conditions, by the way providing the full level of forest ecosystem services “water protection”. Also the remaining forest stand can be kept stable.

Challenges

In many cases there will be a tendency to apply the cheaper tractor-skidding method, also in steep terrain. This will have to be opposed, as within DWPZ only the water protection functionality and the ways to protect this should be followed. Again focused information transfer and persuasive efforts will have to be applied.

- **BP MF22 Prohibition of the Use of Chemicals in Forestry Practices**

Description of the measure

Chemicals like fertilizers, pesticides or herbicides are substances which form a threat for water quality and hence should not be present in forested DWPA. In forests their use is generally only marginal. Despite this fact their use has to be prohibited within forested DWPA. The absence of the application of those chemicals is a crucial advantage of forested watersheds in contrast to agriculturally used ones.

Measure advantages

Pesticides and other agro-chemicals form a strong threat for source water quality in agriculturally used watersheds. The absence of the application of those chemicals is a crucial advantage of forested watersheds in contrast to agriculturally used ones. Hence this measure has to be applied with strict consequences.

Challenges

In most of the countries the application of chemicals in forestry is rare, but in some cases present. Within DWPZ the use of chemicals is in general prohibited. If this should not be the case, focused information transfer and persuasive efforts will have to be applied.

- **BP MF23 Source Water Protection Policy and Institutional Implications**

Description of the measure

In most of the CE partner countries substantial administrative deficits in legislation within the context of the protection of DWPZ and source water quality and quantity were identified. An integrated source water protection policy (SWPP) has to integrate all potential impact factors on water resources. The establishment of an adequate legislative and administrative frame would be a fitting outcome.

Measure advantages

Integrated source water protection policy takes all potential drivers, pressures and impacts on drinking water resources into account and defines routines for adequate response. This results in an encompassing drinking water protection and flood prevention/mitigation policy, which secures water resources.

Challenges

The PROLINE-CE output DriFlu Charta will form a step towards the elaboration and implementation of such an integrated source water protection policy.

- **BP MF24 Integrative Planning Strategy for Watersheds (Forest Ecosystems with drinking water protection as focus)**

Description of the measure

The operative activities within watersheds (DWPZ) need a detailed planning process in order to be efficient. The water protection functionality (WPF) of the forest ecosystems has to be given over space and time. Deviations from an optimal WPF have to be detected by the screening of the current forest dynamics (monitoring). A GIS-based integrative planning strategy provides an efficient schedule for improving or maintaining the WPF of the forest ecosystems. Integration of all relevant impacts on source water protection into the planning strategy is required. The implementation of an adequate watershed classification according to the regional indicators, like e.g. vulnerability of the local ecosystems, tree species sets, etc. have to be set up for each DWPZ.

Measure advantages

The integrative planning strategy would establish a structured and operative tool for well-established management for DWPZ.

Challenges

The establishment of an integrative planning strategy in DWPZ would need the commitment towards such. It would be a huge step for the drinking water protection sector.

- **BP MF25 Sustainable forest management and establishment of protective forests**

Description of the measure

Protective forests are forests that mitigate or prevent the impact of a natural hazard, including a rockfall, avalanche, erosion, landslide, debris flow or flooding on people and their assets. One of the most effective protective functions of forests is reducing soil erosion by water, which degrades water quality. The product of erosion is sediment, which has adverse impacts during transport in running water and as a deposit in stream channels or stagnant water bodies. Thus the protective role of forests in reducing erosion on-site has a far-reaching, off-site effect through reduced sedimentation. The influence of forests and forest alteration on water yield and timing is complex. Where forests were the original land cover, the protective effect consists in maintaining as far as possible the “natural” flow regime, which inevitably consisted of both flooding and low flows to which stream channels and associated biota were adjusted. With human intervention and occupancy, there is a need for better understanding of the forest/water interaction. With regard to floods, it is now quite clear that forests reduce stormflow peaks and delay them better than other land cover. Protecting stream and river banks from undue horizontal erosion is function of a buffer zone of trees along both sides of a watercourse. The buffer area also acts as a filter and depository for sediment, pesticides and fertilizers from upslope land use (FAO, 2008).

- **BP MF26 Investments in forest area development and improvement of the viability of forests**

Description of the measure

The value of forest ecosystem services, especially in the karst areas, greatly exceeds the value of wood. The specific objectives of the measure are:

- Conversion of degraded forest stands, structurally degraded forest stands per tree species, and forest cultures into mixed high forest stands of indigenous tree species;
- improving forest ecosystem services;
- modernisation of the existent and the introduction of innovative and environmentally friendly technologies, machines and equipment, as well as increasing the safety of work processes in wood harvesting, silvicultural works and pre-industrial wood processing;
- promotion of timber and non-timber forest products;
- increase of competitiveness of the forestry sector;
- job creation in the forestry sector.

Sub-measures within BP MF26:

Climate change mitigation and adaptations - The activities within the framework of this measure are aimed at the adaptation of forest ecosystems to climate change. The restoration of the degraded forms of forest stands improves forest ecosystem services, which helps mitigate climate changes. Moreover, activities within the framework of this measure foster the use of more efficient and environmentally friendly machines, tools and equipment for works in wood harvesting and pre-industrial wood processing. Once all the activities within the framework of this measure are implemented, there will be a long-term increase of the availability and use of renewable sources of energy, which will help reduce greenhouse gas emissions.

Environmental protection - The activities within the framework of this measure are aimed at soil protection (erosion), water and air protection (forest ecosystems as water and air purifiers), biodiversity preservation and improvement, preservation and restoration of special habitats and natural landscapes including NATURA 2000 areas. Furthermore, the use of environmentally friendly technologies and machinery reduces soil damage, water pollution and exhaust gas emissions, while the modernisation of the existent and the introduction of new technologies in pre-industrial wood processing reduce the adverse impact on the environment through increased efficiency and a more rational use of resources.

Innovation - Activities within the framework of this measure foster the transfer of advanced technologies and innovative approaches in wood harvesting, pre-industrial wood processing and marketing of forest products, which have numerous effects on business, the most relevant being: increased productivity and employment rate with reduced production costs, improved quality of products and business processes, increased production flexibility and shorter delivery times.

- **BP MF28 Avoiding wide-area open spaces in the forest canopy cover**

Description of the measure

Sites covered by forest in mountain areas have an important protection function for downhill located areas. Mountain forests can reduce the intensity of flood events, provide ecosystem services typical of forest soils (e.g., water purification and water regulation) and protect downhill (downstream) located land-use units. Clear-cuttings and deforestation in these areas mostly leave widespread open spaces in the canopy cover and transform these previous protection zones to potential risk areas in the catchment. Besides the risk of uncovered and thus unprotected areas, steep slopes and shallow soils increase the potential risk associated with open spaces in the forest canopy cover in mountain sites.

However, it is important to note that a dense canopy cover limits the water provisioning of the forest ecosystem due to greater transpiration and interception losses.

Measure advantages

- Positive impacts on the ecosystem service water regulation and water quality regulation;
- protection of downslope located areas;
- preservation of soil stress;
- fosters natural regeneration of the forest;
- increasing activity of soil organisms enhances the soil (aggregate) structure and decomposition processes;
- decreased diffusive discharge of nutrients (e.g. nitrate).

Challenges

- Enhancing ecosystem services such as water provisioning.

- **BP MF29 Optimization of cutting operations**

Description of the measure

Techniques and methods adopted for organizing the cutting operations have a fundamental importance in terms of impacts on soil, shrubland vegetation and forest regeneration. For that concerning cutting practices, the adoption of systems that preserve soil stability and do not damage the underlying vegetation, mainly for multi-aged high stands is very important.

Selection cutting which implies choosing trees with all diameter classes, but without altering the forest structure, are usually applied in multi-aged high stands. Even-aged high stands, are rarely (mainly in case of pests or for stimulating natural renovation) treated with clear-cutting (all trees over a given surface or in small patches – gaps -, sized according to regulations, are cut). More often they are managed with successive cuts, i.e. different small environments are created that favour regeneration and the utilization occurs at successive phases (seed, secondary and final exploitation) according to the procedure and the site characteristics.

Furthermore, there are numerous different equipment and preparation activities. For example whole tree could be prepared, or only the floor where the short wood drops (fall substrate). The former foresees the hauling of the tree completed with branches that are successively organized at the wood storage site, the latter consists in organizing wood and then hauling it already sorted, and is characterized by lower productivity.

Important factor of the cutting operations is the turn (or return period), which represent time interval between two successive cuttings over the same surface. The minimum turn length, both for final harvests and intermediate cuttings, is usually defined by forestry laws, regulations and policies. With a coppice harvesting applied too often (i.e. at short intervals) there is the risk of tree depletion and an increase of soil erosion processes. Increasing the turn duration, while maintaining the management type, could be a good practice, coherently with the species and fertility of the site so to maintain the regeneration capacity of the tree. The maximum efficiency could be reached alternating intermediate cutting (thinning, clearance) and sustainable utilization cuts.

Good options are:

- to promote the use of techniques at low impact for wood hauling and concentration;
- preparation of dropped trees over the fall substrate as practice at low environmental impact that limits the effects on soil from wood dragging during concentration phase;
- temporal limitation of the forestry exploitation to reduce impacts on soils, as well as the negative effects over the wild fauna during the reproduction and migration period;
- limiting the forestry exploitation in reproduction areas for key animal species activities;
- extension of the cutting turns and creation of reserve areas not subjected to cutting within production forests.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change mitigation;
- landscape and biodiversity preservation;
- conservation of health and services of ecosystems;
- phytosanitary conditions improvement and prevention.

Challenges

- If the turn become too long, trees are more aged and lose their regeneration capacity also threatening the ecosystem’s equilibrium;
- reduction of areas available for cutting;

- more costly operations.

- **BP MF30 Optimal dimensioning of cutting areas**

Description of the measure

For proper implementation of silvicultural operations, studying and measuring biomass increments influence the ways and intensity of cutting interventions. The utilization rate is important to increase, besides the mandatory thresholds, the sustainability of forest resources, from an environmental and economic point of view.

The dimensions and continuity of coppice and high stand cutting areas are usually defined by forestry laws, regulations and policies, with the objective to reduce the overexploitation of the topsoil and aboveground vegetation. The utilization rate is defined by the economic efficiency criteria and vary among regions, also in function of species, group of species and site characteristics. In general, the dimension and continuity of cutting areas affects the topsoil ecological equilibrium (by erosion), the slope hydrological stability (by collapse of the surrounding aboveground elements), and the landscape impoverishment due to cutting operations. The optimal surface to be cut is a compromise between economic and ecological criteria. Alternative methods in coppice management and high stand cutting, which create more complex and heterogeneous ecosystem and help to improve functional aspects (e.g. protection of soil, landscape values, water resources quality and quantity, limiting hydrogeological instability etc.) could be:

- A reduction of the maximum combined areas allowed for the utilization cuts. For multi-aged forests, reducing the utilization rate with respect to the increment following specific ecological and silvicultural needs, and planning silvicultural practices during selection cutting.
- For even-aged stands, a diversification of forest structure, still based on specific ecological and silvicultural needs, is an option.
- Maintaining, for a greater number of cutting years than foreseen by regulations, both horizontal and vertical strips (respecting geomorphological and ecological criteria) enough wide to separate and fractionate aggregated surfaces or surfaces larger than allowed (e.g. strips along the contour lines to interrupt the cutting areas), and also to reduce the visual appearance of cuts.
- Preservation of strips and cutting only after the upstream stand is well regenerated. Special care should be paid to areas with slope > 25% and with high to very high landslide hazard risk.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change mitigation and adaptation;

- landscape and biodiversity preservation;
- improvement of the natural renovation capacity of forests;
- benefit for species attracted by shady environments (sciophilous).

Challenges

- Excessive reduction of cutting areas impacts on the utilization costs, increasing the wood hauling costs and reducing the possibility, for the forest utilization enterprises, to benefit of scale and scope economies;
- excessive reduction of cutting areas limit the possibility to monitor the damages by wild fauna to favour natural regeneration renovation establishment;
- shortcomings for species attracted by sunny environments (heliophilous).

- **BP MF31 Intermediate cuttings**

Description of the measure

Intermediate cuttings (cuts between establishment and productive harvesting) are useful especially in Mediterranean regions. Regulations to execute intermediate cuttings have the objective to reduce the overexploitation of the topsoil and the aboveground vegetation, and vary from one region to another. Such cuttings are rarely applied as they are not economical. However, some intermediate cuttings are important to guarantee and improve the ecological efficiency of forests, to safeguard the environment and the biodiversity, and to prevent forest fires as well as the diffusion of phytopathological disturbances. Thinning and clearance for selection and maintenance of sprouts over the stump in case of coppice, as well as interventions to remove the dry biomass and weeds for both coppices and high stands, contribute to topsoil stabilization, limit the wildfire risk and create conditions for improved ecological function and production of stands, and a re-naturalization of those forest plantations with protection purposes. Moreover, it is possible to conduct a more efficient management of the best trees and species still present in coppice stands and produce an economic advantage complementary to that due to wood production. Similarly, interventions directed to single trees allow maintaining high species diversity in aged coppices or high stands.

Measure is valid for mountain and plain sites.

Measure advantages:

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change mitigation;
- landscape and biodiversity preservation;
- increase resilience of species and ecosystems to fires and natural hazards;
- phytosanitary conditions improvement and prevention;

- improvement of the natural renovation capacity of forests;
- for single adult trees, intermediate cuttings can increase their value, production and stability, favouring biodiversity and resilience.

Challenges:

- Not economically opportune because of: the obtained wood, especially for young trees, has low market value; low accessibility; inappropriate mechanization.

- **BP MF32 Selection of species for utilization**

Description of the measure

The cutting turn for coppice usually follows economic principles and consists of a clear-cutting for simple coppices or of coppice with standards, preferring the cutting of one or more species economically more relevant. Using not only economic criteria to select the species will allow valorisation of the stands, guaranteeing on the long term greater species diversity and thus a higher stability of the soil and the aboveground vegetation.

Also for high stands, species selection is driven by economic principles (trees of the most valuable species, of interest for the market, are cut) while, to preserve the ecological equilibrium and ecosystem stability, the maintenance also of the main species, together with those more valuable, sporadic and uncommon, is preferable.

Under usual management practices, as well as under regulations and regional norms, it is already expected the preservation of an appropriate minimum percentage of species/trees with lower economic value, but this could be not sufficient.

Many uncommon and sporadic species, not yet included in the national or regional lists of protected species whose extirpation, removal and damaging are prohibited, have valuable functions for the forest ecosystems and are a resource to preserve the biodiversity of flora and fauna.

Proper actions in selecting species could be:

- Preservation, management and care, to favour growth and renovation, of additional uncommon, less represented and ecologically valuable species, or of more trees for these species if already identified, with respect to what indicated by the Regional regulation;
- Limitation of the standards coverage (in case of coppices), but compliant with regulations;
- Removal of allochthonous species, especially if highly flammable, to favour autochthonous ones;
- Realization of buffer strips with varying width, to reduce the visual impact of cutting areas;
- Valorising those management practices that increase structural diversity;
- Preservation of species useful to feed wild and domestic fauna, and humans;

- Preservation of valuable trees with indefinite ageing;
- Management interventions during cutting operations.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change adaptation;
- landscape and biodiversity preservation;
- improvement of the natural renovation capacity of forests;
- increase resilience of species and ecosystems to fires and natural hazards;
- phytosanitary conditions improvement and prevention.

Challenges

- Cutting of species with low economic value;
- trade-off with BP MF5 (increase of standards dimensions/numbers).

- **BP MF33 Preservation and selection of trees (standards) in coppices**

Description of the measure

In the context of coppice management, the preservation of standards (tree with age equal or greater than the turn) is crucial to maintain the soil and vegetation, as they are the responsible of the gamic renovation of the stumps to substitute in the future the depleted ones. Both the number and the species of standards to be preserved depend on silvicultural, ecological, phytosanitary and economic factors. In some regions, a higher number of standards and/or the maintenance of standards in groups improve the ecological and growth conditions of coppices. Laws regulate the minimum number of standards (in case of a uniform distribution of them) and the dimension and spatial arrangements of clusters (in case of groups of standards) to preserve, providing obligations where usually, for economic reasons, a very low number of standards is maintained, with a high risk for the coppice forest maintenance on the long term.

Although remaining in the context of coppice management, for specific conditions a higher number and types of standards, and a larger dimension of their clusters, is preferable to assure higher ecological stability on the long term and an economic improvement of the stand. Planning in this sense is recommended, as usually decision on standards to be maintained are made during cutting operations, following criteria and regulations in terms of quantity and characteristics, but without a preliminary identification of trees, thus prejudging the environmental and forest protection purposes.

Proper actions in selecting standards could be:

- Selecting standards based on individual tree quality and health, and not on the quantity, with localized selection, also for the not dominant species, with trees to be thus added to those selected for the dominant species;
- Maintaining wider groups, or larger number, of standards with respect to regulations, according to their ecological and hydrogeological functions;
- Studying appropriate standards arrangements according to tree/stand age, fertility, spatial distribution, local conditions, complementary local uses (e.g. for grazing);
- Preservation of "biodiversity islands" well representing the local forest complexity, without intervention for at least one turn;
- Identification of standards by experts and specialized technicians before cutting operations.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change mitigation;
- landscape and biodiversity preservation;
- improvement of the natural renovation capacity of forests;
- migrating from simple coppice to coppice with standards or compound.

Challenges

- More costly planning and cutting operations;
- trade-off with BP MF4 (limitation of standards coverage).

- **BP MF34 Cleaning and mowing of shrub and grass in the forest**

Description of the measure

The cleaning and mowing of shrub and grass vegetation within forest formation is made principally to prevent forest fires, to facilitate silvicultural operations and for the defence of hydrogeological stability. Also, the presence of clearing and marginal areas has a key role in preserving zones with high natural values and connected biological diversity. These areas also safeguard the structure, composition, mosaic and historical characteristics of the landscape. National to regional laws and norms regulate these interventions.

Proper interventions could be: cleaning and mowing in clearing, open and ecotone areas, along riparian strips, road borders, sites of wood storage after cuts, and fire roads, also to be implemented through controlled grazing.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change adaptation;
- landscape and biodiversity preservation;
- improvement of the natural renovation capacity of forests;
- increase resilience of species and ecosystems to fires and natural hazards.

Challenges

- Costs of operations.

- **BP MF35 Managing residues of cutting operations**

Description of the measure

The management of cutting operation residues (brushwood, leaves, lops) could have positive or negative effects in function of site's environmental characteristics. Residues give nutrients to the soil creating a micro-habitat useful to sustain biodiversity, they reduce the rain drop impact over the surface and increase the runoff time limiting soil erosion. At the same time, leaving these residues on the soil can: in case of steep slopes and during intense meteorological events, cause relevant damages to the runoff by obstructing the bridges' spans or the filtering weirs of small watercourse; reduce the radiation reaching the soil so limiting the natural renovation of vegetation; limit carbon sequestration; make difficult the harvesting of non-wood products; obstacle the wild fauna; or cause fires triggering or propagation.

Proper management of operations' residues has benefits for the environments, in preventing fires and the diffusion of pathogens. Moreover, the wood chipping can foster the consumption of other fuels other than fossil ones, and the development of short chains.

Good practices consist in:

- Removal of the residues to be used for energetic use.
- Chipping and/or grinding, distribution and spread on the soil to favour quick decomposition and organic inputs and reduction of windrow and heap size.
- Avoid burning of residues after above interventions.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- improvement of the environment and rural spaces;
- climate change mitigation;

- increase resilience of species and ecosystems to fires and natural hazards;
- phytosanitary conditions improvement and prevention.

Challenges

- Costs of operations.

- **BP MF36 Managing new-establishing forests**

Description of the measure

New-establishing forests, with natural and autochthonous origin, recently (i.e. in the last 15 years) developed after the reduction of agricultural activities and the abandonment of grazing area in mountain sites; they are characterized by phyto-sociological uniformity.

Proper management of these forests could contribute to climate mitigation, biodiversity conservation and to the hydrogeological defence.

Moreover, in terms of production, if well managed since their sapling to pole stages, such formations could be in the medium to long terms an important economic resource, especially for mountainous areas with lower slope and with better soil in respect to the surroundings.

Usually the management of these forests is similar than for other forest types, so driven by economic purposes, and directed to the species with highest economic value.

Good additional options could be:

- Recovery of some antecedent conditions, as open areas and areas to control the forest advancement, or the reactivation of some agriculture and grazing;
- Removal of invasive species to valorise autochthonous valuable species, or sporadic species at risk of disappearing, also through silviculture directed to single trees;
- Planting of precious allochthonous species to increase phyto-sociological complexity, the biodiversity, the resilience to fires, the regulation of the water flow and slope stabilization;
- Favouring natural evolution with site-specific management toward reduction of hydrogeological instability and forest fires, and limiting grazing within new forest areas;
- Mycorrhization and inoculation with mycelium or symbiotic bacteria.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- climate change adaptation and resilience;
- improvement of the environment and rural spaces;
- increase resilience of species and ecosystems to fires and natural hazards;

- landscape and biodiversity preservation;
- phytosanitary conditions improvement and prevention;
- improvement of ecosystem services as wood production;
- favouring of scale economy and short chain.

Challenges

- Interventions are highly site-specific and a right compromise among options is needed.

- **BP MF37 Restrictions of forestry activities in drinking water protection zones (for example in Slovenia)**

In Slovenia there are restrictions and limitation of forest activities in drinking water protection zones (see Table 1).

Table 1. Restrictions of forestry activities in drinking water protection zone

V	HANDLING IN FOREST AND FOREST LAND	VVO I	VVO II	VVO III
1	Afforestation	+	+	+
2	Fertilization with manure, liquid manure and slurry in the woods	–	–	–
3	Temporary storage of compost or digestate sludge of 1 or 2 environmental quality or sewage sludge	–	–	–
4	Fertilization with the remains of cesspools, small wastewater treatment plants or water treatment plants	–	–	–
5	The use of compost and digestate sludge of 1 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	+	+
6	The use of compost and digestate sludge of 2 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	–	–
7	Mobilisation for the control tree pests	–	+	+
8	Supply of machinery and equipment with fuel in the forest	–	+	+

VVO I = DWPZ I: Means the narrowest water protection zone.

VVO II = DWPZ II: Means the narrow water protection zone.

VVO III = DWPZ III: Means the wider water protection zone.

+ Means that the intervention in the environment is permitted.

– Means that the intervention in the environment is prohibited.

- **BP MF38 Pro Silva movement**

Description of the measure

The Pro Silva movement initiated in Central Europe (in Slovenia). This movement promotes the expansion of the goals within silviculture. All PROLINE-CE partner countries are members of Pro Silva movement.

Pro Silva membership is made up of forest owners, foresters, forestry students and others who wish to practice and learn more about Pro Silva forestry practice.

Pro Silva promotes forest management strategies which optimize the maintenance, conservation and utilization of forest ecosystems in such a way that the ecological and socio-economic functions are sustainable and profitable. As a result of the discussions silviculture includes not only wood production but an emphasis on maintaining forest biodiversity, recreational, landscape, soil, air and water protective functionalities as well as socio-economic and cultural functions.

Measure advantages

Pro Silva advocates and promotes "Close to Nature Forest Management Principles" as an alternative to clear felling, short-term tree plantations. These principles ensure the soil and water protection functionality of forest ecosystems over space and time as well. Ensure up-to-date knowledge transfer across 25 countries on integrated forest management for resilience and sustainability.

Challenges

The NGOs have a minor impact on daily practices of forestry and their principles are not sufficiently recognized by the public.

- **BP MF39 Prohibition or restriction of grazing in forests**

Description of the measure

In European countries forest grazing is either entirely prohibited in main state forests or allowed in grazing areas in minor state forests provided that a licence has been obtained and that the grazing activities are in compliance with forest management. The main reasons of prohibition are protection of young forest stands and soil from degradation, increasing game production and biodiversity. The impact of livestock grazing on soil compaction is well known. Compaction of soil can reduce plant growth, inhibit root penetration, restrict water and air movement in the soil and, ultimately, reduce yields.

Overgrazing can occur when undergrowth is exposed to intensive grazing for extended periods of time, or without sufficient recovery periods. It can be caused by either livestock in poorly managed agricultural applications, game reserves, or nature reserves. It can also be caused by immobile, travel restricted populations of native or non-native wild animals. The only thing to stop overgrazing is to limit the animal space for roaming. Overgrazing reduces the usefulness, productivity, and biodiversity of the land and is one of the causes of desertification and erosion. Overgrazing is also seen as a starting point for the spread of invasive species of non-native plants and weeds.

Forest grazing should be restricted in stands in the process of regeneration, in forest with special protective purposes, in replanted young stands, stands within drinking water protection zones etc.

For example, in Hungary forest grazing has been prohibited for the last decades. The grazing in forests was maintained until the middle of the 20th Century, but it had been regulated by laws since the early times. This fact shows the importance of forests in livestock keeping. Since the first law on forestry, the changing rules of grazing in forests and the adjacent land uses ranged from the moderate regulations to the total prohibition (Saláta Dénes, Horváth Soma, Varga Anna, 2009).

Measure advantages

- Negative impacts of overgrazing can be prevented and/or reversed by proper forest management.

Challenges

- Undergrowth management have to solve by forestry. The quality of forest management depends on the owners of the forest.

2.3. Best management practices – Forests – Plain sites (PF)

- **BP PF1 Forest conversion from monoculture to mixed forest**

Description of the measure

In the course of land-use intensification in agriculture as well as in forestry during the last centuries, the pressure on forest ecosystems increased significantly (WORRELL et al., 1997). To supply the increasing traditional demand of the timber processing industry as well as new demands, such as biofuels (GUNDERSEN et al., 2011), monoculture plantations are of great economic importance since their main function is to provide a high yield. Thus, the forestry management and the harvest strategy are primarily designed to purpose the greatest economic benefits. Basically, spruce and other coniferous woods represent frequent forms of monocultures in silviculture.

The conversion from monocultures to mixed forest stands has several positive effects on the ecosystem functions water provision, water quality regulation and water regulation.

In terms of water quantity, coniferous monocultures increase the total water loss due to both higher water storage capacity and greater interception as e.g. short vegetation plantations (CANNELL, 1999). The soil rooting structure of mixed forest stands is far more heterogeneous than soils cultivated with monoculture plantations based on a balanced relationship between deep-rooted and shallow-rooted trees as well as coarse and fine roots. These increase the macroporosity also in deeper soil layers leading to an enhanced connectivity and water transfer to the subsoil in response to rain events (BURGESS et al., 2001). Moreover, SCHUME et al. (2004) indicate that mixed forest stands show higher water absorption capacities than spruce monocultures under dry conditions in summer enabling the forest ecosystem to reduce the run-off contribution during convective storm events. Both properties of polyculture stands can improve the ecosystem service water regulation.

A mixed forest can also positively affect the ecosystem service water provision. BOSCH et al. (1982) and JOST et al. (2004) show that soil water recharge is higher in deciduous forest stands than in coniferous monocultures due to greater interception losses. A greater share of deciduous hardwood stands in a mixed forest thus causes smaller interception losses especially during autumn and winter season. These "open windows" in the canopy cover can increase the transfer of water into the soil system which is especially relevant in drinking water protection zones (DWPZ).

CANNELL (1999) and WAUER et al. (2008) point out that monocultures, especially spruce forests, typically increase the transfer from air pollutants into the terrestrial ecosystem compared to short vegetation plantations and thus enrich the soil water with nitrogen and/or sulphur compounds. Moreover, BRANDTBERG et al. (2004) indicate that the quality of organic matter in the litter layer is less under spruce monocultures compared to spruce-birch mixed stands (expressed by C/N-ratios) emphasizing that polyculture alternatives increase the filtering effect of the organic soil layer. A conversion from monoculture to mixed forest will thus foster the water purification function of a stable litter layer as well as the filtering through a textual and sound soil structure. These effects of polyculture alternatives cause an amelioration of the ecosystem service water quality regulations and may enhance the water quality in DWPZ.

Measure advantages

- Positive impacts on the ecosystem services water regulation, water provision, water quality regulation;
- a mixed forest is more stable than monoculture plantations and thus able to resist natural disturbances such as windthrow or pest infestations;
- increasing activity of soil organisms enhances the soil (aggregate) structure, the connectivity of water paths and decomposition processes;
- decreased diffusive discharge of nutrients (e.g. nitrate);
- decreased interception due to leafless trees in autumn and winter increasing groundwater recharge;
- water regulation and flood mitigation due to interception losses in spring and summer as well as higher water absorption also from deeper soil layers providing protection against convective storm events.

Challenges

- The mitigating effect of forests is limited to small-scale watersheds as well as small-scale flood events. The effect of flood mitigating measures in forest ecosystems are negligible in large catchments and for intense flood events (CALDER, 2007);
- the measure requires a long-term implementation as well as a customized choice of tree species.

- **BP PF2 Natural forest regeneration of mixed-forests using single-tree-selection technique**

Description of the measure

Natural forest regeneration is a technique to naturally reproduce forest stands without any kind of artificial and controlled sowing techniques. Different possibilities of natural reproduction exist that constitute the main drivers for natural forest regeneration: vegetative reproduction as a form of asexual reproduction (seedless, sporeless) and natural sowing of surrounding trees.

To implement natural forest regeneration, the forest management pursues a sound wood harvest technique based on a single-tree-selection. Single trees are selected by a species-dependent exploitable diameter or exploitable weight, respectively. Moreover, the forest management evaluates the vital and stable trees which are worth to leave in order to provide a healthy genetic base for natural reproduction. In this way a quasi-natural selection process takes place between the species that fosters the vitality, stability and resilience of the forest stand.

Since trees with specific exploitable properties basically have a diameter-corresponding treetop (crown), they leave an "open window" in the canopy cover following the harvest. Due to greater insolation and potentially increased water availability (less interception) these areas have adequate site characteristics for natural forest regeneration. Additionally, the forest management avoids widespread open spaces similar to those arising from clear-cutting to ensure the nutrient provision by surrounding trees on regeneration sites and to prevent the soil surface

from extensively increasing temperatures. Thus, the ecosystem function water quality regulation is enhanced compared to extensive open spaces since mineralisation and nitrification processes do not increase significantly and thus limiting the amount of nitrate leaching.

This measure fosters the spreading of understorey vegetation and positively affects the ecosystem functions water regulation and water quality regulation. Understorey vegetation creates a double-layer forest and enhances the filtering properties of the forest. The susceptibility to erosion (especially splash-erosion) decreases simultaneously and thus hinders an outwash of sediments as well as particulate substances into the pre-flooder (CALDER, 2007). In the progress of single-tree removal around already existing regeneration spaces a cone-shaped wood stand structure emerges due to differences in tree height by ongoing natural regeneration.

A mixed forest can also positively affect the ecosystem service water provision. BOSCH et al. (1982) and JOST et al. (2004) show that soil water recharge is higher in deciduous forest stands than in coniferous monocultures due to greater interception losses. A greater share of deciduous hardwood stands in a mixed forest thus causes smaller interception losses especially during autumn and winter season. These "open windows" in the canopy cover can increase the transfer of water into the soil system which is especially relevant in drinking water protection zones (DWPZ).

Since natural regeneration enhances the vitality and the stability of the forest ecosystem, it is more resilient to disturbances, such as bark beetle infestation or windthrow.

Measure advantages

- Positive impacts on the ecosystem services water regulation, water provision, water quality regulation;
- low initial costs to implement this measure in case the desired tree species are present and no further site preparation is required;
- optimal adaptation to the specific site;
- decreased leaching of nutrients (e.g. nitrate);
- decreased interception due to leafless trees in autumn and winter increasing groundwater recharge,
- water regulation and flood mitigation due to interception losses in spring and summer as well as higher water absorption also from deeper soil layers providing protection against convective storm events.

Challenges

- Measures are required to protect the young stands (underwood) from browsing by game, e.g. an adequate deadwood management;
- stand has to provide different tree species and vital genetics to implement natural regeneration;
- the mitigating effect of forests is limited to small-scale watersheds as well as small-scale flood events. The effect of flood mitigating measures in forest ecosystems are negligible in large catchments and for intense flood events (CALDER, 2007).

- **BP PF3 Tree farming for wood**

Description of the measure

A special case to consider is the farming of trees to sustain industrial and energetic use of wood. Tree farming is not considered "agriculture" but "forestry", but as it is conducted over agricultural areas, it is subjected to both forestry and agricultural practices, and falls in between the extensive managed forests and the intensive agriculture in terms of impacts.

Tree farming could consist in:

- Plantations with medium-long cycle (20-40 years) to produce wood valuable for the industry. These plantations could be pure or mixed with prevalence of autochthonous needle leaves, with or without accessories species, possibly subjected to more cycles;
- Plantations with short cycles (8-15 years) to produce wood valuable for the industry, with single species and usually monoclonal (poplar plantations);
- Plantation with very short cycles (less than 8 years) to produce biomass for panel industry or for energetic production, single species and usually monoclonal.

Tree farming is important also for the environment: it represents a landscape peculiarity and a cultural asset of some areas in the country; it fixes CO_2, contributing to climate mitigation; it is a unique habitat for animal biodiversity, and a refuge and ecological corridor in agricultural areas. Tree farming provides many positive externalities: phytoremediation, absorption of heavy metals and pollutants, stabilization of riparian banks and protection strips etc.

Intensive tree farming consists of monoclonal plantations, as poplars, mixed to numerous traditional agricultural activities and many external inputs due to application of fertilizers, pesticides and phytosanitary products, or because of an inappropriate re-input of nutrient removed from the soil (for short rotation forestry, e.g. willows, eucalyptus, locusts) which causes a loss of fertility and a reduction in productivity.

Regional to local regulations fix minimum turns and in some case the re-planting is mandatory to preserve the landscape, but without giving instructions on the size of cutting, on how preserving natural vegetation, on the use of fertilizers and pesticides, or on the use of multi-clonal elements.

Good practices could be:

- Multi-species or multi-clonal (at least two) and multi-cycle plantations, to differentiate the stand composition and increasing the resilience to biotic and abiotic disturbances.
- Maintaining clonal species and hybrid poplars for at least 12 years, with the possibility to prune a least 90 poplars/ha during the commitment period.
- Planting permanent hedges at the plantation borders made of autochthonous trees or shrubs, to increase the vegetation complexity, the plantation biodiversity, and to create semi-natural environments favourable for the animal fauna (with distance among hedges that do not threaten the principal cultivation).
- To favour the recovery of riparian forest environments and the management of fluvial areas, thanks to permanent multi-cycle plantations associating on the same area

clonal species (poplar), or mixtures of genotypes, and valuable needle leaves, so alternating production cycles and never fully removing the tree cover so assuring ecological value and permanent tree corridors.

- Establishment and management of natural grass between tree lines to favour rainwater harvesting, but in quantity that does not favour fire propagation.
- Soil tillage under dry farming and/or close to trunks, to increase carbon sequestration in the soil and mitigate climate change.
- Better use of chemical inputs (fertilizers, phytosanitary products, pesticides) in line with soil fertility and also promoting fertigation with wastewater. The reduction of phytosanitary products and of water could be enhanced by multi-cycle plantations, where more species could also limit diffusion of pathogens, without altering wood quality and quantity.
- Limiting the cutting of tree (especially high poplars), avoiding cutting in the period of nidification for some important species.

Measure advantages

- Water cycle (water and quality) regulation;
- hydrogeological stability (against erosion, landslide);
- climate change adaptation and resilience;
- improvement of the environment and rural spaces;
- increase resilience of species and ecosystems to fires and natural hazards;
- landscape and biodiversity preservation;
- phytosanitary conditions improvement and prevention;
- improvement of ecosystem services as wood production;
- favouring of scale economy and short chain.

Challenges

- Costs of farming practices;
- risk of triggering new under-investigated dynamics counterproductive for the main cultivation.

- **BP PF4 Protective forest management and afforestation of DWPA**

Description of the measure

In countries with low forest cover afforestation of arable land can improve the percentage of forests. The multifunctional and sustainable use of forests and the strengthening of their social and public welfare function can be continued under this measure. The significance and necessity of afforestation can be characterized by favourable impacts on the soil, water, air and biodiversity, in short on the environmental state, in addition to the economic benefits.

In regions with low precipitation and extreme climate conditions the environmental effects of the new forest stands can ameliorate the mesoclimatical relations. The increase of the forested area changes the intensive agricultural areas with very important habitats considering the biodiversity.

Measure advantages

- The main aims of the measure is to increase the forest cover of the country, to increase the environmental protection, social, public welfare and economic role of forests and to improve the level of employment in rural areas by developing the forestry sector, to enable the agricultural restructuring, by the help of alternative use of areas.
- Objectives of forestry also include the establishment of high biodiversity natural forests, through a substantial increase in the ratio of indigenous tree species, particularly in protected areas.
- Environmental development objective is to enrich biodiversity by establishing close-to-nature forests, to preserve the natural components of the rural landscape, and to facilitate appealing landscape appearance.
- The whole area of afforestation contributes to protection against erosion (water or wind erosion) and combating climate change mitigation.

Challenges

- The provisions and the criteria for selecting afforestation areas to ensure that the planned measures are in line with the local conditions and the environment protection/biodiversity requirements.
- The afforestation of protected grasslands and wetlands may not comply with local conditions and environment requirements.

- **BP PF5 Forest administration and control**

Description of the measure

In majority of countries, forest administrative bodies are accountable for the development and implementation of legislative framework composed of various laws, decrees, regulations, norms, programmes, forest policy instruments etc., which are inevitable for sustainable management of forest resources. Forest administration systems differ from one European country to another, mainly in institutional structures, various legal rights and responsibility division between public and private institutions on a national, regional and local level.

The principal duty of forest administration is to provide a concrete base and long-term framework for the fulfilment of set protective and management objectives.

The protection and management of forests and forest land is usually governed by the Ministry who cooperates with other state organizations. The ownership of forests and forest land is divided between public (state-owned) and private sector (privately owned) on different levels. The non-state-owned areas are managed mostly by private management companies or individual

forest owners which are generally part of the numerous groups and associations. Regardless of the ownership, foresters should have the possibility to actively participate in land owner policies, decision making processes, timber trade etc.

Forestry control is usually conducted by means of legal restrictions, binding measures, court decisions and sanctions in case of law breaking. Public authorities on national, regional and local level execute forestry control to enforce compliance with forest law and sustainable management policies.

Measure advantages

- The control on Forestiers ensures to reach sustainable forest management objective;
- clear legislative background system.

Challenges

- Most of the privately owned forests are still inadequately managed. The main issues is the willingness of forest tenures and land owners to implement and promote sustainable forest practices.
- The obligation for the adoption of forest management plans for forest owners on various ownership levels is still important issue.
- Establishing clear mechanisms for monitoring.

