

PROLINE-CE

WORKPACKAGE T2, ACTIVITY T2.2

IMPLEMENTATION OF BEST PRACTICES FOR WATER PROTECTION IN PILOT ACTIONS

D.T2.2.2 PARTNER-SPECIFIC PILOT ACTION DOCUMENTATIONS

PILOT ACTION: PA1.2 - Waidhofen/Ybbs

Lead Institution	PP3 - Municipality of Waidhofen/Ybbs
Contributor/s	See next page
Lead Author/s	Roland Koeck
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Contributors, name and surname	Institution
Roland Koeck	PP3, LP/PP1 - University of Natural Resources and Life Sciences, Department of Forest- and Soil Sciences, Institute of Silviculture
Elisabeth Gerhardt	LP/PP1 - Federal Research and Training Centre for Forests, Natural Hazards and Landscape
Markus Hochleitner	PP3 - Municipality of the city of Waidhofen/Ybbs, Water Works
Hubert Siegel	LP/PP1 - Austrian Federal Ministry of Sustainability and Tourism
Eduard Hochbichler	PP3, LP/PP1 - University of Natural Resources and Life Sciences, Department of Forest- and Soil Sciences, Institute of Silviculture
Daniel Bittner	PP12 - Technical University, Munich
Gabriele Chiogna	PP12 - Technical University, Munich



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1. Introduction

Best management practices (hereinafter BMPs) for drinking water protection and management derived from T1 were reviewed and relevant BMPs were selected for particular pilot action. Implementation status of BMPs was verified in Pilot Actions (T2); in case of lacks identified, possibilities of improvement and implementation were also assessed. Drinking water protection and management and best practices are strategically implemented in the pilot actions, in order to achieve a function-oriented land-use based spatial management for water protection at the operational level. Measures and actions were analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water level. PROLINE-CE pilot actions reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

Review of main land use conflicts and BMPs on Pilot Action level has already been done in Pilot Action BMPs reports, which were a basis for *D.T2.1.2 Transnational case review of best management practices in pilot actions*. Description of natural characteristics of Pilot Site is presented in *D.T.1.4 Descriptive documentation of pilot actions and related issues*.

Activities within Pilot Action were done according to set-up which was described in *D.T2.1.5 Set-up report about adaptation of the transnational concept to pilot action level*.

The Deliverable *D.T2.2.2 Partner-specific pilot action documentations* presents final Pilot Action report regarding the management actions examined in the Pilot Action, description of conducted activities and identified solutions for case-specific adaptations of management concepts. This report presents the final work report regarding the implementation of best management practices for drinking water protection in pilot action PA1.2 Waidhofen/Ybbs.



2. Testing of BMPs in Pilot Action

2.1. Objective(s) of Pilot Action

The Pilot Action 1.2 Waidhofen/Ybbs aims at improving the drinking water supply security through an integral land-use management concept within the mainly forested DWPZ (drinking water protection zone).

For that purpose, the “guideline” was formulated in the course of the project. It is a condensed version of the most important BMP’s of PROLINE-CE relevant for the forested part of the DWPZ. The “guideline” was set up specifically for the boundary conditions of PA1.2. The formulation in German language guarantees the comprehensibility of the elaborate for all related stakeholders and practitioners.

Also, the stone quarries within the DWPZ are thematised, their impact on the hydrological cycle analysed and the necessary consequences for the drinking water supply strategy are outlined.

The overall purpose of identification of gaps within PA1.2 should help to navigate towards fitting response strategies in terms of BMP’s, which are listed in Chapter 2.2. The gaps define the current situation of challenges within the Pilot Action, hence any fitting response strategies can be deduced, if awareness regarding the existing gaps is given.

The strategical implementation of BMP’s within the PA1.2 will include the application of PES (payments for ecosystem services), which will be highlighted in WPT3. For those tasks all elaborates within WPT2 are serving as basis.



2.2 BMPs of the Pilot Action 1.2

Five BMPs regarding forest management were identified as the most important management guidelines for PA1.2. Additionally, the specific land-use category stone quarry was integrated in the BMP list, as it constitutes an important impact on drinking water supply security. Subsequently the most relevant BMP's for PA1.2 are described in detail.

■ Identified GAP provoking action	
GAP short name	Continued application of the clear-cut technique
GAP short description	Within PA1.2 there still can be identified the intent of forest owners to apply the clear-cut technique, which endangers water supply security as this silvicultural technique can impact water quality significantly.
■ Best Management Practice / Management Action	
Name of BMP	Avoidance of the clear-cut technique (BP MF1)
Type of land use regarded	Forestry
Location	Inner water protection zone (e.g. extended protection zone of Hinterlug-spring) in PA1.2. and all other locations within PA1.2 where the clear-cut technique is intended to be applied.
BMP description	Avoidance of the clear-cut technique (CCT) at all locations of the PA. This involves the application of the BMP-alternatives, above all the overall strategy to apply continuous cover forestry systems (BP MF2) and all related BMP's, strategies and measures. The BMP is part of the overall <i>guideline for silviculture within the already decreed water protection zone (WPZ) of Waidhofen/Ybbs</i> . The guideline passed the municipal council of the city, which forms the basic condition to implement PES (payments for ecosystem services provision) for forest owners within the WPZ. Several knowledge transfer meetings and persuasive efforts were necessary to convince the members of the municipal council from the urgency of an integral drinking source water protection strategy, which is given with the "guideline".
Advantages of this BMP in PA	Avoidance of CCT opens the path for a consistent water protection strategy. It assures the avoidance of the most threatening processes caused by forestry in terms of drinking water protection and flood prevention. In PA1.2 it would open an era of consistent drinking water protection strategies, where the protection of the water resource moves into the centre of interests.
Challenges of this BMP in PA	Resistance of the respective forest owner(s), who wants to continue with the classical clear-cut technique and resistance of the district forest authority



	<p>which is responsible for the authorisation of such forest management measures. The district forest authority would have to change the business-as-usual attitude and conform to the Federal Forest Act.</p> <p>There was set up a meeting between the respective forest owner, the regional forest authority, representatives of the municipality of Waidhofen/Ybbs and of the water works, scientists and representatives of the Federal Ministry of Sustainability and Tourism to discuss the issue of clear-cut application within the extended protection zone of Hinterlug spring. The meeting will have to solve the issue and avoid the clear-cut application.</p> <p>There were set up several preparation meetings in the course of which the issue was planned and strategic stakeholder interactions, including persuasive efforts, were implemented. Those yielded already first insights of involved persons.</p>	
Relevance	Water protection functionality	The BP MF1 is highly relevant for the water protection functionality (WPF) of the forest ecosystems. Through clear-cuts WPF is eradicated for several years (7-10 years or even more), and this within the extended protection zone of the second largest spring in PA Waidhofen/Ybbs.
	Cost of the measure	PES (payments for ecosystem services) provision, dependant on the amount assigned to the forest owner through the municipality. Medium cost level is expectable.
	Duration of implementation	Long term
	Time interval of sustainability	Continuous
Limitations	The most important limiting factor is the business-as-usual attitude of forestry players in Austria, who want to continue with the application of the forestry practice detrimental for water protection and flood prevention.	
Implementation of the BMP in PA	<p>The implementation of the BP MF1 “Avoidance of the clear-cut technique” will be facilitated through PES schemes and talks with forest owners. Actually, some of the forest owners within PA1.2 already conform to this BMP. The others will have to be motivated (stakeholder involvement).</p> <p>Through the resolution of the “guideline” through the municipal council the implementation of the BMP will be facilitated.</p>	
Comments	The resolution of the “guideline” through the municipal council can be regarded as milestone towards the implementation of integral drinking source water protection.	
References / sources	Current process of land-use activities within PA1.2, communicated through PP3.	



■ Identified GAP provoking action		
GAP short name	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages.	
GAP short description	Within PA1.2 elevated wild ungulate densities cause browsing, fraying and bark-stripping damages, which lead to instable forest ecosystems. Those cannot provide water protection functionality any more. Hence drinking water supply security can be endangered within a medium-term perspective.	
■ Best management Practice / Management Action		
Name of BMP	Forest Ecologically Sustainable Wild Ungulate Densities (BP MF9)	
Type of land use regarded	Forestry	
Location	The whole drinking water protection zone, hence the whole area of PA 1.2.	
BMP description	High wild ungulate densities provoke severe browsing damages on tree seedlings and saplings, fraying damages and bark-stripping damages. Those inhibit the natural regeneration process of whole forest ecosystems or destabilize those. Natural regeneration is the crucial process in forest ecosystems, which has to be given on an optimal level for all present tree species, especially within DWPA. This can only be guaranteed, if the wild ungulate densities are regulated to a forest ecologically sustainable level, hence providing vital regeneration of all tree species.	
Advantages of this BMP in PA	Forest ecologically sustainable wild ungulate densities provide the huge advantage that the forest ecosystems can evolve naturally, can grow according to their natural inner dynamics. This includes a vital regeneration layer within the forest stands, encompassing all tree species of the respective natural forest community. It is the most essential precondition for providing the water protection functionality of forest ecosystems. Within PA1.2 the application of this BMP would open the path for a sustainable provision of water protection functionality of the forest ecosystems.	
Challenges of this BMP in PA	The main challenge is related to the actual practice of many forest owners within the PA, which is focusing on trophy-hunting activities and related high wild ungulate stocks. The hunters and forest owners within PA 1.2 will have to conform with the regional Hunting Act of the province Lower Austria (Niederösterreich), where all necessary frame-conditions are defined.	
Relevance	Water protection functionality	The BP MF9 is highly relevant for the water protection functionality (WPF) of the forest ecosystems in PA1.2.
	Cost of the measure	Medium costs
	Duration of implementation	Long term
	Time interval of sustainability	Continuous



Limitations	Limitation within the context of BP MF9 is the missing willingness to change behaviour in the field of hunting/rearing “wild” ungulates. Related forest owners show in most of the cases inertia and want to continue their practices devastating for forest ecosystems.
Implementation of the BMP in PA	The implementation of BP MF9 within PA1.2 can be described as truly challenging task, as it involves the change of management purposes for many forest owners. It can be regarded as success if some of the forest owners within PA 1.2 show willingness for change. This could be achieved as one out of the forest players could show disposition for this fundamental change. The PES strategy could also motivate some forest owners to change their management purposes. Also, the regional Hunting Act of the province Lower Austria (Niederösterreich) has to be applied where all necessary frame-conditions are defined.
Comments	The implementation of BP MF9 is not only within PA1.2 crucial as it is relevant for the whole Austrian forest area.
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria.

■ Identified GAP provoking action	
GAP short name	Extensive construction of forest roads
GAP short description	Within the PA1.2 forest roads are constructed according to the aims of the forest owners, the requirements of integral drinking water protection were not taken into account until now.
■ Best Management Practice / Management Action	
Name of BMP	Limitation of forest roads (BP MF20)
Type of land use regarded	Forestry
Location	The whole Pilot Action (PA1.2).
BMP description	Forest Road construction and maintenance can cause several adverse impacts on water bodies and should hence be limited in DWPZ. The increase of surface runoff and of water storage loss is the main negative effect. Only in cases, if forest roads are necessary for the stabilization of forest areas, their construction could be considered. In those cases, their construction has to meet strict environmental restrictions.
Advantages of this BMP in PA	For avoiding potential contaminations and hydrological adverse impacts caused by forest roads, the limitation of their construction within DWPZ is an indispensable need.



Challenges of this BMP in PA	Forest owners within the PA1.2 have to be confronted with the potential negative effects of forest roads on the karst water bodies. Through information and motivation for BMP application through PES the change of the business-as-usual attitude could be achieved. Furthermore, the actual situation requires an authorization of each forest road construction project according to the Austrian Federal Water Act. This new situation is due to the fact that PA1.2 is now a legally decreed DWPZ (since June 2018). Specific legal frame-conditions are now in force for the whole PA1.2.	
Relevance	Water protection functionality (WPF)	For WPF it is of high relevance that forest roads do not occur in specific areas of the PA and that their overall proportion in DWPZ is rather low.
	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The BMP application is limited to forest owners who are willing to accept the change of management and also the amount of PES as motivating asset. But in the new situation with the legally decreed DWPZ (since June 2018) each forest road construction project will have to be passed and authorized according to the Austrian Federal Water Act. This will make it much more difficult to construct forest roads within the DWPZ (PA1.2).	
Implementation of the BMP in PA	The implementation of BMP MF20 will be dependent on the knowledge transfer process and the related negotiations with the forest owners. It is planned to provide a motivating aspect of PES for those forest areas which are kept free from forest roads. The necessary authorization of each forest road project according to the Austrian Federal Water Act will make it more difficult to construct forest roads within PA1.2.	
Comments	Forest road construction is still seen as basic condition for the application of forest management in Austria. This basic condition in terms of willingness to change has to be overcome for DWPZ, especially in PA1.2.	
References / sources	Current process of land-use activities within PA 1.2 communicated through PP3 and further through different actors in the field of forestry in Austria. New legally decreed DWPZ in PA1.2.	