- **BP PF6 Establishment of agro-forestry systems (grazing) and wood-pastures**

Description of the measure

The agro-forestry systems are extensive land-use systems where trees are attended and agricultural activities are pursued simultaneously, thus a mosaic of agricultural and forestry systems is created. The agro-forestry systems are of great ecological, landscape and social value since they combine extensive agricultural and forestry systems aimed at the production of excellent quality wood and other forestry products.

The measure is considered as a great possibility to introduce new land-use systems. From farming point of view, by introducing agro-forestry system in certain special regions (floodplains, regions of threat to wind and water erosion), it is expected to achieve major positive environmental effects.

The measure, due to its multifunctional character, extends the income gaining opportunities of the population, and it may secure the continuation of farming in previously intensively used areas with unfavourable conditions and in case of Natura 2000 areas.

Measure advantages

- The measure has major importance in reintroducing sustainable landscape management of plain areas. The environmental state of the areas affected by the creation and maintenance of agro-forestry systems will improve due to the strengthening of the mosaic character; biodiversity will grow and the permanent green cover will decrease the level of erosion significantly.

- The measure aids the protection of rural natural resources and improves their state.
- It contributes to the reaching of environmental targets, to the protection of the soil and to the prevention of disappearing biological diversity.
- The measure provides a good opportunity for integrated and ecological farming and the utilization of species that are typical for the region (geographical indications).
- The agro-forestry systems are perfect for making the rural area more attractive, for maintaining jobs and creating new ones, and for improving the living conditions of people in rural areas.

Challenges

- The traditional use of woodlands and its essential influence on the land's structure and dynamics have become commonly known for example among the Hungarian ecologists only in the past few years. The view of the Carpathian-basin vegetation is significantly influenced by the effect of used and abandoned wood-pasturing. The wood-pasturing was one of the basic components of a highly varied pasturing system concerning the coming season and weather, the whole activity was regulated by rules. The wood-pasturing occurred in all types of forests. In all cases the decrease of pasturing livestock was the reason for the abandonment of the areas. A consciously controlled and sustained landscape of woods evolved as a result of wood pasturing. In case of abandoning bushy shrubbier, saplings filled, low-diversified, closed shrubbier and woods were developed (Varga & Bölöni, 2009).
- Although, wood pasturing based on the traditional knowledge has a great importance in conserving nature and landscape, there are a lot of obstacles to overcome for the re-establishment of agro-forestry systems, for example: intensive husbandry has replaced grazing or the last descendants of shepherd dynasties are already pensioners, etc.

Best management practices concerning forests are systematically shown in Table 2, where relevance of each BMP can be seen (water protection functionality, cost of the measures, duration of implementation and time interval of sustainability). Some BMPs are valid for both mountain and plain sites (*).

Table 2. Best management practice relevance – Forests

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
MOUNTAIN SITES				
Avoidance of the clear-cut technique*	High	Low	Long Term	Long Term
Establishment of a Continuous Cover Forest System*	High	Medium	Long Term	Long Term
Defined Crown Cover Percentage of Forest Stands*	High	Medium	Long Term	Long Term
Limitation of the Percent-age of Timber Extraction*	High	Medium	Long Term	Long Term
Continuous Regeneration Dynamics*	High	Low	Long Term	Long Term
Foster Stability, Vitality and Resilience of the Forest Ecosystems*	High	Low	Long Term	Long Term
Tree Species Diversity According to the Natural Forest Community*	High	High	Long Term	Long Term
Improve the structural diversity of the forest stands*	Medium	Medium	Long Term	Long Term
Forest Ecologically Sustainable Wild Ungulate Densities*	High	Medium	Long Term	Long Term
Protection of the Gene Pool of the Autochthonous Tree Species*	High	Medium	Long Term	Long Term
Foster old, huge and vital tree individuals*	High	Low	Long Term	Long Term
Establishment of an adequate deadwood management*	High	Low	Long Term	Long Term
Buffer Strips along Streams, Dolines and Sinkholes*	High	Medium	Long Term	Long Term
Adaptive Forest Management under Climate Change*	High	High - Medium	Long Term	Long Term
Natural Forest Succession in Case of Stable Forest Ecosystems*	High	Medium	Long Term	Long Term
Small-Scale Regeneration Techniques*	High	Low	Long Term	Long Term

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
Structural Thinning Operations*	Medium	Medium	Long Term	Long Term
Artificial Recruitment Techniques*	High	High	Long Term	Long Term
Forest Fire Prevention*	High	High	Long Term	Long Term
Limitation of Forest Roads*	High	Low	Long Term	Long Term
Adequate Timber Yield Techniques*	High	High	Short Term	Medium Term
Prohibition of the Use of Chemicals in Forestry Practices*	High	Low	Long Term	Long Term
Source Water Protection Policy and Institutional Implications*	High	High	Long Term	Long Term
Integrative Planning Strategy for Watersheds (Forest Ecosystems with drinking water protection as focus) *	High	High	Long Term	Long Term
Sustainable forest management and establishment of protective forests*	N/a	N/a	N/a	N/a
Investments in forest area development and improvement of the viability of forests	N/a	N/a	N/a	N/a
Avoiding wide-area open spaces in the forest canopy cover	High	Medium	Short	Long Term
Implementation of a resource-friendly exploitation system in mountain sites	High	Medium	Medium	Medium
Optimization of cutting operations	Medium	Low	Short periodically	Long Term
Optimal dimensioning of cutting areas	Medium	Medium	Short periodically	High
Intermediate cuttings	Medium	Medium	Short periodically	High
Selection of species for utilization	Medium	Medium	Short periodically	High
Preservation and selection of trees (standards) in coppices	Medium	Medium	Short periodically	High

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
Cleaning and mowing of shrub and grass in the forest	High	High	Short periodically	High
Managing residues of cutting operations	High	High	Short periodically	High
Managing new-establishing forests	High	Low	Medium	Medium
Establishment of protective zones in forest areas	N/a	N/a	N/a	N/a
Pro Silva movement*	High	Low	Long Term	Long Term
Prohibition or restriction of grazing in forests	High	Low	Long Term	Long Term
PLAIN SITES				
Forest conversion from monoculture to mixed forest	High	Medium	Long Term	Long Term
Natural forest regeneration of mixed-forests using single-tree-selection technique	High	Low (if stand comprises adequate tree species)	Long Term	Long Term
Tree farming for wood	Medium	Medium	Medium	Medium
Protective forest management and afforestation of DWPA	High	Medium	Long Term	Long Term
Forestry administration and control	Medium	Low	Long Term	Long Term
Establishment of agro-forestry systems (grazing) and wood-pastures	Medium	Medium	Long Term	Long Term

* - valid for both mountain and plain cluster

N/a – not available

2.4. Review of best management practices – Forests

The majority of countries have well developed strategies, plans and best management practices regarding forest policy. Namely, it is obvious that older EU member states (Austria, Germany – Bavaria and Italy) have better developed strategies and concepts in the protection of forest ecosystems and forest-related water issues. Such result is not surprising, as older states have been under EU legislation for a longer period of time, thus having more time to implement common EU framework into national policies and strategies. Furthermore, older states have participated in numerous projects (e.g. CC-WARE).

Best management practices reported by Austria are derived from CC-WARE project and cover numerous issues in today's forest management. Although numerous best management practices are *de-facto* physical measures, there is still considerable amount of non-physical best management practices, such as limitations, avoidances, institutional implications and integrative planning. Regarding relevance of measures, the majority of best management practices provided by Austria have high water protection functionality, long time interval of sustainability, long implementation time and variable costs.

Croatia does not have well developed best management practices in the forest sector. Existing measures are general and lack specific actions, thus the only active measures are those contained within current Forest Law. Poor forest management is evident within privately owned forests (20%) due to several reasons: private forest owners are mostly old age in rural areas; state stimulus practically does not exist; poor scientific research of forests and poor education of forest owners.

Best management practices reported by Poland are identical to those reported by Austria and are derived from CC-WARE project.

Germany – Bavaria has a wide spectrum of best management practices, resulting from numerous studies and/or projects. Provided measures have a strong theoretical and practical background, as well as numerous quotations and references to specific studies. Bavarian measures are mostly physical, separated into mountain and plain site cluster, and encompass physical and non-physical measures. Regarding relevance of measures, the majority of best management practices in Bavaria have high water protection functionality, medium to long time interval of sustainability, variable implementation time and variable costs.

Italian best management practices are divided into mountain and plain sites cluster. Provided measures are partly derived from Orientgate project and are well structured, with solid theoretical and practical background. Measures are both physical and non-physical. Furthermore, some measures also provide a list of general good practices that could be done in specific scenarios. Provided measures have medium to high water protection functionality, long time interval of sustainability, short (periodical) implementation time and variable costs.

Best management practices provided by Slovenia deal mostly with the establishment of protective forests and establishment of protective zones and restrictions within forest areas. Restrictions are related to specific activities and to specific water protection zones.

Hungarian measures are similar to those provided by others, focusing mostly on the sustainable management, prohibitions and regulations – resulting in steady increase of forest area. Hungary

also developed agro-forestry system, a type of land-use system where forestry and agriculture are pursued simultaneously, resulting in sustainable landscape management.

"Forest man of India" - positive example of reforestation

Perhaps one of the most inspiring examples of how a single person can make a great change is a story of Jadav Payeng, forestry worker from Jorhat, India. Over the course of 30 years, he single-handedly planted and tended trees on a sandbar of the river Brahmaputra turning it into a forest reserve – the Molai forest. The forest encompasses an area of about 1,360 acres / 550 hectares.

Prior to Payeng's actions, Molai forest used to be barren land, lifeless and treeless sandbar exposed to constant erosion. A scheme was launched at that time by the social forestry division of the district, involving the planting of trees on only 200 hectares. The project was completed after 5 years and all the labourers left, except Payeng. Dedicated to the forest, he stayed on and single-handedly looked after the trees, continuing to plant more of them. Eventually, the forest expanded to 550 hectares. This could perhaps be the world's biggest forest in the middle of a river.

Molai forest now houses Bengal tigers, Indian rhinoceros, over 100 deer and rabbits besides apes and several varieties of birds, including a large number of vultures. There are several thousand trees, such as: *Terminalia arjuna, Lagerstroemia speciosa, Delonix regia, Albizia procera, Archidendron bigeminum and Bombax ceiba*. Bamboo covers an area of over 300 hectares.

A herd of around 100 elephants regularly visits the forest every year and generally stays for around six months.

Figure 3. "Forest man of India" planting trees on barren land

3. Grassland

3.1. Grassland in general

In Europe there are various types of grasslands, ranging from almost desertic types in south-east Spain through steppic and mesic types to humid grasslands/meadows, which dominate in the north and north-west.

Since almost all European grasslands are more or less modified by human activity and have to a major extent been created and maintained by agricultural activities, they could be defined as "semi-natural grasslands", although their plant communities are natural. These grasslands are maintained through farmers' grazing and/or cutting regimes. There are also some more natural "permanent grasslands" that occur in Europe. The distribution of these is determined by natural conditions including climate, topography and soil structure.

Grassland area in the EU declined by 12.8% from 1990 to 2003; only a few Member States managed to mitigate this trend.

According to EEA (1999):

- Except for very limited areas of special natural grassland types, all European grasslands are maintained through grazing or cutting, the continuation and intensity of which are crucial for the protection of the grasslands and the species they harbour.
- Pressure on grassland habitats is increasing steadily. Some 60% of the newly afforested area in the EU was formerly permanent pasture or meadows, 37% was arable land and only 3% was permanent cropland.

Common threats to grassland in the EU:

- Changes in land use and land abandonment / abandonment of traditional activities
- Afforestation
- Changes in livestock density
- Intensification of grassland management and mowing
- Lowering of water tables
- Deposition of airborne nitrogen (ammonia)

Source: LIFE and Europe's grasslands - Restoring a forgotten habitat (EC, 2008)

3.2. Best management practices – Grassland – Mountain sites (MG)

Some of the best management practices are applicable in both plain and mountain sites. Unless indicated within the measure description, the applicability is shown in overview table at the end of the chapter.

- **BP MG1 Establishment or enhancement of grassland by regeneration process**

Description of the measure

Alpine ecosystems are characterised by unfavourable climatic conditions with limiting effects on growth and bio-mass production of plants that are increasing with altitude. At an altitude of 2000 m, the number of growing days (average daily temperatures > 5°C) is reduced to 67 days. In alpine environments, vegetation has therefore a growing season of two to three months. Because of the limited growing period, restoration activities at high altitudes should be carried out the first weeks after the snow melt. The results of investigations on climatic site conditions indicate that large scale interventions and thus restoration with seed mixtures generally should be avoided above altitudes of 2.400 m.

Above timberline, more dense vegetation with a cover of about 80% is recommended. Therefore, a sufficient combination of application technique and adapted seed mixture, reaching the minimum requirement of sustainable vegetation with 70 to 80% cover within the first two vegetation periods has to be the goal of restoration in high altitudes. Under average conditions of high altitudes the necessary minimum demand on cover can be achieved in the second vegetation period at the earliest. This requires application techniques with sufficient protection of top soil for the first two vegetation periods.

The best protection against erosion can only be reached by additional cover of the topsoil with straw mulching, hay mulching, different mats, nets, three-dimensional mats etc. causing a clear decrease of superficial soil losses and water flow rate.

Measure advantages

One of the most severe problems within recultivation works in mountainous areas (with 30-45% slope gradient) is the increased surface run-off and soil erosion (Krautzer, AREC). Seeding procedures with adequate protection against erosion are important requirements for a successful revegetation. Without the adequate cover of the topsoil indigenous and fast-growing species show a comparable bad erosion-behaviour within the first 4-8 weeks after seeding.

In view of an economic evaluation, the set up costs indicate that commercial seed mixtures would be much cheaper than seed mixtures including indigenous species. But when looking at the years following the set-up, the sites that use commercial seed mixtures have to anticipate follow up costs (reseeding and steady fertilisation). So in the long term in order to reach a sustainable restoration, the use of indigenous species is meaningful not only from an ecological but also from an economic standpoint.

Challenges

Within the whole Alpine area, thousands of hectares are affected every year, e.g. by ski slopes, ski lifts, tourist infrastructure, improvement of Alpine pastures and roads. After intervention, those areas are re-seeded and normally used as pastures. Such areas, mainly within the sub-alpine and Alpine stage, are one of the most sensible parts of the Alps. Every intervention in such Alpine living spaces leads to interference that requires different technical and ecological measurements to reach the goal of a sustainable restoration of those affected areas. This can only be reached with the help of indigenous plant material. For the need of indigenous vegetation, seed mixtures have to be used in most cases.

On 8 localities of the Alps, in different altitudes from 1.230 m to 2.340 m, the research project "Seed Propagation of Indigenous Species and their Use for Restoration of Eroded Areas in the Alps" (FAIR CT98-4024, short title "ALPEROS"), supported by the EC, was carried out in order to assess the possibilities of restoring damaged areas using a combination of improved application techniques alongside seed mixtures of indigenous species.

To get basic information about the effects of different application techniques on superficial soil losses and water flow rate, a mobile erosion facility with three chambers was built up at the location Hochwurzen (1,830 m ASL) in order to measure erosion in dependence on different application techniques after restoration.

- **BP M(P)G2 Establishment or enhancement of grassland by sowing or planting**

Description of the measure

Only autochthonous or regional seed from the natural surroundings of the respective construction project is optimally adjusted to the specific site conditions. As it usually origins from high-quality crops rich in species, it generates an especially dense, dynamic and powerful root system. The choice of the target vegetation must be based on the natural vegetation of the site to gain ecological stability and ensure a higher resistance to environmental stress and diseases and to reduce the maintenance demands and costs.

Measure advantages

Due to the especially dense, dynamic and powerful root system an optimal protection against soil erosion and the improvement of biodiversity can be guaranteed. Technical functions of primary importance in terms of the stabilisation properties of plants in the frame of soil and water bioengineering interventions are:

- Covering of the ground using plant communities as protection against heavy precipitation, soil erosion by water and wind.
- Mechanical anchoring and buttressing of the soil by the roots.
- Cohesion and stabilisation of the soil trough the aggregation of soil particles by plant roots, humus, mycorrhizae and micro-fauna as well as interlocking or anchoring of topsoil and subsoil and prevention of the washout of fine material through their retention and filtering by the network of fine roots.

- Slowing down and diverting air and water flow. Effects in the area of the root, in particular compression through the increase in root thickness, soil loosening due to movement of the root system induced by the movement of the stem and branches and soil compaction due to the weight of the vegetation.
- Increase in overall soil cohesion through the extraction of water by evapotranspiration.
- Positive management of the local and regional water balance trough the evaporation of soil water, retention of precipitation water, retention of soil water and balanced water infiltration.

But in areas with no or only little vegetation in gullies and other drainage channels intensive rainfall events may cause strong surface run-off causing intense erosion. That is why a dense vegetation cover is needed as associated with complementary measures to increase the roughness of the surface. A suitable coverage with vegetation such as wood, bushes and hedges can be used to regulate the water regime particular in extreme or very disturbed sites like gullies, steep slopes or other erosion prone areas. The impact of these bioengineering measures can be especially important in catchments which are situated above an area of flood risk as well as a catchment belonging to hydro-dam and other constructions of water supply.

Challenges

For example, in Austria, research on grassland farming in the Alpine area exists since 1889. After successful breeding of cultivars of forage crops, a comprehensive programme for breeding of grasses and legumes for the use in seed mixtures for permanent grassland has been started. Additionally, also a programme for the propagation of seed of Alpine and subalpine ecotypes for erosion protection and landscaping has been conducted.

One result of these efforts is the launch of a special cultivar. A number of indigenous species have been selected during the last years, optimising the production and harvesting technique for successful seed production.

The slow growing rate of the alpine grasses and forbs, their subsequently low competitive capacity and their susceptibility to fungal diseases make seed production difficult in context of organic farming. Therefore, 18 subalpine and Alpine grasses, legumes and herbs have been selected by means of intensive research procedures, to be propagated and used for high zone restoration.

- **BP M(P)G3 Supporting guidance for creation of low-input grassland to convert arable land at risk of erosion or flooding**

Description of the measure

The purpose of this best practice is to establish a new sward by sowing a low productivity grass mix containing at least four flowering species. The sward has to be established before beginning of June (in the first year) – sawing in spring or autumn. The wildflower mixture should be made up of autochthonous species. At least 15% of the mixture should be herbs and the rest grasses.

Grazing animals are good at creating variety with their trampling, dunging and eating. Grazing should be at light to moderate levels to keep the sward at a range of heights and to allow some plants to flower. A way to create as diverse habitats as possible and to consider as many species as possible is „rotational grazing", which means a spatial and temporal change of grazed and un-grazed areas. Where no stock are available to graze, grassland should be cut (not before mid of August) to a height between five and ten centimetres.

Measure advantages

The benefit of this BP is the improvement of soil and water quality as well as biodiversity within arable fields which are prone to flooding and / or soil erosion. The grass area should be located within fields or areas at risk to help prevent soil erosion. For example:

- Particularly long uninterrupted slopes;
- field valleys, low corners or other areas which tend to concentrate run-off;
- light soils (with a relatively high sand or silt content) tend to be more prone to erosion particularly those with a low organic matter content;
- areas which drain directly to a watercourse will be of greater risk of transferring eroded soil to the watercourse;
- areas with flooding risk (adjacent to watercourses).

Challenges

Challenges associated with this measure can be seen on Austria's example in the so-called "Austrian Agrarian Environmental Programme" ÖPUL for environmentally friendly management of agrarian land provides a funding system for certain sustainable measures:

- Protection, restoration and conservation of biodiversity also in Natura 2000 sites, endangered or rural areas, land management with high nature value;
- enhancement of water management incl. manure management and pesticides;
- reduction of soil erosion, enhancement of soil management;
- reduction of emissions from agriculture (through site-appropriate cultivation, reduction of fertilisation, field-related fertilisation accounting in combination with soil samples, compulsory participation at trainings);
- promotion of carbon storage in agriculture and forestry;
- Nitrate Action Plan 2012: regulation of nitrate-fertiliser;
- promotion of buffer strips, especially along water courses to avoid erosion and pollution through nutrients;
- Groundwater 2020 (in Upper Austria): comprehensive protection of groundwater sources and the respective funding of sustainable land-use management measures.

- **BP M(P)G4 Weed control against invasive plant species**

Description of the measure

Invasive plant species are considered as one of the major threats to biodiversity. They can reduce yields from agriculture, forestry and fisheries, are known to decrease water availability and to cause land degradation. They suppress native plants that play an important role in binding soil with their roots and may thereby contribute to increased soil erosion. The main identified costs in Europe comprise eradication and control costs and damage to agriculture, forestry, commercial fisheries, infrastructure and human health. Comprehensive management measures against these invasive plant species have to be pursued continuously by all countries to minimize their expansion.

Measure advantages

Through intensive destruction of invasive species, especially plant species as they are most important concerning water resources protection and flood mitigation, native species can spread over their original range and provide again the necessary ecosystem services (e.g. minimizing soil erosion and land degradation, improvement of water quality).

Challenges

The REGULATION (EU) No 1143/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species has to be implemented in national law and applied directly. A surveillance system and official controls need to be conducted as well as management of invasive alien species that are widely spread.

For example in Austria, based on the nature protection laws, several institutions offer information tools and practical instructions as well as special courses and trainings. Numerous projects are being implemented in practice. In Austria for instance several guidelines, directives, regulations, action plans, management plans, Funding Programmes [Life+, Leader, Rural Development Programme 2014-2020, Framework Programmes, Environmental Programmes (e.g. ÖPUL in Austria)], information campaigns and initiatives, specific regional and national projects are actually conducted. Main goal is the optimization of existing legal instruments and tools for implementation and monitoring together with voluntary measures, but clearing invasive alien species is an expensive business.

<u>Some Best practice examples in Austria:</u>

- **Effective management in Carinthian nature parks** „Dobratsch and Weißensee“ against *Fallopia japonica* and *Impatiens glandulifera*. The priority initiative in co-operation with “ARGE Naturschutz” is relevant for the protection of biodiversity. Management plans include repressing of invasive plants, public awareness and voluntary measures (articles in newspapers, municipality newsletters, and clear directions for disposal).
- **School initiatives (science practice) in District Liezen (Styria)** together with Mountain and Nature Rescue Service, Styrian Society of Nature Conservation, Austrian Service for Torrent and Avalanche Control, District Office, local municipalities. The

annual activities include active management, monitoring, research activities, documentation, public awareness, information brochures, science in school activities (outdoor activities, matriculation projects, internships and information workshops).

- **LIFE Nature Project "Gesäuse"** (Styria, Enns valley):
- The **LIFE project „Flusslandschaft Enns"** (2011-2015): "Conservation strategies for forests and torrents in the region "Gesäuse" incl. management of invasive plant species (especially Impatiens glandulifera) forms the starting point of the renaturation of the river Enns. The management plan for invasive species was implemented at the different river sections with ongoing activities.
- **LIFE+ Project Ausseerland**: management plan for invasive plant species

- **BP M(P)G5 Reduction of nutrient inputs into water resources**

Description of the measure

Due to land-use management measures within grassland/agricultural areas concerning adequate fertilisation, especially adjacent to water courses and lakes, water pollution through nutrients can be mostly prevented. The following measures should be considered: optimum timing of application, reduction of fertiliser-amount, special techniques of application, avoidance of soil compaction, and maintenance/establishment of a dense grass sward.

By means of indicator plants the specific site status can be identified (Bohner, AREC). Changes of site characteristics as well as wrong fertilisation and cultivation measures can be recognised at an early stage. Site specific improvement measures and the adequate demand for fertilisation can be estimated accordingly.

Measure advantages

Through suitable cultivation measures within arable and grassland areas losses of nutrients (e.g. phosphorus) to the groundwater and surface water can be reduced and the respective water quality will be improved.

Challenges

In the framework of the INTERREG IV project "Gewässer-Zukunft" (2009-2013) – "Water-future: reduction of nutrient inputs into surface waters in the cultural landscape of the Bavarian and Austrian foothills of the Alps" a sustainable improvement of the water quality of river "Antiesen" in Upper Austria was envisaged. To reach this target, phosphorus inputs from agriculturally used areas have to be reduced. Most of the investigated grassland soils exhibit very low levels of CAL-soluble phosphorus. Arable land, cropped with cereals, maize or oil plants (rapeseed, flax), has on average higher contents of CAL-soluble phosphorus in the topsoil than grassland. In the agricultural used soils, the levels of water-soluble phosphorus in the uppermost 15 cm are sometimes very high, increasing the risk of greater phosphorus losses in surface runoff in dissolved form on slopes.

Within the INTERREG IIIA project "Nachhaltige Landwirtschaft in der EU Regionalen Seenlandschaft" (2004-2007) – sustainable fertilisation of drained grassland areas in the EU Regio-Alpine upland lake landscape was developed. The primary aim of this study was to develop

suitable measures to reduce losses of phosphorus from agricultural used soils to the groundwater and to the surface water in the catchments of Mondsee, Irrsee and Waginger-Tachinger See. In the study area grassland is a very important land-use pattern. Therefore, phosphorus losses from grassland by surface runoff are prevailing. In order to minimize these phosphorus losses the optimum timing of fertilizer application, the avoidance of soil compaction, and the maintenance or establishment of a dense grass sward without gaps are important measures. On sites very susceptible to leaching and surface runoff – especially nearby surface waters - measures such as reduction in the rate of phosphorus-fertilizer application or cessation of fertilizing and the resulting decrease in management intensity as well as – especially on drained grassland - special techniques of slurry application (for example flat injection) are further effective and sustainable measures for the protection of the groundwater and the surface water in the long-term.

- **BP MG6 Site-appropriate extensive management of mountain pasture land**

Description of the measure

Through the abandonment of pastures or inadequate intensive management measures in mountainous areas the adequate ecosystem service "protection of surface and soil" gets lost. Mudslides and erosion processes increase and important areas and soils are destroyed as the former vegetation and its root-system changes. After intensive fertilisation or abandonment of pastures the rooting decreases and thus the potential risk of erosion processes increases. Fallow lands of 15 up to 20 years are the most unstable areas (TASSER et al., 2004).

Within sensible sites (e.g. steep gullies, sensitive wetland areas, DWPZ) also erosion processes and soil losses can occur by trampling damages through livestock. Grazing should be accordingly limited or totally abandoned within these areas. On already destroyed sites the improvement of the sward through site-specific seeds should be conducted supplemented with adequate fertilisation. Important in this connection is the diversity of the vegetation to provide different root-lengths, so that the interlocking with the underground and the stabilisation of the topsoil get improved.

Measure advantages

Site-appropriate management of pastures cause a positive effect on water storage capacity and run-off behaviour during rainfall. The risk of dangerous torrent-flows or erosion processes throughout heavy rainfalls decreases.

Challenges

The adequate extensive management of mountain pastures is very labour-intensive, difficult and uneconomic. Therefore in some areas of Austria the danger of abandoned pastures in the mountains increases.

Nevertheless some positive examples exist, e.g.:

Within the **DWPZ of the City of Vienna**, cattle-grazing is regulated in a way, that dolines and sink-holes are fenced so that cattle cannot approach these highly vulnerable sites. Through these measures the cattle dung is intended to be kept away from these areas, which have a direct connection to the aquifer. In order to avoid the direct entrance of precipitation water,

technical constructions were also used, like e.g. dams which prevent precipitation water from directly flowing into dolines or sinkholes. The water can subsequently infiltrate slowly via the soil matrix, so that the potential contaminants are reduced (soils are acting like a filter). Additionally, in order to avoid erosion processes and consequently threat for source water quality by trampling damages through livestock (above all cattle), fencing of erosive sites was done for keeping livestock at a distance. A subsequent planting with autochthonous vegetation is a further step towards prevention of such erosion processes.

- **BP MG7 Preservation of the turf on grazed Alpine grasslands**

Description of the measure

Grasslands in mountain areas are typically used for Alpine farming and grazing. The impact of grazing activities can have serious consequences for shallow topsoils and thus for the water balance as well.

LAMARQUE et al. (2011) identified the ecosystem services water quantity (provision), water quality (regulation) and natural hazard regulation (including water regulation) as three of the most important functions of Alpine grasslands. The turf, the humus content of the topsoil along with a loosely-layered, not compacted soil structure of grasslands, favour the water storage capacity and the process of water purification. Bioturbation further enhances the soil (aggregate) structure; it improves the connectivity of macropores and enhances the water storage and infiltration capacity (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water provision and water regulation function of the grassland.

Through intensive grazing and livestock trampling the turf properties can persistently deteriorate. As a consequence, the mentioned ecosystem services of the turf and the underlying soil layer(s) to store and retain water degrade. NGUYEN et al. (1998) indicated the impact of intensive grazing especially on steep slopes. Livestock trampling leads to an increased bulk density in the topsoil which conversely increases the surface runoff and contaminant discharge (e.g. nitrate and phosphorus). The outwash of nitrate can further be increased through livestock urine and faeces acting as point sources for contamination (STOUT et al., 1997). Similar results have been obtained by COURNANE et al. (2011). The increase of bulk density is attributed to a reduction of macroporosity in the topsoil as a result of livestock trampling (LEITINGER et al., 2010).

To sustainably protect the ecosystem services of grasslands in drinking water protection zones of mountain areas, grazing activities are prohibited for example in Germany within zone II while further limitations should be implemented in zone III. An adaptation to a sound grazing strategy can limit the extensive soil degradation through livestock trampling to sustain the turf qualities and the physical properties of the soil system. Moreover, the exposure to water pollutants is reduced due to a lower input from animal faeces and reduced conversion of biomass. This measure thus hinders an enhanced outwash of contaminants into the receiving waters and maintains the ecosystem services water regulation and water provision of grasslands.

Measure advantages

- Positive impacts on the ecosystem service water provision, water regulation and water quality regulation;
- protection of downslope located areas;
- preservation of soil stress;
- increasing activity of soil organisms enhances the soil (aggregate) structure and the connectivity of water paths;
- decreased diffusive discharge of nutrients (e.g. nitrate).

Challenges

- Measure implementation and control of grazing activities.

- **BP MG8 Soil management**

Description of the measure

In steep slope zones with degraded grazing areas, even after fire burning, that under peculiar geomorphological conditions generate erosion, solifluction and landslide phenomena, transversal water-holding furrows and transversal to longitudinal ditches are useful in the short and medium term on the hillslope and hydrographic basins. However, grazing should be prohibited, in case of fires, for the five years after the event (ISPRA, Manuali e Linee Guida 85/2013).

Measure advantages

- Water regulation, reduction of sheet and rill erosion;
- reduction of solifluction and landslides;
- reduction of floods thanks to longer concentration time (time from the rain dropping the soil to reaching the basin outlet);
- higher edible surface for animals, thanks to the maintenance of organic matter;
- soil improvement (organic and mineral elements);
- time for recovery of soil after fire.

Challenges

- Not appropriate for some type of topography and soils (e.g. geo-mechanical characteristics of clays);
- work risks and economic costs for operations.

- **BP MG9 Plantation of tree-shrub lines**

Description of the measure

Using appropriate and autochthonous species, permanent and visible field borders in steep slope areas could be established through lines of tree and shrubs. They could serve also to produce wood for energy purposes (estimated as 0-200 euro per km). It is estimated a maintenance of organic matter thanks to this practice of about 10t/ha/yr (ISPRA, Manuali e Linee Guida 85/2013).

Measure advantages

- Reduction of sediment transport and of runoff;
- increase of infiltration on the hillslope;
- increase of the biodiversity for flora and fauna, providing opportunities for biological control, natural or anthropic;
- refuge for wild fauna;
- creation of ecological corridors and increase of the landscape value.

Challenges

- Loss of surface for grazing, however balanced by greening payments of the CAP.

- **BP MG10 Establishment of grassland in DWPA I. (inner zone)**

Description of the measure

Grassland can act as a sort of filter for the rain and eventual surface runoff inside the inner (I) drinking water protection zone (direct protection of the abstraction site). In these zones already existing land-use categories such as forests (that are managed sustainably) and constructed areas (without pollution), are to be maintained. Furthermore, natural grasslands that are managed according to the nature conservation principles (without grazing), should be conserved or if degraded, restored. In order to conserve or improve water resources quality and quantity, extensive and intensive grasslands and arable lands should be transformed and managed specifically as low input grasslands.

Measure advantages

- Inside a surface catchment of drinking water resources in erosion sensitive agricultural areas (for reducing erosion and retaining pollutants from surface runoff), grassland is one of the suitable land cover.
- From large meadows to thin buffer strips between patches of arable lands, all sizes and management types can be applied.
- Forests (or arboreal vegetation in strips) or wetlands in locally deeper zones represent other efficient options, but arable land with appropriate cultivation practices can also be applied.

- Grassland ESSs may reduce quantitative and qualitative vulnerability of groundwater and surface water resources by: retaining water, filtering and attenuating pollutants, reducing erosion.
- As a new establishment, grassland has the advantage of "producing" the needed continuous land cover much quicker than forest.

Challenges

- Forest (in particular natural or semi natural forest) must not be replaced by grasslands.
- Constructed areas cannot be converted to grassland.
- Conversion from arable land to grassland is influenced by the present stakeholders (i.e. farmers and land owners), landscape management strategies or agricultural development plans and corresponding subsidizing system.

- **BP MG11 Establishment of grassland in DWPA II. (outer zone)**

Description of the measure

Inside outer (II) water protection zones (protection against bacterial and degradable pollutants in the case of groundwater abstraction) grassland can efficiently filter surface runoff or recharge water. Already existing land-use categories such as wetlands and forests (that are managed sustainably), constructed areas (without pollution) and natural or extensive grasslands (without grazing) are to be maintained. Intensive grasslands and arable lands should be transformed and managed as extensive grasslands without grazing or specifically as protective vegetative cover (e.g. buffer strips along water bodies that are no less than 1 m wide). Given the potential of providing the needed continuous vegetative cover much rapidly than forests, grassland are preferable land cover. Nonetheless, in case of the larger outer zone, forests and intensive grassland (with applied appropriate good management practices) can also be established outside of the protective buffer.

Measure advantages

- Same as BP MG10

Challenges

- Same as BP MG10

- **BP MG12 Establishment of grassland in DWPA III. (recharge area or catchment)**

Description of the measure

Inside extended (III) drinking water protection zones in the recharge areas (protection against persistent pollutants) grassland may retain surface runoff, increase and filter water recharge. Any type of grassland management can be applied if the corresponding good practices are respected. Forest (or arboreal vegetation in strips) and arable land with appropriate cultivation

practices can also be applied. Notable fact is that grassland retain less potential pollutants and water (surface water and recharge) that forests.

Measure advantages

- Same as BP MG10

Challenges

- Same as BP MG10

- **BP MG13 Prohibiting use of chemicals, limiting irrigation in the DWPAs on grassland**

Description of the measure

Weed and invasive species elimination is one of the essential practices of grassland management. It contributes to the biodiversity, grassland stability and ESSs. Use of chemicals (fertilizer, pesticides, and herbicides) is prohibited in the I., II. zone in buffer strips along water bodies. By infiltrating into the soil, chemicals can reach well fields or be transported into surface waters and the abstraction sites, causing water contamination. Adaptation of the measure to the DWPA requirements is a must. Instead of the chemical treatment, weeds can be controlled by the mechanical methods or specific grazing activities (allowed only in II. zone).

Extensive management of grassland practically means forage production (mowing) and livestock farming (grazing) without use of chemicals, transported manure and irrigation. The basis is the natural management scheme. Changes in mowing and grazing practices, and in the mechanical weed control is possible according to extensive type of forage production and grazing, which has to be planned in such a way that natural structure and dynamics are ensured. Appropriate (traditional) rotation of the extensive mowing/grazing sites provides suitable diversity in time and in space. Although there are some alterations compared to natural species composition, native species are still dominating. Oversowing is rare but possible if it is not specifically prohibited due to nature protection reason.

All other aspects are similar to those of the natural management. This management type can occur in primary and secondary grasslands, as well as in grasslands established artificially. It is applicable in any type of DWPAs, except in the inner zone.

Irrigation can cause changes of the local water regime but also affect water quality (e.g. irrigation with water containing plant nutrients or other contaminants). Individual inadequate water captures for the irrigation purposes can have significant effect on local water resources and soil. They can cause soil marshification, impoverished soil due to washing of nutrients, soil erosion and degradation of morphological characteristics. Irrigation should be prohibited in inner and outer DWPA.

Challenges

- Grazing is not allowed in inner water protection zone and buffer zone. In outer protection zone it is allowed only if there is no chance of pollution.
- Prohibition or limiting the burning of weeds.

- Informing and educating farmers on the sustainable methods for weed control within DWPA.
- Prohibit the irrigation with water that does not have drinking characteristics (i.e. contaminated or polluted water is not suitable for the irrigation purposes in areas near water bodies or in water recharge areas).
- Irrigation can be essential factor in the recovery process of degraded grasslands, especially in drought-prone areas.
- Pressure of uncontrolled or scattered water captures for the need of irrigation will increase as a result of climate change.
- On the other hand, irrigation can be essential factor in the recovery process of degraded grasslands, especially in drought-prone areas.

- **BP MG14 Establishment of buffer zone along rivers, lakes and sinkholes**

Description of the measure

Vegetated buffer zones along water bodies can be seen as ecologically significant areas that have the potential to reduce lateral erosion (in case of flood events) and sediment transport, to mitigate the surface runoff but also protect water from the pollutants or nutrient loads of surrounding land. Especially in the case of arable land adjacent to water body, it is recommended to establish and maintain vegetated buffer strip of at least 1 m width. These areas should not be cultivated or treated with substances such as fertilizers or pesticides. Grassed buffer strips can be adequate solution along sinkholes, which as specific karstic features should be treated and protected as much as other water bodies.

- **BP MG15 Promoting the application of buffer strips of grass between plots of arable lands**

Description of the measure

Grassed buffer strips between plots of arable lands have ecologically significant purpose. They not only provide habitat for pollinators and birds, but can also directly affect the spreading of weeds and pollutants, reduce soil erosion and retain sediment transport. Grassed strips should be sufficiently wide and should contain at least several grass types. They should be extensively mowed according to the flowering stage. Also, using them as paths or passages for the machinery is not recommended.

Implementation of grassed strips can be encouraged by specific subsidies which can be granted to farmers or land owners.

- **BP MG16 Enhancing self-regenerating capacity of grasslands fitting the ecoregion, supporting native species**

Description of the measure

Autochthonous vegetative material is of crucial importance for the stability and resilience of ecosystems, especially under climate change. Thus it should be used in the recovery process of degraded grasslands (especially protected ones) and when establishing grassland areas on converted, abandoned arable land.