■ Identified GAP provoking action	
GAP short name	Creation of conifer plantations, even within deciduous forest communities (forest hydrotopes)
GAP short description	Plantation of Norway spruce (<i>Picea abies</i>) over all available forest sites within a region, in this case PA1.2.



■ Best management Practice / Management Action	
Name of BMP	Tree Species Diversity According to the Natural Forest Community (BP MF7)
Type of land use regarded	Forestry
Location	The whole area of PA1.2.
BMP description	Tree species diversity according to the natural forest community (to the forest hydrotope type) guarantees the highest level of stability and resilience. Tree species diversity provides a high level of adaptability, also under climate change. Forest stands created by diverse tree species can utilize a broader scope of the forest soils, if deep-rooting and shallow-rooting trees are growing together. Knowledge about spatial distribution of the natural forest communities (forest hydrotopes) is required for the operational stratification of the DWPA and adaptive forest management. Man-made plantations with non-natural tree species should be transformed gradually to stands dominated by native species, depending on the local experience and legislation. In PA 1.2 the whole DWPZ is represented through the Forest Hydrotope Map, defining the optimal tree species set for each forest site.
Advantages of this BMP in PA	In many forest areas tree species diversity according to the natural forest community is a definite advantage, as homogeneous conifer plantations are partially dominating the forest sites in PA1.2. Especially in times of climate change tree species diversity becomes mandatory for achieving forest ecosystem stability. Diversity has also positive side effects, e.g. for conservation purposes. Within PA1.2 the implementation of the tree species diversity according to the Forest Hydrotope Model becomes mandatory. This will increase stability and resilience of the forest ecosystems and hence improve their water protection functionality.
Challenges of this BMP in PA	In some cases of forest owners there can be expected resistance against tree species diversity according to the natural forest community (forest hydrotope type), if the habitual forestry practices had put a strong focus on conifer plantations or other homogeneous timber yield focused plantations. It will be part of stakeholder talks and negotiations to overcome this hindrance and to convince the forest owners from the necessity to adapt tree species diversity to the site conditions. Through the resolution of the “guideline” by the municipal council the implementation of the BMP will be facilitated, as the PES scheme will now be available.
Relevance	Water protection functionality The application of this BMP is of crucial importance to improve the water protection functionality of the forest ecosystems within the PA1.2, as it will provide stability and resilience for the related forests.



	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The potential limitation for this BMP is, if forest owners are not willed to cooperate with the municipality. Almost all forest owners within the DWPZ will be cooperative within the context of PES schemes available, but also exceptions can be expected.	
Implementation of the BMP in PA	Some forest owners within PA1.2 actually are allowing the natural regeneration of the natural tree species set. Others still are planting Norway spruce on their forest sites. Those have to be convinced from the need for tree species diversity through knowledge transfer and the application of PES schemes. This process is facilitated through the resolution of the “guideline”.	
Comments	The water protection functionality of the forest ecosystems within PA1.2 depends on the creation of diverse forest stands where the natural tree species set is implemented.	
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria.	

■ Identified GAP provoking action	
GAP short name	Cutting of old, huge and vital tree individuals
GAP short description	Huge, old and vital tree individuals in most of the cases are cut for timber yield as those trees provide a considerable amount of biomass for any given purpose.
■ Best management Practice / Management Action	
Name of BMP	Foster old, huge and vital tree individuals (BP MF11)
Type of land use regarded	Forestry
Location	The whole area of PA1.2.
BMP description	Old, huge and vital tree individuals carry excellent genetic information. They can supply younger and smaller tree individuals with nutrients via their common mycorrhizal network. Thereby they provide a substantial contribution to forest stand stability. Hence, they have to be selected and protected, so that they can provide their services as long as possible. Especially within PA1.2 the application of this BMP could contribute significantly to improved forest ecosystem stability.
Advantages of this BMP in PA	The genetic information provided by old, huge and vital tree individuals has a high value for the sustainability of forest ecosystems. Old and huge tree



	individuals can provide stability for the whole forest stand (in a quasi-mechanical way) and are also important for the nutrition of young trees (including the regeneration phase), who may receive nutrients from the old trees via the mycorrhiza-interconnected root system. In PA1.2 stability and resilience of the forest ecosystems could be improved through the implementation of this BMP.	
Challenges of this BMP in PA	Forest owners in general cut old and huge tree individuals for timber sale. Within PA1.2 forest owners will have to be informed about the advantages of this BMP and also will have to be motivated to implement it through the application of the PES scheme. Now the basic condition for the implementation of PES, the “guideline”, was passing through the municipal council.	
Relevance	Water protection functionality	The application of this BMP is of crucial importance within PA1.2, as it will increase stability and resilience for the related forest ecosystems.
	Cost of the measure	Medium
	Duration of implementation	Long Term
	Time interval of sustainability	Continuous
Limitations	The potential limitation for this BMP is again given, if forest owners are not willed to cooperate.	
Implementation of the BMP in PA	The implementation of this BMP will need motivation, knowledge transfer, and training for the related stakeholders. Protection of those tree individuals requires specific silvicultural knowledge. This process is again facilitated through the resolution of the “guideline”, as it will allow the implementation of the PES scheme.	
Comments	---	
References / sources	Current process of land-use activities within PA1.2 communicated through PP3 and further through different actors in the field of forestry in Austria.	