This method should generally be used for the extensive grasslands management. Furthermore, use of chemical such as pesticides and fertilizers but also manure is contrary to the principle of natural regeneration and conservation. Therefore, their application should be limited only to intensive agricultural area.

During self-regenerating process, grassland should be maintained (mowing, mechanical weed and invasive species control) with the respect to species characteristics.

Measure advantages

- Appropriate grassland management can enhance the transformation of existing GL-system to natural one.
- Cost of self-preservation is lower than implementation of agricultural techniques.

Challenges

- Not suitable if rapid development and special species composition is important (mainly in special grasslands.
- Education of farmers on the grassland regenerative processes and significance of native species in sustainable management.

- **BP MG17 Promoting the occurrence of species adaptive to CC**

Description of the measure

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 among other vegetative cover leave mark on grasslands too. The significance of its impact will depend not only on the location and current climate, but also on the species composition or their stability and resilience. Therefore grassland management strategies should include long-term plans and scenarios based on the habitat vulnerability assessment. Adaptive grassland management under climate change has to ensure the provision of the ESS over space and time.

Grassland adaptation to climate change should consider modifying the intensity of mowing and grazing activities that need to be in accordance to the optimal need of the modified natural species composition. Oversowing and irrigation should be prohibited in natural and extensive grasslands.

Challenges

- Getting better understanding of climate change effects on vulnerable habitats prone to fire events, invasive species and diseases;
- raising awareness on the climate change and adaptive management practices among relevant stakeholders;
- financial support in form of subsidies for adaptation;
- conservation of biodiversity in order to maintain grassland stability and resilience.

- **BP MG18 Grassland management only with maintenance purposes (nature protection schemes)**

Description of the measure

Natural grasslands as habitats rich in plant and animal species have high nature conservation value. Adequate maintenance activities play an essential role in the preservation of their balance, structure and biodiversity. Saving natural structure and dynamics by extensive grassland management practices include: appropriate mowing/grazing schedule (at least once a year, rotation of the mowing/grazing sites); individual plant species not suitable for grazing (toxic and alien species) should be removed manually; removal of shrubs or other woody vegetation on overgrown grasslands; leaving some areas unmaintained if possible; hydro-melioration activities, application of chemicals and manure should be prohibited.

Measure advantages

- All of the above mentioned activities are aimed at the enhancement of high nature value areas.

Challenges

- Farmers not willing to comply with commitments related to specific maintenance activities. Proper education and clear guidance have to be provided;
- support in the form of annual grant for farmers who implement activities in compliance with the special conditions/requirements;
- the need for grazing and mowing on areas where there has been no previous history of these activities should be evaluated in relation to nature conservation interests.

- **BP MG19 Avoiding permanent injury of the surface, compaction of soil**

Description of the measure

Morphological characteristics of soil can be disturbed by inadequate use of heavy machinery or ploughing, especially on water saturated soil. Therefore it is necessary to undertake cultivation (harvesting) activities in drier soil conditions. Ploughing is prohibited.

Also soil damaging can appear in case of livestock overload by overgrazing. Although moderate trampling can be beneficial, excessive trampling and poaching, cause damage to vegetation

layer and soil surface (hooves crush vulnerable plants and can create depression several centimetres deep) causing both soil erosion and a decrease in species-richness and structural diversity.

Likewise improper recreational activities can be associated with soil compaction and erosion.

Measure advantages

- Limiting structural soil damage will positively affect grassland stability and diversity but will also indirectly reduce surface runoff.

Challenges

- Bare compacted soil will result in increased surface runoff and soil erosion. Also in these areas more vigorous, potentially invasive weed species can spread.
- Implement adequate cultivation methods in appropriate period of year.

- **BP MG20 Groundwater regulation by drainage**

Description of the measure

Regulation of groundwater level can optimise the water supply of the grassland by eliminating the long wet period with appropriate drainage system. The measure is expensive, so it should be supported by economic assessment (CBA).

- **BP MG21 Promoting regular flooding, permitting mandatory irrigation, avoiding too long water cover**

Description of the measure

Proper water supply of grassland supports grassland growth and can reach maximal grassland ecosystem services. Grasslands are proper places for water retention but the resistance, sensitivity against water cover should be considered.

- **BP MG22 Promoting reasonable nutrient and water balance management (regular over-sowing) in planning process**

Description of the measure

Over-sowing is the process of introducing seed into a living, often established stand of turf, in order to make repairs or to maintain adequate turf density. To many farmers, over-sowing has advantages over the plough. It's cheap, quick and is of low risk, with existing grass being retained and improved without loss of forage or time. The success of over-sowing depends on the presence of gaps in the sward which are large and persistent enough for seeds to germinate and establish free from competition. Seeds must land and then be pressed into the bare soil in the gaps with sufficient moisture to germinate and sustain them.

Grazing is much preferred to cutting once the seed has been sown as bulking up for silage or hay will smother newly emerging seedlings. Grazing should be resumed five weeks after sowing, but

the sward should not be over grazed. Cattle or sheep may be employed, but sheep should not be left on for too long as they will graze too close, damaging new seedlings. Although cattle exert more pressure on the ground, they do not bite so accurately or as close and are the preferred choice provided that dry ground conditions prevail. Generally used to repair smaller areas, for example after pugging damage, or to establish white clover in spring into pastures where the land is too steep or stony for cultivation. Not recommended for improvement of lowland pastures due to high seeding mortality. Sowing rates are generally higher, as establishment rates of seed placed on the ground surface are lower (Cotswold, 2017).

Measure advantages

- Simple, effective and low cost way to improve worn leys or old pasture without ploughing and re-seeding.

Challenges

- Variable results;
- not all grasses and clovers are suitable for over-sowing.

- **BP MG23 Controlling the use of manure (amount, timing)**

Description of the measure

Use of manure in inner safeguard zone and in buffer zone is prohibited. In outer safeguard zone grazing is permitted if dropping does not represent risk of pollution. Regarding application of manure, the following special rules can be listed:

- Storage of manure in grassland is prohibited;
- even if vulnerability is low, amount of nutrient should be limited for eliminating cauterizing of grass;
- broadcasting of nutrient on frozen or saturated soil or on snow cover is prohibited;
- while selecting period of deposition, possibility of flash floods should be considered.

In intensive agricultural grasslands the efficient production and the “no significant pollution” principle need to be harmonised. To this end, the plan for nutrient application should be prepared for every growing period, The allowed threshold of surplus of nutrients (for surface waters resources phosphorus and for groundwater nitrogen) should be determined in national regulation in harmony with WFD, EU Nitrate Directive and considering intrinsic vulnerability. In nature reserve and extensive areas the natural balance is to be maintained, only manure of local grazers during grazing (by dropping) can be considered, deposit from external sources (both manure and fertilizer) is prohibited. Point source pollution by manure storage/dump should be avoided, too much nutrient cauterizes the grass, and (flash) flood washes manure into the surface water, which reduces water quality.

Measure advantages

- Good practices of nutrient application are feasible everywhere, without limitation;
- the measure prevents the pollution of water resources and reduces quality vulnerability of drinking water supply.

Challenges

- Financial support for compensating loss of production due to reduced use of nutrient;
- insufficient education of farmers (information for calculating nutrient balance: actual nutrient content of the soil, planned rotation of mowing and grazing, nutrient load from local grazers, fertilizers and transported manure or green manure related to mowing);
- manure over-use is hard to control and supervise.

- **BP MG24 Anaerobic digestion of livestock manures**

Description of the measure

Use anaerobic digestion (AD) of livestock manures to generate CH_4 for biogas production. CH_4 generated from livestock manures during (mesophilic) anaerobic digestion can be used to produce heat and power, and to replace fossil fuel use. Also, CH_4 emissions during subsequent manure storage prior to land spreading will be reduced.

Anaerobic digestion of organic materials by microbial populations in a sealed container to generate CH_4 that is used to produce heat and power. During AD, organic N is mineralised to ammonium NH_4 (i.e. readily available) N; typically NH_4-N is increased by around 10% of the total N content. As a result of the digestion process, FIO numbers and BOD and the dry matter of the digestate is reduced.

- **BP MG25 Sustainable production (no over-mowing and promoting self-regeneration processes)**

Description of the measure

Grasslands in almost natural condition are core areas for saving biodiversity and they provide the highest stable ESSs, both in primary and regenerated secondary grasslands. To achieve and maintain their good status is among the basic objectives of the NATURA 2000 and Water Framework Directive. Good practices should follow the local management schemes of NATURA 2000 sites (even if the area is not part of the network) of the sub-ecoregion. It may include rules of mowing and natural and small scale grazing covering the role of natural weed control (in particular against invasive species), so providing suitable conditions for regeneration of native species. Over-sowing and additional disposal of manure and use of chemicals is generally prohibited. Grazing cannot be applied in inner safeguard zone and in buffer zones (I). In outer safeguard zone, only if it is proved that grazing does not represent risk of pollution. Area under nature conservation can be part of any type of DWPAs. Impact of climate change would need adaptation of mowing practices. Artificial water supply (in droughts, compensating impact of CC) is prohibited.

Measure advantages

- The measure promotes naturally stable grassland and consequently it provides the highest locally possible grassland's ESSs;

- maintenance cost is low (cost efficiency);
- since use of manure and chemicals is excluded the risk of local pollution is practically eliminated.

Challenges

- Financial support for compensating low production (practically the price of the ESSs) is needed;
- the only limitation related to drinking water supply is that grazing cannot be part of the management in inner safeguard zone and in buffer zones. In outer safeguard zone, only if it is proved that grazing does not represent risk of pollution (it depends on intrinsic vulnerability).

- **BP MG26 Appropriate treatment of the mowed material**

Description of the measure

The main cut each year is the summer "hay cut". This is when the main part of the year's growth is cut back using a scythe, heavy duty strimmer, reciprocating knife or other suitable mower (lawn mowers are generally not up to this task). The growth should be cut back to a height of 40-75mm. The cut grass should be dried on site, turning it to assist drying and disperse seeds (this also significantly reduces the weight and bulk of material to be removed). The dried 'hay' should be removed within 7 days of cutting. On larger areas it may be practical to cut and bale quality hay. Where hay making is impractical, arisings may be composted or placed in heaps on sacrificial parts of a site.

After the main cut, additional mowing or grazing during late summer and autumn is very effective in removing excessive grass growth and encouraging flowers -particularly on more fertile sites. Mow with a rotary, flail or other suitable mower to 40-75mm. Ideally cut at least twice from the time the hay is removed to the end of November, aiming to leave the grass short through winter. The amount of mowing required will again depend on the fertility of the site; areas can be mown regularly (weekly) if a more tidy appearance is wanted. If any cut produces significant quantities of material this should be removed.

Spring cutting to remove the first flush of grass can produce a later flowering meadow that is shorter, more open and less prone to collapse. Spring cutting or grazing is particularly useful on more fertile soils and in the early years of newly sown grassland; on settled infertile sites this may be unnecessary. The need to mow can be assessed by the amount and type of growth in the spring. Mow with a rotary, flail or other suitable mower to 40-75mm. For meadow grassland mow around Easter, and no later than the first week in May. For short flowering turf and pasture grassland, regular mowing or grazing may continue into June provided the grass is kept short enough to discourage use by nesting birds (source: Wildseed).

- **BP MG27 Appropriate establishment of infrastructures**

Description of the measure

Most common types of infrastructure in grasslands are water objects, fences, power lines, leisure objects, farms and settlements. This causes significant pressures due to changes in land use, increase of concrete surface area and changes in hydrological regime. Although the majority of EU grasslands are semi-natural due to human activity and modifications, special caution must be made during the construction of infrastructure, especially in DWPZ.

- **BP MG28 Fence off rivers and streams from livestock**

Description of the measure

Erect stock-proof fences in grazing fields and on trackways adjoining rivers and streams.

Trampling by livestock can erode river/stream banks and increase sediment inputs to watercourses. Livestock can also add pollutants directly by urinating and defecating into the water. Preventing access eliminates this source of pollution.

Livestock, particularly cattle, can cause severe damage to river and stream banks when attempting to gain access to drinking water. The vegetative cover is destroyed and the soil badly poached, leading to erosion of the bank and increased transport of soil particles and associated nutrients into watercourses. Livestock also add nutrients and FIOs by defecating and urinating directly into the water. Fencing to prevent bank access eliminates this source of pollution.

- **BP MG29 Conservation grazing**

Description of the measure

Conservation grazing is the use of semi-feral or domesticated grazing livestock to maintain and increase the biodiversity of natural or semi-natural grasslands, heathlands, wood pasture, wetlands and many other habitats. Conservation grazing is generally less intensive than practices such as prescribed burning, but still needs to be managed to ensure that overgrazing does not occur. The practice has proven to be beneficial in restoring and maintaining grassland and heathland ecosystems. The optimal level of grazing will depend on the goal of conservation, and different levels of grazing, alongside other conservation practices, can be used to induce the desired results.

The use of conservation grazing is dependent on what type of ecosystem, habitat, and plant community are desired to be maintained or restored. Grazing is a beneficial tool used to create a grass and small shrub dominated area.

One issue of controversy with grazing is whether conservation grazing is in fact beneficial to a grassland community and what intensity of grazing management needs to be taken. Rambo and Faeth (2001) found that the use of vertebrates for grazing of an area would increase the species richness of plants by decreasing the abundance of dominant species and increasing the richness of rarer species. The decrease in abundance may lead to a more open forest canopy and more room for other plant species to emerge.

Measure advantages

- Conservation grazing can deliver substantial benefits to local communities. Local production of good quality meat and dairy produce with high welfare standards is a key outcome of many conservation grazing schemes;
- rejuvenation of local economies;
- increased biodiversity and sustainable grassland management;

Challenges

- Conservation practices such as grazing need to be monitored closely. If they are not, the practice can become overused and have an opposite effect than intended. Overgrazing may cause erosion, habitat destruction, soil compaction, or reduced biodiversity (species richness).

- **BP MG330 Establishment and application of grazing plan**

Description of the measure

In order to avoid overgrazing, an adequate grazing plan is necessary. The following questions are a guide through decision-making process of developing grazing plan (Blanchet et al., 2003):

What are my goals for the grazing system?

What land resources are available for the grazing operation? What is the productivity of the soils? Are there sensitive land areas or soil limitations for grazing in the pasture?

What are the existing forage species in the pasture? How healthy or in what condition is the pasture? What are the estimated yields and seasonal distribution of the existing forages?

What are the existing water sources and where are the drinking facilities? What are the other potential water sources?

What are the types and condition of the existing fences?

How many paddocks are needed for a rotational grazing system? How do I decide paddock size? What are some considerations for paddock layout?

What kind of fence should I install?

How can I supply adequate water to the livestock? Where should drinking facilities be located?

What do I consider when planning livestock lanes? How do I stabilize the livestock lanes? How do I keep the area around water facilities from becoming mud-holes?

What is proper grazing management for the desired forage species? How do pasture and livestock management affect plant growth and forage quality? When do I start grazing in the spring? When do I move livestock from paddock to paddock?

Can nutrients from livestock manure be utilized more efficiently in pastures? When is increasing soil pH with lime important for forage production? How much nitrogen fertilizer do I need to put on my pasture? Does phosphorus and potassium fertilizer improve pasture productivity?

Can unwanted weeds be controlled through grazing? What are the cultural and mechanical brush and weed control alternatives for pastures? When is control of brush and problem weeds with herbicides the best option?

How will the livestock be managed during times of drought or wet conditions? Will sacrificial paddocks be rejuvenated after removal of livestock?

How do I know I have enough forage available? Is the productivity of the pasture increasing? Are the natural resources improving?

- **BP MG31 Extend the grazing season for cattle**

Description of the measure

Where soil conditions allow, the grazing season is extended (either earlier in the spring or later in the autumn).

Urine deposition by cattle at grazing rapidly infiltrates into the soil and is therefore associated with lower NH_3 emissions, compared with higher emissions from urine deposition on concrete floors within cattle housing (and associated emissions during storage and following manure spreading).

When cattle are grazing at pasture, excreta returns (urine and faeces) are deposited directly in the field. NH_3 emissions derive predominantly from the urea content of the urine, which must first be hydrolysed to ammonium carbonate before NH_3 emissions can occur. Urine will generally rapidly infiltrate into pasture land and hydrolysis will occur within the soil. The soil presents a physical (by reducing air movement) and chemical (by binding NH_4) barrier to NH_3 emissions, compared with urine deposited on a concrete (impermeable) floor in cattle housing.

- **BP MG32 Alternating grazing and mowing**

Description of the measure

To prevent degradation of high nature-value grasslands, common practices include mowing the land or grazing with livestock. Land managers are also usually restricted from applying fertilisers. However, there is scarce evidence on how these different practices affect the nutrient levels of the plants and soils, and therefore the grassland productivity.

To address this knowledge gap, in 2004 researchers established long-term experiments at two sites in the White Carpathian Mountains, between the Czech Republic and Slovakia. At each site they divided the grassland into plots, and applied different management treatments: mowing in mid-July, livestock grazing in June and August, or being left fallow (untouched). Seven years later, the scientists assessed the amount of biomass, amount of plant diversity, and the nutrient levels in both the plants and the soils. The scientists found that plots grazed by livestock showed the lowest amount of phosphorus available for plants in the soil, and plots that were mown had the lowest available potassium. Yet there was no difference in levels of above-ground biomass between grazed, mown and fallow plots. However, the management treatments did change the biodiversity, as different plants were better adapted to growing in different nutrient conditions. Over time, species composition between the management plots diversified. Grazing was found to

facilitate more grasses (plants with shallow but dense root system), while mowing allowed more forbs (plants rooting usually very deep in the soil) to grow. The scientists suggest that a high level of plant biodiversity in grasslands can help to sustain their productivity over time when little or no fertilisers are used. For example, grasses and forbs provide grasslands with different yet equally important benefits. Forbs can help to prevent shortage of phosphorus by mobilising its reserves from deep soil layers and grasses aid in efficient capture of nitrogen from mineralisation of plant litter on the soil surface or from atmospheric deposition. These nutrients are both important for maintaining the productivity of the grasslands. Consequently, the scientists concluded that grassland management practices should attempt to facilitate the growth of both grasses and forbs, since they are valuable components of grassland productivity. They recommend a mix of grazing and mowing could be used to encourage co-existence of both forbs and grasses, and to maintain optimal nutrient levels in grassland soil. As world reserves of superphosphates are quickly decreasing and mineral fertilisers negatively impact ecosystems, the researchers say that agro-environmental measures that encourage higher plant biodiversity could help to sustain stable grassland biomass under low or nil inputs of fertiliser.

Measure advantages

- High plant-species diversity helps grasslands to maintain productivity and to resist depletion of phosphorus caused by livestock grazing and depletion of potassium caused by mowing.

3.3. Best management practices – Grassland – Plain sites (PG)

- **BP P(M)G1 Preservation of permanent grasslands**

Description of the measure

The conversion from arable land to grassland is not the only measure that can positively affect the ecosystem services water provision, water quality regulation and water regulation. The preservation of permanent grasslands is at least of equal importance. By definition, a permanent grassland is an *"agricultural land which is currently, and has been for five years or more, used to grow grass and other herbaceous forage, even though that land has been ploughed up and seeded with another variety of herbaceous forage other than that which was previously grown on it during that period"* (ECJ, 2014). This definition has been introduced by the European Court of Justice (ECJ) as a result of a legal dispute of a German farmer who considered reseeding actions on his grassland sites would break the five-year regulation so that he keeps the status *"arable land"* for these sites. Generally, farmers try to avoid the status of permanent grasslands due to a lower sales value and the ban on ploughing. Thus, the implementation of ecologically valuable permanent grasslands is difficult since the economic value of arable land sites and permanent grasslands as well as the legal restrictions on both land-use entities mostly are of top priority.

According to the legal restriction a degradation of the site conditions with heavy machinery is avoided by law. Thus, soils of permanent grasslands are characterized by a loosened structure which has an enhanced water storage and retention capacity compared to more compacted, tilled soils on arable lands. In this context, Ajayi et al. (2016) evidence the importance of long-

term soil recovery for the physical soil properties on permanent grasslands fostering the water-related ecosystem services.

The enriched content of soil organic matter of the topsoil of a permanent grassland favours the water storage capacity and the process of water purification. Since permanent grasslands are not intensively used, the activity of soil organisms is high and keeps the bioturbation on an adequate level (BAUCHHENß, 2005). Bioturbation positively affects the soil (aggregate) structure; it improves the connectivity of macropores and enhances the infiltration capacity (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water provision and water regulation function of the soil system.

A dense turf on permanent grasslands provides a protection function against erosion processes, soil aggregate destabilization and evaporation losses. The turf decreases the susceptibility to surface sealing and lower the probability of breaching the infiltration capacity and the resulting Hortonian Overland Flow. Analogous to less surface sealing, enhanced vertical connectivity and increased losses through interception and evaporation, this measure can enhance the mitigation of floods in small catchment areas during convective storm events (DWA, 2015).

It is important to note that a ploughing up of permanent grasslands can significantly increase the leaching of nitrate since on the one hand, huge amounts of organic matter can be decomposed by soil organisms and on the other hand, the natural nutrient uptake by vegetation is interrupted (WHITMORE et al., 1992). The decomposition process is also enhanced by high solar radiation acting on the unprotected surface. Thus, the preservation of permanent grasslands in drinking water protection zones represents a valuable contribution to protect the drinking water quality.

Measure advantages

- Positive impacts on the ecosystem service water provision, water regulation and water quality regulation;
- preservation of soil stress and recovery of (physical) soil properties;
- increasing activity of soil organisms enhances the soil (aggregate) structure, the connectivity of water paths and decomposition processes;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffusive discharge of nutrients (e.g. nitrate).

Challenges

- Need for scarification to avoid hydrophobic effects of matted roots (SCHOBEL, 2005);
- economic efficiency depending on production emphasis of the farmer;
- "permanent grassland" definition introduced by the ECJ: loss of status "arable land", lower sales value, ban on ploughing;

- **BP PG2 Restriction of fertilisers and manure use in DWPZs**

Description of the measure

In the 1st DWPZ (adjacent to the capture area) is forbidden: fertilization with mineral fertilizers containing nitrogen, fertilization with manure and slurry, ploughing of permanent grassland, irrigation with water with added plant nutrients. Farmers get money compensations because of smaller harvest.

Best management practices concerning grassland are systematically shown in Table 3, where relevance of each BMP can be seen (water protection functionality, cost of the measures, duration of implementation and time interval of sustainability). Some BMPs are valid for both mountain and plain sites (*).

Table 3. Best management practice relevance – Grassland

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
MOUNTAIN SITES				
Establishment or enhancement of grassland by regeneration process*	High	High	Medium	Long Term
Establishment or enhancement of grassland by sowing or planting*	Medium	Medium	Medium	Long Term
Supporting guidance for creation of low-input grassland*	High	Medium	Long Term	Long Term
Weed control against invasive plant species*	High	High	Long Term	Long Term
Reduction of nutrient inputs into water resources*	High	Medium	Medium	Long Term
Site-appropriate extensive management of mountain pastures	High	High	Long Term	Long Term
Preservation of the turf on grazed Alpine grasslands	High	Low	Short Term	Medium
Soil management	High	High	Medium	Medium
Plantation of tree-shrub lines	High	High	Short Term	Medium
Establishment of grassland in DWPA I. (inner zone)*	High	Low	Medium	N/a
Establishment of grassland in DWPA II. (outer zone)*	Medium	Low	Medium	N/a
Establishment of grassland in DWPA III. (recharge area or catchment)*	Medium	Medium	Medium	N/a
Prohibiting use of chemicals, limiting irrigation in the DWPAs on grassland*	High	Medium	Short Term	N/a
Establishment of buffer zone along rivers, lakes and sinkholes*	High	Medium	Long Term	N/a

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
Promoting the application of buffer strips of grass between plots of arable lands*	Medium	Medium	Medium	N/a
Enhancing self-regenerating capacity of grasslands fitting the ecoregion, supporting native species*	Medium	Low	Long Term	N/a
Promoting the occurrence of species adaptive to CC.*	Medium	Low	Long Term	N/a
Grassland management only with maintenance purposes (nature protection schemes)*	Medium	Medium	Long Term	N/a
Avoiding permanent injury of the surface, compaction of soil*	Medium	Low	Short Term	N/a
Groundwater regulation by drainage*	Low	High	Long Term	N/a
Promoting regular flooding, permitting mandatory irrigation, avoiding too long water cover*	Medium	Medium	Short Term	N/a
Promoting reasonable nutrient and water balance management (regular oversowing) in planning process*	High	Medium	Long Term	N/a
Controlling the use of manure (amount, timing)*	Medium	Low	Short Term	N/a
Anaerobic digestion of livestock manures	N/a	N/a	N/a	N/a
Sustainable production (no over-mowing and promoting self-regeneration processes)	N/a	N/a	N/a	N/a
Appropriate treatment of the mowed material*	Low	Low	Short Term	N/a
Appropriate establishment of infrastructures*	Low	Medium	Short Term	N/a
Fence off rivers and streams from livestock*	Medium	Medium / High	Long Term	Short Term
Conservation grazing*	High	Medium / High	Long Term	N/a
Establishment and application of grazing plan*	Medium	Low	Short Term	N/a
Extend the grazing season for cattle	Low	Low	Short Term	N/a

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
Alternating grazing and mowing*	Medium	Low	Long Term	N/a
PLAIN SITES				
Preservation of permanent grasslands	High	Low	Short Term	Short Term
Restriction of fertilisers and manure use in DWPZs	High	Medium	Short Term	Long Term

* - valid for both mountain and plain cluster

N/a – not available

3.4. Review of best management practices - Grassland

Provided best management practices concerning grassland are less developed and fewer in number than practices in other sectors (e.g. forest, agriculture). Further efforts must be put into grassland preservation and restoration, mainly due to the fact that European grassland territory has reduced by more than 12% in the past 20 years.

Measures provided by Austria are a result from several LIFE, LIFE+ and INTERREG projects. Measures are well developed and cover all most essential issues in grassland management, while focusing on sustainable practices, such as regeneration, sowing, planting or battling invasive species. Regarding relevance, provided measures have high water protection functionality, medium to high costs of implementation, medium to long duration of implementation and long-time interval of sustainability.

Croatia has not reported any best management practices regarding grassland.

Germany – Bavaria provided one measure for each cluster. Those measures focus on preservation of alpine and permanent grasslands, mitigation of grazing effects and furthermore, emphasis is put on following ecosystem services: provision (water quantity), regulation (water quality) and natural hazard regulation as the most important functions of grassland ecosystems. Bavarian measures have high water protection functionality, low cost of implementation, short duration of implementation and short to medium interval of sustainability.

Italy provided two measures concerning grassland which focus on soil management and protection and plantation of the tree-shrub lines. Measures have high water protection functionality, high costs, short to medium duration of implementation and medium time interval of sustainability.

Poland has reported numerous measures that are derived from CC-WARE catalogue. Those measures cover variety of grassland related issues, such as establishment of grasslands in DWPZs, prohibition of chemical use, establishment of buffer zones, soil protection, promoting regular flooding, etc. Those measures have mostly variable water protection functionality (from low to high), generally low to medium cost of implementation and highly variable implementation time (from short to long).

Slovenia reported single best management practice that focuses on Restriction of fertilisers and manure use in DWPZs. Furthermore, the measure sets out several other prohibitions related to fertilization, slurry and ploughing. The measure has high water protection functionality, medium cost, short duration of implementation and long-time interval of sustainability.

Hungarian measures are focused on regulations related to DWPZ, prohibiting fertilizers, manure and pesticides. Furthermore, measures deal with grazing and proper management practices related to it. These measures are low in cost, but have high water protection functionality.

“UK: Limestone pavements” - a restoration success story

The Lowland Limestone pavements and other limestone habitats around the Morecambe Bay area in northern England are botanically the richest of their type in the country. Its rich ecosystem has come under increasing threat as a result of its exploitative past, including much removal of limestone pavement for domestic garden decoration. This has been reduced by recent legal protection and awareness, but heavy commercial afforestation with non-native species has resulted in equally serious deterioration of habitats, through needle-fall and gradual closing of the tree canopy. Funding from LIFE project was able to achieve major restoration and establish a sustainable management pattern.

Work began with felling of conifers in some of the most badly affected areas. Rotational coppice cycles were reintroduced within the yew and lime woodlands. Low-intensity grazing was established on grasslands, preventing the expansion of woodland and bracken and increasing the number of flower species. Scrub and bracken clearance programmes were carried out and deer controlled by fencing and culling to prevent destruction of tree re-growth. Water levels in the marl lake were restored to return marginal habitats to near-natural conditions.

The most dramatic result was the transformation achieved by early clearing of 100 ha of pine at Whitbarrow. In less than four years, the reclaimed limestone grasslands were being grazed by cattle. Project funds were used to purchase 204 ha of that area, benefiting the grazing and allowing public access to the spectacular area created – some of which had been under conifer cover for 30 years.

In all, 266 ha of non-native plantations were removed using techniques developed to preserve the habitat, including the disposal of woodchips; 300 ha of land was brought into sympathetic management through the land-purchase and through agreements with private landowners over deer management. Coppicing was carried out in eight areas, which became high-profile demonstration models. Grazing was achieved on over 330 ha in addition to the Whitbarrow area, resulting in maintenance of species-rich grasslands.

Coppicing and scrub clearance produced an immediate response from ground flora, including violets and primroses. This resulted in greater numbers of butterflies, among them High Brown Fritillaries, which in one area increased by 400%. Habitats of the endangered whorl snail were restored through deer control and resulting numbers of the snail were estimated in the tens of thousands.

The work attracted considerable public attention, particularly where landscape change was dramatic. This resulted in many visits, increased awareness and support and encouraged one local parish council to purchase further land for conservation.

Figure 4. Limestone pavement in Morecambe Bay Nature Park (EC, 2008)

4. Wetlands

4.1. Wetlands in general

Wetlands are one of the planet's most productive ecosystems. Incredibly biodiverse, they sustain some of Europe's most important bird, amphibian, invertebrate and plant species during key stages in their life-cycle. They provide spawning grounds for fish and feeding and breeding areas for many migratory birds. Representing around 6% of the Earth's land area – some 570 million hectares, of which 2% are lakes, 30% bogs, 26% fens, 20% swamps, and 15% floodplains – they also provide important goods and services to society.

Wetlands occupy around 4.8% of European territory. There are many different types of wetland in Europe and their classification is not easy, due to their complexity, dynamic characteristics and their fluctuating and undefined borders. The wetland habitats listed in the Annex I of the Habitats Directive (92/43/EC) and included in the Interpretation Manual of European Union Habitats – EU-27 (July 2007), are largely identified by their plant composition and in some cases by a range of ecological characteristics. Altogether, the directive lists some 40 wetland habitat types. However, for the sake of simplicity, wetlands can be more broadly categorised into seven general types:

- Marine and coastal wetlands,
- estuaries and deltas,
- rivers and floodplains,
- lakes,
- freshwater marshes,
- peatlands,
- artificial wetlands, such as canals and reservoirs.

Wetlands are amongst the most threatened ecosystems as a result of drainage, land reclamation, land conversion, pollution and overexploitation. According to the Wetlands International, an NGO dedicated to wetlands' preservation, some 50% of the world's wetlands have disappeared in the last century.

All project partners' states have signed The Ramsar Convention, an international treaty for the conservation and sustainable use of wetlands. It is also known as the Convention on Wetlands. It is named after the city of Ramsar in Iran, where the Convention was signed in 1971.

Source: LIFE and Europe's wetlands - Restoring a vital ecosystem (EC, 2007)

4.2. Best management practices – Wetlands – Plain sites (PW)

Some of the best management practices are applicable in both plain and mountain sites. Unless indicated within the measure description, the applicability is shown in overview table at the end of the chapter.

- **BP PW1 Preservation and revitalization of wetlands on floodplains**

Description of the measure

Floodplains are areas immediately adjacent to the stream and are periodically inundated with water. They present a vital part of the river ecosystem. The main function of these areas is carrying excess water in time of flood events and consequently reducing the flood water's potential energy. Besides, the functions of these areas are improving water quality, reducing runoff and erosion, providing an environment for a diversity of plant and animal life and helping to sustain base flow of adjacent streams and rivers during drought conditions. Floodplains are also important regulators of the movement of energy and materials through the catchment area towards the river and water flowing from surrounding hills and across the floodplain.

Wetlands are often located within floodplains and provide important functions within the context of water quality and quantity. They work as natural water treatment areas, removing pollutants from inland river waters, maintain sufficient quantity of water during the whole year and represent one of the most productive and biologically diverse ecosystems, providing the essential breeding and feeding habitats for many species of water birds, fish, invertebrates and plants.

The preservation or revitalization of those wetlands encompasses all measures necessary for this purpose.

Measure advantages

The preservation of wetlands in floodplains is of crucial importance for both the protection of drinking water resources and for the protection against floods. Only if the wetland areas are in natural or close-to-nature conditions, their ecosystem services can be rated as functional for water protection.

Challenges

Wetlands as one of the most complex ecosystems of paramount importance due to their biodiversity and role in water regime, are also most threatened ones. Around 50% of world's wetlands have disappeared in the last century. In Europe they are among most endangered landscapes due to land reclamation, drainage, pollution and overexploitation of its resources. According to the European Commission, it is estimated that two thirds of Europe's wetlands have disappeared since the beginning of the 20th Century, mainly lost through development processes which did not take their functions and values adequately into account. Overall, drainage and conversion to farm land alone have reduced the wetland area in Europe by some 60%.

Despite recognized significance and considerable interest in their global protection, comprehensive overview of the remaining wetlands without appropriate protective status is still

lacking. Numerous wetlands proclaimed as Ramsar sites are surrounded with agricultural land, making them vulnerable to farming practices. Throughout Europe roads and railway generate proximity problems and hence pressure on these habitats.

Furthermore, wetlands hydrological function and regime can be degraded by activities such as improper forestation, water regulation (changing of river flow and channelization), over-exploitation of groundwater resources etc. Therefore, spatial planning along with river basin management planning must consider objectives for conservation of these types of habitats.

For example in Austria, floodplain wetlands were under threat during the last half of the 20th century, when various hydro-electric power plants were constructed at the main rivers like Danube or Mur. In 1984 protests allowed the creation of the "Donau-Auen National Park" (Danube Floodplain National Park), that now protects the hugest floodplain area and forest in Europe and also the wetlands within. From this huge floodplain area, the City of Vienna also derives drinking water for the supply in critical situations (drought periods or other challenging situations). The share of floodplain wetlands is actually very low in comparison to the times prior to human settlements (pre-Neolithic phase). At those times the wetlands in the floodplains were a hindrance for human settlements (marshes and malaria) now the last floodplain wetlands have to be protected for the purposes of water protection.

- **BP PW2 Establishment of constructed wetlands for water treatment**

Description of the measure

The constructed wetlands operate by the principle of imitation of natural processes of self-cleaning or purification. Effectively constructed wetland consists of the properly selected plants and soil substrates as well as suitable water flow.

Nutrients are deposited into wetlands from stormwater runoff, from areas where fertilizers or manure have been applied and from leaking septic systems. The nutrient excess is often absorbed by wetland soil and taken up by plants and microorganisms, reducing their concentrations in the discharge water before entering the streams. Several investigations and actions around the world proved artificial wetlands as a very successful solution for the reduction of nutrient amount in the environment.

Measure advantages

The constructed wetlands can retain nutrients and suspended particles from water stemming from arable land (agriculture, livestock). For an example, in local depressions inside arable land artificial wetlands can retain the excess water, thus preventing surface runoff through channels or streams. Another potential use is the reduction of the stormwater runoff. Also, the constructed wetlands can act as a filtering field for wastewater before it enters the environment, giving the opportunity for its treatment and reuse (watering, fire-fighting, etc.). They enable a purification of municipal (deriving from individual houses, settlements, tourist resorts etc.) or industrial wastewater (process waters and leachate, factories waste, mine drainage and refinery process waters etc.), instead of their direct discharge by canal systems to streams.

Challenges

Artificial wetlands can be used in several exceptional cases. Establishing them within the DWPZ may be useful when no other adequate measure for water purification can be selected.

- **BP PW3 Natural management of wetlands**

Description of the measure

Areas of protected natural value (e.g. Natura 2000 or wetland areas), can be used as green infrastructure and natural retention against floods.

The aim of this best practice is to benefit a range of existing, restored or newly created wetland - floodplain habitats by maintaining appropriate grazing regimes. Wetlands support a wide range of plant types. Limiting or not practicing grazing activities during the summer and then grazing in the autumn will ensure that flowering species can set seed and germinate. Mowing should be conducted after mid of August and before end of September.

Furthermore, this best practice can be used in order to reduce flood risk downstream.

Measure advantages

Through adequate management concepts for wetland areas respectively Natura 2000 areas, the biodiversity of habitats, fauna and flora will be improved. Consequently also the function of the ecosystems, which provide us with important resources as oxygen, drinking water and food, playing an important role within the regulation of climate and protection against natural hazards, will be maintained.

Wetlands support a variety of plants, insects, amphibians, reptiles, mammals and birds. They also help slow water flow and act as natural water storage zones helping to reduce the impacts of downstream flooding.

Challenges

Wet meadows are species-rich ecosystems. They provide habitats for many rare and endangered species. With ongoing structural changes in agriculture, a great number of wet meadows are abandoned because their management requires a lot of manual work. Therefore, today's challenge is to find sustainable management practices that are not very time-consuming and have a low environmental impact.

In some Austrian areas (e.g. Enns valley, Danube area and Mur) manifold projects were implemented:

- **"Protection of wetlands in the Enns valley"** (1995-1998) - main goals were the protection of wetland areas and protection and conservation of biodiversity incl. natural retention areas;
- **LIFE-Project "Gesäuse"** (Enns valley): Management plan for invasive species;
- **The LIFE project „River landscape Enns"** (2011-2015): Conservation strategies for forests and torrents in the region "Gesäuse" incl. management of invasive plant species were developed and renaturation measures of the river Enns were. The

implementation of measures was an important step towards habitat improvement and the so called ´passive flood protection´ in specific stretches of the river Enns.

- In the framework of "**BE-Natur**"(INTERREG SEE, 2011-2015) - „Better management and implementation of NATURA 2000 sites" action plans for calcareous marshes, fens and wetlands were developed within the Styrian Enns valley and the "Ausseerland". The focus was laid on the development and bundling of procedures for sustainable agricultural use of protected areas and the awareness raising of their socio-economic value.
- The use of horses with modern equipment for mowing was established for wetland management in Natura 2000 sites in "Salzkammergut", Styria. The use of workhorses supports small-scale grassland farming and creates awareness for ecological sustainable landscape management practices. Mowing with horses has a low impact on wet soils and maintains the high biodiversity of wet meadows preventing forest and scrub encroachment. The ecological benefits are minimal noise, no emissions, no fossil fuels involved, and insects and birds can easily escape. Apart from mowing, horses could be used in versatile ways such as thinning of forests, clearing of bushes or dwarf shrubs, cultivation of potatoes and transport services. Working with horses also has positive effects on children, teenagers and people with mental problems.