■ Identified GAP provoking action	
GAP short name	Dolomite quarries are causing a decrease in groundwater recharge
GAP short description	The pilot area, in particular the recharge area of the Kerschbaum spring, suffers from increasing spaces used for dolomite mining.
■ Best management Practice / Management Action	
Name of BMP	Continuous monitoring of relevant, hydrological data and hydrological modelling



Type of land use regarded	Forestry	
Location	The whole area of PA1.2.	
BMP description	The impact of dolomite mining on the quality and quantity of the Kerschbaum spring can be assessed by a continuous monitoring of the spring discharge and the electrical conductivity, as a sum parameter of individual ions. As the quarry areas are considered being compacted without remarkable amounts of infiltration, surface runoff drains the quarries into the Waidhofenbach. Monitoring of electrical conductivity in the Waidhofenbach and the Kerschbaum spring helps evaluating the impact of mining on the spring water quality. Moreover, using hydrological modelling to continuously evaluate the changes of spring discharge due to extending of quarry areas in the pilot area helps to support future decision-making.	
Advantages of this BMP in PA	The continuous monitoring is a cheap but powerful measure. It is a sustainable way to assess any changes occurring in the pilot area. A continuous validation of the existing hydrologic model further supports the prediction of available water resources considering further land use changes.	
Challenges of this BMP in PA	A challenge of the presented BMP is to analyse the monitored data and to apply the hydrologic model. Still, this is a task typically pursued by experts (hydrologists). To overcome this issue, water managers should be trained to assess hydrological data and to run a hydrologic model.	
Relevance	Water protection functionality	The application of this BMP is of crucial importance within PA1.2, as it will support to ensure the future water supply with high quality freshwater.
	Cost of the measure	Low
	Duration of implementation	Short
	Time interval of sustainability	Continuous
Limitations	The potential limitation for this BMP is given by the introduced challenges, which is that the hydrological tasks are typically performed by hydrologists.	
Implementation of the BMP in PA	The implementation of this BMP was done during the project period of PROLINE-CE.	
Comments	---	
References / sources	Bittner, D., Sheikhy, T., Kohl, B., Disse, M., Chiogna, G. (2018): Modeling the hydrological impact of land use change in a dolomite-dominated karst system in: Journal of Hydrology, 267-279; DOI://doi.org/10.1016/j.jhydrol.2018.10.017.	



3 Activities in the Pilot Action

Within PA1.2 there were already done several further activities. In 2017 there were tested specific BMP's. At sites where, small-scale gap-cuts (cutting of trees on areas with maximum one tree-length in diameter, this is a small-scale silvicultural regeneration technique) in line with BMP's guidelines (BP MF1, see chapter 2.2) were carried out the succession of the establishing natural regeneration was checked. This check brought the insight that browsing damages caused by wild ungulates were hindering the growth of the natural regeneration layer. Instead of young trees actually *Atropa belladonna* plants are dominating the gap areas. This situation highlights the significance of an implementation of BMP "**Forest Ecologically Sustainable Wild Ungulate Densities (BP MF9 - see chapter 2.2)**", as only if this is guaranteed, forest succession can take place in a way congruent with the requirements of drinking water protection.

As a result of all PA activities the relevance of the implementation of the BMP catalogue has to be highlighted. The set of the most relevant BMP's was integrated in the "**guideline for forest owners within the DWPZ**" (GFD). Their usefulness (of the whole BMP catalogue) for drinking water protection purposes was proved by various scientific publications. The testing of most of the BMP's within PA1.2 will need time. Two ones out of the whole set were already tested in the course of the PROLINE-CE project. Drinking water supply security could be improved through the implementation of GFD.

3.1 Guideline for forest owners within the DWPZ (GFD)

Within PA1.2 the main activities were related to persuasive efforts for the main stakeholders, which are the local councillors of the municipal council. They were informed about the requirements of integral drinking source water protection within the forested watershed. The whole set of BMP's was presented and discussed. The most important BMP's were condensed into a "guideline for forest owners within the DWPZ" (drinking water protection zone) of Waidhofen/Ybbs. This "guideline" is written in German and is based on the BMP catalogue of PROLINE-CE. The purpose of this effort was the preparation of the municipal council meeting, where the guideline should be passed. The **resolution** of the "**guideline for forest owners within the DWPZ**" (GFD) through the municipal council can be regarded as **milestone** towards the implementation of integral drinking source water protection and was accomplished in May 2018. This was the main test for the whole catalogue of BMP's assigned for PA1.2.

Explanatory Abstract of GFD:

The structure of GFD encompasses a short description of the drinking water protection functionality of forest ecosystems. This is the introduction into the thematic field of drinking water supply security. The next section of GFD deals already with the explanation that only



targeted silviculture with the overall purpose of drinking water protection can secure water supply security. Subsequently the most important Best Practices for forest management within PA1.2 are described. Only if forest owners implement those Best Practices in their silvicultural practice they are allowed to receive payments from the water works of Waidhofen/Ybbs.

Contracts with the forest owners (on voluntary basis, each forest owner can decide whether this is an advantage) will regulate all monetary issues and the forest management rules which have to be followed in order to receive the payments on a yearly basis.

Hence GFD will form the basis for the implementation of the PES (payments for ecosystem services) scheme within PA1.2, when forest owners receive transfer payments if they apply BMP's relevant for the PA. Further talks with stakeholders will take place within this context. Also, the testing process of several BMP's together with related stakeholders will take place in near future.

The GFD is now part of the strategic actuation of the water works of Waidhofen/Ybbs. It is part of their negotiation with forest owners within the DWPZ. Through this strategy drinking water supply security will be facilitated.

More about stakeholder involvement, their acceptance of BMPs and BMP implementation is written in the report D.T2.3.1.

3.2 Hydrological modelling and land use change impacts

The primary goal of the modelling activities is to investigate the impacts of the mining activities in the Kerschbaum spring catchment on the spring discharge, since a considerable increase from 4% to 7% of dolomite quarries was observed in the Kerschbaum recharge area from 2007 to 2010. The reason for modelling the hydrological impacts of this increase of the quarries is that we expect the discharge to decrease the more the space of quarries increases due to decreasing groundwater recharge. Therefore, PP13 (TUM) developed a hydrological modelling approach to simulate spring discharge that is a) simply based on a conceptual storage approach due to missing, physical information about the subsurface and b) able to integrate the different land use units present in the recharge area.

A particular challenge for the modelling activities in the Waidhofen/Ybbs pilot action (PA1.2) is introduced by the lithologic sequence of dolomitic basement rocks. This karstified bedrock is prone to dissolution processes that lead to preferential flow paths, such as pipes and conduits.

In these conduits, flow processes similar to channel flow can occur and cause rapid increases in the spring discharge in response to rainfall events. Since detailed information about the present conduit network are not given, typical karst modelling approaches conceptualize the karst system as one storage system that transforms a given input signal, i.e. rainfall, into a certain output signal, i.e. spring discharge. However, these modelling approaches do not take into account particular impacts of land use activities.



Based on preliminary field works in the framework of CC-WaterS, a detailed classification of the Forest Hydrotope Types, i.e. catchment units characterized by similar hydrophysical properties as a result of similar land use and soil types, was performed in the whole study area Waidhofen/Ybbs (Fig. 1) (Koeck & Hochbichler 2012). This classification also includes the dolomite quarries in the Kerschbaum recharge area as one hydrotope (Hyd 222). We used the given hydrotope classification and implemented a modelling approach based on the model proposed by Tritz et al. (2011). The new developed model was recently proposed in Bittner et al. (2018) and was named LuKARS (Land use change modelling in KARSt systems). Fig. 2 shows the model structure of LuKARS.

We used the LuKARS model to simulate the spring discharge in the Kerschbaum and Hinterlug spring and calibrated and validated the models for the years 2006 and 2007. A simple snow model was integrated into the model structure to account for the snow processes that are relevant in pre-alpine catchments like the Waidhofen/Ybbs pilot action. Thus, the inputs for the model are only precipitation and temperature, which are measured at the Mitterlug spring.

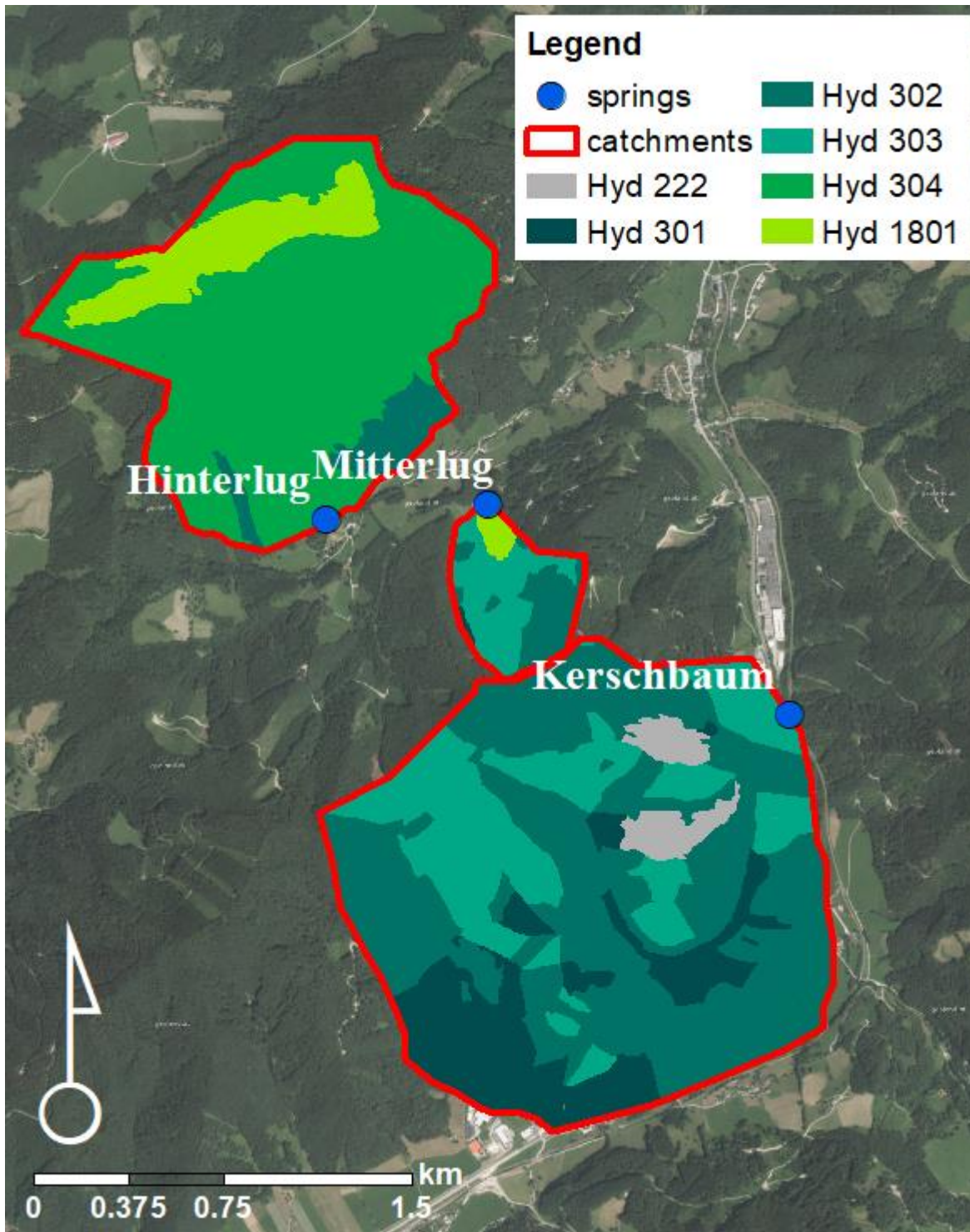


Figure 1: Forest Hydrotape Types in the Kerschbaum, Hinterlug and Mitterlug catchments as mapped in the framework of CC-WaterS (Koeck & Hochbichler 2012). Basemap: basemap.at.