LIFE Project "Towards wise use in Lonjsko Polje Nature Park" (2001-2004) - Croatia

Set in the floodplains of the Middle Sava River Basin in Posavina, the Lonjsko Polje Park covers over 50,000 hectares of wetlands and represents the largest floodplain area of the Danube River catchment. It is both a Ramsar site and an Important Bird Area and hosts seven habitats and 89 species listed in the Habitats Directive. In 1998, the Croatian government established the Lonjsko Polje nature park public service (the project beneficiary) to protect, maintain and promote the park.

Specifically, the project focused on: (1) protecting it's biological and landscape diversity; (2) improving its benefits for the local people; (3) raising public awareness; and (4) insuring effective and environmentally-sound water management for the whole Sava River Basin.

The project ran for three years and on completion had successfully met its objectives. Over the project duration, the number of permanent staff employed at the park was increased from six to nine, and the park authority's capacity was reinforced through training and the upgrading of equipment. In addition, the project established a network of visitor and information centres. A number of dissemination and awareness-raising actions were also carried out, including seminars and study tours on basic ecology, communication, interpretation (guiding) and monitoring. The experience and the results were published in a ranger's handbook, which was presented at regional and national level and, according to the beneficiary, has generated a high level of interest. In addition, the beneficiary hosted a GIS (Geographic Information Systems) training course which also proved popular among participants. The beneficiary also delivered a number of lectures targeted at local schools, farmers, students, and experts. These helped to gain support for the park and to generate greater awareness of ways of meeting recreational needs whilst also addressing conservation concerns. The project also gathered feedback from visitors on the measures implemented by the project. In general, this feedback was "very positive".

Despite some difficulties, the project managed to involve stakeholder participation at both planning and implementation stages – although the beneficiary reports that this objective was the most difficult to achieve. Nevertheless, a stakeholder committee was set up and co-operation was established with various organisations including the Croatian water and forest authorities, the police, building services, livestock breeders, and nature conservation and environmental protection organisations.

- **BP PW4 Technical measures, defence measures**

Description of the measure

Measures for reducing the risks of climate change to the wetlands are traditionally based on supply-side options (Rilasciati & Clini 2002). For instance, the implementation of coastal defence measures, including artificial reefs (shore parallel rock mound structures), near shore breakwaters, artificial channelling and drainage, and feeding (generally in high-profit touristic areas) (OrientGate 2014). For the delta parts, this measure is implemented by the construction of new dams, reservoirs and pipelines. These engineering designs are based on knowledge of wide range of scientists such as hydrologists, civil engineers, water planners, and water managers. Practically, each engineering work is designed to protect human and ecosystem, within its lifetime, from extreme events based on the recorded historical data (e.g. climate and hydrological data).

Measure advantages

- These interventions increase the steadiness of shores and touristic attractiveness;
- these kinds of constructions usually affect immediately in term of mitigation in the short time horizon;
- high protection degree in selected location and designed site.

Challenges

- These measures contribute to reduce their resilience to coastal erosion and increase marine/coastal habitat vulnerability as well as environmental degradation;
- climate changes are likely to produce – in some places and at some times – hydrologic conditions and extremes of a different nature than current systems were designed to manage;
- climate changes may produce similar kinds of variability but outside of the range for which current infrastructure was designed and built;
- this approach assumes that no special efforts or plans are required for the protection against surprises or uncertainties;
- in case climate change impacts turn out to be different from what was expected, the investments in these measures could be wasted (Rilasciati & Clini 2002);
- highly require investment and civil work;

- require operating rules, contingency plans, and water allocation policies under a wider range of climate conditions.

- **BP PW6 Enlarging wetland areas**

Description of the measure

This measure can be implemented by creating artificial lakes, lagoons and retention areas or enlarge current wetland areas in order to storage runoff, regulate water resources for flood control, irrigation and hydropower, and maintain the quality of water (OrientGate 2014). Sometimes, the designed and operated human-made wetlands may provide a range of services well beyond the primary aim of their construction. For instance, provision of habitat and wildlife diversity, support of recreational activities such as walking, bird- and wildlife watching, water storage during periods of shortage and excess, and aesthetic value in urban environments (Bergh et al. 2009). The researchers recommended a four-step process. Firstly, there should be a clarification of the local requirements and limitations of the wetland and secondly, a definition of the spatial scale of the project. Thirdly, if more than one objective is pursued then conflicts and compatibilities should be identified and investigated before finally defining a strategy (ENV 2012).

Measure advantages

- Storage and regulate water resources, e.g. enhancement of groundwater recharge, flood control during flood season, ensure water regime during dry season;
- water quality improvements: reduction of nutrient load, sediment and purify water;
- high potential for landscape and waterscape;
- provide recreational areas for local residents.

Challenges

- This measure possibly changes the natural hydrological condition such as flow rate, velocity and component of flow. Therefore, applying this technical measure requires a careful consideration and provision as well as accurate regulation plan;
- highly required investment and civil work.

- **BP PW7 Behavioural strategies**

Description of the measure

This measure encompasses actions that promote awareness for the altered conditions under climate change and adaptation. For instance, changing location of recreational facilities, infrastructure and related things far from vulnerable and dangerous areas such as costal line and flooded areas (OrientGate 2014). Climate change awareness raising, plays an important component of adaptation process that manages the impacts of climate change, enhance adaptive capacity, and reduce overall vulnerability. Awareness raising addresses the knowledge of individuals and organisations. It aims to ensure that all relevant regional and sub-regional

bodies understand the impacts of, and take actions to respond to certain climate impacts. Awareness raising can be delivered through various form of media, for instance through television, internet, and newspapers.

Measure advantages

- This strategy has measure advantages in the reduction of receptors (exposure elements) exposing to hazards, thus leading to reduction of economically substantial losses;
- require low investment cost in which places have not been invested;
- strengthen awareness raising among communities;
- have long-term effects on mitigating the impacts of climate change.

Challenges

- The implementation of this measure requires huge investment for moving the existence infrastructure;
- strongly require political decisions;
- it does not work in some particular places such as heritage sites, reserved sites, traditional infrastructure and habitats;
- required long-term campaign for implementation, monitoring and assessment.

- **BP PW8 Political decisions**

Description of the measure

Guidelines for the protection of wetlands have been defined based on the integration of both Ramsar and CBD Convention with the Bird and Habitat Directives, Water Framework Directive and the Marine Strategy Framework Directive. Other possible option can be the land-use planning (e.g. Regional Coastal Plan of Puglia, 2011).

Measure advantages

- This guideline has been considered as one of the case studies of the working group set up by the European Commission dealing with the integration of European Directives;
- no need to involve large investments of public resources.

Challenges

- Sometimes, the practical application of this legislation is an issue, due to the difficulties in interpretation, contradictions, financial and/or technical gaps and insufficient control;
- monitoring exists, but there are some gaps about measured components, spatial density of the monitoring points and the frequency of measurements.

- **BP PW9 Capacity building**

Description of the measure

For example in Italy many activities of education, communication and informing on environmental issues and on climate change for citizens and schools are carried out in coordination by different structures: the Provincial Agency for Environmental Protection, the network of environmental educators for sustainable development, the Science Museum of Trento, the Adamello Brenta Natural Park. Other activities undertook in such sense are the organization of periodic events with public lectures, scientific conferences, workshops and theatre performances, that discuss the issues of climate change and their implications (e.g. "Trentino Clima 2008" (Trento 20-24 February 2008); "Climatica…mente cambiando – Trentino Clima 2011" (Trento, 5-10 September 2011)).

Measure advantages

- This measure captures wide range of participants from administration to civils, thus, has influence on a huge range of subjects;
- no need for large investments of public resources.

Challenges

- Participants, both at the waterworks and administration, are required a sufficient professional experience and knowledge to comply with new challenges in term of new practices and new technologies;
- the short-term economic gains of this strategy are relatively low and they could be easily dissipated by the impact of future climate events.

- **BP PW10 Recreation plans**

Description of the measure

The recreation plan consists of two parts: (i) reshaping the site's morphology, and (ii) providing infrastructure for recreational purposes. The first part consists of placing the vegetation in a way that improves water quality by trapping nutrients and increase the attractiveness of the site, as well as provides habitat for wildlife. Also, in those sites in which water quality has degraded because water circulation is compromised, reshaping must include moderate excavation to restore earlier hydraulic conditions in this respect (Bodini et al. 2000).

Measure advantages

- The creation of a natural reserve does not cost much as no intervention is planned to restore environmental quality in those sites. This is justified by the fact that only wetlands that are not severely degraded will occupy the best positions in the multi-criteria scheme, and good environmental conditions will be restored simply by prohibiting human access. Thus, the only financial requirement for natural reserves is for surveillance;
- water quality improvement;

- creation of land for local habitats.

Challenges

- Since different wetland areas have different characteristics, the implementation of this measure requires a careful analysis (e.g. economic analysis, multi-criteria analysis, and stability analysis) with wide range of participants and stakeholders;
- modify morphological conditions and hydrological conditions.

- **BP PW11 Wetland restoration**

Description of the measure

Wetlands perform multiple essential functions including flood and erosion management, climate and water regulation. Wetlands induce wave and tidal energy dissipation and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland vegetation also help to stabilise soil and sediments, thus reducing erosion. Wetland restoration means re-establishes these advantageous functions for the benefits of floods, erosion and water protection. Restoration of existing wetland ecosystems and their services is required as they have been increasingly degraded by both natural and human activities. Different kinds of techniques can be used to reintroduce wetlands in areas where they previously existed depending on the habitat type and the level of degradation. In terms of flood and water quality protection, the main benefit of wetland restoration is related with their function to act as "buffer zone", improving flooding and erosion protection by reducing incoming wave and tidal energy. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel (Nicholls et al., 2007b). In contrast to hard defences, wetlands are capable of undergoing "autonomous" adaptation to increase sea levels, through increased accumulation of sediments to allow the elevation of the wetland to keep pace with changes in sea level (Nicholls & Klein, 2005). In this way, coastal wetlands also provide a natural barrier to salt water intrusion into coastal aquifers, which can be maintained without additional investments. Restored wetlands also provide a number of additional ecosystem services including water quality and climate regulation, representing valuable accumulation sites for sediment, contaminants, carbon and nutrients coming from productive activities located upstream.

Challenges of wetland restoration are minimal if compared with benefits provided.

Measure advantages

- Improve surface and groundwater quality by collecting and filtering sediment, nutrients and pesticides in runoff;
- reduce soil erosion and downstream floods by slowing overland flow and storing runoff water;
- wetland plants and ponded conditions utilize trapped nutrients, restore soil organic matter and promote carbon sequestration;
- provide food, shelter and habitat for many species and enable the recovery of rare or threatened plant communities;

- may significantly reduce sea water intrusion into coastal aquifers;
- improve groundwater supply recharge by slowly releasing water into the ground;
- provide recreational and aesthetical functions.

Challenges

- Require large surface to be implemented which is likely to create conflicts with alternative land uses (i.e. agriculture, forestry);
- require a degree of expertise, especially in locations where wetland re-colonisation has to be encouraged by transplanting wetland plants.

Best management practices concerning wetlands are systematically shown in the Table 4, where relevance of each BMP can be seen (water protection functionality, cost of the measures, duration of implementation and time interval of sustainability). Wetland BMPs are valid only for plain sites.

Table 4. Best management practice relevance – Wetlands

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
PLAIN SITES				
Preservation and revitalization of wetlands on floodplains	High	Medium	Long Term	Long Term
Creation and maintenance of riparian wetlands	High	Medium	Long Term	Long Term
Establishment of constructed wetlands for water treatment	High	Medium	Short Term	Long Term
Natural management of wetlands	High	Medium	Long Term	Long Term
Technical measures, defence measures	High	High	Medium	Medium
Enlarging wetland areas	Medium	Medium	Medium	Long Term
Behavioural strategies	Low	Low	Long Term	Long Term
Political decisions	Medium	Low	Long Term	Long Term
Capacity building	Medium	Low	Medium	Long Term
Recreation plans	Medium	Medium	Medium	Long Term
Wetland restoration	Medium	Low	Long Term	Long Term

4.3. Review of best management practices – Wetlands

Best management practices concerning wetlands have not been reported by Croatia and Germany (Bavaria). Namely, measures concerning wetlands are most likely contained within sectoral policies, laws or strategies. Furthermore, both Croatia and Germany participated in several LIFE or LIFE+ projects, focusing on wetland restoration and protection (e.g. LIFE and Europe's wetlands: Restoring a vital ecosystem).

Austrian best management practices are based on numerous studies and projects. Measures are well developed, cover variety of issues concerning wetlands and have a strong theoretical background. Furthermore, all provided measures are accompanied by strong administrative leverage. According to Austrian report, further advantage is efficient and timely implementation of actions from various studies, projects, etc. Provided measures have high water protection functionality, medium costs, generally long duration of implementation and long-time interval of sustainability.

Italian best management practices are mostly derived from Orientgate project (2014). Numerous measures provide opposing approach to problems (structural measures vs. administrative/non-structural measures): technical measures, enlarging of wetland area, awareness raising, capacity building, recreation plans, wetland restoration and establishment of artificial wetland for water treatment. Provided measures have generally moderate water protection functionality, highly variable costs and duration of implementation and generally long time interval of sustainability.

Poland has reported three best management practices which are derived from the CC-WARE project. Those measures mostly focus on wetland restoration, preservation, revitalization and construction of artificial wetland for water treatment. Theoretical background and performed studies were not provided, as well as measure advantages and descriptions. Provided measures have high functionality of water protection, medium to high costs and long duration of implementation.

Slovenia has reported two best practices regarding wetlands – one focuses on preservation and revitalisation of riparian wetlands, while other focuses on establishment of constructed wetlands for water purification. Provided measures have high water protection functionality, moderate costs, medium duration of implementation and long-time interval of sustainability.

Hungarian measures focus on the protection and natural management of wetlands. Hungary is well positioned in implementation of obligations and management plans related to numerous Ramsar sites.

Eden Again Project – restoration of Mesopotamian Marshes

At the start of the twenty-first century, the once-lush, richly diverse wetlands of Mesopotamia had been decimated. In the decades leading up to the new century, hydro engineering (dams for flood control and hydroelectricity, canals and reservoirs for agricultural irrigation) had greatly reduced the volume of the annual marsh-renewing floods. Then, in the 1990s, the marshes became a political pawn: former Iraqi leader Saddam Hussein drained large areas at least in part to punish the tribes living there, the Marsh Arabs, for participating in the anti-government rebellions.

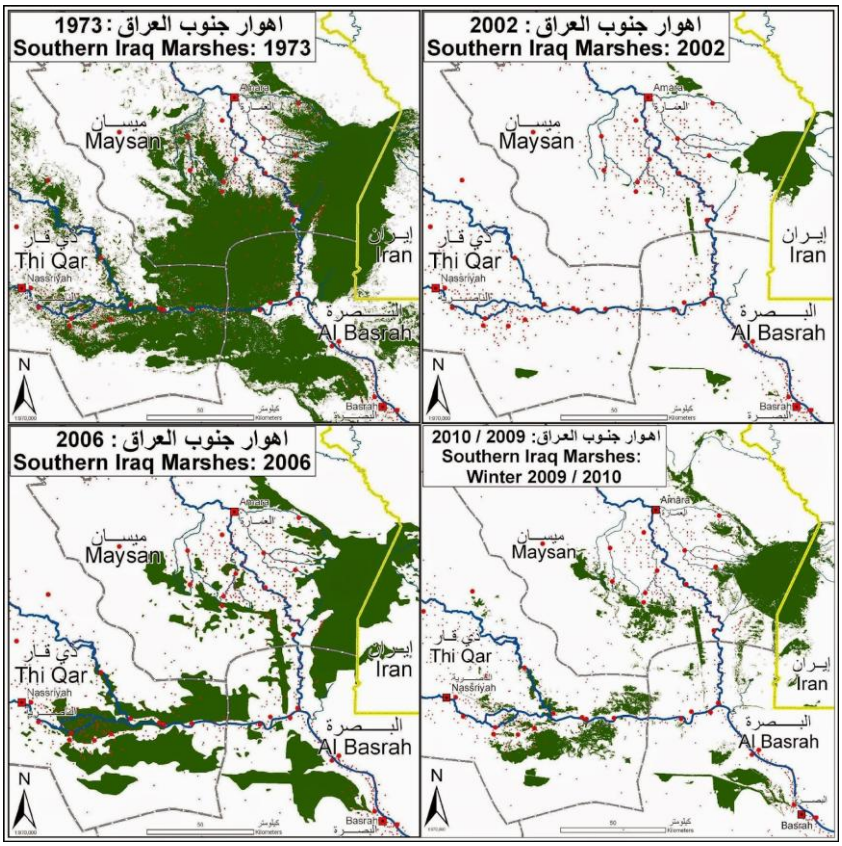


Figure 5. Iraqi marshes through the years

Following the Second Gulf War and the end of Saddam Hussein's regime in 2003, Iraqis began demolishing the dikes and canals that had drained the marshes. By February 9, 2004, a dramatic transformation was underway in Mesopotamia. Several large marsh areas north and south of the Euphrates had been re-flooded, and the dry land south of Al Hawizeh Marsh was being systematically filled. These areas appear almost purely dark blue or nearly black, which indicates that standing water was present, but that vegetation was absent or extremely sparse. By 2005, additional areas were flooded, especially north of the Euphrates. In some places, the water appeared more greenish than it did in 2004; this could be because plants or algae were growing or because the water was shallower than it was the previous year.

In 2007 and 2008, the marshes stood out starkly from the surrounding bare ground.

As the decade drew to a close, the recovering marshes faced new threats, including new dam construction upstream and drought. The amount of flooding visible in the 2009 image was

considerably less than in 2008; not only the marshes, but also the adjacent irrigated crop areas appeared far less lush than they did the previous year. The 2009 drought had a severe impact on winter and spring crops in Iraq. The image from 2010 seems to tell a different story, however. While the marshes appeared to have shrunk still further, the irrigated agricultural areas in the centre of the image appeared more extensive and greener than they were the previous year.

A United Nations Environment Program assessment of the Iraq marsh restoration in 2006 concluded that roughly 58% of the marsh area present in the mid-1970s had been restored in the sense that standing water was seasonally present and vegetation was reasonably dense. Two years of field research by Iraqi and American scientists concluded that there had been a "remarkable rate of reestablishment of native macroinvertebrates, macrophytes, fish, and birds in re-flooded marshes". However, the lack of connectivity among the various re-flooded marshes remained a concern for species diversity and local extinction. In addition, the volume of water that flowed into the marshes in the first years of restoration may not be able to be sustained as the country stabilizes and economic and agricultural activity resume. As a result, the ultimate fate of Mesopotamian marshes is still uncertain.

Figure 6. Iraqi marshes recovery and native marsh Arabs (NASA, 2010)

5. Agriculture

5.1. Agriculture in general

Agriculture has a big influence on Europe's landscapes and the quality of its environment. With farmers managing almost half of the EU's land area, the agricultural sector is a major source of pressure on Europe's environment. Over the past five decades, the EU Common Agricultural Policy (CAP) - accounting for around half of the EU budget — has encouraged the sector to become rapidly modernised and agricultural production itself to increase intensification.

As a result, the agricultural sector is responsible for a large share of the pollution of surface waters and seas by nutrients, for the loss of biodiversity, and for pesticide residues in groundwater. Reforms of the CAP in the 1990s, and measures taken by the sector itself, have brought about some improvements, but more is needed to balance agricultural production, rural development, and the environment. Farmers represent only 4.7% of the European Union's (EU's) working population, yet manage nearly half of the EU's land area.

The loss of traditional farming practice to intensive agriculture throughout the EU has led to: soil erosion, water pollution, over-exploitation of water resources the loss of biodiversity (semi-natural habitats, wild species) pesticide-born damage and risks for human health.

Agriculture is changing to provide many services that society demands, it generates important impacts on the environment, which, dependently on agricultural practices applied, might be very negative or very useful:

- Soil erosion by water and wind, which affects close to 15% of EU land, with specific problems concentrated in the Mediterranean and Eastern European region.
- Greenhouse gas emissions from agriculture have declined across Europe since 1990, particularly in the new EU Member States: EU-27 GHG emissions from agriculture decreased by 120 Mt CO_2-equivalent (20%) between 1990 and 2008.
- Climate change is a crucial factor influencing recently observed processes such as i.a. changes in phenology, length of growing season and northwards shift of crops species (IPCC, 2007a). Therefore, the whole Europe needs to tackle shifting and future implementation of more effective cropping systems (caused by both: seasonality and structures' changes).
- The agricultural sector is the most important contributor of land to artificial development's needs. The land-use change from agriculture to artificial surfaces (defined as urban residential sprawl and sprawl of economic sites and infrastructure) is the main reason of the UAA decrease. According to some scenarios, in the period from 2000 to 2020, arable land will decrease by 5%, grassland by 1%, and permanent crops by 1%; forest will increase in land cover by 1%, and other natural vegetation by 2%, recently abandoned land by 3% and urban land by 1%. In addition, CLC results show that the area of land-use change from agriculture to artificial surfaces is underestimated.
- The irrigable area in Mediterranean member countries has increased by about 20% between 1990 and 2005 whereas it declined in northern and Eastern European

countries. In southern and Eastern Europe irrigation is a key factor for agricultural productivity but causes significant environmental pressure on aquatic ecosystems and groundwater resources. In 2007, EU-27 irrigable area accounted for 8.8% European Utilized Agricultural Area (UAA); c.a. 6% of EU-27 UAA was irrigated.

- Pollution from agriculture is a major pressure on the quality of ground and surface waters in the EU, in particular in north-western countries. Diffuse pollution from agriculture provides about 30-40% of the nitrogen load and 50-60% for the phosphorus load in the Danube River.
- Agricultural nitrogen surpluses (the difference between all nutrient inputs and outputs on agricultural land) show a declining trend, thereby potentially reducing environmental pressures on soil, water and air. All European countries exhibit a nitrogen surplus. Overall however, these surpluses have declined since the mid-1980s, reducing the environmental pressures on soil, water and air. The adoption of nutrient management plans and environmental farm plans has had a key role in this reduction
- Europe's biodiversity is inextricably linked to agricultural practices creating valuable agro-ecosystems across whole of Europe. A large number of highly valuated wildlife species and semi-natural habitats types in Europe are dependent on continuing low-intensity agricultural practices.
- Negative trends on agricultural practices are consistent with reports from EU Member States on the conservation status of species and habitats types targeted by the Habitats Directive. Habitat types linked to agro-ecosystems generally have a relatively poor conservation status, with only 7% of assessment being favourable, compared to 17% for habitat types not related to agro-ecosystems.
- Organic farming is a farming system that has been explicitly developed to be environmentally sustainable, and is governed by clear, verifiable rules. It relies on a number of objectives and principles, as well as common practices designed to minimise the human impact on the environment, while ensuring the agricultural system operates as naturally as possible. Thus organic farming appears suitable for identifying environment-friendly farming practices. The total organic area in the EU (i.e. the area fully converted to organic production and area under conversion) was 11.1 million hectares (ha) in 2015 and it still expected to grow in the coming years. The increase in area between 2010 and 2015 was 21%. Not only has the total area under organic farming and the number of organic producers increased, but there is potential for further growth, as shown by the proportion of the area already fully converted to organic farming and the area still under conversion. The number of organic producers increased by 23.5% between 2010 and 2015. EU agro-environment programmes and consumer demand are key factors for the above mentioned inclination as well as for this recent strong increase in trends.

Source: European Environmental Agency (2016)

5.2. Best management practices – Agriculture – Mountain sites (MA)

Some of the best management practices are applicable in both plain and mountain sites. Unless indicated within the measure description, the applicability is shown in overview table at the end of the chapter.

- **BP M(P)A1 Maintaining the share of grassland**

Description of the measure

The total share of grassland within a farm/district/region remains unchanged. Whenever grassland is converted into arable land, arable land has to get converted into grassland elsewhere.

Measure advantages

Grassland is a highly effective for the stabilization of soil surface and decrease of soil erosion. Stabilisation of soil also helps to improve the hydraulic properties of soil thus increasing infiltration capacity and decreasing surface runoff. BP A1 is easy to control.

Challenges

Willingness to accept this measure is good because it is compliant with current practice and does not interfere with agricultural management decisions in single farms. There is also a certain choice to select grassland areas.

- **BP M(P)A2 No conversion of grassland into arable land**

Description of the measure

Existing grassland may not be converted into arable land. This measure is a step further to BP M(P)A1. Again the total share of grassland within a farm/district/region remains unchanged but there is no choice on the location of future grassland areas.

Measure advantages

Maintaining grassland stabilizes soil surface and decrease soil erosion. Stabilisation of soil also helps to improve the hydraulic properties of soil thus increasing infiltration capacity and decreasing surface runoff. BP M(P)A2 is easy to control.

Challenges

The acceptance of this measure is lower compared to BP M(P)A1, because no choice to select future grassland areas exists.

- **BP M(P)A3 Retention ponds**

Description of the measure

Retention ponds are artificial structures that are built at crucial sites of concentrated runoff within catchments. They are designed to retain some portion of the superficially flowing water. There are different strategies for the construction of retention ponds. They differ in construction details, but also in placement strategies within catchments. Placement strategies within catchments mainly may be divided into “end of pipe” strategies with a placement at some outlet point of a catchment and a “distributed” placement strategy using sub-catchment outlets to place retention ponds. Depending on the choice of a particular placement strategy, the design of retention ponds will considerably be different. Typically “end of pipe” strategies need much larger volumes and higher costs. For both placement strategies, detailed knowledge about surface runoff pathways within catchments is a necessary prerequisite.

Measure advantages

If properly designed retention ponds can effectively retain some amount of surface runoff during rainfall events. Thus they can be used to smooth peak flow rates. If it is possible to identify suitable sites for instalment within catchments it would be possible to avoid the “end of pipe” strategy. Retention ponds distributed over sub-catchments also offer the possibility to minimize implementation costs. However this largely depends on agricultural volunteers who would offer land to implement such structures. This usually needs either existing awareness of the contribution of agricultural land to flood generation or measures to generate such awareness.

Challenges

Retention ponds are among the most expensive measures for the retention of water in catchments. When collecting surface water during rainfall events they may also collect large quantities of sediment, nutrients and undesired elements (heavy metals, pesticides….). This may increase maintenance costs. It is therefore highly important to combine the use of retention ponds with adequate measures to retain sediment already on agricultural land.

- **BP M(P)A4 Linear retention features**

Description of the measure

Linear retention features are living or dead hedges that are placed temporarily or semi permanently across concentrated surface runoff flow paths. As already indicated with other best management practices the practical implementation of this measure may vary considerably. Main differences concern the use of either dead or living obstructions and the widths and implementation techniques.

Measure advantages

Linear retention features obstruct the free flow of surface runoff. They reduce flow velocity and create temporary retention. To a certain extent this leads to increased infiltration and sediment deposition. Similarly to retention ponds they may act as buffer element to smooth runoff peaks for surface runoff. Because linear features are typically placed within smaller sub-catchment areas, they also do provide some possibility to follow a distributed placement strategy.

Challenges

Application of this measure acquires knowledge on the actual flow paths within a catchment. To be most effective, the catchments amount of delivering water to linear features should not be too large. Linear retentions features do not have a very high effectivity but they have relatively little implementation costs.

- **BP MA5 Protection of water from pollution caused by nitrates originating from agriculture**

Description of the measure

According to the Nitrates Directive, Member States must among other fulfil the establishment of action programmes which include a set of measures to prevent and reduce water pollution by nitrates and are implemented on an obligatory basis within designated nitrates vulnerable zones (NVZs) or throughout the entire territory. The programmes must be comprised of measures already included in Codes of Good Agricultural Practice, which become mandatory in NVZs and other measures, such as limitation of fertilizer application (mineral and organic), taking into account crop needs, all nitrogen inputs and soil nitrogen supply, maximum amount of livestock manure to be applied (corresponding to 170 kg nitrogen /hectare/year) etc.

For example Croatian 1st Action Programme - Protection of water from pollution caused by nitrates originating from agriculture (2013) defines that during the period of one calendar year, for fertilizing purposes farmers can use maximum 170 kg/ha of nitrogen. In case of flood events, fertilizing must be done after the floods have ended. In order to decrease the loss of nitrogen by evaporation and leeching, it is prohibited to perform the first fertilization with slurry on agricultural land in the period from 15th of November to 15th of February. Additionally, it is prohibited to perform the second fertilization with slurry in the period from 1st of May to 1st of September.

Furthermore, 1st Action Programme forbids fertilizer application on the ground covered with snow blankets; on the frozen ground; on the flooded soil; on non-agricultural land; at 20 meters distance from the outer edge of the lakebed or other standing water; at 3 meters distance from the outer edge of the river beds with width of bed of 5 meters or more; on slopes near rivers – with a slope of more than 10% within a distance of 10 meters from the outer edge of the river bed; mixed with sewage sludge.

This best practice is also applicable to the plain sites.

Measure advantages

- Protection and possible improvement of water quality.

Challenges

- Education of farmers on sustainable use of fertilizers and manure;
- limitation and control of fertilizers application;
- farmers' compliance to the Action Programmes and Nitrates Directive.

- **BP MA6 Sustainable use of pesticides**

Description of the measure

The achievement of sustainable use of pesticides in European countries, by reducing the risks and impacts of pesticide use on human health and the environment is defined by the Directive 2009/128/EC. All Member States are obliged to draw up National Action Plans to implement the range of actions set out in the Directive. These actions include raining of users, advisors and distributors of pesticides, inspection of pesticide application equipment, the prohibition of aerial spraying, limitation of pesticide use in sensitive areas, and information and awareness raising about pesticide risks.

For example, Croatian National Action Plan to achieve the sustainable use of pesticides (NAP, 2013 - Croatia), is aimed at:

- gaining better understanding of the methods of pesticide use,
- ensuring the application of scientific and other evidence to recognise pesticides and procedures requiring attention, aimed at developing and promoting measures and procedures that will reduce the detrimental impacts of the use of these chemicals, and enable the user to economically control pests, diseases and weeds;
- ensuring the recognition of the roles of all stakeholders and interest groups in reaching the common goal - to achieve the sustainable use of pesticides.

The action plan includes numerous submeasures such as pesticide residues monitoring in food, authorization of plant protection products (PPP); training of professional pesticide users, distributers and advisors; regular inspections of pesticide application equipment; a control of trade and sale of plant protection products. This best practice is also applicable to the plain sites.

Measure advantages

- Protection and possible improvement of water and soil quality;
- protection of human health.

Challenges

- Education of farmers on sustainable use of pesticides;
- farmers' compliance to the National Action Plans and Pesticides Directive;
- control of trade and monitoring of applied amount of pesticides.

- **BP MA7 Encouraging organic farming**

Description of the measure

According to the European Commission, between 2014 and 2020, over € 100 billion will be invested in the European Union's rural areas to help farming meet the challenges of soil and water quality, biodiversity and climate change. At least 30% of the rural development programmes' budget will have to be allocated to agro-environmental measures, support for

organic farming or projects associated with environmentally friendly investment or innovation measures.

The support is granted to farmers in the form of direct payments, on the condition that they respect strict rules on human and animal health and welfare, plant health and the environment. Green direct payments account for 30% of EU countries' direct payment budgets. Farmers receiving an area-based payment have to make use of various straightforward, non-contractual practices that benefit the environment and the climate. These require action each year. They include: diversifying crops; maintaining permanent grassland; dedicating 5% of arable land to "ecologically beneficial elements". Organic farmers automatically receive their greening payment for their holding, as they are considered to provide environmental benefits. Additional payments are available, for example for farming methods that go beyond basic environmental protection or for farmers working in areas with natural constraints. The amount of support they receive is not linked to the quantities they produce.

Action Plan for the future of Organic Production in the European Union presents strategy for organic production, controls and trade. EU offers funding possibilities to operators for campaigns which aim to increase consumer awareness on the main features of the organic production scheme, on specific products produced according to the EU organic production rules, the EU system of control and on the EU organic logo.

This best practice is also applicable to plain sites.

Measure advantages

- Ensure awareness of organic farming benefits;
- organic farming combines best environmental practices, supports biodiversity and natural resources conservation.

Challenges

- Compliance to strict EU definition of organic farming and food.

- **BP M(P)A8 Advisory services, farm management and farm relief services**

Description of the measure

EU Member States have the obligation to establish a Farm Advisory System (FAS) for advising farmers on land and farm management and helping them gain better understanding of EU rules for the environment, public and animal health, animal welfare and the good agricultural and environmental condition. In conditions of increasing specialization and strict environmental requirements in agriculture, food production and food processing industry and forestry, tailored and qualified individual advice on the use of new technologies, as well as approaches and techniques for mitigation and adaptation to climate change is needed to improve the sustainable management of natural resources and the economic and environmental performance of farms and forest holdings.

Indicative, non-exhaustive topics on which advices may be offered are:

- Cross-compliance obligations (Regulation (EU) No 1306/2013), the relevant criteria and minimum activities (Regulation (EU) No 1307/2013), relevant minimum requirements for fertilisers and plant protection products use, and relevant mandatory requirements established by national law;
- The sustainable use of pesticides (such as the minimum requirements for plant protection products use, general principles for integrated pest management introduced under Directive 2009/128/EC, requirements to have a licence to use the products and meet training obligations, requirements on safe storage, the checking of application machinery and rules on pesticide use close to water and other sensitive sites as established by national legislation;
- The Codes of Good Practice introduced under Directive 91/676/EEC for farms outside Nitrate Vulnerable Zones, and requirements concerning phosphorous pollution;
- Agro-Environmental practices;
- Organic farming;
- Natura 2000 areas and areas of high natural value;
- Biodiversity preservation and protection;
- Mitigation and adaptation to climate change; Kyoto protocol basic, farm management activities contributing to climate change mitigation and/or adaptation;
- Water protection in accordance with Water Framework Directive (Directive 2000/60/EC).

According to the Report of European Commission (2010), FAS helped to increase farmers' awareness of material flows and on-farm processes relating to the environment, food safety and animal health/welfare. One-to-one advice using checklists was considered particularly effective, as it is a very individualised and structured way of providing advice. In some Member States, the establishment of the FAS represented a good opportunity to rethink and improve their wider advice and knowledge information systems in the agricultural sector.

As an example for this best practice the overview of Croatia's Advisory Service is given. Since the new requirements lie before farmers and forest owners in Croatia, the role of Advisory Services is widening. It covers the fields such as the reduction in pesticide use in accordance with the National Action Plan, the protection of soil and water, animal health and welfare, the implementation of agro-environmental measures, reducing air pollution, management of Natura 2000 areas, etc. Currently, the Advisory Service is providing assistance and services to rural stakeholders with reference to IPARD measures through its well-distributed network of county offices. However, given the significant widening of the scope of support in the RDP (Rural Development Programme of the Republic of Croatia for the Period 2014-2020), including to new sectors such as the forestry sector, and the need to provide RDP beneficiaries with tailored advice on the use of new technologies, responsible management of natural resources as well as mitigation and adaptation to climate change, the provision of advisory services faces constant need to be increased. This includes tailored advice to the agricultural sector on the reduction of GHG (greenhouse gas) and ammonia emissions. Furthermore, specific training for those providing

advisory services given the new requirements and wider scope of activities listed above is necessary.

Through the RDP (networks and operational groups), cooperation in INTERREG Europe (thematic platforms) and other Cooperation programmes and thematic networks foreseen under Horizon 2020, knowledge exchange can better orientate R&D activities and improve innovation transfer which could affect not only technological and productive areas but also the organisational sphere (Rural Development Programme of the Republic of Croatia for the Period 2014-2020).

This measure is relevant for the plain sites too.

Measure advantages

According to the Report of European Commission (2010), FAS helped to increase farmers' awareness of material flows and on-farm processes relating to the environment, food safety and animal health/welfare. One-to-one advice using checklists was considered particularly effective, as it is a very individualised and structured way of providing advice. In some Member States, the establishment of the FAS represented a good opportunity to rethink and improve their wider advice and knowledge information systems in the agricultural sector.

Challenges

The FAS efficiency is limited, because the farmers can use FAS on a voluntary basis and remain responsible for action on advice they receive. In many cases farmers are not willing to accept the advice and small number of them sought the advice in the first place.

- **BP MA9 Increasing the efficient use of water in agriculture and adapting to climate change**

Description of the measure

Along with the public water supply and industry, agriculture is one of the sectors that uses enormous amounts of water. According to the European Environment Agency, about a quarter of abstracted water is used for the agriculture and this amount can be up to 80% in southern parts of Europe. Countries are facing an increased exposure to extreme weather conditions causing floods and droughts, attributed to climate change. Water scarcity is not only leading to serious economic losses but also have severe impact on the environment, agriculture and food production and consequently human welfare. Therefore substantial efforts must be taken in order to ensure resource-friendly and efficient water management.

The practice of irrigating crops is present in Europe for centuries, especially in semi-arid and arid areas where it is essential for the crop production. Irrigation efficiency can be improved by implementing various methods, e.g. pressurised pipe network instead of open channels or sprinkles and drip systems rather than furrows. Furthermore, notable factor can be subsidies given to farmers who apply more efficient practices, or financial support for the modernization or reconstruction of unmaintained systems.

An illustration of this measure was given by the Croatian project partners. Drought in Croatia occurs on average every three to five years and depending on intensity and duration can reduce

crop yields by 20-70% and cause billion damages in agricultural production. Considering Croatian natural resources, which are favourable temperate climate, good soil and rich water resources irrigation is not carried to the extent offered by the real opportunities, as indicated by the fact that in 2011 in Croatia only 1.1% of agricultural land was irrigated. National strategy adopted in 2004 (National Project of Irrigation and Management of Agricultural Land and Water in the Republic of Croatia) has set a target that by 2020 on 65.000 ha of agricultural land irrigation will be provided, giving priority to agricultural land that has a high and very high suitability for irrigation (484.026 ha). Construction of irrigation infrastructure and the introduction of sustainable irrigation techniques on farm allow improving economic performance of agricultural holdings and facilitate process of restructuring and modernization and provide an effective mechanism at farm level for climate-change adaptation and mitigation of the damage caused by drought. The modernization and reconstruction of existing farm irrigation systems lead to an increase in water efficiency. The development of irrigation infrastructure is only undertaken where it does not conflict with the Water Framework Directive (Directive 2000/60/EC) and does not cause any deterioration in water status. Furthermore, all actions include the appropriate prevention and mitigation measures to offset potential environmental impact.

This measure is also valid for plain sites.

Measure advantages

- Water resources conservation and awareness-raising;
- avoiding economic loss;
- encouraging the use of technically efficient measures.

Challenges

- Inefficient use of water for the irrigation purposes;
- in some countries irrigation infrastructure is outdated and needs to be reconstructed and modernized;
- numerous individual water captures for crop irrigation, which can lead to significant impacts on local soil (washing of soil nutrients and erosion) and water resources.

- **BP MA10 Soil erosion prevention and increasing of soil fertility and soil organic matter**

Description of the measure

Around 12.7 % or 140,373 km² of arable land in EU is estimated to suffer from moderate to high erosion (Eurostat, 2015). Increased soil erosion risk is particularly present on arable land located on sloping terrains. Not only does it lead to degradation of soil morphological structure, but also to decline in organic matter and nutrient and reduction of available water storage capacity.

A particularly negative effect of soil erosion occurs on cultivated soils without vegetation cover for a certain period during the year. The removal of topsoil means the disappearance of the organic matter essential for soil fertility. Forming ridges and gullies makes mechanisation harder and reduces the net surface suitable for usage.

Practices or sustainable agro-technical measures that could be implemented with the aim of mitigating soil erosion on agricultural land are just to name a few:

- Crop rotation which contributes not only to the conservation of soil fertility but also decreasing of erosion;
- sowing inter-row crops and proper soil management will reduce this. For perennial crops on slopes, negative erosion impact is reduced by maintaining vegetation cover between rows as well as the construction and maintenance of terraces;
- conservation tillage increases crop production an at the same time reduces soil erosion risk;
- mulching which improves soil's physical characteristics (reduction of soil erosion and compaction) and enrichment with organic matter;
- keeping vegetative cover on sloped land throughout the year (winter crops or grass sowing on areas with erosion risk). A rich root system of permanent pastures and meadows retains humus, reducing the impact of intense rainfall, thus imposing the need to maintain such surfaces. Increasing the land permanently covered with vegetation increases organic matter in the soil, which has an irreplaceable role in the formation of granular structure. This increases aeration, drainage and the water capacity of the soil making humus rich soils less exposed to erosion.

Low soil organic matter levels are a concern in some arable systems; they can give rise to soil structural problems and increased risks of soil erosion. Long-term use of synthetic and mineral fertilizers and pesticides can have negative impact on organic components, ultimately impoverishing the soil and reducing the quality of other segments. Enhancing and maintaining soil organic matter levels can be conducted by regular addition of organic materials (e.g. livestock manures, biosolids, compost, digestate) and retention of crop residues. It helps to maintain soil fertility and good structure which improves infiltration, retention and movement of water through the soil therefore reducing the risks of surface runoff and erosion. The long-term benefits of improved soil structure should be effective in reducing particulate P and associated sediment losses. Well-structured soils are more easily cultivated, resulting in more uniform crop establishment and growth and associated nutrient uptake (particularly N).

Measure advantages

- Conservation of soil morphological structure and quality.

- **BP MA11 Tillage across slope**

Description of the measure

Agricultural management will not be carried out along the slope (upward – downward) but across the slope.

Measure advantages

Tillage across the slope creates micro roughness within fields and contributes to higher infiltration of surface water because of more superficial water storage and less flow velocity of surface runoff. This measure is most effective on less inclined slopes up to a slope of say 8-10%.

Challenges

Application of this measure largely depends on field dimensions. In Austria, field sizes are usually quite small. In addition with unsuitable geometric field proportions it may make little economic sense for farmers to carry out this measure. It should also be considered as an add-on measure because it is only suitable for particular field conditions. For arable land with steep slopes it has little effectiveness.

- **BP MA12 Maintenance of water, soil and air quality in agriculture**

Description of the measure

Lack of education and awareness among farmers on the importance and benefits of sustainable management of ecosystems in agriculture has resulted in intensive agricultural practices and over-usage of fertilizers and pesticides with a consequently significant environmental impact. Inappropriate levels of fertilizers and improper manure storage are the main groundwater nitrate polluters. Together with specific education of farmers, it is necessary to encourage the use of a balanced multiannual fertilization plan corresponding to the real needs of the crop, so optimum rather than maximum amount of fertilizers is used. Inappropriate manure disposal additionally contaminates the soil, water and air so it must be stored properly thereby reducing emissions of greenhouse gases in the atmosphere. This contributes to achieving the overall objectives of the Water Framework Directive. In addition to training on the use and disposal of fertilizers, farmers must receive essential information about the responsible use of pesticides and waste disposal, in order to raise the level of knowledge about agricultural practices and methods that reduce the negative environmental impact of agriculture (organic farming, the introduction of a wide crop rotation, mulching) which ultimately reduce the impact of agriculture on climate change. Sustainable agricultural production includes reduced energy consumption; thus there is a need to modernize farms through the construction and reconstruction of facilities, purchasing machinery and the application of technology, especially in the livestock sector, which best reduces the emission of greenhouse gases and air pollutants into the atmosphere. Livestock farms can be a source of air pollutants such as dust particulates, microorganisms and gases, including ammonia and carbon dioxide, potentially harmful to the welfare of farm workers, livestock and surrounding areas, which could be addressed by innovative approaches to air cooling, air circulation and air purification. Strengthening cooperation with the scientific community to address these challenges through the take-up of innovation by farmers is also needed.

- **BP MA13 Optimized application of phytosanitary products**

Description of the measure

Several studies have demonstrated that around 50% of contamination of superficial water bodies is due to an incorrect use of phytosanitary products during transportation, storage, application and waste management (TOPPS-Life project). Besides being careful in the transport and conservation of products, especially when planning field operations, it is crucial to identify areas vulnerable to pollution (e.g. if there are inappropriately protected wells or highly permeable soils), and it is recommended to not apply products in case of soil covered by ice, snow or water, or if weather forecasts predict heavy rains. Then, sprayers should be completed with sippy devices.

Measure advantages

- Reduction of pollution risk for soil and superficial and underground water bodies.

Challenges

- More costly operations;
- not timely operations if weather and soil conditions do not recommend applications

This best practice is also applicable to plain sites.

- **BP MA14 Reducing runoff of phytosanitary products and fertilizers**

Description of the measure

The following information is fundamental to estimate the risk of phytosanitary products distributed by runoff when infiltration capacity is reduced: the distance from the water body, soil permeability, and slope. According to the results of the LIFE project TOPPS, for fields close to the water bodies, the risk is high when: permeability is low and the slope is medium-high (>2%), or when permeability is medium but under high slope (>5%).

If the field is not adjacent to water bodies, the contamination risk is high if the runoff finds the way to reach the water body.

Best practices consist in: minimum tillage; tillage along the contour lines; conducting cultivation with interrupted or alternated strips; establishing vegetated buffer strips within thalwegs; establishing hedges or forested strips; building retention or dispersion structures (thanks and constructed wetlands) or canals and vegetated ditches. For icy soils, at risk of erosion during thawing or snow melting, the hillslope length could be reduced through cultivation arranged in bands, buffer strips and hedges in the fields. Buffer strips could be established also at the borders of water courses.

An experimental study in the Chienti basin in Italy, demonstrated that buffer strips of 5 m between the agricultural areas and water course reduced pollutants by 90% over 60% of the surface (ISPRA, Manuali e Linee Guida 85/2013). In addition, low lying fields could suffer from concentrated runoff generated from upstream fields or in the filed itself.

In this case best practices could be: the interception of the runoff from the upstream through buffer strips and retention structures; the appropriate orientation and width of operations' roads; reduce soil compaction in the access area to the field; double seedling, buffer strips or retention thanks (or other structures as hedges or small wetlands) at the border of the field, along channels and thalweg; establishing buffer strips also inside the field to interrupt the dimension of the cultivation area; adopting minimum tillage; filling erosion furrow.

No tillage or minimum tillage, also combined with cover crop and cultural rotation, contribute to reduce also degradation (SoCo: Sustainable Agriculture and Soil Conservation, 2007-2009).

All the above practices could be also combined and applied to prevent pollution/contamination from fertilizers.

This best practice is also applicable to plain sites. In low lying agricultural fields, the risk of runoff for phytosanitary products is high when soil saturates, in particular when, in absence of artificial drainage, there is a lower layer due to ploughing or any other interruption of permeability along the soil, and water holding capacity is < 120 mm, or when lower ploughing surface is combined with additional impermeable layers within the soil for any value of water holding capacity.

Measure advantages

- Reduction of the risk of pollution and contamination of water bodies (ditches, rivers, lakes up to the sea);
- increase of the deep infiltration capacity, reducing sediment transport and sheet erosion;
- increase of soil organic matter in the superficial soil layers allowing reducing the use of pesticides and herbicides, safeguard of the groundwater, and organic carbon stock;
- increase of the soil biomass, favouring macro-pores that increase water infiltration and resistance to compaction.

Challenges

- Costs of practices implementation, of mechanization and of training;
- practices occupy a surface no more devoted to cultivation; however, the loss of surface is counterbalanced by CAP payments for greening.

Some more information is needed when runoff generates from soil saturation, and the risk is high when, in absence of artificial drainage, there is a lower layer due to ploughing plus any other interruption of permeability along the vertical of the soil, for any value of water holding capacity.

In both cases, if runoff generates from soil reduced infiltration or increased saturation, if the field is not adjacent to water bodies the contamination risk is high if the runoff finds the way to reach the water body.

- **BP MA15 Soil management**

Description of the measure

In steep slope areas with arable crops that, under peculiar geomorphological conditions generate erosion and landslide phenomena, transversal water-holding furrows (e.g. 30 cm depth) and transversal to longitudinal ditches (e.g. 50x50 cm), or ploughing according the contour line (over slope between 10-20%) or just over the surface (first 25-30 cm of soil) are useful in the short and medium terms on the hillslope and hydrographic basins. Some experimental data from the Research Centre on Agrobiology and Soil of the Council for Agricultural Research and Agricultural Economics Analysis (CREA) show that without water furrow erosion is 33t/ha/yr, decreasing to 10t/ha/yr in case of furrows (-67%) (Report on cross compliance implementation in Italy, 2010).

Measure advantages

- Water regulation, reduction of sheet and rill erosion;
- reduction of solifluction and landslides;
- reduction of floods thanks to longer concentration time (time from the rain dropping the soil to reaching the basin outlet);
- higher agricultural productivity, thanks to the maintenance of organic matter
- soil improvement (organic and mineral elements);
- minor need of mineral fertilizers;
- minor sediment deposition into reservoirs, improving water availability, less maintenance costs and higher hydropower production (cost saving estimated in about 120 M €).

Challenges

- Not appropriate for some types of topography and soils (e.g. geo-mechanical characteristics of clays);
- risks and economic costs for operations.

- **BP MA16 Plantation of tree-shrub lines**

Description of the measure

Using appropriate and autochthonous species, permanent and visible field borders in steep slope areas could be established through lines of tree and shrubs. They could serve also to produce wood for energy purposes (estimated as 0-200 euro per km). It is estimated a maintenance of organic matter thanks to this practice of about 10t/ha/yr (ISPRA, Manuali e Linee Guida 85/2013).

Measure advantages

- Reduction of sediment transport and of runoff;
- increase of infiltration on the hillslope;

- increase of the biodiversity for flora and fauna, providing opportunities for biological control, natural or anthropic;
- refuge for wild fauna;
- creation of ecological corridors and increase of the landscape value.

Challenges

- Loss of surface for the cultivation, however balanced by greening payments of the CAP.

- **BP MA17 Maintenance of terraced agricultural areas**

Description of the measure

Construction of terraces leads to a complete reshape of landscapes. It is most of all employed in landscapes that need to be used for some kind of agricultural activity although steep slopes are dominating. Different ways to construct terraces exist but independently of technique employed detailed construction plans are necessary to effectively install terraces. Because setting up of terraces is costly, terraces are most frequently installed when high revenue crops such as vine or orchards are grown.

Concerning permanent crops over terraced hillslopes, it is fundamental here to guarantee function of walls and embankments with grassy slope to avoid instability and loss of soil (e.g. landslide and hillslope instability). Soil erosion can be reduced of 10-40 t/ha/yr (-200/-500%) (Report on cross compliance implementation in Italy, 2010).

The main practices consist in removing weeds from walls, recovering drainage systems and crown of the drywall, and in placing grass among tree lines (in general for olive and vineyards and citrus groves) or grass or shrubs over terrace cliffs. More invasive practices are the recovery of the walls in their more instable parts. Ordinary maintenance should be every 2 years.

This allows recovery or maintaining PDO and PGI cultivations, together with landscape improvements also favouring tourism.

Measure advantages

Terraces reduce slopes in landscape thus decreasing flow velocity of runoff and increasing infiltration. Variants exist that employ piped drains to divert surface runoff. This offers an additional possibility to effectively control and divert runoff in agriculturally used catchments. However, even without piped drains terraces are very effective tools for runoff control. BP PA6 belongs to the group of onsite measures, which exhibit distinct advantages over “end of pipe” technologies such as BP PA3 (filter strips) or BP M(P)A3 (retention ponds) because onsite measures are a) relatively cheap compared to end of pipe measures and b) it is more effective to reduce surface runoff directly at those places where it initiates. Control of this measure is easy. Given their ecological, landscape and cultural heritage value, these landscape forms should be protected (e.g. cultural landscapes).

Challenges

- Risks and economic costs for operations;
- agricultural management is usually limited due to very small parcel sizes (restricted practical implementation to high revenue crops).

- **BP MA18 Convert arable land to unfertilized and ungrazed grass**

Description of the measure

Change the land use from arable cropping to unfertilized grassland (without livestock and associated manure inputs). There are only small losses of nitrate (NO_3) in drainage waters from arable reversion grasslands and the permanent vegetation cover minimises the erosion of soil particles and loss of associated particulate phosphorus (P) in surface runoff.

N uptake by the permanent vegetative cover and N immobilisation into accumulating soil organic matter provide a long-term sink for N.

Conversion to permanent grassland also avoids the frequent cultivations which under arable cropping stimulate the mineralisation of organic matter and thereby increase the amount of NO3 that is potentially available for leaching. In most cases, losses of NO3 in drainage waters will respond rapidly to the change of land use.

At elevated soil P levels, significant reductions in the leaching of soluble P are unlikely to be achieved in the short-term (<10 years) because there are effectively no nutrient offtakes in grazed grass/livestock products. The more immediate effect of this method would be to reduce particulate P losses in surface runoff, provided that the grassland was not compacted by vehicle traffic.

This is an extreme change in land use that is unlikely to be adopted by farmers without the provision of suitable incentives. It is likely to be particularly suited to areas where the converted land would have amenity or conservation value.

- **BP MA19 Arable reversion to low fertiliser input extensive grazing**

Description of the measure

Change the land use from arable cropping to permanent grassland, with a low stocking rate and low fertilizer inputs.

There are only small losses of NO_3 in drainage waters from arable reversion grasslands and the permanent vegetation cover minimises the erosion of soil particles and loss of associated particulate P in surface runoff.

N uptake by the permanent vegetation cover and N immobilisation into accumulating soil organic matter provide a long-term sink for N. Conversion to permanent grassland also avoids the frequent cultivations that under arable cropping stimulate the mineralisation of organic matter and thereby increase the amount of NO_3 that is potentially available for leaching. In most cases, losses of NO_3 in drainage waters will respond rapidly to the change of land use.

At elevated soil P levels, significant reductions in the leaching of soluble P are unlikely to be achieved in the short term (<10 years) because there are only low nutrient offtakes in cut grass/livestock products from extensively grazed systems. The more immediate effect of this method would be to reduce particulate P losses in surface runoff, provided that the grassland was not poached or badly compacted by vehicle traffic.

- **BP MA20 Convert arable/grassland to permanent woodlands**

Description of the measure

Change the land use from agricultural land to permanent woodland. There are only small losses of NO_3 in drainage waters from permanent woodlands and the permanent cover, provided by leaf litter mulch and vegetation, minimises the erosion of soil particles and loss of associated particulate P in surface runoff.

Conversion to permanent woodland avoids the frequent cultivations that under arable cropping stimulate the mineralisation of organic matter and thereby increase the amount of NO_3 that is potentially available for leaching. Changing from arable and (to a lesser extent) grassland agriculture to permanent woodland will reduce soil N and carbon losses.

At elevated soil P levels, significant reductions in the leaching of soluble P are unlikely to be achieved in the short term (<10 years) because there are only low level of nutrient uptake by woodland over this time scale. The more immediate effect of this method is the reduction of particulate P losses in surface runoff, provided that the woodland developed vegetation covers the soil surface.

- **BP MA21 Convert land to biomass cropping (i.e. willow, poplar, Miscanthus)**

Description of the measure

Grow perennial biomass crops (e.g. willow, poplar, Miscanthus) to displace fossil fuel use, either through direct combustion or through biofuel generation (e.g. by gasification).

Cultivation of arable land stimulates the mineralisation of organic matter and release of soil N and carbon. Following the establishment of perennial biomass crops, soils are not cultivated annually which will reduce NO3 leaching losses compared with conventional arable cropping. Also, lower levels of N fertiliser additions are made to willow, poplar and Miscanthus (typically no N is applied in the establishment year and 60-80 kg/ha N per annum thereafter) than most arable and grassland cropping systems, which reduces NO_3 leaching loss risks.

Conversion to permanent perennial biomass cropping avoids the frequent cultivations that under arable cropping stimulate the mineralisation of organic matter and manufactured fertiliser N inputs are moderate, thereby reducing the amount of NO_3 that is potentially available for leaching.

Challenges

- In some countries plants such as Miscanthus are alien species and their inadequate cultivation can result in potential risks to biodiversity. Therefore special permit is needed for the cultivation. The permits are given to farmers by the responsible

authoritative bodies (e.g. in Croatia Ministry of Environment and Energy issues permits based on the submitted request).

- **BP MA22 Establish Cover crops in autumn**

Description of the measure

If land would be "bare" over-winter, establish a cover crop immediately post-harvest or, at the latest, by mid-September. Alternatively, undersow spring crops with a cover crop that would be in place to take up nutrients and provide vegetation cover once the spring crop had been harvested.

In order to protect the soil surface throughout the period when surface runoff could occur, do not destroy the cover until the land is due to be prepared for the following crop.

Without a cover crop, NO_3 can be lost through over-winter leaching and particulate P can be lost through sediment transport in surface runoff.

Measure advantages

- Cover crops help to reduce NO_3 leaching by taking up N and reduce particulate P losses by protecting the soil from rainfall induced surface runoff and soil erosion. A cover crop will take up soil N (and other nutrients) after the main crop has been harvested in the summer/early autumn, leaving less NO3 available for leaching over-winter. Ensuring that the land is not left exposed helps reduce surface runoff and soil erosion.
- Living or dead plant material protects the soil surface against sealing. Biomass will in addition increase soil biota activity and organic carbon content of soil. All these effects positively affect infiltration of rainfall water and reduce surface runoff. In contrast to measure PA3 which follows an "end of pipe" strategy, use of cover crops protects land exactly where surface runoff is generated, within agriculturally used fields. It is easy to control.

Challenges

- The measure is only effective during winter time because usually soil cover is destroyed before seeding to enable planting of cash crops. The highest effectiveness of this measure can be obtained in combination with BP PA6 (conservation tillage).
- For most autumn-sown arable crops, it is not possible to establish a cover crop that will take up sufficient N to significantly decrease NO_3 leaching losses ahead of sowing the main autumn crop. A cover crop could be broadcast into the main crop before harvest, however, this can damage the standing crop and lead to yield losses. Soil structural damage caused by establishing a cover crop (either late or in wet conditions) may compromise cover crop establishment and result in poor utilisation of soil N by both the cover crop and subsequent crops, and increased particulate P and sediment loss risks. Where cover crops were established as part of the Nitrate Sensitive Area scheme, it was shown to be preferable (for agronomic reasons) to destroy the crop in January or February (at the latest).

This best practice is also applicable to plain sites.

- **BP MA23 Early/Late harvesting and establishment of crops in the autumn**

Description of the measure

Harvest crops such as potatoes and maize early (e.g. in September rather than October (TIMING IS COUNTRY/REGION SPECIFIC).

Establish autumn sown crops earlier (i.e. early October or sooner) (TIMING IS COUNTRY/REGION SPECIFIC).

Earlier/later harvesting of crops, especially those that are traditionally harvested late, would enable harvesting to be undertaken when soil conditions were drier, reducing (severe) compaction and soil structural damage risks, and associated sediment and nutrient losses in surface runoff. Establishment of autumn drilled combinable crops by early October would enable the crop to take up (some) N before the onset of over-winter drainage and provide good vegetation cover (at least 25 to 30%) over the winter months to protect the soil from rainfall induced surface runoff and associated erosion.

When soils are compacted and there is no growing vegetation to intercept rainfall or take up nutrients, the land is very susceptible to the generation of surface runoff and associated soil erosion. By harvesting/establishing crops early/late, compaction at harvest would be reduced and the crop would be better established in the autumn to take up N and reduce NO_3 leaching losses.

For most autumn-sown arable crops, it is not possible to establish a cover crop that will take up sufficient N to significantly decrease NO_3 leaching losses ahead of sowing the main autumn crop. A cover crop could be broadcast into the main crop before harvest, however, this can damage the standing crop and lead to yield losses. Soil structural damage caused by establishing a cover crop (either late or in wet conditions) may compromise cover crop establishment and result in poor utilisation of soil N by both the cover crop and subsequent crops, and increased particulate P and sediment loss risks. Where cover crops were established as part of the Nitrate Sensitive Area scheme, it was shown to be preferable (for agronomic reasons) to destroy the crop in January or February (at the latest).

- **BP MA24 Adopt reduced cultivation systems**

Description of the measure

Reduced cultivations, using discs or tines, to cultivate the soil surface as the primary cultivation in seedbed preparation (typically 10-15 cm cultivation depth).

Direct drilling or broadcasting of seed (i.e. no-till).

Reduced/no-till cultivations (rather than ploughing) can retain soil surface organic matter and preserve good soil structure, with the resulting soil conditions improving water infiltration rates and thereby reducing loss risks of particulate P and sediment.

Maintaining good soil structure and improving water infiltration rates reduces soil erosion risks; large reductions in surface runoff can be achieved where a mulch of crop residues is left on the surface. NO_3 leaching is generally decreased as there is less soil disturbance and hence less organic matter mineralisation.

Reduced cultivation systems are less appropriate in wet autumns and only suitable where soil structural problems have been alleviated. Reduced cultivations may increase resistant weed populations and therefore increase reliance on agro-chemical control. The incorporation of large volumes of straw into a small volume of soil (as part of a reduced cultivation system) may immobilise N and create a small need for additional N application. No-tillage is generally unsuitable for light soils that are prone to capping.

- **BP MA25 Cultivate compacted tillage soils**

Description of the measure

Cultivate compacted tillage soils to increase aeration and water infiltration rates.

Endeavour to establish a vegetative cover from a drilled crop, through natural regeneration or broadcast (barley) seed.

Cultivation disrupts compaction, increases surface roughness and water infiltration rates. The method will reduce particulate P and associated sediment losses

The method reduces surface runoff and soil erosion. When soils are compacted or capped and there is little crop residue or vegetation cover to intercept rainfall, soils can be susceptible to surface runoff.

Cultivation of the soil surface (during dry conditions) will increase surface roughness, which will enhance water infiltration rates into the soil and reduce surface runoff volumes.

- **BP MA26 Cultivate and drill across the slope**

Description of the measure

Cultivate and drill land along the slope (contour) to reduce the risk of developing surface runoff.

On fields with simple slope patterns, cultivating and drilling across the slope will reduce the risk of surface runoff being initiated and increase re-deposition rates where surface runoff does occur. The ridges created across the slope increase down-slope surface roughness and provide a barrier to surface runoff. As a result, particulate P and associated sediment losses will be reduced.

Cultivating across the slope reduces the risk of developing surface sheet and rill flow. Furrows (and tramlines) orientated down the slope will tend to collect water and develop concentrated surface flow paths; this risk can be reduced if they are aligned across the slope.

- **BP MA27 Irrigate crops to achieve optimum yields**

Description of the measure

Irrigate crops (potatoes, vegetables and soft fruit) to reduce soil moisture deficits at critical times during growth to optimise yields and nutrient uptakes.

The supply of water at appropriate times during the growing season ensures optimal crop growth and nutrient uptake, and reduces the amount of NO_3 available for leaching over the following winter, as a result of restricted N uptake due to drought.

Irrigation scheduling is designed to maintain soil moisture at optimum levels at critical times in the growing season. Yields are optimised, such that more N is taken up by the crop and less NO_3 is available for leaching post-harvest.

- **BP MA28 Establish and maintain artificial wetlands to capture agricultural pollution**

Description of the measure

Construct (or establish) wetlands with fences and channels that will be sufficient to capture runoff and sediment from fields or farm hardstandings.

Constructed wetlands can be used for the "treatment" of lightly contaminated runoff from farm hardstanding areas and to intercept runoff water from a field or group of fields. They can trap sediment and through the retention of runoff, reduce nutrient and FIO loads in water exiting the wetland.

Wetlands act by intercepting pollutant delivery through providing a "buffer zone" and can potentially clean up polluted water. They can be natural or artificial, permanent or temporary, with water that is static or slow flowing. Constructed wetlands can be either surface (overland) flow or subsurface (percolation) flow systems. A surface flow wetland is akin to a natural wetland; in the form of a reed bed, bog, wet grassland, wet woodland, sedimentation pond or lake. A subsurface flow wetland is generally a highly engineered, confined system of graded gravels and reeds. A range of biological, physical and chemical processes occur in the wetland environment, which can reduce nutrient and FIO concentrations in water that passes through the wetland.

- **BP MA29 Establish new hedges**

Description of the measure

Plant new hedges along fence lines and use them to break-up the hydrological connectivity of the landscape. Increasing the number of hedgerows can help to reduce sediment and associated nutrient losses by "trapping" and lowering surface runoff volumes. Hedges can also help to protect soils from wind erosion. Installing hedges reduces the slope length and helps to prevent the delivery of pollutants in surface runoff by reducing the force of flow. Hedges also act as "natural" buffer strips and sediment traps, and enable separate parts of the landscape to be managed in different ways.

- **BP MA30 Incorporate manure into the soil**

Description of the measure

Incorporate manure rapidly into the soil using a plough, discs or tines. The rapid soil incorporation of manure can reduce pollutant losses in runoff and also reduce the exposed surface area of manure from which NH_3 emissions can occur.

Incorporation of manure can reduce the detachment and entrainment of manure particles by increasing surface roughness, promoting infiltration and preventing the exposure of manure to the hydrological forces of raindrop impact, surface runoff and drainflow loss. The rapid soil incorporation of manure (e.g. within 6 hours of spreading for slurry and 24 hours for solid manures) also reduces NH_3 volatilisation by reducing exposure to the air. NH_3 emission reductions depend on the time period between manure application and soil incorporation, and also on the cultivation technique employed. There is a considerable decrease in the abatement efficiency achieved if soil incorporation is delayed; incorporation as soon as possible after application should be the aim.

- **BP MA31 Do not apply manure to high-risk areas**

Description of the measure

All riparian areas and areas close to the streams and rivers draining directly towards the streams and rivers are high risk areas.

Do not apply manure to field areas where there is a high-risk of direct loss to watercourses. For example, directly adjacent to a watercourse, borehole or road culvert, to shallow soils over fissured rock or widely cracked soils over field drains, to areas with a dense network of open (surface) drains, spring lines or wet depressions (flushes).

These areas have a high-risk of rapid transport of manure-borne pollutants to watercourses, so manure applications (particularly of slurry) should be avoided wherever possible.

The method applies to areas where there is a high degree of hydrological connectivity between the field and watercourse; avoiding applications to such areas reduces the risk of pollutant transfer. The Code of Good Agricultural Practice advises that slurry and solid manures should not be spread within 10 m of a watercourse or within at least 50 m of a spring, well or borehole.

- **BP MA32 Store solid manure heaps on an impermeable base and collect leachate**

Description of the measure

Manure heaps are sited on an impermeable base, with leachate collection facilities.

The impermeable base and leachate collection prevents the direct loss of pollutants in surface runoff and drainflow.

If stored directly on the soil surface, leachate from solid manure heaps will seep into the soil and/or flow over the soil surface in response to rainfall events. Storing manure on an impermeable base prevents the seepage and accumulation of nutrients in the soil below the heap, which may subsequently be lost in surface runoff/drainflow or leaching to groundwater. Also, storage on an impermeable (e.g. a concrete base) reduces soil compaction caused by farm machinery, during the forming and subsequent spreading of field heaps. The leachate collected can be spread at a later date when soil conditions are suitable and the nutrients can be utilised by crops, or the leachate may be added back to the heap or into a slurry store.

- **BP MA33 Compost solid manure**

Description of the measure

- Encourage the breakdown of solid manure by active composting.
- Turn the solid manure windrow twice in the first seven days of composting to facilitate aeration and the development of high temperatures within the windrow.

The aim is to facilitate naturally occurring microflora to degrade cellulose and other carbon compounds in the manure to produce a friable, stable and spreadable material, with reduced volume. As part of the composting process, the manure is "sanitised" and the readily available N content is reduced, thereby lowering the risks of faecal indicator organisms FIO and NO_3 losses when the composted manure is spread to land.

Increased temperatures during active composting inactivate microbial pathogens and most weed seeds; and reduce the readily available N content of FYM. Composting has little effect on the proportion of readily available N in poultry manure. The readily available N content of

FYM is typically reduced from 20-25% (in "fresh" FYM) to 10-15% of total N (in composted FYM). The whole process should be monitoring to ensure that temperatures increase to above 55˚C for three days after each turn. Turning of the heap ensures that all parts are treated (i.e. composted).

- **BP MA34 Establish in-field grass buffer strips on tillage land**

Description of the measure

On sloping tillage fields and outdoor pig land, establish (unfertilised) grass buffer strips along the land contour, in valley bottoms or on upper slopes to reduce and slow down surface runoff.

In-field grass buffer strips can reduce particulate P and associated sediment losses by slowing surface runoff and intercepting sediment delivery.

An in-field grass buffer strip is a vegetated area of land, located along the land contour, on upper slopes or in valley bottoms; it is usually a permanent feature, although it can be temporary. Both the Entry Level and Higher Level Environmental Stewardship (ELS/HLS) schemes have options to establish in-field grass areas to prevent surface runoff and erosion. Buffer strips can also act as a sediment-trap, helping to reduce nutrient and other associated losses in surface runoff.

- **BP MA35 Establish riparian buffer strips**

Description of the measure

Establish vegetated (and unfertilised) grass/woodland buffer strips alongside watercourses (see BP MG 14). The grass/woodland strip will act as a "natural" buffer feature to reduce the transfer of pollutants from agricultural land to water.

Riparian buffer strips can reduce pollution delivery in two ways. They distance agricultural activity from watercourses and therefore reduce direct pollution from fertiliser and organic manure additions, and can restrict direct livestock access to watercourses. They can also

intercept surface runoff from agricultural land before it reaches the watercourse, therefore acting as a sediment trap and filter for nutrients.

Riparian strips should ideally be free-draining and have a good surface porosity to intercept surface runoff. The Entry Level Environmental Stewardship scheme offers options for buffer strips between 2 and 6 m in width, and 10 m around in-field ponds.

- **BP MA36 Maintain/improve field drainage systems**

Description of the measure

Actively maintain field drainage systems through jetting, re-installation and renewed moling.

A functioning drainage system ensures that water is able to move through the soil profile, allowing the soil to be maintained in a "well drained" condition and extending the window of opportunity for machinery operations and livestock grazing, particularly in autumn and spring. Maintaining field drainage systems minimises the risk of poaching, compaction and waterlogging, and can reduce surface runoff; an important pathway for the loss of particulate P and sediment (particularly from tillage land).

The method reduces the period when soils are at risk from compaction and poaching, and reduces the risk of surface runoff and associated particulate P/sediment losses.

However, drainflow losses of nutrients (particularly NO_3 and P) are likely to be increased.

- **BP MA37 Ditch management**

Description of the measure

Clear out ditches on a regular basis to ensure field drainage systems are able to function. This may include cutting vegetation in the bottom of the ditch to prevent flooding.

To ensure a drainage system functions at its optimum the water needs to be able to exit the ditch system. Clearing out ditches will achieve this.

This method will allow field drainage systems to function thereby reducing the risk of waterlogging, soil compaction, poaching and surface runoff.

- **BP MA38 Use plants with improved nitrogen use efficiency**

Description of the measure

Develop new plant varieties with improved genetic traits for the capture of soil N.

During the growing period, the efficiency of uptake of applied manufactured fertiliser N typically ranges between 55 and 70%, according to site conditions, the amount of soil N and the inherent physiology of the plant. If the plant can be rendered more competitive for soil N, reduced emissions of N to water and air would be expected. Improving N use efficiency of plants could potentially therefore:

  - Reduce fertiliser N additions to agriculture;

- improve nutritional characteristics of new forage plant varieties (e.g. improved amino acid profile, reduced rumen protein degradation, improve fibre digestibility);
- improve N efficiency in agriculture;
- plants remove more mineral N from the soil and so reduce the amount that can be lost to water and air.

- **BP MA39 Fertiliser spreader calibration**

Description of the measure

Improve the accuracy and spread pattern of fertiliser spreaders.

Inaccurate fertiliser spreading (i.e. poor spread patterns) result in the under-application of fertiliser on some areas and over-application on other areas. Under-application of N fertiliser results in reduced yields and over-application can also result in reduced yields (through lodging) and increased NO_3 leaching losses.

Tray tests are used to determine the coefficient of variation (CV) and accuracy of a fertiliser spreader. A low CV (less than 10%) ensures that fertiliser is spread evenly and all parts of the field receive the recommended rate. This optimises the uptake of soil and fertiliser nutrients, and reduces the amount of residual (autumn) mineral N available for leaching over-winter. Fertiliser spreaders should be checked at least annually and ideally, whenever the fertiliser type is changed.

- **BP MA40 Do not apply manufactured fertiliser to high-risk areas**

Description of the measure

Do not apply manufactured fertiliser at any time to field areas where there are direct flow paths to watercourses. For example, areas with a dense network of open drains, wet depressions (flushes) draining to a nearby watercourse, or areas close to road culverts/ditches.

The risk of N and P pollution is reduced by not applying fertiliser at any time to areas where it could easily be transferred to a watercourse.

Avoiding fertiliser spreading to hydrologically well-connected areas helps prevent the transfer of pollutants to water.

- **BP MA41 Reduce dietary N and P intakes**

Description of the measure

Adjust the composition of livestock diets to reduce the total intake of N and P per unit of production.

Avoiding excess N and P in the diet and/or making dietary N and P more available allows nutrient concentrations in the diet to be reduced, without adversely affecting animal performance.

These methodologies reduce the amount of N and P excreted, either directly to fields or via handled manures, and thereby minimise additions as sources of diffuse pollution.

Farm animals are often fed diets with higher than recommended contents of N and P, as a safeguard against a loss of production, arising from a deficit of these nutrients. However, surplus N and P will not be utilised by the animal and will be excreted. Restricting diets to recommended levels of N and P will limit the amounts excreted.

Nutrient excretion can also be reduced by changing the composition of the diet to increase the proportion of dietary N and P utilised by the animal; for example, by optimising the balance of N to carbohydrate in ruminant diets or by reducing the proportion of rumen-degradable protein. Additionally, in non-ruminants, N excretion can be reduced by increasing the digestibility of the ration. In both ruminants and non-ruminants, feeding a ration that supplies amino acids in the ideal proportions required for protein synthesis will reduce the quantities of “surplus” amino acids that remain un-utilised and contribute to N excretion. Supplementing the diet of pigs and poultry with the enzyme phytase increases the availability of P in the feed and allows total P contents to be reduced without affecting productivity (this is not applicable to ruminants as rumen microbes produce phytase naturally).

5.3. Best management practices – Agriculture – Plain sites (PA)

- **BP PA1 Conversion of arable land into grassland**

Description of the measure

The total share of grassland within a farm/district/region increases by switching from arable land into grassland for particular areas.

Measure advantages

Grassland is a highly effective measure to stabilize the soil surface and decrease soil erosion. Stabilisation of soil also helps to improve the hydraulic properties of soil thus increasing infiltration capacity and decreasing surface runoff. BP PA1 is easy to control. Comparing with management practices M(P)A1 and M(P)A2, PA1 is certainly the most effective because it is able to improve the environmental situation instead of not deteriorating it.

Challenges

Willingness to accept this measure is little because usually it comes along with a decrease in agricultural income. It usually needs a large change in agricultural practices. This makes this measure also very expensive in terms of compensation payments that are necessary to balance the loss of income.

- **BP PA2 Planting/Maintenance of areas as green fallow when soil quality is low (Ackerzahl < 30)**

Description of the measure

Arable land with very low soil quality may be taken out of the production process. Soil quality may be determined according to the Austrian taxpaying system for farmers ("Einheitswert") which is using a so called "Ackerzahl" to determine the soil quality of each particular field of a farmer. If the "Ackerzahl" drops below a certain value (for instance 30) very small yields are to be expected.

Measure advantages

Green fallow exhibits similar effects as grassland. It is thus a highly effective measure to stabilize the soil surface and decrease soil erosion. Stabilisation of soil also helps to improve the hydraulic properties of soil thus increasing infiltration capacity and decreasing surface runoff. BP PA2 is easy to control.

Challenges

Willingness to accept this measure depends largely on the amount of compensation payments. Farmers usually know quite well about the quality of their fields. For fields with low yields it may be easier to turn them into fallow.

- **BP PA3 Filter strips along permanent streams**

Description of the measure

Filter strips are zones of extensive management alongside of permanent streams. They may consist of permanent vegetation such as riparian trees and bushes or strips of grassland which are managed with low intensity. The width and the type of vegetation strongly influence the effectiveness of the measure.

Measure advantages

The measure will reduce sediment input and input of coarser materials into streams thus affecting those processes within streams that may interact with increased retention of water for instance clogging of pipes or decreasing retention capacity of retention ponds. Improved habitat for a wide range of biota is considered a positive side effect. Depending on the actual type of the measure a huge difference in effectiveness may be observed. Strip widths below 25 m will not be very effective. In addition the effectiveness is also largely dependent on the size of the catchment area entering the buffer strip. Some small effect may be expected from increased infiltration within the buffer strip. BP PA3 is easy to control.

Challenges

As usual when dealing with agricultural land willingness to accept this measure depends largely on the amount of compensation payments. In agricultural areas with relatively high rainfall amounts it is quite common to establish at least riparian filter strips made of trees and shrubs. Furthermore, it is desirable to establish grassed riparian areas because of higher retention effectiveness.