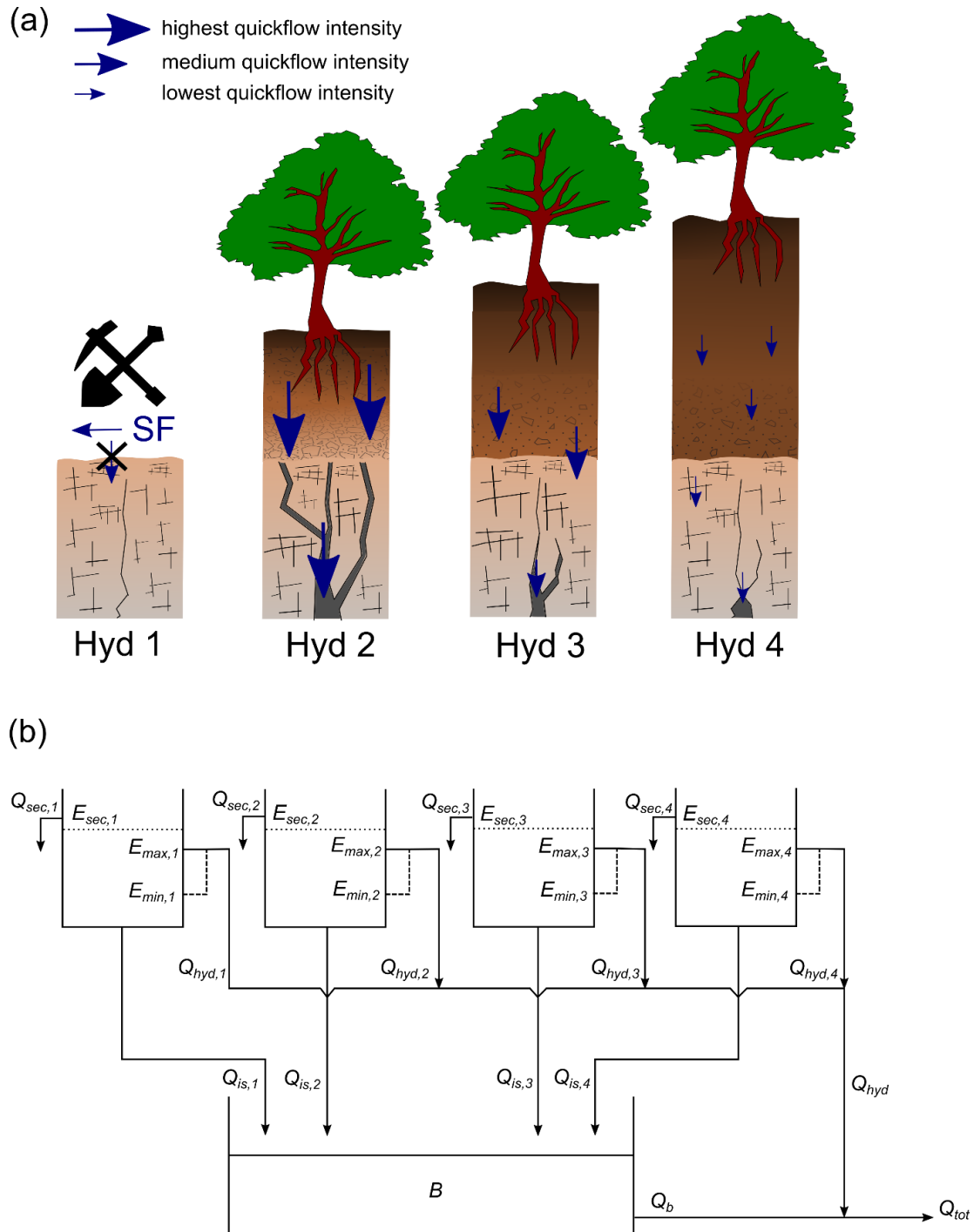


Figure 2: Example of the conceptualization of the hydrotopes (Hyd) and the model implementation as performed for the Kerschbaum recharge area. (a) The conceptual representation of the present hydrotopes. Hyd 1 indicates the dolomite quarries with no groundwater recharge and the dominance of surface runoff (SF). The connectivity to the karst system is largest in Hyd 2 with shallow and coarse-textured soils and lowest in Hyd 4. (b) Model implementation of the four hydrotopes in the Kerschbaum recharge area.

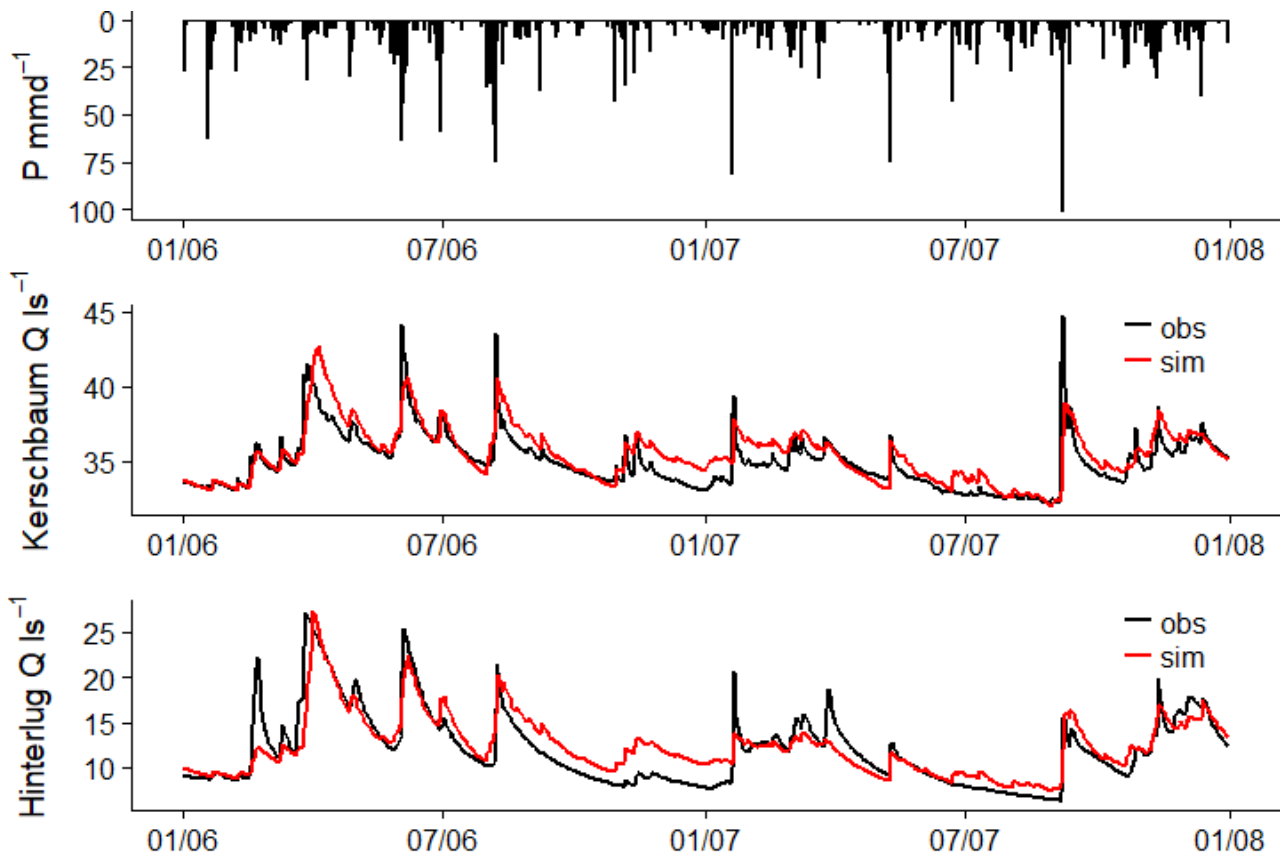


Figure 3: Modelling results of the Kerschbaum and Hinterlug springs for the period from 2006-2007. The upper figure shows the precipitation during the modelling timeframe. The middle and lower plots show the simulated (sim, red) vs. the observed (obs, black) spring discharge time series at Kerschbaum and Hinterlug spring, respectively.