- **BP PA4 Grassed waterways**

Description of the measure

Grassed waterways can be thought as filter strips along “thalweg” situations, which are zones within catchments where surface runoff accumulates. In contrast to filter strips they are mainly placed within catchments. They are managed with low intensity as permanent grassland. Fertilisation is not desirable because they are designed to act as sinks for nutrients, sediment and, to a certain extent also for water.

Measure advantages

Correctly applied, the retention effectiveness for sediment and associated nutrients is very high. There is also some effectiveness to increase infiltration of surface runoff. Additional side effects include a better connection of landscape elements that may act as habitat for biota. BP PA4 is easy to control.

Challenges

The measure needs thorough landscape planning to be implemented efficiently. This is because a) the measure usually occupies agriculturally used land thus exhibiting negative economical side effects, and b) good planning is necessary to guarantee good hydrological effectiveness.

- **BP PA5 Non-turning tillage (conservation tillage)**

Description of the measure

Traditional tillage or more precisely conventional tillage is usually based on soil-turning methods, such as ploughing. Thereby the topsoil is loosened and turned so that the organic residues are extensively and equally distributed folded in the topsoil. Primarily, this measure is used to prepare the agricultural land for the following sowing. The ploughing also provides a mechanical weed control and enhances the aeration of the topsoil (SCHEFFER et al., 2010). However, this technique can adversely affect the ecosystem services water provision, water regulation and water quality regulation.

This technique destroys the aggregate structure of the topsoil due to the mechanical impact of the plow. The increased aeration in the topsoil fosters the decomposition (mineralisation) process of the organic matter and thus reduces the humus content (SCHEFFER et al., 2010). Both, the destroyed aggregate structure as well as the reduction of the humus content reduce the water storage capacity as well as the purification and filtering function of the topsoil. For example, KANWAR (1985) described higher nitrate leaching from conventional tillage sites than from no-till sites.

In terms of susceptibility to erosion, the detachment of particles intensifies and increases the amount of eroded material. Moreover, the susceptibility to interflow processes at the ploughing pan and surface runoff processes in response to surface sealing increases as well (SHIPITALO et al., 2000; BRONSTERT et al., 2002). These fast discharge units can also carry significant amounts of nitrate and phosphorous and thus pose a risk for the receiving waters (GOSS et al., 1993).

A transition from conventional soil tillage to non-turning alternatives (conservation tillage) counteracts these negative impacts of soil-turning methods. The concept of conservation tillage can be considered as a part of the concept of low-input farming to which the concept of extensive crop rotations is associated as well. Conservation tillage fosters the preservation of the soil structure and its pore system so that the soil maintains its water transferability and storage capacity. Especially the preservation of the vertical pores is of vital importance for water infiltration at the soil surface (SHIPITALO et al., 2000). Moreover, the humus content of the topsoil increases compared to conventional tillage favouring the water storage capacity and the process of water purification. Since the topsoil is not turned in conservation tillage the activity of soil organisms does not decrease and keeps the bioturbation on an adequate level (BAUCHHENß, 2005). Bioturbation positively affects the soil (aggregate) structure; it improves the connectivity of macropores and enhances the infiltration (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water provision and water regulation function of the soil system.

Since the organic residues are almost completely left on the soil surface they provide a protection function against erosion and evaporation. Furthermore, these residues decrease the susceptibility to surface sealing and lower the probability of breaching the infiltration capacity and the resulting Hortonian Overland Flow. Analogous to less surface sealing and enhanced vertical connectivity, this measure can enhance the mitigation of floods in small catchment areas during convective storm events (DWA, 2015).

In summary, conservation tillage may increase the water use efficiency and helps the soil to maintain its ecosystem services water regulation, water provision and water quality regulation on an adequate level.

Measure advantages

- Positive impacts on the ecosystem services water regulation and water quality regulation;
- preservation of soil stress and recovery of (physical) soil properties;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffusive discharge of nutrients (e.g. nitrate);
- increasing activity of soil organisms enhances the soil (aggregate) structure, the connectivity of water paths and decomposition processes;
- coupling with other measures (e.g. extensive crop rotations, catch crop cultivation) can enhance the effect of conservation tillage.

Challenges

- Enhancing ecosystem service water provision;
- likely to need more herbicides which can be hindered with other measures, e.g. catch crop cultivation.

- **BP PA6 Implementation of a permanent and extensive plant coverage with catch crops**

Description of the measure

Exposed and uncovered surfaces represent unprotected areas which are susceptible to negative environmental influences. Splash effects of rainfall can destroy soil aggregates and lower the water storage capacity. More detached, fine-textured soil particles can favour surface sealing processes and lower the infiltration capacity. Moreover, harvest residues on temporally unused lands are likely to foster the mineralisation of nitrogen and lead to increasing amounts of nitrate in the topsoil which can enhance the diffused discharge into the groundwater (SCHEFFER et al., 2010).

In order to lower these negative effects on the ecosystem services water quality regulation and water regulation, catch crops are frequently used to cover the soil surface between successive plantings. Catch crops are mostly fast-growing species which overlast the intermediate phase between two main crops and at best remove excess nutrients. Moreover, catch crops are also cultivated simultaneously with species that require a wider row spacing (e.g. maize fields or vineyards) to cover the bare soil between the crop rows. These catch crop species have to be adapted to the main crop since both should not be in nourishment competition for nutrients and at best benefit from each other.

The cultivation of catch crops can significantly decrease the nitrate leaching (e.g. greening in winter). Depending on the species, catch crops can store a certain amount of nitrate which is mineralised after the harvest and thus available for the following main crops (THORUP-CHRISTENSEN et al., 2003; SCHEFFER et al., 2010). Moreover, catch crops cover the bare soil and increase the content of organic matter in the topsoil. Thus, these plantings protect the soil from soil aggregate destabilization and erosion processes. The increased content of organic matter also hinders surface sealing and the related probability to increased surface runoff (MEISINGER et al, 1991; GLAB et al., 2008). Catch crops also increase interception and transpiration losses and may thus counteract the ecosystem service water provision.

Depending on the site and main crop characteristics, the cultivation of leguminous species as catch crops should be refrained. Leguminous crops increase the amount of plant-available nitrogen in symbiosis with bacteria (rhizobiaceae).

Measure advantages

- Positive impacts on the ecosystem services water regulation and water quality regulation;
- fostering a more efficient use of the growing space;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffusive discharge of nutrients (e.g. nitrate);
- coupling with other measures (e.g. extensive crop rotations, conservation tillage) can enhance the effect of catch crop cultivation.

Challenges

- Enhancing ecosystem service water provision.

BP PA7 Fostering extensive crop rotations

Description of the measure

The basic intention of farmers is to obtain the maximum economic benefit from their estates. In this context the tendency towards intensively-used farmlands is not more than a logical consequence. An intensively-used farmland enhances the cultivation of economically profitable crops always seeking to increase the efficiency of the production factor "soil". As a result, the use of yield-improving (genetic) seeds, synthetic fertilizers, pesticides as well as the use of non-conserving tillage methods (conventional tillage) can be considered as the basis for the intensification of farmlands. Moreover, rising world market prices and current legal regulations in agricultural policy foster the intensification of farmlands as well.

However, the intensive use of farmlands may lead to an increasing exposure to negative environmental impacts, such as stormwater runoff, high discharge of contaminants (e.g. nitrate and phosphorous) and soil erosion. In this context, an integrated management of the crop rotation systematics (extensive crop rotations) can make a significant contribution to reduce the likelihood of those hazards. Such an adapted management strategy has to be economically viable and environmentally compatible at the same time.

The concept of extensive crop rotations can be considered as a part of the concept of low-input farming to which conservation tillage is associated. The objective of this management strategy is to reduce the required input of (synthetic) pesticides and fertilizers by harmonizing the crop rotation strategy. This could mean that a previous crop should leave, as far as possible, optimal site conditions for a subsequent crop to minimize the use of production inputs (DIEBEL et al., 1992).

Due to less production inputs the pollution of surface waters and the groundwater can be avoided to a certain extent. The implementation strategy of extensive crop rotations should incorporate aspects to conserve the structural and textual properties of the soil as well as the soil fertility. If adapted in an adequate manner, this measure can enhance the ecosystem services water quality regulation, water provision and water regulation.

Measure advantages

- Positive impacts on the ecosystem services water provision, water regulation and water quality regulation;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers, genetic engineering);
- decreased diffusive discharge of nutrients (e.g. nitrate);
- coupling with other measures (e.g. catch crop cultivation, conservation tillage) can enhance the effect of extensive crop rotations.

Challenges

- Selecting adequate crop rotations and simultaneously sustaining the economic efficiency for the farmer.

- **BP PA8 Conversion of intensively-used agricultural lands to short-rotation plantations (SRP)**

Description of the measure

Short-rotation plantations (SRP) represent extensive agricultural land-use measures which mainly serve for the production of firewood. The plantation focus is principally based on fast-growing tree species, such as poplars or willows, which are ready to harvest in between 3 to 8 years depending on the site and species characteristics. At harvest, the trees are cut near the soil surface leaving a small part of the trunk. This trunk rest puts out new shoots in spring time so that a new sowing as well as tillage is not required. The new shoots benefit from the existing root structure of the harvested stand since the existing root network simplifies the nutrient and water uptake (ZACIOS et al., 2011).

A use of heavy machinery is only required at the initial phase for site preparation from intensive agricultural use to SRP sites as well as for the harvest. Moreover, SRP plants create a deeper-reaching root system due to their longer growth phases compared to annual crops. Thus, the root system of SRP plants also develops in soil layers under the former ploughing depth and loosens up the whole soil structure. Thanks to less soil compaction, the prevention of soil tillage

and a high availability of organic matter results in an increase of activity of soil organisms, e.g. earthworms. These structural changes of the soil system can improve the water storage capacity of the soil as well as the water transferability to deeper soil layers (ZACIOS et al., 2012, ZACIOS et al. 2015).

The interception and transpiration losses generally increase as a consequence of the land-use change due to a dense and continuous vegetation cover, increased water uptake from deeper soil layers and greater leaf areas (e.g. of poplars). These changes have a two-fold effect: On the one hand, the canopy cover continuously protects the soil surface from erosion processes and increases the water retention. Thus, the conversion to SRP sites is positively affecting the ecosystem services water quality regulation and water regulation. On the other hand, the water recharge of the water supplying aquifer decreases. ZACIOS et al. (2012) calculated a decrease of recharge of 75% on SRP sites in Kaufering (Bavaria).

Furthermore, SRP sites foster the ecosystem service water quality regulation by avoiding the use of fertilizers. ZACIOS et al. (2012) showed that the discharge of substances from the soil as well as the input of matter into the groundwater decreased following the land-use change. For nitrate, they calculated a decrease of 50% compared to the amount of outwash from the former agricultural area.

Measure advantages

- Positive impacts on the ecosystem services, water regulation and water quality regulation;
- preservation of soil stress and recovery of (physical) soil properties;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffusive discharge of nutrients (e.g. nitrate).

Challenges

- Enhancing the ecosystem service water provision;
- implementation costs;
- economic efficiency depending on production emphasis of the farmer.

- **BP PA9 Crop diversification**

Description of the measure

Within cultivated lands, diversification of crops, by increasing perimeters among fields, could be useful. This allows various scheduling of sowing, cultivation and harvesting, due to different phenological phases of the crops, reducing time between clod breaking and sowing.

Measure advantages

- Increase of biodiversity in the area, for general fauna and insect, fundamental for the defence from biotic disturbances;

- reduction of erosion and increase of infiltration, both from direct rainfall and from runoff;
- natural control of weeds, reducing use of herbicides.

Challenges

- More complex operations in the field because of spatial and temporal diversification.

- **BP PA10 Implementation of agricultural advisory service**

Description of the measure

The task of the Agricultural Advisory Service is to inform farmers about their duties in case they receive different subsidies. If farmers receive subsidies, they are required to comply with the requirements. Agricultural Advisory Services provide aid to farmers in technology, design fertilization plan, organise trainings for the use of pesticides (plant protection products). Trainings for pesticide use are compulsory every 5 years. Agricultural Advisory Services cooperate with farmers through personalized advice and lectures in the winter, which are mandatory each 5 years (in Slovenia; in other countries it may vary).

- **BP PA11 Fertilization plan and diary**

Description of the measure

Fertilization plan is made on the basis of soil analysis and type of crop. Measured parameters for soil analyses are: pH, P and K content, content of organic matter and depth of soil sample. Fertilization plan includes the amount of manure/fertilizer that can be applied in a single parcel, which type of crop will be cultivated and which plant nutrient will be applied. 170 kg N/ha is allowed.

Basic fertilization is carried out in the autumn (N-P-K fertilizers and livestock manure). During the growing season it is additionally fertilized (for vegetables is added N), which is prohibited in farming in DWPZ.

Fertilization diary is conducted for each parcel. The farmer must keep a diary of fertilization in which it can be seen when it fertilizers were applied and how many plant nutrients have been applied per parcel (varies between countries).

- **BP PA12 Storage facilities for manure**

Description of the measure

EU Member States are required to establish one or more action programmes related to nitrates, which include measures defining conditions for manure storage.

Storage facility must be large enough to store manure and slurry for six months. The farmer has to keep a record of slurry amount and have a plan for manure spreading. 170 kg N/ha is allowed. The farmer has to have manuring diary with information about time, locations and amounts of manure spreading. All these data are not checked and are based upon honesty.

For example, in 2006 Slovenia subsided grants for the arrangements of storage facilities for livestock manure in 2006. The control was carried out by the Inspectorate of the Republic of Slovenia for agriculture, forestry, hunting and fisheries, who only inspected schemes and building project, but not implementation in the space.

- **BP PA14 Restrictions of agricultural activities in drinking water protection zones (for example in Slovenia)**

In Slovenia there are restrictions and limitation of agricultural activities in drinking water protection zones (see Table 5.)

Table 5. Prohibitions, restrictions and protective measures for agricultural activities in drinking water protection zones in Slovenia

I	FERTILIZATION OF AGRICULTURAL LAND	VVO I	VVO II	VVO III
1	Fertilization without fertilization plan	–	–	–
2	Fertilization with mineral fertilizers containing nitrogen	–	+	+
3	Fertilization with manure and slurry	–	+	+
4	Fertilization with seasoned manure	+	+	+
5	Ploughing of permanent grassland	–	+	+
6	Irrigation with water with added plant nutrients	–	+	+
7	Temporary storage of organic fertilizers, determined in accordance with regulations governing the protection of waters against pollution caused by nitrates from agricultural sources	–	–	–
8	The use of sewage sludge, determined in accordance with the regulations governing the use of sludge from sewage treatment plants in agriculture	–	–	–
9	Fertilization with the remains of cesspools, small wastewater treatment plants or water treatment plants			
10	Fertilization with sludge produced on the holding and is a mixture of urban wastewater, slurry and manure, irrespective of the time of its storage	–	–	–
11	Temporary storage of compost or digestate sludge of 1 or 2 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	–	–
12	The use of compost and digestate sludge of 1 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	–	+
13	The use of compost and digestate sludge of 2 environmental quality, as determined to the	–	–	–

	regulations governing the treatment of biodegradable waste			
14	Temporary storage of sewage sludge, determined in accordance with the regulations governing the use of sludge from sewage treatment plants in agriculture	–	–	–

II	FERTILIZATION OF NON-AGRICULTURAL LAND	VVO I	VVO II	VVO III
1	Fertilization with manure and slurry	–	–	+
2	Fertilization with seasoned manure and compost from crop residues	+	+	+
3	Fertilization with mineral fertilizers containing nitrogen	–	+	+
4	Irrigation with water, which had the added plant nutrients	–	+	+
5	Fertilization with sludge produced on the holding and is a mixture of urban wastewater, slurry and manure, irrespective of the time of its storage	–	–	–
6	Temporary storage of organic fertilizers, determined in accordance with regulations governing the protection of waters against pollution caused by nitrates from agricultural sources	–	–	–
7	Temporary storage of compost or digestate sludge of 1 or 2 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	–	–
8	The use of compost and digestate sludge of 1 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	+	+
9	The use of compost and digestate sludge of 2 environmental quality, as determined to the regulations governing the treatment of biodegradable waste	–	–	–
10	Temporary storage of sewage sludge, determined in accordance with the regulations governing the use of sludge from sewage treatment plants in agriculture	–	–	–
11	Fertilization with the remains of cesspools, small wastewater treatment plants or water treatment plants	–	–	–
12	Fertilization with the remains of cesspools, small wastewater treatment plants or water treatment plants	–	–	–

III	USE OF PLANT PROTECTION PRODUCTS ON AGRICULTURAL LAND	VVO I	VVO II	VVO III
1	Use of unauthorized plant protection products in accordance with the regulations on plant protection products	–	–	–
2	The use of plant protection products in accordance with the regulations on plant protection products on agricultural land			

IV	USE OF PLANT PROTECTION PRODUCTS ON NON-AGRICULTURAL LAND	VVO I	VVO II	VVO III
1	The use of plant protection products in accordance with the regulations on plant protection products in parks, cemeteries, green areas and sports grounds	–	–	–
2	The use of plant protection products in accordance with the regulations on plant protection products on the objects of transport infrastructure	–	–	–

VVO I = DWPZ I: Means the narrowest water protection zone.

VVO II = DWPZ II: Means the narrow water protection zone.

VVO III = DWOZ III: Means the wider water protection zone.

+ Means that the intervention in the environment is permitted.

– Means that the intervention in the environment is prohibited.

Best management practices concerning agriculture are systematically shown in Table 6, where relevance of each BMP can be seen (water protection functionality, cost of the measures, duration of implementation and time interval of sustainability). Some BMPs are valid for both mountain and plain sites (*).

Table 6. Best management practice relevance – Agriculture

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
MOUNTAIN SITES				
Maintaining the share of grassland*	Medium	Low	Long Term	Long Term
No conversion of grassland into arable land*	Medium	Low	Long Term	Long Term
Retention ponds*	Medium	High	Short Term	Short Term
Linear retention features*	Medium	Medium	Long Term	Long Term
Protection of water from pollution caused by nitrates originating from agriculture*	High	Medium	Long Term	Long Term
Sustainable use of pesticides*	High	N/a	N/a	N/a
Encouraging organic farming*	High	High	Long Term	Long Term
Advisory services, farm management and farm relief services*	N/a			
Increasing the efficient use of water in agriculture and adapting to climate change				
Soil erosion prevention and increasing of soil fertility and soil organic matter*				
Tillage across slope*	Medium	Low	Long Term	Long Term
Maintenance of water, soil and air quality in agriculture*	N/a	N/a	N/a	N/a
Optimized application of phytosanitary products*	High	Medium	Short periodically	Medium

Reducing runoff of phytosanitary products and fertilizers*	High	High	Medium	Medium
Soil management	High	High	Medium	Medium
Plantation of tree-shrub lines	High	High	Short Term	Medium
Maintenance of terraced agricultural areas	High	High	Medium	Medium
Convert arable land to unfertilized and ungrazed grass*	High	Location specific	Short to medium	N/a
Arable reversion to low fertiliser input extensive grazing*	High	Location specific	Short to medium	
Convert arable/grassland to permanent woodlands*	High	Location specific	Short to medium	
Convert land to biomass cropping (i.e. willow, poplar)*	High	Location specific	Short to medium	
Establish Cover crops in autumn*	High	Location specific	Short to medium	
Early/Late harvesting and establishment of crops in the autumn*	High	Location specific	Short to medium	
Adopt reduced cultivation systems*	High	Location specific	Short to medium	
Cultivate compacted tillage soils*	High	Location specific	Short to medium	
Cultivate and drill across the slope*	High	Location specific	Short to medium	
Irrigate crops to achieve optimum yields*	High	Location specific	Short to medium	
Establish and maintain artificial wetlands to capture agricultural pollution*	High	Location specific	Short to medium	
Establish new hedges*	High	Location specific	Short to medium	
Incorporate manure into the soil*	High	Location specific	Short to medium	
Do not apply manure to high-risk areas*	High	Location specific	Short to medium	
Store solid manure heaps on an impermeable base and collect leachate*	High	Location specific	Short to medium	
Compost solid manure*	High	Location specific	Short to medium	N/a

Establish in-field grass buffer strips on tillage land*	High	Location specific	Short to medium	
Establish riparian buffer strips*	High	Location specific	Short to medium	
Maintain/improve field drainage systems*	High	Location specific	Short to medium	
Ditch management*	High	Location specific	Short to medium	
Use plants with improved nitrogen use efficiency*	High	Location specific	Short to medium	
Fertiliser spreader calibration*	High	Location specific	Short to medium	
Do not apply manufactured fertiliser to high-risk areas*	High	Location specific	Short to medium	
Reduce dietary N and P intakes*	High	Location specific	Short to medium	
PLAIN SITES				
Conversion of arable land into grassland	Medium	Medium	Long Term	Long Term
Planting/Maintenance of areas as green fallow when soil quality is low	Medium	Medium	Long Term	Long Term
Filter strips along permanent streams	Medium	Medium	Long Term	Long Term
Grassed waterways	High	Medium	Long Term	Long Term
Non-turning tillage (conservation tillage)	High	High	Long Term	Long Term
Implementation of a permanent and extensive plant coverage with catch crops	High	Medium	Short Term	Short Term
Fostering extensive crop rotations	High	Medium	Medium	Short Term
Conversion of intensively-used agricultural lands to short-rotation plantations (SRP)	High	High	Medium	Medium
Crop diversification	Medium	Medium	Medium	Medium
Implementation of Agricultural Advisory Service	High	Medium	Short Term	Long Term
Fertilization plan and diary	High	Low	Short Term	Long Term
Storage facilities for manure	High	Medium	Short Term	Long Term

Prohibitions, restrictions and protective measures for drinking water protection zones depending on the protection level in DWPZ I (VVO I), DWPZ II (VVO II) or DWPZ III (VVO III)	N/a

* - valid for both mountain and plain cluster

N/a – not available

5.4. Review of best management practices – Agriculture

Austrian best management practices are primarily focused on sustainability, protection and other physical measures concerning grassland, arable land, retention and soil protection. Provided measures display strong theoretical and practical background, as well as advantages and disadvantages of each measure. Austrian best management practices generally have medium to high water protection functionality, variable costs of implementation, long term duration of implementation and long-time interval of sustainability.

Croatian best management practices are contained existing laws, acts and agricultural policies. Since Croatia's entry into EU, new measures are proposed via 2014-2020 Rural Development Programme. During the last few years, positive trends in agriculture are observed, such as drastic increase in % of organic farming. However, Croatia still faces a big challenge as new measures must be implemented from various studies, projects and other action plans on EU level. Lastly, Croatia has to put greater effort into supervision and monitoring of agricultural practices, since large percentage of farmers are insufficiently educated and use outdated technology, resulting in agricultural malpractice, such as over-fertilizing, water pollution and pesticide overuse.

Germany – Bavaria provided several best management practices that tackle important issues in today's agriculture, such as conversion of arable land to grassland, establishment of catch crops and conversion to short rotation plantation. Provided measures are focused on soil preservation, protection of groundwater and generally aim towards positive impact on water provision ecosystem service. Measures have strong theoretical and practical background, supported by numerous quotation, advantages and disadvantages. Bavarian best management practices generally have high water protection functionality, variable costs of implementation, short to medium term duration of implementation and short to medium time interval of sustainability.

Italy has provided several best management practices for both clusters – plain and mountain sites. Broadly speaking, Italian measures focus on proper usage of phytosanitary products (and prevention/minimization of their runoff), sustainable soil management, terracing on the hill slopes and crop diversification. For each measure, study and its results are mentioned in practical context, along with advantages and disadvantages. Measures are mostly derived from LIFE project TOPPS (link in chapter 5.5). Italian measures have high water protection functionality, medium to high costs of implementation, short (periodically) to medium duration of implementation and medium time interval of sustainability.

Polish best management practices are derived from CC-WARE project. Numerous measures covering vast amount of agricultural issues are listed and only briefly described, while advantages and challenges of each measure are missing. Implementation of measures in practice is unknown. Provided measures have high water protection functionality, unspecified costs of implementation (location specific) and short to medium duration of implementation.

Slovenia reported several best management practices, focusing on establishment of advisory services, organic farming in DWPZ, ban of fertilizers and manure use in DWPZ and improvement of manure storage. Furthermore, Slovenian measures are supported by prohibitions, restrictions and protection levels in DWPZ which sets out clear rules concerning which actions are allowed and where.

Hungarian measures are mostly related to plain sites, as mountain sites include only small amount of vineyards. Measures are mostly related to protective measures and prohibitions related to DWPZs, as well as for fertilizer and manure usage and storage. Furthermore, same as majority of EU countries, Hungary also strongly encourages organic farming and also agro-environmental payments system, which encourages producers of agricultural lands to adopt farming and production methods which are compatible with the sustainable use of environment, landscape, and natural resources and with the preservation of genetic resources.

Sky Greens – world's first commercial vertical farm

The prospect of growing crops in vertical farms directly inside of cities has been on the collective wish-list of environmentalists, sustainable developers, and futurists for quite some time now. Opened in 2012 in Singapore, Sky Greens is world's first low carbon, hydraulic driven vertical farm. Major problem facing Singapore (and many other cities) today is land scarcity. Sky Greens are using green urban solutions to achieve production of safe, fresh and delicious vegetables, using minimal land, water and energy resources. The vertical farm consists of 120 aluminium towers that extend over 9 meters in height. In total, the vertical farm is able to produce vegetables at a rate of 0.5 tonnes per day.

Figure 7. Sky Green vertical farm

When compared with traditional monolayer farms, the Sky Greens patented vertical farming system intensifies land use and can result in at least 10 times more yield per unit land area. With the harnessing of natural sunlight, there is no need for artificial lighting. Only 40 W electricity (equivalent to one light bulb) is needed to power one 9 m tall tower. With the plants irrigated and fertilised using a flooding method, there is no need for a sprinkler system thereby eliminating electricity wastage, as well as water wastage due to run-offs. Only 0.5 litres of water is required to rotate the 1.7 ton vertical structure. The water is contained in enclosed underground reservoir system and is recycled and reused.

6. Special sites

6.1. Dry areas

- **BP SD1 Drought and Water Scarcity Management System**

Description of the measure

Climate change that is continuing globally and in Europe, will increase the probability of numerous extreme weather and climate events and consequently have impacts on ecosystems, nature resources and human well-being. Expected long-term and recent years' trends in drought occurrence implied that there is a need to change our reactive approach towards a proactive and operative way of thinking about drought management. All of the following projected changes will directly affect domestic water management.
Temperature:

- average annual temperature will increase significantly with each season, as well as temperature extremes,
- global average temperature is projected to exceed 2°C above pre-industrial levels (the upper limit according to the Paris Agreement under the UNFCCC) by 2050,
- annual average land temperature over Europe is projected to increase in the range of 1 to 4.5°C by the end of this century (compared to the reference period 1971-2000)
- decrease in the number of frosty days, many studies show a lengthening of the period between the occurrence of the last spring and first autumn frost,
- increasing number of heat waves

Precipitation:

- changing precipitation patterns, making wet regions wetter, particularly in winter and dry regions drier, especially in summer,
- heavy precipitation events are projected to become more frequent (an increase of up to 35% over most of the Europe), as well as droughts
- for the period of 2021-2050 winter precipitation will increase all over Europe, while summer precipitation will decrease
- longer dry periods in the summer by 2050 and also in autumn and spring by 2100
- possibility of water storage in soil needed for crop production has already been decreased

Hungarian Project Partners gave the illustration of this measure based on their national drought and water scarcity management system. Hungary is considered highly vulnerable from climate change point of view. Facing these challenges it was decided that a national drought monitoring system should be elaborated with its integration into the existing water damage control system, involving currently flood and excess water management. Proper thresholds and respective drought stages will be established as a basis for operative actions.

To this end the development of the Hungarian Operative Drought and Water Scarcity Monitoring System has been started. The system will provide farmers and decision makers with timely information on the extent of water scarcity (supporting irrigation) and the current drought stage in order to avoid or reduce drought damage. It will also support irrigation development and further research programmes.

The drought monitoring network established with 16 stations in 2016, will be extended in the upcoming years. As a heart of the monitoring system, the Hungarian Drought Index (HDI) based on meteorological parameters and soil's water content and a data processing software was also developed. The preparation of a publicly accessible online platform for the dissemination and visualization of drought information is now in the process.

Measures, usually put in place by the water sector in case of serious droughts, could be more elaborated and implemented after the system fully comes to life. For instance: water retention in canals; filling reservoirs; water transfers; pumping due to low water levels; limiting regional water transfer between water directorates etc.

Measure advantages

The measure's biggest advantage is timely prevention. Instead of the current follow-up assessments it provides up-to-date data of the evolution of drought and the current water scarcity. Prevention of drought losses has measurable effects on the national economic costs.

With the Hungarian Operative Drought and Water Scarcity Monitoring System water scarcity of soils will be expressed in mm which enables the determination of soil specific proper operative measures.

Nature of the HDI index (meteorological parameters and soil's water content) enables to characterize the drought/water scarcity on a daily basis. The index is modular, its meteorological parameter can be used alone where proper soil water content data is not available. Data needs can be satisfied from national monitoring systems up-to-date. Its calculation can be eased with algorithmization depending much less from subjective decisions.

Its integration into the existing water damage control system will ease the introduction and usage of the system and make it less expensive.

The system will continuously support the agricultural sector by providing timely relevant data. It can be further developed with web tools, mobile applications etc.

The data stemming from the monitoring system can contribute to new developments in drought and agricultural research while it will also build a much needed new and detailed data base. There is the possibility to interpret the drought index and water scarcity for different crops.

Through the system's internet portal drought and water scarcity data will be available for free for users.

Challenges

In order to have an adequate drought picture in national level proper density of monitoring network should be ensured. Existing monitoring stations could be used if arrangement with their operators is concluded. Funds should be ensured for long term maintenance.

- **BP SD2 Promote integrated ecosystem-based solutions of natural water retention measures**

Description of the measure

Hungarian Ministry of Interior, as coordinating beneficiary, applied for the Life Project titled "Municipalities as integrators and coordinators in adaptation to climate change". The General Directorate of Water Management will also be a project partner.

One of the main objective of the project is to raise awareness and increase knowledge of decision makers at Hungarian local governments, relevant public administration bodies and economic actors about the impacts of climate change and about ecosystem-based natural water retention measures (NWRM) as a powerful tool to improve climate resilience.

It seeks ecosystem-based solutions for the mitigation of the water challenge. Water resources and ecosystems are primarily impacted by climate change, but water retention is also a key element in CCA (Climate Change Adaptation). The prototypes of NWRM that will be developed and implemented on the pilot sites will serve as a replicable model to other municipalities in the Danube basin, facing similar water and climate risks. The demonstrated water retention measures will build on ecosystem services and form part of the local green infrastructure, which serves as natural habitat and support biodiversity.

Measure advantages

The project will develop and promote integrated ecosystem-based solutions of natural water retention measures that support the sustainable land-use practices and increase ecological flows, the quantity of water available for nature. Green infrastructure contributes to the retention of water in landscape, restoration of ecosystem services and halting the loss of biodiversity.

The project targets pressures on biodiversity that are classified by the Prioritized Action Framework (2013) as the most significant threats on the status of the Natura 2000 network in Hungary, namely factors influencing the natural water regime and water supply, land use – especially farming and forestry – and biotic and abiotic natural processes, such as the drying out of natural ecosystems due to climate change.

Challenges

Action A.2 will be "Preparation of NWRM pilot project in Püspökszilágy". The location of the village is extraordinary, as it lies on the drainage divide between the Danube and Tisza river basins. The key surface water is the Szilágyi stream, which is a minor brook with a small catchment area (10 km^2). The annual mean precipitation is only ~600 mm/y. All these geographical characteristics make the village extremely exposed to droughts. Besides, the village has experienced record level flash floods in every two-three years in the last 10-20 years which had never happened before. Both flash floods and droughts cause many damages to agriculture, urban areas and infrastructure. In the upper watershed, the croplands and some forests dominate the landscape, covering steep slopes which significantly increased soil erosion and flash flood risks. Huge amount of sediment (soil loss) can be observed in certain creeks and gullies in case of flash floods. In the lower watershed, where the settlement is built, the floodplain along the Szilagyi stream does not fulfil its water retention role which leads to a broken balance between the stream and the valley bottom. In summer the valley bottom is

completely dry, what negatively impacts on agriculture, ecosystems and the groundwater level. On the other hand, flash floods cause damages to public and residential buildings.

6.2. Riparian strips

6.2.1. Riparian strips in general

Catchment riparian areas are considered key zones to target mitigation measures aimed at interrupting the movement of diffuse substances from agricultural land to surface waters. Hence, unfertilized buffer strips have become a widely studied and implemented "edge of field" mitigation measure assumed to provide an effective physical barrier against nitrogen (N), phosphorus (P), and sediment transfer. Furthermore, they stabilize river bank and control floods. To ease the legislative process, these buffers are often narrow mandatory strips along streams and rivers, across different riparian soil water conditions, between bordering land uses of differing pollution burdens, and without prescribed buffer management. It would be easy to criticize such regulation for not providing the opportunity for riparian ecosystems to maximize their provision for a wider range of ecosystem goods and services. The scientific basis for judging the best course of action in designing and placing buffers to enhance their multifunctionality has slowly increased over the last five years (Stutter et al., 2012). Overall the riparian zone class covers about 90,415 km^2, approximately the 2% of the European continental area (Clerici et al., 2011). European riparian zones are strongly dominated by natural forested habitats (around 69%).

6.3. Best management practices – Special sites – Riparian strips

- **BP SR1 Creation and maintenance of riparian wetlands**

Description of the measure

Riparian wetlands are typically narrow, wet areas that are adjacent to streams and are periodically water-logged because both surface and subsurface water flows towards them. The soil is in most of the cases alluvial (water deposited). They usually present the buffer zone between arable i.e. agricultural land and the stream. Therefore, main function of the riparian wetlands is purification of water. The riparian wetlands form part of the forested riparian buffer strips, but can be seen as a unique type of riparian buffer strip.

Measure advantages

The riparian wetlands primarily affect water quality (i.e. reduction of the water pollution) of drainage water flowing through these areas. The main agricultural pollutants from the arable lands are nitrate (dissolved in water) and phosphorus (attached to soil particles), which are nutrients essential for crop growth but harmful to humans and animals in higher contents.

Mechanisms of nutrient removal within riparian areas include denitrification, assimilation by vegetation and transformation to ammonium and organic nitrogen followed by retention in the soils. All these mechanisms may occur in different seasons and environments. Removal of nutrients from surface inflows is induced by deposition of sediment-bound nutrients and exchange of dissolved nutrients with the soil/litter surface. Removal of nitrogen in subsurface flows can partly be explained by vegetation uptake, but the main mechanism for removal is usually denitrification.

The main and also the most researched mechanism is denitrification where soil bacteria convert nitrates to nitrogen gas that returns to the atmosphere. Natural floodplains can provide ideal conditions for denitrification, due to the occurrence of both saturated and non-saturated soils, a high organic matter concentration and a high water table.

Another crucial aspect is the protection from lateral erosion given by stable forest vegetation within these riparian strips. Lateral erosion can form a huge threat during flood events and could also harm drinking water resources.

Hence the creation or maintenance of riparian wetlands is a crucial measure, especially within DWPZ.

Challenges

The riparian wetlands should be protected, as they currently do not have a specific status of protection in most of the countries. A trade-off between the protection from driftwood and the protection from lateral erosion has to be found for all those areas. Although, this could stimulate discussions among stakeholders and is an integral step towards protection from floods or their mitigation and towards an integral drinking water protection strategy, still persuasive efforts should be made.

- **BP SR2 Buffer Strips along Streams**

Description of the measure

Streams are sensitive sectors in many DWPZ, hence they have to be protected with the highest priority. EU legislation related to the Common Agricultural Policy (CAP) from 2014 to 2020, confirms that farmers, in order to qualify for economical subsidies, are required to comply with certain conditions (basic rules on the environment, climate change, good agricultural and environmental conditions land, public health, animal health, plant health and animal welfare). Conditionality applies through a set of Management Criteria Required (SMRs) and standards of Good Agricultural and Environmental (BCAA), identified in Annex II to Regulation (EU) No. 1306/2013, and adopted annually by a Decree Mipaaf. BCAA1- Establishment of buffer strips along water courses is a conditionality aimed to protect surface and groundwater pollution resulting from agricultural activities. The term “buffer” identify linear formations of herbaceous vegetation, tree and/or shrub interposed between the crops and the stream/channel which intercept surface and sub-surface runoff water, acting effectively as a filter against pollutants / sediments carried by water. The efficacy of nitrogen removal is variable in function of the selected type of buffer strip and, in particular, varies in function of its complexity.

Buffer strips with dense and vital forest cover can also protect the streams from lateral erosion. Within buffer strips forest vegetation has to be stable and management operations have to be carried out in an extremely cautious manner.

For example, in Emilia-Romagna (Italy) the realization of buffer strips is defined with the Submeasure 4.4 - support for non-productive investments linked to the achievements of agro-environment-climate targets of the Rural Development Plan of the Emilia-Romagna Region (PSR 2014-2020). The Emilia-Romagna region has large areas vulnerable to nitrates and areas at risk of erosion to which transport of nutrients in sediments is associated. The measure of PSR is

designed to mitigate the impacts resulting from the use of fertilizers, but also to control the pollution associated with the sediment transport through a farm scale creation of buffer strips and wetland basins.

The PSR among other envisages following types of interventions (Operazione 4.4.03 - Realizzazione di fasce tampone e bacini di fitodepurazione di contrasto ai nitrati):

- buffer strip with herbaceous band and single-strand arboreal and / or shrubby: farmland band 4 m wide, adjacent to the cultivated field, sown with a mixture of long life forage species and single-strand arboreal and / or shrubby of 1 meter wide interposed between the grassy strip and the drainage water body;
- buffer strip with herbaceous band and single-strand arboreal and / or shrubby, with load ditch: load ditch parallel to the channel/stream that collects the waters, with higher water levels to facilitate a subsurface flow between the ditch and the canal/stream; strip of land between the load ditch and the channel/stream consisting of grassy band of 3 m width seeded with a mixture of long life forage species and single-strand arboreal and / or shrubby 1 m wide.
- basin for the phytoremediation of farm land runoff waters: basin, not waterproofed, of area equal to 1-5% of the UAA, buffer strip surrounding the basin of at least 5 m covered with vegetation, main entrance ditch, outflow ditch able to ensure the maintenance of a 50 cm average level in the basin, depressions of 0.50 and 2 m on at least a third of the surface of the basin.

Similar measures exist in other Regions, e.g. Veneto, Lombardia, where it is possible that technical characteristics required for the realization of buffer strips are a little different.

Measure advantages

Buffer strips along streams are common best management practices on global scale. They have high ecological and water protection value since they prevent spreading of contaminants (e.g. nitrates) from adjacent surfaces (e.g. industry, agriculture) towards water bodies.

Challenges

Many water bodies are heavily modified by human activities (e.g. regulation of water courses and maintenance, mowing of vegetation in the buffer zone, artificial material used for surfaces on embankments, construction of access roads, drying up of riparian forests due to hydro-technical modifications), and therefore, the ESS functions are reduced.

As usual when dealing with agricultural land willingness to accept this measure depends largely on the amount of compensation payments. In agricultural areas with relatively high rainfall amounts, it is quite common to establish at least riparian filter strips made of trees and shrubs. Moreover, it is desirable to establish grassed riparian areas because of higher retention effectiveness.

- **BP SR3 Implementation of extensively-used grasslands**

Description of the measure

Riparian strips represent sensitive ecosystems due to their natural interface between the catchment area and the river system. These strips are either affected by the dynamics of the adjacent river or the inflow from the catchment or even both. These strips represent sensitive areas especially in drinking water protection zones of river bank filtrate extraction plants.

An adapted land-use management of these sites is of vital importance to keep or even to improve their protective function during flood events and low water discharge as well as their potential to purify the inflow coming from the catchment area and to regulate the diffused discharge of nutrients into the river.

Extensively used grasslands represent good land-use options for riparian strips. To maintain the ecosystem service water quality regulation of riparian strips the use of fertilizers and pesticides should be prohibited for riparian strips. Due to the proximity and connectivity to both the river and bank filtrate extraction plants these substances can quickly be transported towards one of them. To provide further protection the plowing up of these sites has to be prohibited. In this context, an intensive grazing has to be avoided as well since livestock excretions may provide sources of contamination as well. Grazing should be limited to one or two times a year.

By avoiding intensive grazing on these sites a destruction of the turf by cattle treading can be reduced. To prevent riparian strip grasslands from further degradation the tillage with heavy machinery should be prohibited. Thus, the soil loosens its structure which improves the infiltration capacity as well as the water retention capacity. These processes are additionally enhanced through the root zone of the turf. A dense turf also provides a protection function against soil aggregate destabilization, surface sealing, erosion processes and evaporation losses. Since grasslands typically have a high surface roughness they serve as a momentum sink for overland flow and thus improve the ecosystem service water regulation.

Moreover, the organic matter content of the topsoil on grassland sites favours the water storage capacity and the process of water purification. By avoiding an intensively use of grasslands in riparian strips the activity of soil organisms is encouraged and keeps the bioturbation on an adequate level (BAUCHHENß, 2005). Bioturbation positively affects the soil (aggregate) structure; it improves the connectivity of macropores and enhances the water storage and infiltration capacity (SCHEFFER et al., 2010). Additionally, the intensity of bioturbation positively correlates with the distribution of macropores which in turn is crucially important for the water storage and water retention capacity of the soil system. An increase of interception and transpiration losses on grasslands in general counteract the ecosystem service water provision but do positively affect the water regulation function.

Measure advantages

- Positive impacts on the ecosystem service water provision, water regulation and water quality regulation;
- preservation of soil stress and recovery of (physical) soil properties;
- increasing activity of soil organisms enhances the soil (aggregate) structure, the connectivity of water paths and decomposition processes;

- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffused discharge of nutrients (e.g. nitrate).

Challenges

- Need for scarification to avoid hydrophobic effects of matted roots (SCHOBEL, 2005);
- economic efficiency depending on production emphasis of the farmer

- **BP SR4 Conversion of intensively-used riparian strips to short-rotation plantations (SRP)**

Description of the measure

Short-rotation plantations (SRP) are extensive agricultural land-use measures which mainly serve for the production of firewood. The plantation focus is principally based on fast-growing tree species, such as poplars or willows, which are ready to harvest in between 3 to 8 years depending on the site and species characteristics. Moreover, SRP sites do not need the use of fertilizers to increase the productivity. At harvest, the trees are cut near the soil surface leaving a small part of the trunk. This trunk rest puts out new shoots in spring time so that a new sowing as well as tillage are not required. The new shoots benefit from the existing root structure of the harvested stand since the existing root network simplifies the nutrient and water uptake (ZACIOS et al., 2011).

A use of heavy machinery is only required at the initial phase for site preparation from intensive agricultural use to SRP sites as well as for the harvest. Moreover, SRP plants create a deeper-reaching root system due to their longer growth phases compared to annual crops. Thus, the root system of SRP plants also develops in soil layers under the former plowing depth and loosens up the whole soil structure. Thanks to less soil compaction, the prevention of soil tillage and a high availability of organic matter an increase of activity of soil organisms, e.g. earthworms, is favoured. These structural changes of the soil system can improve the water storage capacity of the soil as well as the water transferability to deeper soil layers (ZACIOS et al., 2012, ZACIOS et al. 2015).

The interception and transpiration losses generally increase as a consequence of the land-use change due to a dense and continuous vegetation cover, increased water uptake from deeper soil layers and greater leaf areas (e.g. of poplars). Hence, the conversion to SRP sites is positively affecting the ecosystem service water regulation. Moreover, the canopy cover reduces the particle detachment through splash effects while the understorey vegetation increases the retention of already detached sediments. Both, the canopy cover and the understorey vegetation prevent the water body as well as a near water extraction plant (e.g. bank filtration) from an oversupply of nutrients and thus contribute to the water quality regulation (ZACIOS et al. 2015).

Measure advantages

- Positive impacts on the ecosystem services, water regulation and water quality regulation;

- preservation of soil stress and recovery of (physical) soil properties;
- decreased use of production inputs (e.g. synthetic pesticides, fertilizers);
- decreased diffused discharge of nutrients (e.g. nitrate).

Challenges

- Enhancing the ecosystem service water provision;
- implementation costs;
- economic efficiency depending on production emphasis of the farmer;

- **BP SR5 Integrated hydraulic-environmental restoration of water streams within the piedmont belt**

Description of the measure

This best management practice originates from the results of LIFE 11 ENV/IT/000243 RII ("Integrates hydraulic –environmental restoration of water streams within the piedmont belt of the Emilia-Romagna region"). The LIFE RII project is designed to enhance the environmental conditions and hydraulic safety of some minor water streams within the piedmont belt and high plains in the province of Reggio-Emilia (Italy). More specifically, it points out that the key concepts underlying the Water Framework Directive 2000/60/EC and the Floods Directive 2007/60/EC, on the need to reduce the flooding risk by improving the ecological status of rivers, can also be applied on the minor water streams network.

A first feasibility study was developed in 2009 to secure waterways, which envisaged the construction of a series of dams to decrease the slope in the mountain stretches. Yet, this solution would have caused a significant deterioration of the ecological status of the watercourses, thus resulting into a disruption of the biological continuity and blocking the natural dynamics of river beds. With the LIFE RII project it has instead been decided to apply experimental alternative technical solutions, based on "river restoration" principles, on the minor watercourse network.

To retain water in the upstream stretch of towns at most, the river section was expanded, wherever possible, to recover the stream bed width lost over the years due to human intervention. In the mountain stretches, due to steep slopes, simple riverside enlargements were not sufficient to "retain water". Hence, stream bed enlargements, "closed" downstream by pebble narrowings, were developed, replenishing green-belt vegetation, in order to retain water during floods. The creation of large floodplains upstream from narrowings, which would be often flooded, encouraged the development of wetlands, characterized by the temporary presence of water, being rather rare habitats in that local context.

Furthermore, in mountain stretches the water outflow was slowed down by creating natural differences in elevation by means of pebbles and timber by fastening trunks with roots to the river banks. It should be highlighted that these works, besides reducing the steepness of the stream bed slope locally, contribute to an environmental enhancement both due to the diversification introduced in the stream bed itself but also thanks to the creation of new natural habitats. To reconnect existing floodplains to the stream bed, making them periodically

floodable, alternative solutions were implemented by rising the stream bed elevation to make streams more easily floodable during floods, also allowing morphology and habitat diversification.

Finally, environmental and natural enhancement measures were implemented in all streams. In particular, the continuity of riparian vegetation strips was improved by planting native hardwoods species and by replenishing green-belt vegetation in barren stretches. Locally sourced indigenous selective plant species cuts were carried out to promote the regrowth of plants and to enhance natural vegetation along the most deteriorated stretches. In all plant management actions a special attention was paid to preventing the proliferation of invasive species.

Measure advantages

- Positive impacts on both river flood protection and hydromorphological quality;
- decreased diffused discharge of nutrients (e.g. nitrate).

Challenges

- Availability of strips of territory facing the river beds to be allocated to riverine/floodable areas;
- implementation costs.

- **BP SR6 Naturalistic restoration for the integrated hydraulic-environmental sustainability of the canals**

Description of the measure

The best practice originates from the results of the project LIFE13 ENV/IT/000169 RINASCE ("Naturalistic Restoration for the integrated hydraulic-environmental Sustainability of the Emilian Canals"). The project proposes to realize for demonstrative purposes the hydraulic-environmental restoration of some drainage canals in the Emilia-Romagna region and aims to show that the key concepts of the "floods" (2007/60/EC) and "water framework" 2000/60/EC directives, concerning the need to reduce flood risk, at the same time improving the ecological status of the water courses, can also be applied to the artificial water network.

The emilian plain is crossed by a dense network of artificial canals, built by man in the course of centuries for the hydraulic drainage: in the artificial network, waters flow not only because of gravity, but also thanks to pumping stations. Therefore malfunctions of a system so distinctly artificial can cause catastrophic damages, thus is essential to increase the levels of flood safety. At the same time, the ecological restoration of the drainage canals represents an important opportunity for the joining of the ecologic network and the improvement of the quality of the environment. The canals selected for the interventions suffer in similar degree of environmental and hydraulic problems: they characterize themselves for a rectilinear course and a geometrical section of trapezoidal shape and there are no floodable areas linked to them. It is important not to forget that the development of urban settlements of the last decades, has further increased runoff outflow, leading to an efficiency crisis of the various hydraulic networks. Add to this the problems of discharge of polluting substances, thus worsening the quality of the waters.

On the whole, the interventions consist of the requalification of canals, by creating floodable naturalistic areas along the banks, the forestation of banks and the creation of an expansion area destined to become a naturalistic humid zone for the accumulation of flood and the phyto-depuration of the water.

Measure advantages

- Positive impacts on both river flood protection and hydromorphological quality;
- decreased diffused discharge of nutrients (e.g. nitrate).

Challenges

- Availability of strips of territory facing the canals to be allocated to riverine/floodable areas;
- implementation and maintenance costs.

- **BP SR7 Guidelines for integrated requalification of natural watercourses**

Description of the measure

The Emilia-Romagna Region is pursuing strategies aimed at mitigating the adverse consequences of floods and of morphological dynamics of the watercourses, which may occur to human health, properties, cultural heritage, economic and social activities, territory and environment. The territory is potentially subject to flooding of lowland areas caused by disruption or overlap of defence levees or hydraulic failure; in the mountainous-hilly areas the prevailing phenomena are linked to hydro-morphological dynamics of river beds and are expressed by local floods and, especially, by intense erosive processes in river beds, which can lead to destabilization of the infrastructure close or overlying the rivers. The causes are partly natural, however are due to a large extent to the change of land use, and to the progressive artificiality of the hydrographic network, who removed part of the areas naturally appointed to the morphological evolution of riverbeds and floods restraint.

The Guidelines, approved by the Regional Council of Emilia-Romagna in 2015 (Bollettino Ufficiale della Regione Emilia-Romagna n.301 del 20.11.2015 (Parte Seconda), aim to develop a territorial defence strategy that addresses toward an approach to the management of the watercourses more in accordance with their natural processes, aiming at a synergy between the river ecosystem objectives and at decreasing the risk from floods and morphological dynamics, as indicated by the EU, which requires to a joint implementation of the directives "Water" (2000/60/EC) and "Flood" (2007/60/EC). The guidelines are directed to the natural hydrographical network, and focus specifically on innovative interventions of "land protection" that allow to reach the objectives of the "Water" Directive by improving the ecological status of rivers.

The guidelines deal specifically with those interventions of morphological requalification which can bring positive effects on flood and morphological dynamics risk mitigation. The measures suggested are intended to reduce the danger of the areas potentially subject to flooding and are designed to be a tool that aims to clarify what are the possible alternatives, the related areas of application, the relevant variables involved, the expected effects.

Measure advantages

- Positive impacts on both river flood protection and hydromorphological quality enhancement.

Challenges

- Compatibility with current land uses and infrastructures in the territory near the riverbeds;
- implementation and maintenance costs.

- **BP SR8 Guidelines for integrated rehabilitation of drainage canals**

Description of the measure

Italian project partners gave an illustration of this measure. The Emilia-Romagna Region in 2003 has created, within the European project LIFE Econet, the activity entitled "The canals and waterways of the provinces of Modena and Bologna - Towards the creation of lowland ecological network". This project has identified a first set of operating procedures relevant to the establishment of the ecological network substantiated in the first "Guidelines for the rehabilitation of drainage canals" and 17 project sheets for redevelopment feasible in situations and specific sites. The Region, 5 years after the first interventions, decided to integrate and further develop the 2003 document by using, as a starting point, an analysis of the redevelopment projects of canals is made under the LIFE Econet.

The Guidelines, approved by the Regional Council of Emilia-Romagna in 2012 (Bollettino Ufficiale della Regione Emilia-Romagna n. 52 del 28.03.2012 periodico (Parte Seconda), are the result of this study and represent an initial list of usable techniques for environmental rehabilitation of the canals; these are to be meant not so much as a technical-design manual, but rather as a tool to address operators in the address of project types and “environmental management” of canals.

Each type of intervention described in the Guidelines is accompanied by a brief description of the suggested technique and problems that it intends to deal with, the precautions that must be taken in its implementation and possible need for future research; there are also “Project Box” related to interventions on the Italian territory, which show a possible practical application.

Similar Guidelines/Manuals exist in Lombardia region (“Linee guida per la Riqualificazione dei Canali Agricoli” (LIRICA) funded by Piano per la Ricerca e lo Sviluppo 2006, Delibera n. 2216 del 29 marzo 2006) and Veneto region (“Manuale per la gestione ambientale dei corsi d'acqua a supporto dei Consorzi di bonifica” edited by Veneto Agricoltura under the agreement signed with Region of Veneto, Regional Council Decision no. 3759 of December 9, 2009).

Measure advantages

- Positive impacts on both river flood protection and hydromorphological quality enhancement.

Challenges

- Compatibility with current land uses and infrastructures in the territory near the channels;
- implementation and maintenance costs.

BP SR9 Implementation of the Technical regulations for the maintenance of natural and artificial watercourses in the RN2000 sites

Description of the measure

The "Habitats" Directive 92/43/EC provides for the establishment of the European ecological network Natura 2000, requiring conservation / restoring of the related habitats. This means that even the maintenance of the watercourses, must take into account, among other things, the possible presence of habitats and animal and plant species of conservation interest.

The Technical Regulations for the maintenance of natural and artificial watercourses in the RN2000 sites, approved by the Regional Council of Emilia-Romagna in 2009, contains provisions that identify the types and methods of intervention in river areas and environmentally compatible costs, trying to combine the preservation of biodiversity in the areas included in the Natura 2000 sites with hydraulic safety criteria and water management which are the basis of the routine maintenance of the waterways, natural and artificial.

The Disciplinary has the main purpose to regulate the maintenance of natural and artificial waterways that can be considered to low environmental impact and that, consequently, if located in the Natura 2000 network sites, are exempt from the execution of the incidence evaluation or pre-assessment, if the works are compliant with the conditions, the types and the execution times indicated.

Measure advantages

- Positive impacts on both river flood protection and riverine habitats quality.

Challenges

- Implementation and maintenance costs.

BP SR10 Guidelines for programming and implementation of maintenance operations on vegetation and riparian forests

Description of the measure

In the operative management of the territory emerge the needs to combine the hydraulic safety requirements with the need to protect biodiversity and landscape, to define process of information and participation in the definition of the programs, to establish the procedures of transparency and efficiency in the allocation of works and control their execution.

The guidelines help to ensure the coordination of measures aimed at hydraulic risk reduction with the need for protection and enhancement of forests and tree and shrub vegetation in the

riparian areas, through managing modes of programming and control of the activities of maintenance of the vegetation.

The guidelines propose, in relation to the different requirements of securing intervention (insufficient maximum hydraulic discharge flow, need to laminate the flood flow, etc.), the type of action on vegetation riparian and of river bed more consistent with the environmental quality objectives of the water course his critical issues highlighted (macrobenthos, diatoms, fish communities, etc).

Beyond Emilia romagna Region, similar Guidelines exist for Provincia di Trento ("Linee guida per la gestione della vegetazione lungo i corsi d'acqua in Provincia di Trento" produced within the project T.E.N. Trentino Ecological Network: a focal point for a Pan-Alpine Ecological Network, LIFE11 NAT/IT/000187, http://www.lifeten.tn.it/) and Regione Marche ("Linee guida per l'elaborazione dei progetti generali di gestione dei corsi d'acqua", Deliberazione n. 100 del 29 Aprile 2014).

Measure advantages

- Positive impacts on both river flood protection and riverine ecological quality;
- decreased diffused discharge of nutrients (e.g. nitrate).

Challenges

- Compatibility with current land uses and infrastructures in riparian strips;
- implementation and maintenance costs.

- **BP SR11 Wooded Buffer Strips in rural areas (LIFE99 ENV/IT/000083)**

Description of the measure

The pollution of water resources is one of the main problems connected with agricultural activities. 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. The pollutants transfer is linked to water flows: for substances with lesser absorbance by soil particles (e.g. nitrates) the transfer happens mainly through surface flow or deep percolation of solutions; for highly absorbed substances, (phosphorus compounds), erosion and sedimentation are the main transfer systems. The Woody Buffer Strips (WBS) are an effective mean to retain, assimilate and remove nutrients coming from agricultural fields.

The LIFE project "Progetto dimostrativo sull'impiego di Fasce Tampone Boscate (FTB) in ambiente agricolo" aimed to demonstrate that WBS offered an efficient method for reducing nutrients-leaching from agricultural field and also could provide an interesting economic opportunity for farmers, by enabling the production of wooden biomass for energetic use and giving economic support through financial subsides (Structural Funds).

A cost-benefit analysis quantified the results in terms of Measure advantages for the environment and opportunity for the farmers. The environmental benefits were clearly

quantified with an analysis of the conditions that make the investment convenient for farmers, with or without public incentives. The main results of such assessment are:

- water quality and nitrogen retention: young WBS are able to reduce up to 50% the amount of total fluid nitrogen that percolates through them by the sub-superficial layer;
- in terms of % retention no appreciable difference was observed between 5 and 15 meters wide WBS, confirming the key role of the first 5 meters of the hedge as the main area where waters enriched with nitric nitrogen meet favourable conditions for denitrification; retention capacity of a 100 meters long and 5 meters wide WBS was 6.3 kg per year of total fluid nitrogen;
- the most evident effects were a decrease in the releasing of nitric nitrogen and an increase in the releasing of organic nitrogen;
- the main factor limiting denitrification processes is carbon, energy source for bacteria; this leads to the assumption that trees growth with a higher biomass production will support an increase in nitrate-reducing bacteria's activity;
- when WBS is intended mainly for environmental purposes or where the wood production is meant for construction purposes it's not profitable; WBS that partially uses species aimed at producing wooden biomass for energy purposes, shows profitability only when there are public incentives, it's clearly profitable in those cases in which plants are used to produce wood biomass, even without public incentive.

Similar experiences have been obtained in central Italy with the projects REWETLAND (Widespread introduction of constructed wetlands for a wastewater treatment of Agro Pontino, LIFE+08 ENV/IT/000406) and RIPARI (Reduction of impacts of agricultural pressures on water resource, funded by Regione Toscana, POR FESR 2007-2013).

Measure advantages

- Decreased soil erosion;
- decreased diffused discharge of sediments and nutrients (e.g. nitrate, phosphorus).

Challenges

- Compatibility with current land uses and infrastructures in riparian strips;
- reduction of extension of productive farmland;
- implementation and maintenance costs.

- **BP SRF12 Protective forests**

Description of the measure

In general protective forests are forests that mitigate or prevent negative impacts of natural hazards (e.g. rockfall, avalanche, erosion, landslide, debris flow or flooding) on people and their assets. Protective forests should be established along watercourses, in order to mitigate flooding and prevent agricultural pollution from reaching the water.

Protective forests are forests that prevent the impact of natural hazards (rockfall, avalanche, erosion, landslide, debris flow or flooding) on people and their assets. Their vital protective function is reducing soil erosion which degrades water quality. Regarding floods, forests reduce stormflow peaks and delay them better than any other land cover. A buffer zone of trees along both sides of a watercourse has a purpose of protecting stream and river banks from undue horizontal erosion, as well as act as a filter and depository for sediment, pesticides and fertilizers from upslope land use (FAO, 2008). Establishing protective forests prevents leaching of agricultural pollution to waters, increases water infiltration and reduces and slows down the runoff.

Best management practices concerning special sites are systematically shown in Table 7, where relevance of each BMP can be seen (water protection functionality, cost of the measures, duration of implementation and time interval of sustainability).

Table 7. Best management practice relevance – Special sites

Best management practice	Water protection functionality	Cost of the measure	Duration of implementation	Time interval of sustainability
DRY AREAS				
Drought and Water Scarcity Management System	High	Medium	Medium	Long Term
Promote integrated ecosystem-based solutions of natural water retention measures	High	Low	Medium	Long Term
RIPARIAN STRIPS				
Creation and maintenance of riparian wetlands	High	Medium	Long Term	Long Term
Buffer strips along streams	High	Medium	Long Term	Long Term
Implementation of extensively-used grasslands	High	Medium	Medium	Medium
Conversion of intensively-used riparian strips to short-rotation plantations (SRP)	High	Medium	Medium	Medium
Integrated hydraulic-environmental restoration of water streams within the piedmont belt	High	Medium	Medium	Medium
Naturalistic restoration for the integrated hydraulic-environmental sustainability of the canals	High	High	Medium	Medium
Guidelines for integrated requalification of natural watercourses	Medium	Medium	Long Term	Medium
Guidelines for integrated rehabilitation of drainage canals	Medium	Medium	Long Term	Medium
Implementation of the Technical regulations for the maintenance of natural and artificial watercourses in the RN2000 sites	Low/Medium	Low/Medium	Short Term	Medium

Guidelines for programming and implementation of maintenance operations on vegetation and riparian forests	Low/Medium	Low/Medium	Short Term/Medium	Medium
Wooded Buffer Strips in rural areas (LIFE99 ENV/IT/000083)	High	High	Medium	Medium
Protective forests	High	Medium	Short Term	Long Term

6.4. Review of best management practices - Special sites - Riparian strips

Best management practices concerning riparian strips are generally smaller in number than BMP's in other types of land use, but nevertheless they cover wide variety of issues. Some measures overlap – e.g. establishment of protective forests and buffer strips along streams and rivers. Buffer strips along streams are one of the classical Best Practices on global scale, since they have high water protection functionality, medium costs and long term sustainability. Buffer strips protect streams and rivers from direct infiltration of sediments and nutrient loads (nitrogen, phosphorus, sulphur) and prevent lateral erosion.

Only Slovenia and Croatia have reported single measure – establishment of protective forests. Further efforts must be put into enforcement and implementation of best management practices for riparian strips, mostly due to the fact that both countries are rich concerning water resources and have similar issues regarding pollution from agricultural sources.

7. General Best practices

This chapter describes best practices regardless of land-use type, divided into two main groups: flood measures and measures for drinking water quality and quantity.

7.1. Drinking water quality and quantity measures

EUROPEAN UNION

The following measures are recognized as most significant in scope of drinking water protection and are derived from Water Framework Directive.

- **Establishment of water protection zones/areas**

According to the Article 6 of Water Framework Directive (2000/60/EC), all Member States shall ensure the establishment of a register or registers of all areas lying within each river basin district, which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water. They shall ensure that the register is completed at the latest four years after the date of entry into force of this Directive.

The register or registers shall include all bodies of water identified under Article 7(1) and all protected areas covered by Annex IV. For each river basin district, the register or registers of protected areas shall be kept under review and up to date.

- **Monitoring of surface water status, groundwater status and protected areas**

According to the Article 7 of Water Framework Directive (2000/60/EC), Member States shall ensure the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each river basin district:

for surface waters such programmes shall cover:

- the volume and level or rate of flow to the extent relevant for ecological and chemical status and ecological potential;
- the ecological and chemical status and ecological potential;

for groundwater such programmes shall cover:

- monitoring of the chemical and quantitative status;

for protected areas the above programmes shall be supplemented by those specifications contained in Community legislation under which the individual protected areas have been established.

These programmes shall be operational at the latest six years after the date of entry into force of this Directive unless otherwise specified in the legislation concerned. Such monitoring shall be in accordance with the requirements of Annex V.

Technical specifications and standardised methods for analysis and monitoring of water status shall be laid down in accordance with the procedure laid down in Article 21 of WFD.

The following section describes how particular countries implement general measures (BMP) originating either from Water Framework Directive, Floods directive or Drinking Water Directive or any other specific measure. Although all EU countries are obliged to implement measures from WFD and Floods directive, not all have included those measures within their country specific best management practice report (D.T.1.2.1). Therefore, the following section provides measures which are described on country specific level (particularities, establishment of DWPZ, methodologies, limitations).

AUSTRIA

- **Catchment areas of Vienna Water Supply (VWS)**

The City of Vienna supplies its citizens since 1873 with drinking water from catchments situated in the Northern Calcareous Alps. Actually more than 95% of the water resources (some 380.000 m² per day) originate in those areas. The catchments comprise some 1000 km² and are also used for the water supply of Graz – the second largest city in Austria - and numerous local communities. In sum more than 2 million people are supplied with drinking water from this area.

Situated in the mountains the elevations of the catchments range from some 450 m a.s.l. up to 2200 m a.s.l. The mountains are characterised by steep slopes and "flat" tops. On the slopes forests prevail, on the mountain tops pastures and "krummholz"- vegetation are dominant. The land uses are – besides water supply – forestry, mountain pasture and tourism. From the hydrogeological point of view the area can be described as karstic. Small settlements are situated in the valleys.

Figure 8. Map of Vienna and the water catchment areas

- **BP VWS1 Purchase of catchment areas**

Description of the measure

When the centralised water supply of Vienna started in 1873 some area of the first spring – Kaiserbrunn – was given to the city of Vienna by the emperor. This symbolic act to acknowledge the importance of the centralised water supply for Vienna was the starting point for the strategy of purchasing areas important for catchment and spring protection. This strategy is still valid.

Measure advantages

Property is a very strong right in all European legal systems. Two thirds of the area is covered by forest and one third by pastures, meadows and stone. The city of Vienna owns some 325 km² in the area. This area is explicitly appointed for spring protection. The forest department of the city is managing the estate with the priority objective of water protection. On the area of some 1000 km² there is just one rack railway opened in 1897 and one cable car opened in 1926 which is peculiar in a touristic country like Austria. Also the extensive manner of the different land-use activities is due to the ownership.

Additionally the water right is connected to the premises. Although the water right can be sold separately it is of advantage to own the parcels on which the springs are located.

As a single measure it is surely the most effective one for water protection reasons.

Challenges

The costs pose a big problem. Additionally the owner of the premises needed for water protection has to be willing to sell.

- **BP VWS2 Decreed Water protection zones**

Description of the measure

Areas used for water supply can be decreed by law as protection zones. Some activities are not allowed, other activities have to be approved by the public authorities. The authorities can also request specific conditions under which activities may be undertaken.

For the catchment areas of the city of Vienna there are two protection zones in force: “VO Schutz der Wasservorkommen im Schneeberg-, Rax- und Schneealpengebiet“ (BGBl. 353/1965) and „VO Schutz der Wasservorkommen im Hochschwabgebiet” (BGBl. 345/1973).

Measure advantage

The measure is quite effective. Water suppliers are parties in the official procedure and can forward documentary evidence.

Challenges

The negotiations with other stakeholders may take long time. The evidence asked from the water supplier by the authorities may take a long time to compile and may be costly.

- **BP VWS3 Spring observation**

Description of the measure

Vienna Water undertakes so called spring observations in order to monitor the catchment areas and document peculiarities. It is also important to communicate with other stakeholders (keepers of huts, herders, tourists…) and get informed about their observations and possible needs and also to inform them about water protection measures and behaviour in water protection areas.

Measure advantage

It is the best possible information you can get about the situation in the catchment area concerning natural changes, land-use trends and developments. The communication with other stakeholders helps to create mutual understanding and confidence.

Challenges

Depending on size of the area it takes time and the observations have to be documented and evaluated. There also has to be appropriate response.

- **BP VWS4 Implementing and maintaining disposal infrastructure**

Description of the measure

The appropriate disposal of faecal waste is crucial for the protection of water, especially within the water protection zones, where it is one of the most dangerous contaminant. In mountain huts the problem is occurring and in most cases not easy to solve. There are different technical possibilities to dispose human faecal waste.

Measure advantage

The disposal of human faeces minimises the hazard of microbial contamination and thus reduces the risk for the water supply.

Challenges

This measure is also cost-intensive.

- **BP VWS5 Set up and implementing meteorological and hydrological measuring stations**

Description of measure

All springs used for drinking water supply have to be equipped with sensors in order to assess water quality and quantity. Additionally an appropriate number of meteorological stations have to be set up and equipped with sensors measuring different parameters. The implementation has to be consulted by meteorological experts.

Measure advantage

Knowing about precipitation, discharge and many other parameters can serve in assessing the quantity and quality of the tapped water. You can decide to direct the water to the end user or to divert the water to the recipient body. Additionally you can use the data for research activities, preservation of evidence in case of contaminations.

Challenges

In this case it is not only the cost of implementing the measuring system. Maintenance costs are also significant. For this staff has to be trained in order to fix at least less serious problems. Additionally the data has to be processed and used for decisions.

- **BP VWS6 Karst research programme**

Description of measure

In the late 1980s it became evident –due to the nuclear disaster of Chernobyl and the following fall-out - that Vienna Water did not know enough about the karst system and the predominant processes governing water infiltration, storage and flow. Vienna Water decided to start a systematic and catchment area covering survey. The main objective of the research activities was to support the supply of Vienna with drinking water in a sufficient quantity and quality that is meeting all hygienic standards throughout the year.

The task was to map and describe this natural system by gathering, evaluating and interpreting data and processes.

Measure advantage

Research activities help to describe and identify hazards, but also to assess and calculate risks. They are indispensable when designing and locating specific measures.

The results of research activities are the basis for evidence presented in official procedures deciding about activities of third parties. They help to gain evidence in case of contamination and to design measures of future calamities prevention.

Challenges

A research programme like the karst research programme of Vienna Water is intended to be thorough, comprehensive and fundamental. This means it is long-lasting and costly. Some of the investigations are at the edge of science. Many different faculties are involved. The coordination effort is enormous. Sometimes it is not easy to find scientists who are able to perform the necessary tasks.

- **BP VWS7 Developing and implementing tools**

Description of measure

An IT-System based on the geographical information and connected to a data base storing the data from the monitoring stations was designed, planned and implemented at Vienna Water. It is continuously upgraded with each study and survey performed.

Measure advantage

Only such a tool where all results of the research activities and the data of the monitoring system are retrievable makes it possible to realize the goals and objectives intended but also necessary for an appropriate water supply system for almost 2 million people.

Challenges

The design of such an IT-system is labour-intensive, costly and long-lasting. To operate such a system effectively and to reach an adequate value from the system, well trained users are needed, which is an additional effort.

CROATIA

- **BP DWPM1 Establishment of sanitary protection zones**

Description of the measure

Sanitary protection zones are protected areas, or areas of special water protection, where additional protection measures need to be implemented in order to protect water and the aquatic environment. In line with the Water Act, areas or springs or other water resources that are used or are reserved for the public water supply, as well as areas where water is captured from rivers, lakes, reservoirs etc., must be protected from intentional or accidental pollution and from other impacts that could negatively affect the health suitability of the water or its abundance.

In Croatian case, particular interest is put on springs that capture groundwater (84% of drinking water is abstracted from GW). Sanitary protection zones in this case are divided according to type of aquifer:

1a) Sanitary protection zones for springs that capture groundwater from aquifers with intergrain porosity are:

- restriction and control zone – zone III,
- strict restriction and control zone – zone II, and
- strict protection and control regime zone – zone I.

1b) Sanitary protection zones for springs that capture groundwater from aquifers with fracture and fracture-cavern porosity are:

- restriction zones – zone IV,
- restriction and control zones – zone III,
- strict restriction and control zones – zone II, and
- strict protection and control regime zones – zone I.

Table 8. Restrictions and prohibitions within the individual sanitary protection zone in Croatia

Zone	Aquifer with intergrain porosity
III	wastewater discharge without previous treatment
	temporary or permanent waste disposal
	construction of facilities for recovery, treatment and disposal of hazardous waste
	construction of chemical industrial facilities
	mining excluding geothermal and mineral waters
	exploration and exploitation wells, except for water research
II	prohibitions from zone III, and additionally:
	agricultural production, except ecological (organic)
	cattle production (maximum 20 livestock units)
	recycling or waste transfer stations
	the formation of new cemeteries and expansion of existing
	discharge of treated and untreated wastewaters from roads
I	all activities except those related to: abstraction, conditioning, transfer of water in the supply system.
Aquifer with fracture and fracture-cavern porosity	
IV	wastewater discharge without previous treatment
	construction of production facilities for hazardous substances
	construction of facilities for recovery, treatment and disposal of hazardous waste
	construction of facilities for storage of radioactive, hazardous or oil-based fuels and materials
	removal of topsoil, use of powder explosives
	exploration and exploitation wells, except for water research
III	prohibitions from zone IV, and additionally:
	temporary or permanent waste disposal
	pipeline construction (hazardous fluids)
	construction of gas stations without proper technical precautions
	surface of underground mining excluding geothermal and mineral waters
II	prohibitions from zone III, and additionally:
	agricultural production, except ecological (organic)
	cattle production (maximum 20 livestock units)
	the formation of new cemeteries and expansion of existing
	construction of all industrial facilities that pose threat to water environment
	forest clear cuts except sanitary cuts
I	all activities except those related to: abstraction, conditioning, transfer of water in the supply system.

In sanitary protection zones active or passive protective measures are undertaken. Passive measures include restrictions and prohibitions (as seen in Table 8.), while active measures, which are proposed by an expert (e.g. hydrogeologist) and approved by competent authority, include:

- Monitoring of water quality on entire catchment area;
- construction of public water supply infrastructure;
- construction of wastewater infrastructure (sewage);
- encouraging clean industry and organic farming;
- construction of proper manure storage areas.

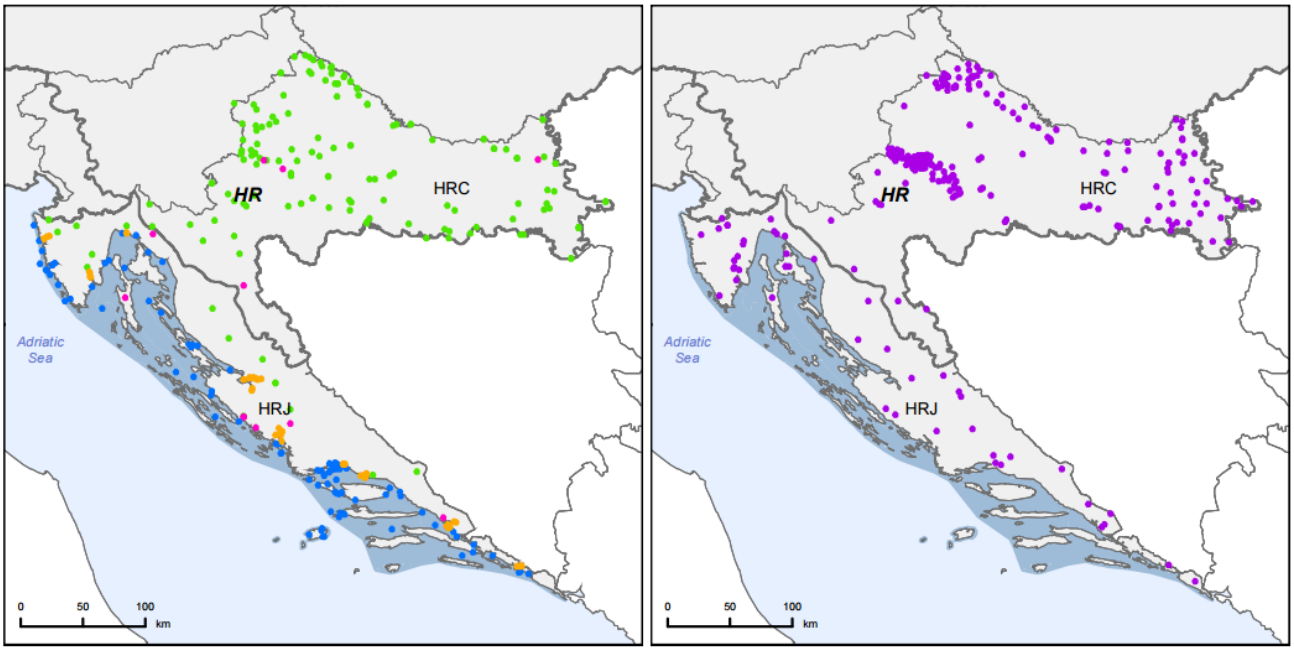
- **BP DWPM2 Monitoring of ground- and surface waters**

Description of the measure

In Croatia monitoring of water quality is performed by the Head Water Management laboratory of Croatian Waters, and laboratories authorised by the Ministry of Agriculture. Indicators that are being monitored:

- Volume, level, flow, speed, hydromorphological characteristics, ecological and chemical status, and ecological potential for surface waters;
- ecological and chemical status and ecological potential for coastal waters;
- chemical status for waters of the territorial sea;
- quantity and chemical status of groundwater.

In Croatia there are 281 surface water monitoring sites and 371 groundwater monitoring sites. Three types of monitoring are being carried out: surveillance monitoring, operational monitoring and quantitative monitoring.



Maps of surface water (left) and groundwater (right) monitoring stations

- River monitoring stations
- Lake monitoring stations
- Transitional water monitoring stations
- Coastal water monitoring stations
- Unclassified surface water monitoring stations
- Groundwater monitoring stations
- River Basin Districts
- Countries outside EU

Source: WISE, Eurostat (country borders)

Figure 9. Maps of surface water (left) and groundwater (right) monitoring stations in Croatia

Water quality for public water supply (drinking water) is supervised by the Croatian Institute for Public Health. Samples for water quality control are taken minimum four times a year.