Table 1: Evaluation criteria for the modelling results in the period from 2006-2007.

Evaluation criteria	Kerschbaum	Hinterlug
NSE [-]	0.63	0.74
MAE [$l s^{-1}$]	0.78	1.8

The results of the modelling in both recharge areas are presented in Fig. 3. The results of the calibration year 2006 and the validation year are promising in terms of the simulated discharge volumes and hydrograph. We used the Nash-Sutcliffe Efficiency (NSE) and the Mean Absolute Error (MAE) as evaluation functions to quantitatively evaluate the modelling results and are presented in Table 1. Both criteria are calculated as follows:



$$NSE = 1 - \frac{\sum_{i=1}^n (Q_{sim}^i - Q_{obs}^i)^2}{\sum_{i=1}^n (Q_{obs}^i - \overline{Q_{obs}})^2} \quad \text{Eq. 1}$$

$$MAE = \frac{\sum_{i=1}^n (Q_{sim}^i - Q_{obs}^i)}{n} \quad \text{Eq. 2}$$

where Q_{sim}^i and Q_{obs}^i are the simulated and observed discharge at time step i and $\overline{Q_{obs}}$ represents the mean value of the observed discharge during the considered time period.

The obtained evaluation criteria show that the modelling approach adequately reproduces the observed discharge trends and volumes in both, the Kerschbaum and the Hinterlug spring. The major deviations between the simulated and observed hydrographs result from over- and underestimations of the snow processes in both catchments, e.g. during the winter 2006/2007.

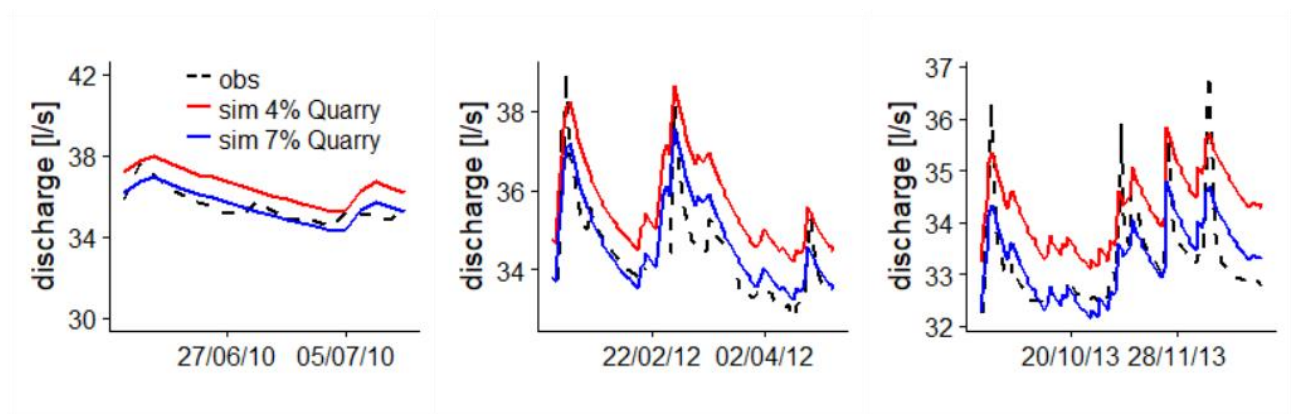


Figure 4: Modelling results of the land use change simulations performed for three distinct periods between 2010 and 2013.

In order to proof the applicability of the model to investigate the hydrological impacts of this land use change, we increased the spatial share of the dolomite quarries hydrotope from 4% to 7% to validate the calibrated model in the period from 2010 to 2013. Due to the fact that the measured discharge time series of the Kerschbaum spring includes measuring errors, we validated the model for three distinct periods in 2010, 2012 and 2013, comprising low flow and peak flow periods (Fig. 4). Moreover, we simulated different land use change scenarios, including no quarries, 5%, 10%, 20% and 30% quarries in the Kerschbaum spring catchment (Fig. 5).

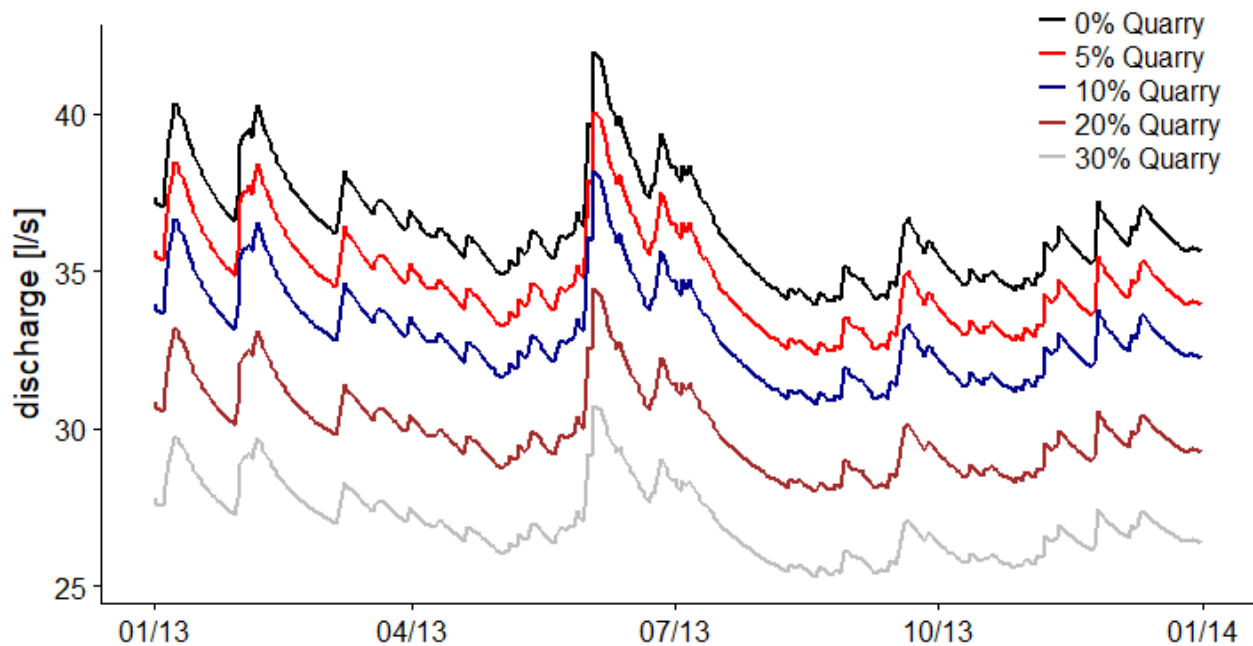


Figure 5: Results of the model performance for land use change scenarios assuming 0%, 5%, 10%, 20% and 30% of dolomite quarries in the Kerschbaum catchment in the year 2013.