According to Croatian regulations on the parameters of assessment and methods of analysis of water for human consumption (OG 125/13) there are two types of monitoring, audit and regular monitoring. Audit monitoring includes a large number of microbiological, chemical and indicator parameters to be carried out in order to determine the status of all parameters and their compliance with the requirements of water for human consumption. The purpose of regular monitoring is to obtain basic data on sensory, physical, chemical and microbiological parameters of water for human consumption. Mandatory parameters tested in regular monitoring are the following physico-chemical and chemical parameters: aluminium, ammonia, color, conductivity, hydrogen ion concentration (pH value), odour, turbidity, nitrite, taste, iron, chloride, nitrate, KMnO4 consumption, residues of disinfectants (sip, chlorite, chlorate, ozone, ...), temperature, and microbiological parameters: Escherichia coli, total coliforms, enterococci, the number of colonies 22°C, 37°C number of colonies, Clostridium perfringens (including spores), Pseudomonas aeruginosa. Those parameters for which it was established that the period of two years has not reached the limit, and that the risk assessment determines that there is little chance of finding discrepancies further sampling can be excluded in the annual monitoring.

- **BP DWPM3 Establishment of protected areas**

Description of the measure

In Croatia, over 2700 protected areas have been designated: over 900 areas are designated for drinking water abstraction under Art. 7 of the WFD and a similar number are designated as bathing protected areas. According to WISE there are 649 protected areas in HRC (continental) river basin district and 254 in HRJ (Adriatic) river basin district. Electronic register (Water Information System) operated by Croatian Waters has been established, and it is comprised of:

- Register of protected areas for drinking water;
- cadastre of water, water resources and water buildings;
- cadastre of water protection and water usage;
- cadastre of extreme hydrological phenomena;
- cadastre of erosion conditions and measures against erosion;
- database of measuring stations and laboratories performing water analysis.

Water Information System keeps track of issued water permits and concessions for economic use of water (including amounts of abstracted water). Through the issuance of water permits, control is being performed, and if necessary, utilization of water resources is limited.

Furthermore, hydrological information system has been set up (HIS 2000). HIS 2000 is under the authority of Croatian Meteorological and Hydrological Services and available to public via http://hidro.dhz.hr/.

- **BP DWPM4 Measures for mitigating accidental and sudden pollution of waters**

Description of the measure

In the reporting period 2009-2012 there have been 258 cases of water pollution (35 accidental and 223 sudden). Most common pollutants were: industrial wastewater discharge, traffic (including traffic accidents), municipal wastewaters, disasters related to oil/gas (transport accident, spills), pollution from oil industry, pollution from farms and pollution from unknown sources. In 2011 Croatia has issued „State plan – measures for mitigating accidental and sudden pollution“ (OG 5/11) which contains detailed guidelines, activities and plans which need to be undertaken in case of pollution event of any scale.

- **BP DWPM5 Proclamation of sensitive areas**

Description of the measure

In compliance with the obligations resulting from the activities and decisions of the Danube River Protection Convention and Decision on determination of sensitive areas (OG 23/10), Croatia proclaimed the area of the Danube river basin a sensitive area due to eutrophication of the Danube Delta and applied more advanced treatment with nitrogen and phosphorus removal in all agglomerations larger than 10.000 PE (population equivalent).

Croatia proclaimed the mainland part of the Adriatic Sea basin a single sensitive area for protection of protected areas designated for abstraction of water for human consumption and shall applied more advanced treatment with nitrogen and phosphorus removal if necessary in all agglomerations larger than 10.000 PE for all discharges into inland waters. In order to protect the areas designated for the abstraction of water for human consumption, the mainland part of the Adriatic Sea basin is given the highest level of protection. This is an area of significant strategic water reserves, whose protection is a national priority of utmost importance. This area is a karst area which, in comparison with other areas, has specific characteristics in view of groundwater flow and pollution transfer, which makes the implementation of groundwater and groundwater ecosystem protection measures additionally complex.

- **BP DWPM6 Prohibition of emissions into groundwater**

Description of the measure

Regulations strictly prohibit direct discharge of treated wastewater into groundwater. Only indirect discharge is allowed, in following cases where:

- recharge area is at such distance from the discharge area that the costs of drainage would be irrationally high

  or

- it is proven that such discharge has no negative effect on status of groundwater and environment

- **BP DWPM7 Monitoring of production, import and use of chemical products**

Description of the measure

As a way of reducing chemical pollution of waters, Croatia has put in power the new legislation concerning better monitoring of production, import, use and management of chemical products (e.g. agriculture, industry). The Law on chemicals (OG 18/13) orders that records must be kept on all chemical products entering Croatia, which is being controlled by Croatian Institute for Toxicology and Antidoping.

Concerning use of chemicals in agriculture, regular monitoring of pollution state is being performed by Croatian Agricultural Agency.

SLOVENIA

- **Measures for drinking water quality and quantity**

Description of the measure

Following measures are defined in the Slovenian Waters act (Official Gazette of the Republic of Slovenia 67/02, 2/04 – ZZdrI-A, 41/04 – ZVO-1, 57/08, 57/12, 100/13, 40/14 in 56/15), Rules on drinking water (Official Gazette of the Republic of Slovenia 19/2004, 35/2004, 26/2006, 92/2006, 25/2009 in 74/2015) and Rules on criteria for the designation of a water protection zone (Official Gazette of the Republic of Slovenia 64/2004, 5/2006, 58/2011, 15/2016).

1. Determination of limit values for drinking water;

2. Yearly monitoring for drinking water (sampling sites, frequency of sampling, samplers and laboratories that perform testing of samples);

3. Delineation and establishment of the drinking water protection zones (DWPZ) for karst, porous and fissured aquifers and for surface waters: capture area (fenced); the narrowest area with the most rigorous protection regime (I); narrow area with rigorous protection regime (II); and, wider area (the whole recharge area) with moderate protection regime (III) with prohibitions, restrictions and protective measures within particular drinking water protection zone depending on the protection level.

With the delineation of drinking water protection zones for particular drinking water source, prohibitions, restrictions and protective measures are defined and depend on the protection level in particular DWPZ (DWPZ I (VVO I), DWPZ II (VVO II) or DWPZ III (VVO III)).

Protective measures for different interventions in DWPZ, such as facilities constructions, implementation of the construction work, etc., for which it is expected that during the construction and implementation a risk for pollution of the water body can exist, must be planned based on the risk analysis, so that the risk of pollution of the water body due to facilities constructions and implementation of the construction works is acceptable. The risk analysis for pollution of water bodies is provided by investor of intervention in the environment in DWPZ.

7.2. Flood mitigation measures

This subchapter lays out best practices and measures related to flood defence and mitigation of harmful flood effects on water quality and quantity related to drinking water sources, focusing on non-structural measures. While it provides a framework for a broad set of mitigation measures relative to protection of drinking water, other measures (i.e. reduction of potential flood damage on housing and structures) which are usually part of the flood damage reduction planning documents are not addressed.

Although some countries have not dedicated chapter for flood measures, many measures are contained within existing best practices in various clusters.

All EU member states are obliged to implement Directive on the assessment and management of flood risks (2007/60/EC). The aim of EU Floods Directive is to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity. The Directive requires member states to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015. The Directive applies to inland waters as well as all coastal waters across the whole territory of the EU. The Directive shall be carried out in coordination with the Water Framework Directive, notably by flood risk management plans and river basin management plans being coordinated, and through coordination of the public participation procedures in the preparation of these plans. All assessments, maps and plans prepared shall be made available to the public.

The following section describes how particular countries implement general measures (BMP) originating from EU Floods directive. Although all EU countries are obliged to implement measures from EU Floods directive, not all have included those measures within their country specific best management practice report (D.T.1.2.1). Therefore, the following section provides measures which apply to all EU states, but they are described on country specific level (particularities, methodologies, limitations).

CROATIA

- **BP FM1 Flood hazard and flood risk maps**

Description of the measure

During 2013 and 2014 Croatia participated in EU IPA 2010 TWINNING PROJECT “Development of Flood Hazard Maps and Flood Risk Maps” with purpose of implementing EU Floods Directive (with final aim of developing flood hazard maps and flood risk maps).

Developed flood hazard and flood risk maps are in 1:25000 scale and contain 3 scenarios:

- High probability T ≈ 25 years
- Medium probability T=100 years
- Low probability T ≈ 1000 years - large dam and dike breach

Flood risk maps include following content: number of population in danger; land-use data from CORINE Land Cover 2006; infrastructure (school, airport, hospital…); environment protection data from Register of protected areas (DWPZ, Natura 2000, national parks etc.) and cultural heritage data.

Maps are published in WebGIS format and are available to public via http://voda.giscloud.com/ .

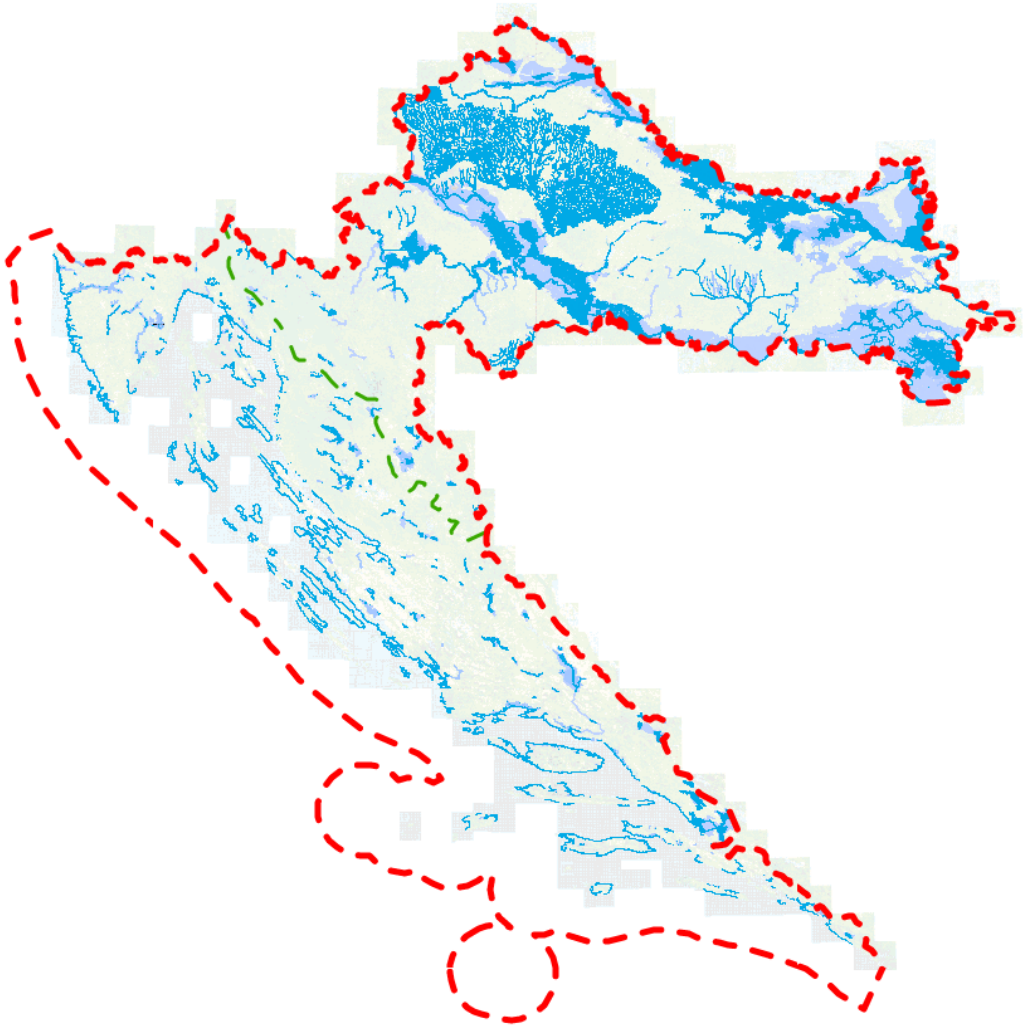


Figure 10. Flood hazard map
(Croatian waters, 2014)

- High probability of flood hazard
- Medium probability of flood hazard
- Low probability of flood hazard

- **BP FM2 Operational flood control**

Description of the measure

An example of this measure is provided by Croatia. Operational flood control is being implemented according to the National Flood Defence Plan (Official Gazette No. 84/10). Flood defence is spatially organized into river basin districts, sectors, areas and sections. Body responsible for the implementation of operational flood control is Croatian Waters. Status of operational flood control is generally regarded as good, with numerous successful actions to support that claim. National Flood Defence Plan sets out the following sets of measures:

Monitoring, planning and study measures:

- Planning and implementation of the monitoring system of water regime and announcements of flood waters;
- planning and development of mathematical simulations and forecast systems of hydrological models;
- planning and management of flood risks by monitoring the development of spatial planning documents and by the issuance of water rights acts;
- creation and updating of implementation plans of flood;
- update of hydrological forecasting models;
- maintenance and upgrading of information and communication system.

Water regulation measures:

- Planning and implementation of construction, reconstruction and extension of the protective buildings and structures for basic amelioration drainage that can accept and evacuate high waters;
- planning and implementation of maintenance of natural and artificial watercourses and other waters, regulation and protection of buildings and structures for basic amelioration drainage in flood control system.

Preventive preliminary work:

- Regular checks on the state (condition) of structures;
- regular checks on the state of river beds;
- ensuring adequate retention area for reception of high waters;
- ensuring adequate equipment and materials for flood defence and its storage.

Direct measures of regular and extraordinary flood protection:

- Forecast time and size of encountering water wave;
- frequent checks on the condition of protective building and structures;
- further work on protective infrastructures and melioration drainage that can accept or evacuate high waters;

- removal of causes that impede the flow of water in waterbeds;
- functional provision of the facilities built for the relief of high waters (drainage canals, accumulations with retention area, overflows, dams…);
- construction of second defence line in case there is a risk of breach, demolition and overflow of protective buildings;
- in case of flooding caused by ice accumulation in streams or when ice barriers (caps) which interfere with the flow of the water are present, breaking the ice surface and preventing and stopping the accumulation of ice masses in waterbeds.

Actions after the end of regular flood protection:

- Urgent overhaul of regulative and protective structures in case new water waves may arise;
- removal of waste, sediment or any other flotsam caused by water wave;
- geodetic survey of the flood line;
- data acquisition (e.g. actions, material costs, expenses) followed by reimbursement of expenses;
- preparation of a comprehensive report on the conducted flood control with proper analysis and assessment of implemented measures.

- **BP FM3 Monitoring and forecasting of hydrometeorological phenomena**

Description of the measure

For more efficient implementation of the operational flood protection, Croatian Waters and Croatian Meteorological and Hydrological Services have automated the majority of water level meters, making data on water levels available in real-time. Data is available to centres for flood control, teletext of Croatian National Television, website of Croatian Waters as well as all mobile phone users.

Hydrological forecasting is insufficiently developed. Croatian Waters and Croatian Meteorological and Hydrological Services are putting effort into improvement.

Meteorological data from automated stations are available in real-time to flood control centres and Croatian Waters, via special web-portal.

- **BP FM4 Water resources**

Description of the measure

To prevent inappropriate use of land which plays an important role in maintaining of water regime, the Water Act (Official Gazette No. 153/09, 63/11, 130/11, 56/13) defines particular land particles (water-bearing and abandoned river beds of inland surface waters, regulated and unregulated inundation zones and islands in the water-bearing beds) as water resources. If a land particle is declared as a water resource, it becomes a part of land registers and spatial

plans for which the law prescribes specific measures and limitations. Main issue – disorderly registers.

- **BP FM5 Financial property insurance from uncovered flood risks**

Description of the measure

Poorly developed so far, but by increase of market economy, insurance measures are expected to rise in the near future.

- **BP FM6 Mitigation of risks due to sudden collapse or overflow of dams**

Description of the measure

Prepared documentation about possible consequences of sudden collapse or dam overflow. Possible flood zones have been designated and systems for population alarming have been developed.

SLOVENIA

Description of measures defined by the National Flood Risk Management Plan (NFRMP)

Of the entire list of measures defined by the Slovene NFRMP only following could be defined as constructional measures, or measures related to the maintenance of structural measures:

- Planning, design and construction of flood management structures;
- Regular maintenance of the watercourses, hydraulic works and river banks;
- Adequate management of hydraulic structures.

Other measures defined by the NFRMP could be considered as non-structural:

1. Identification of flood hazard zones and consideration of their limitations;
2. Identification, development and protection of flood retention volumes;
3. Adaptation of land use on watershed level;
4. Performance of hydrological and meteorological monitoring;
5. Management archives and registries in the field of flood management;
6. Education and awareness rising on flood risk and flood management;
7. Development of individual flood protection measures (flood-proofing);
8. Regular control of the existing constructive flood protection measures;
9. Regular supervision of river network status;
10. Stable financing of flood management services;
11. Development of emergency plans and response mechanisms for the flooding scenarios;
12. Flood forecasting systems;
13. Flood warning systems;
14. Emergency and response measures in the case of floods;
15. Flood damage assessment protocols and mitigation/reconstruction works after the flood events;
16. Documentation and analysis of past flood events;
17. Applied measures addressing legal, financial and system framework.

Identification of flood hazard zones and consideration of their limitations – measure (4) flood risk mapping is the first measure on the list and key measure affecting many procedures and long term land-use development. It is also closely related to the measure (5), as identified flood hazard zones are related to non-structural measure: “Identification, development and protection of flood retention volumes”.

It was defined by the Regulation on methods for the identification of areas at flood hazard and related erosion of inland waters and sea and classification of land into risk categories (Off. Gazette 60/2007) a later Decree on conditions and limits for the implementation of activities and interventions in place in areas threatened by flooding and the associated erosion of inland and marine waters (Off. Gazette 89/2008).

Flood risk maps are developed on different levels of precision and purpose:

- The most general level are "Warning maps of floods" – they are defined for three return periods (frequent floods Qn10, rare floods Qn50-Qn100, and extremely rare floods Qn100 – Qn500), they are experienced – based, with high level of uncertainty.
- Far more precise are "Flood hazard category maps" developed usually on the LIDAR based hybrid 1D-2D hydraulic modelling with improved hydrological modelling background. Due to demanding development of these models, they are only gradually covering the most important flood zones in Slovenia.
- Important concept is also "Evidence of flood events" showing the extent of the floods from the flood event of 9.10.1980 until September 2010. Flood events after that (especially 2012, 2014) are still missing.

All maps are available on the web map server: http://gis.arso.gov.si/evode/

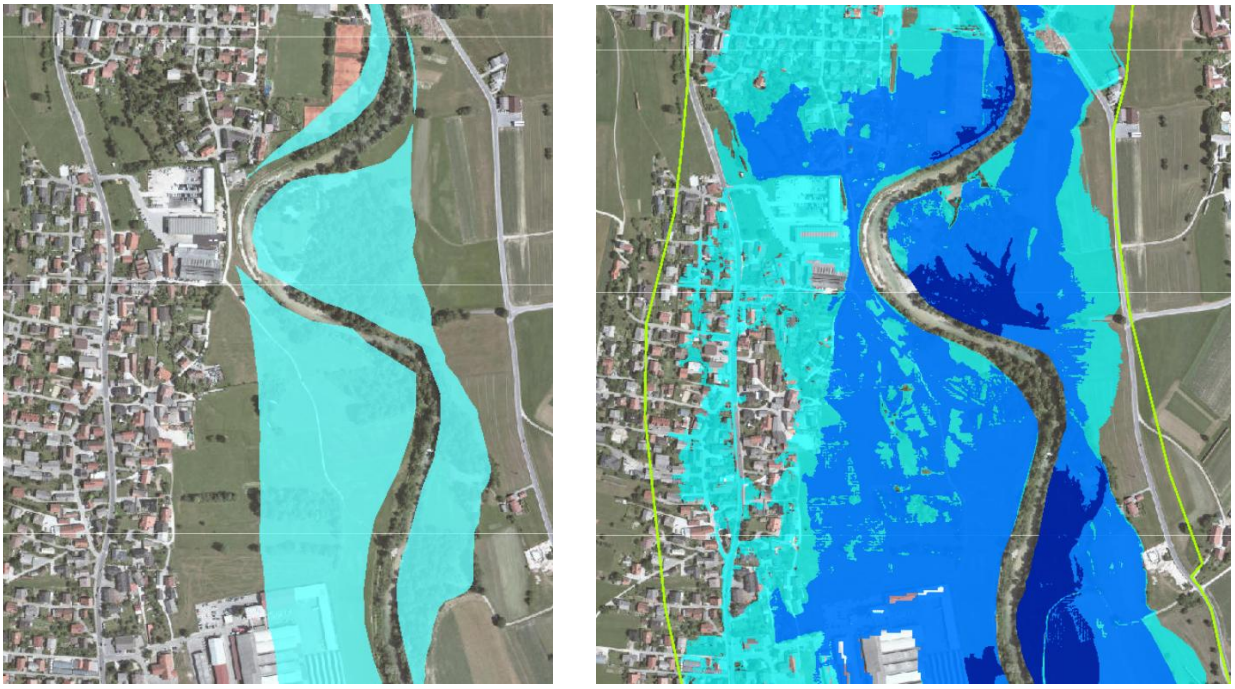


Figure 11. Comparison of "Warning maps of floods" and "Flood hazard category maps" for the same area demonstrating difference in extend, precision and methods applied for the production of the map.

Developed flood hazard maps are basis for the water consent as a part of the construction permit. In the permitting process the investor adopts the project according to the water management requirements, including flood management. The requirements are defining also flood mitigation measures which should be part of the investment. They are of protective nature – i.e. building on adequate flood secure elevation, but also of replacement nature – i.e.

necessary retention measures replacing for the increased runoff or reduced inundation volume. Other measures which could be associated with the pollution prevention in the case of flood events can also be requested by the water permit. Of other non-constructive measures we can consider several measures could be considered as already quite well operational in Slovenia, especially the NSM:

7. Performance of hydrological and meteorological monitoring;
15. Flood forecasting systems;
16. Flood warning systems;

These measures are performed by the Slovenian Environment Agency, which significantly improved the monitoring, forecasting and warning system also by the support of EU within the EU project "BOBER" (http://www.arso.gov.si/o%20agenciji/EU%20sofinancira/BOBER/). It is specific task of the water utility, which is managing the water source in the flood hazard zone, to define the necessary procedures in their Water Safety plan and implement them in the case of issued flood warning for their location.

Of the non-constructive measures, which could be associated with the PROLINE-CE project we can underline following ones:

- **BP FM7 Adaptation of land use on watershed level (Slovenia);**

Adaptation of land use is related to the decrease of runoff, but also omitting the vulnerable categories from the flood hazard zones. Later is also closely related with the adequate spatial planning procedures. Spatial planning procedures in this way connect and integrate floods with the protection of water sources.

- **BP FM8 Development of individual flood protection measures (flood-proofing) (Slovenia);**

Flood proofing as general approach is related to several best management practices already proposed such as:

  - Flood proofing of water abstraction wells;
  - flood proofing of potential sources of accidental pollution induced by the flood events (i.e. spillage from the oil tanks).

In this way the important connection between the general approaches to flood management on national level, defined by the National Flood Risk Management Plan is related to selected best management practices, defined and elaborated in more detail by the PROLINE-CE project. This bridging component is important, as the specific elaborations of the PROLINE-CE project should be observed as a part of a comprehensive flood management system, and not a stand-alone elaboration.

HUNGARY

- **BP FM9 Protective forest management on floodplain**

Description of the measure

Riverine forests (mainly alders, willows and poplars) have been heavily transformed, but important areas still remain along the large rivers. The most of them show rather pristine state and they are Natura 2000 sites. Because of the spread of invasive species of non-native plants and of weeds, only a few "relicts" show the original natural vegetation. These gallery forests can be divided into parts: softwood and hardwood. The former are willow and poplar associations covering the lower, regularly inundated floodplains. The latter represent a transition between the former and climax dryland forest. Gallery forests have high biodiversity. The best stands are in the lowland reaches of the river Drava, near the tributaries of upper Tisza and on the Szatmar-Bereg plain (IUCN, 1993).

Man-made flood defences – engineered embankments, flood walls and temporary structures – are an essential part of the fight against flooding. However forests/trees can provide a sustainable and low maintenance solution to lessening the risk of flooding as well as delivering other environmental and economic benefits when combined with other flood defences on floodplain.

Establishing protective forests at banks or in DWPAs prevents leaching of agricultural pollution to waters. Planting trees can be effective in increasing water infiltration, and reducing and slowing runoff. Woodland located on floodplains can mitigate large flood events by absorbing and delaying their progress downstream. Trees and green space could play a critical role in adaptation to climate change in addition to reducing flood risk.

- **BP FM10 Non-structural flood defence measures**

Description of the measure

In Hungary the preliminary flood risk assessment has been done based on the readily available information. Three types of flood were examined in order to establish maps on inundation hazards:

- Floods of large rivers protected by dykes (riverine floods);
- floods of river and stream sections not protected by dykes (so called flash floods);
- inland inundations (excess water).

Along the rivers in Hungary about 4,200 km of flood protection dykes have been built. Their establishment and protective ability are on different levels, so the hazard of flooding in the areas they protect varies as well. The hazard of inundation in these areas is fundamentally affected (apart from the hydrological load) by the protective ability of the dykes, and the by the defence potential (the human and material resources of the defence organization).

Flash floods on the small streams in mountainous and hilly areas were simulated by 1D hydraulic model. The risk calculation based on the inundation depth and the water velocity. Inland inundation can be interpreted as the opposite situation than that of the previous cases, as in this case the inundation of the area does not originate from the river, but directly from rainfall and

high groundwater level. Consequently, the simulation of the process is based on the modelling of the soil water balance.

During the years 2014-2015 the hazard and risk maps were supervised and strategic risk management plan was prepared.

Flood hazard maps, showing the extent and expected water depths/levels of an area flooded in three scenarios, a low probability scenario or extreme events, in a medium probability scenario (at least with a return period of 100 years) and if appropriate a high probability scenario.

Flood risk maps, shall also be prepared for the areas flooded under these scenarios showing potential population, cultural economic activities and the environment at potential risk from flooding, and other information that Member States may find useful to include, for instance other sources of pollution.

Risk management plans include several structural and non-structural measures, like preparation of Flood Riverbed Management Plans.

The negative process taking place in riverbed caused higher flood levels and decreased our flood protection facilities. This fact and high cost of flood protection developments needed to improvement of the conveyance capacity of the flood bed.

Making of the Flood Riverbed Management Plans (FRMP) specify Act LVII of 1995 on water management and the preparation of the planning ordered by the 83/2014. (III.24.) Government regulation.

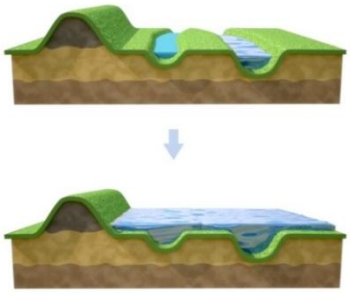
The aims of the FRMP are reducing flood levels, keeping or repairing capacity of riverbed and ensure the flood protection safety. FRMP includes:

Identification of flood hazard zones and consideration of their limitations;

- Identification, development and protection of flood retention volumes;
- development of individual flood protection measures;
- revision of the existing constructive flood protection measures;
- maintenance of the watercourses, hydraulic works and river banks;
- adequate management of hydraulic structures.

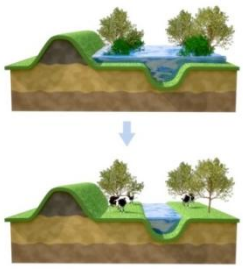
FRMP includes some measures on land use as well including changing, optimization of plant cultivation or land use on floodplain. The following pictures demonstrate these measures:

EVOLVING OF WETLANDS WITH FLOOD PROTECTION FUNCTIONS



Taking advantage of terrain conditions, the deeper areas are constructed of bands that remain in under water. This implementation helps to providing better run-off conditions, increasing biodiversity and operating like wetlands.

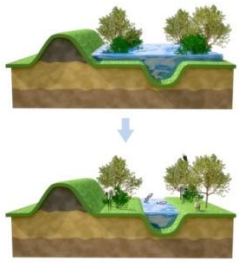
MODIFY LAND USE IN FLOODPLAIN AND INUNDATION AREAS,



Liquidate flooding runoff barriers of land-use practice by cultivation changes and modifying land uses.

Criteria: ecological status, nature conservation, sediment and nutrient retention.

VEGETATION CONVERSION AND RESERVATION



Removing of the vegetation which caused run-off barriers. This implementation helps to provide better run-off conditions.

Figure 12. Land-use scenarios – influence on floods

ITALY

- **BP FM11 The Flood Forecast Centre for the Po River and FEWS Flood Early Warning System**

Description of the measure

The Po operational forecasting and modelling system for flood events on the Po river FEWSPO (Figure 1) was designed and implemented by the Environmental Agency of Emilia Romagna ARPA-ER on the base of the 2005 Agreement among the National Civil Protection (DPCN) the Interregional Agency for the Po river, the Po River Basin Authority, the Emilia-Romagna, Lombardia, Piemonte Valle d'Aosta and Veneto Regions. The FEWS is a pillar o for the National and regional Distributed Early Warning System Network for hydrogeological extremes, build according to the Civil Protection Directive on 27.2.2004 Directive. The Civil protection Directive on 8.2.2013 successively established the Command and Control Unit for the Po river Floods, the Flood Forecast Centre for the Po river, in charge to the Interregional Agency for the Po river supported by the Hydrology Unit of ARPA-ER , managing the FEWS PO system. Through FEWS PO it is possible to manage observed data (in situ and remote sensed), and forecasts obtained from meteorogical-hydrological- hydraulic simulation in order to early detect floods, their occurrence entity and characteristics in order to support Civil Protection System. The numerical modelling system used includes 3 chains of hydrologic and hydraulic model. Both models are fed with real-time precipitation, temperature and discharge data. The modelling framework also allows for forecasting up to 72 hours and up to 120 hours for ensemble simulations. The hydro-meteorological monitoring network consists of 600 water level gauges, more than 1000 rain gauges and more than 700 thermometers. The outcomes provides the information on the basis of which flood warnings can be issued and provided in time to allow a proper response by the responsible authorities. The modelling chain is completed by a number of scenarios simulating different possible operations of the flood control structure in real time to support the flood service management.

Measure advantage

- It is a regional and national guide for flood alert strategies;
- An early flood warning and flood management could minimize the risk of damage and casualties caused by a flood event.

Challenges

- Verification and validation of forecast models, tools and procedures;
- Manage and reduce the lead time, the time between the moment the warning is issued and the moment flooding starts. In fact, the fast flood propagation has pointed out the necessity of implementing specific modelling procedures allowing the forecast of rapid phenomena, for instance by more frequent runs of hydrometeorological chains when hydrological thresholds are reached or statistical decisional trees based decision support system.

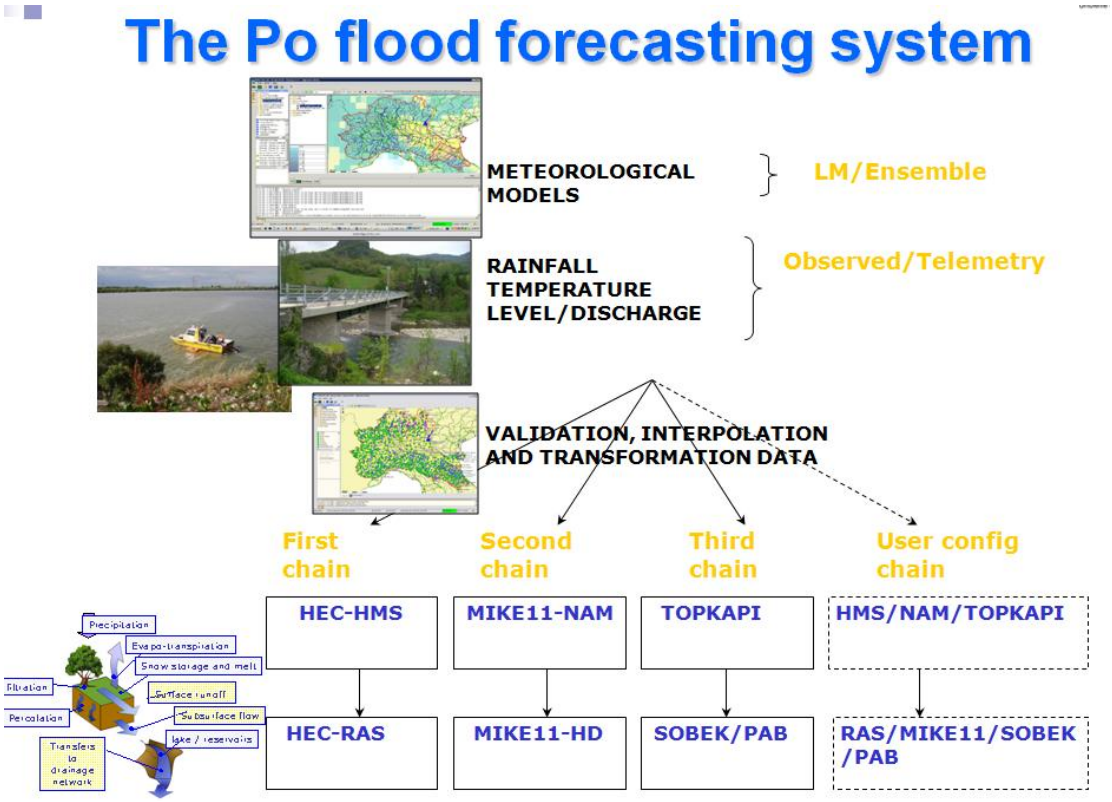


Figure 1. The Po flood early warning system FEWS.

- **BP FM12 Preventing flooding risk by making resilient communities (PRIMES LIFE+ project)**

Description of the measure

This measure is based on the project LIFE+ PRIMES, which is aimed to reduce flood risk (mainly in terms of vulnerability) through the increase of community's resilience. The main goals of the Project are the improvement of alerting systems in the three partner regions in Italy (Emilia Romagna, Abruzzo and Marche), through the development of uniform and integrated procedures and information systems at interregional level, the definition of risk scenarios and the creation of a shared web space with local communities also account for climate change scenarios.

The project has identified pilot areas in the three regions: Imola, Mordano, Lugo, Sant' Agata sul Santerno, Poggio Renatico (Gallo), Ravenna (Lido di Savio) in Emilia-Romagna; Senigallia and San Benedetto del Tronto in the Marche region; Scerne di Pineto and Torino di Sangro in Abruzzo. In these areas, information and risk awareness activities and exercises will be carried out; in addition, active participation by citizens in local policies for government of the territory will be tested, through the collective construction of "civic plans" that will be integrated into municipal emergency plans. In some municipalities, in the pilot areas, "participatory alert systems" will be tested in particular, allowing rapid spread of alerts in situations of flooding and storms requiring very quick response.

Measure advantages

- Increasing the awareness of communities;
- involvement of stakeholders in the decision-making process;
- explicitly taking into account climate change issue.

Challenges

- Limited spatial coverage;
- dependent by the political determination of decision-makers.

Many other best management practices also concern flood mitigation (both structural and non-structural measures) but are indirectly mentioned in previous chapters (especially forest, grassland and wetland), as their provision in flood mitigation is indirect.

7.3. Review of general best practices

General best practices regarding drinking water quality and quantity were provided by Austria, Croatia and Slovenia, even though all EU member states are obliged to implement measures from Water Framework Directive and Drinking Water Directive, such as water protection zones. Austria provided an excellent example - Vienna Water Supply catchment areas, where effective governance can be observed on the whole catchment area. Croatian measures are mostly related to proclamation of sanitary protection zones (with according prohibitions related to the particular zone) and various monitoring measures (e.g. surface and groundwater monitoring, chemical products monitoring). Slovenian measures are similar to Croatian, as they deal mostly with proclamation of DWPZ and various restrictions for particular zone (in urban, industrial and transport areas).

Flood defence measures originating from EU Floods Directive apply to all partner countries, but specific measures were provided by Croatia, Slovenia, Hungary and Italy while other countries have flood topics within various other best management practices (e.g. forest, agriculture). In this report, only non-structural measures are shown, as they are one of thematic focal points of PROLINE-CE project. While non-structural measures are well developed on paper, their implementation is still low. Non-structural measures in this report include identification of flood hazard zones, hydrological and meteorological monitoring, forecasting and warning system. Furthermore, focus is put on development of emergency plans, response mechanisms and individual flood protection. In practice, structural measures prevail due to the fact that they are faster to implement, generally cheaper and produce desired effect quickly; and on the other hand, they are not sustainable over a longer period of time.

8. Conclusions

Transnational best management practice report provides a synthesis of best management practices regarding water management in drinking water recharge areas and flood management. As presented, best management practices provided by PROLINE-CE partners are well developed, structured and cover majority of important issues and future challenges. For some types of land use it is obvious that there are numerous best management practices (e.g. forests, agriculture), since those types of land use (woodland and cropland) can be considered prevailing and dominant within majority of EU territory.

As a major weakness it is necessary to point out the unknown degree of implementation of some best management practices. As the majority of best management practices are derived either from past projects (e.g. CC-WARE, Orientgate and DrinkAdria) or existing national legislation (EU directives and country-specific policies), their application in practical sphere remains unknown in many cases. Many countries share common problem – although the laws, practices and measures are well written and have a good concept, their implementation is sometimes insufficient. Furthermore, this problem is enhanced by low penalties and lack of enforcement mechanism for those who do not respect or disregard directives, laws and practices. Considering this, greater efforts must be put into inspection and supervision structures, which should react promptly in case of environmental misdemeanour (e.g. illegal clear cuts, pesticide overuse, improper manure storage, etc.).

This report (contributed by inputs and lessons learnt from stakeholder's workshops) will serve as a comprehensive basis for DT.1.3.4 "*Transnational catalogue of strategies and measures to be integrated into existing policy guidelines*". While a strategic approach to improving water efficiency will generally emphasize national action, the end result should be action at lower levels, from the household and community levels on up (CC-WARE, 2014).

Further PROLINE-CE activities will need to assess each best management practice according to its contribution to the solution regarding various drinking water/flood issues. To achieve this, multi angle approach is needed and it is necessary to define the evaluation scheme of each best management practice. Factors in evaluation scheme could involve: relevance of the measures (water protection functionality, cost, time of implementation and duration of sustainability); geographical applicability or specificity; measure efficiency; funding options and necessary preconditions for implementation of measure.

Lastly, this report will also contribute to the generation of PROLINE-CE output O.T1.2 "Strategy for the improvement of policy guidelines", which will head towards a new cross-sector management regulations.

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