The comparison of the results obtained with the model including 4% and 7% of dolomite quarries are visualized in Fig. 4. The results show, that assuming 4% of quarries in the Kerschbaum catchment leads to an overestimation of the discharge volume and that the model results including 7% of quarries adequately match the measured discharge. From a water management perspective, these results show that the increase in space used for dolomite mining led to a decrease of spring discharge. Regarding the different scenarios of land use change performed for the year 2013 (Fig. 5), the model results lead to the conclusion that a continuous increase of the dolomite quarries causes a substantial decrease in the discharge volume of the Kerschbaum spring. Such a decrease can negatively affect the provision of drinking water for the city of Waidhofen/Ybbs.

Since the study of climate change impacts was not part of the works that had to be performed for Waidhofen/Ybbs, no simulation runs were performed including forecasted precipitation data.



3.3 Solutions for case specific adaptation of best management practices

All five selected BMP's for PA1.2 are described in the following tables (Tab. 1-3). The most important issues are highlighted there.

Table 1: GAPS and proposed BMPs with recommendations for implementation in Pilot Action.

Actual management practice (GAP)		Continued application of the clear-cut technique	Unnaturally elevated wild ungulate densities as result of trophy-hunting activities and resulting browsing and bark-stripping damages
Proposed BMP		Avoidance of the clear-cut technique (BP MF1)	Forest Ecologically Sustainable Wild Ungulate Densities (BP MF9)
Proposed solutions and recommendations	adaptation of existing land use management practices	As alternative small gap-cuts can be applied for the creation of forest stand regeneration dynamics.	Hunting should follow the purpose of balancing the wild ungulate densities.
	Adaptation of existing flood/drought management practices	The BMP is also relevant for flood/drought management practices	The BMP is also relevant for flood/drought management practices
	Adaptation of policy guidelines	The avoidance of the clear-cut technique (BP MF1) should be implemented in an Austrian federal guideline for forested DWPZ.	The execution of the province-based-laws for hunting should be the central agenda of federal and province policy in Austria.
Remaining issues to be solved		---	---

Actual management practice (GAP)		Extensive construction of forest roads	Creation of conifer plantations, even within deciduous forest communities (forest hydrotopes)
Proposed BMP		Limitation of forest roads (BP MF20)	Tree Species Diversity According to the Natural Forest Community (BP MF7)
Proposed	adaptation of	Instead of forest roads, skyline-	Fitting tree species should be



solutions and recommendations	existing land use management practices	cranes should be used for timber yield within DWPZ.	planted, and the natural regeneration process should be successful for all natural tree species of a given forest site.
	Adaptation of existing flood/drought management practices	This measure is also in line with flood mitigation concepts.	This measure is also in line with climate change adaptation strategies and supports the overall forest ecosystem stability.
	Adaptation of policy guidelines	Forest roads should not be enhanced anymore within DWPZ instead they should be limited by law at such locations.	The Austrian Federal Forest Act should support the establishment of forest stands which are in line with the natural forest community.
Remaining issues to be solved		---	---

Actual management practice (GAP)		Cutting of old, huge and vital tree individuals	Increase of the dolomite quarries causes a substantial decrease in the discharge volume of the Kerschbaum spring
Proposed BMP		Foster old, huge and vital tree individuals (BP MF11)	Modelling of spring discharge, with the aim to predict the impacts of increasing dolomite quarries
Proposed solutions and recommendations	adaptation of existing land use management practices	To strengthen forest, stand stability through keeping old huge and stable tree individuals on-site would improve the overall water protection functionality of the ecosystem and also the gene-pool.	The spaces used for dolomite mining should not be increased, since this probably leads to an increase in the mean spring discharge in the Kerschbaum spring.
	Adaptation of existing flood/drought management practices	This measure also supports flood mitigation.	This measure also supports flood and drought management
	Adaptation of policy guidelines	Enhanced awareness about old-growth trees and forests would be of importance.	Quarries in DWPZ should not be allowed - regulation on DWPZ has to be changed or newly implemented
Remaining issues to be solved		---	---



4 Conclusions

Within PA1.2 Waidhofen/Ybbs several gaps which are typical for Austrian forest areas were identified. The sustained application of the clear-cut technique, unnaturally elevated wild ungulate densities, extensive construction of forest roads, creation of conifer plantations within areas where broadleaved forests would grow naturally, and the cutting of huge, old and stable tree individuals were identified as the most severe gaps. All those management practices can endanger drinking water supply security, in most of the cases through threatening source water quality.

As response to this situation several meetings and talks with key-stakeholders were carried out. The most important part of those stakeholder events was the information and knowledge transfer meeting with members of the municipal council, in order to convince them from the urgency of an integral drinking source water protection strategy, which is given with the “guideline”. The “guideline” defines the most important BMP’s within the forested part of the DWPZ in PA1.2.

A milestone was accomplished when the “guideline” passed the municipal council of the city Waidhofen/Ybbs in May 2018. This forms the basic condition to implement PES (payments for ecosystem services provision) for forest owners within the DWPZ, which will facilitate the application of the defined BMP’s within the PA.

Additionally, the whole DWPZ of PA1.2 was legally decreed as water protection zone at 20th of June 2018. This new situation also facilitates the application of BMP’s within the PA.

The strategy to solve the situation with the existing gaps within PA1.2 hence can be applied. It consists of the PES scheme for forest owners, who will receive transfer payments if they apply the defined BMP’s of the “guideline” within their forests in the DWPZ. The whole strategy is part of the “guideline”. As the municipal council of Waidhofen/Ybbs supports the implementation of the “guideline”, it will be possible to communicate with the forest owners with regard to the BMP application process. Hence the solution of the current situation will facilitate the improvement of drinking water supply security within PA1.2.

The application of the hydrologic model revealed that a continuous increase of the spaces used for dolomite mining in parts of the pilot area can lead to a decrease in the mean discharge of the freshwater supplying springs (here: Kerschbaum). Therefore, hydrological modelling and the monitoring of water quantity and quality related parameter are proposed as BMP’s to support future decision-making actions regarding land use changes.



5 References

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