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TECHNIQUES AND STRATEGIES

Water retention measures must be accompanied by active revitalization of vegetation. A case project: Slovenská Ves

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Abstract. The aim of the project was to propose appropriate and effective anti-flood measures. The study area covered the cadastre of the village Slovenská Ves. The area is located on geological substrate represented by Central Carpathian flysh with unfavourable infiltration conditions. Hydro-physical soil properties (permeability and water infiltration), slope and slope exposure were the main indicators we considered in the project. Two steps were suggested in the land improvement: improvement by technical measures and improvement by land-ecological measures. As technical measures we proposed constructing water holding dikes, water holding dams, absorption ditches, wooden diverters etc. As land-ecological measures we proposed a recultivation with the aim to use and restore a special vegetation composition with high water retention capacity. For this aim we suggest to plant selected tree species, restore swampy forests and promote the spread of moss layer. Thus increasing vegetation retention capacity.

Key words: technical measures, land-ecological measures, land revitalization, waterholding dikes, absorption ditches, *Alnus incana*

Introduction

In recent years the problem of floods in our country has become a difficult task to solve. The sole occurrence of intense precipitation does not present a great risk of flooding. The greatest risk factor in flood events seems to be the logging activity, especially clear cutting. The negative effects of this activity occur in connection with the damage and disturbance of soil surface compaction (Minďáš *et al.* 2001).

In order to select proper methodology for land revitalization in our project area, we had to take into account the local substrate properties, characterized by extremely unfavourable infiltration conditions due to the hardly permeable Central Carpathian flysh bedrock. Slate cracks allowing higher water infiltration rates are only sporadic in our project area. The characteristics of geological substrate influences soil cover properties. Soils in our project area are mainly composed of clay and clay-aluminum soil, which show typically low saturation capacity. These conditions are reflected in low groundwater reserves. Although water sources are numerous, they only have a low yield and they are directly linked with rainfall and usually disappear during thedry season. In summer, during a drought period, the water level is very low and surface water almost disappears. The snowfall is relatively abundant with average snow pack thickness of about 40 cm during the winter until March-April. Melting snow feeds surface streams, which reach the highest flow rates in the spring.

The combination of soils with low water permeability and torrential rainfalls is damaging to the forest-agricultural landscape. Low permeability subsoil is prone to waterlogging in both permanent grasslands as well as arable land. Since the infiltration rate is low, the surface runoff is directly related to the rainfall. Erosion grooves in forest ecosystems thus quickly develop into deep ravines more than 1.5 m deep. Erosion grooves are usually found in agricultural soil as well as in permanent grassland.

Within this project we considered two different methodical proposals on how to approach and solve the problem of floods:
(a) Improvement by technical measures – building waterholding pits, waterholding dikes, diverters, absorption ditches with retention areas, slope levelling.
(b) Improvement by land-ecological measures

Improvement by technical measures

- waterholding dikes in streams
- waterholding dikes in wet agricultural soils
- waterholding measures on unused unimproved agricultural roads (absorption ditches, hoeing on road surface)
- waterholding measures on working unimproved agricultural roads (drainage, local slope corretion)
- waterholding measures in forest ecosystems (absorption ditches with retention areas)
- waterholding measures on working forest roads (drainage, local slope correction)
- waterholding measures on unused forest roads (transversal holes)
- improvement of erosion grooves (dikes)
- construction of wooden dikes on small water flows and periodically drying water flows

Improvement by land-ecological measures

Increasing water retention by moss layer expansion:

Peat mosses can absorb water volume of 26 times their dry weight and brown mosses can absorb water volume 5 – 10 times of their dry weight. By the irrigation of permanent grass growth the succession to hydromorphic communities will be accelerated. Retention capacity of mosses is a renewable source of humidity, which operates continuously. The intensity of transpiration in wet meadows is 6.5 - 7.8 mm.day^{-1} (Busch 2000). This intensity of transpiration assumes full water saturation.

Transformation of ecosystem to an ecological regime of swamp forests:

Woody plants in wet areas transpirate high amount of water that can reach up to 80% of maximum potential evapotranspiration. This amount of water represents 70% of the groundwater reserves and 10% of the precipitation (Ewel and Smith 1992; Krtik 2007). The meanders of the Slovak creek close to the Jewish cemetery were selected as the most convenient area for such implementation.

Revitalisation of wet ecosystems by tree planting (*Alnus glutinosa*):

We proposed to restore the wet ecosystem by planting alders. For 2-year old seedlings of *Alnus glutinosa* average total annual transpiration is about 428 mm. Average transpiration rate of a 60-year old alder stand is approximately 538 mm.year^{-1} (Herbst *et al.* 1999).

Background for soil cover recultivation:

The study area, especially the large ridge parts Magura mountain range were affected by a major wind storm and subsequent logging and processing of wood in this flysh area. Many places in this area were affected by: soil nitrification due to the destruction of the upper layers of soil, subsequent soil compression, formation of erosion furrows, soil compression by using logging machinery, reduction of transpiration and changes in surface forest structure.

The project is carried out in a country where drainage conditions are significantly altered compared to the original conditions of the forest. Although the forest itself regenerates quickly, forest soils are renewed only gradually and the recovery of forest streams and wetlands proceeds very slowly (Webster *et al.* 1992). In an adult spruce stand, 30-90 percent of precipitation return in the form of interception and transpiration to the atmosphere, whereas in the clearings water runs off the surface in great masses (Vacek and Podrazský 2006, Baláž *et al.* 2008). On the clearings the soil density up to doubles by reducing the soil porosity and thus the soil infiltration capacity also decreases (Perry 1994). The surface runoff occurs even during relatively small precipitation events on areas where heavy machinery is used and a timber harvest occurs. On logging roads runoff can reach up to 1300 times the runoff in adult forest (Midriak 1995). Up to 95% of precipitation that drops on the logging road flows as runoff and continues to the water streams (Midriak 2000). Such changes affect the forest hygric functions by a rapid runoff, and paradoxically by water deficit in dry periods (Podrazský and Remeš 2005).

After logging interventions, we can expect that our study area will show a deficit of the crown interception, stemflow, throughfall as well as of tree transpiration that is being reflected in the water regime. In the areas with high ground water level the loss of transpiration can even lead to permanent waterlogging. Periods of extreme waterlogging and drying occurs in areas with rapid drainage. The water content of a deforested soil profile can visibly fluctuate more frequently than the forest covered soil profile (Vacek and Podrazský 2006). Significant differences affecting the accumulation of runoff water occur during snow melting, when the snow located under the forest canopy is melting two weeks longer than in the deforested areas (Zelený 1974).

The whole effort is not only focused on measures leading to the retention of primary water by dikes or diverters but it mainly leads to the recultivation aimed at the restoration and use of vegetation succession with high water retention capacity.

Study area

In terms of geomorphology the area of Spis Magura is located in Fatra - Tatra and Podhôlno - Magura area. The geological structure of Spis Magura consists of flysh rocks of Central Carpathian Paleogene. The lower part is formed by claystone flysh with carbonate conglomerates, breccias and ankerites.

The study area is situated in the cadastral territory of Slovenská Ves and its centre is located at an altitude of 650 m a. s. l. and geographical coordinates 49˚ 13’ 60” N, 20˚ 25’ 60”E. The village Slovenská Ves belongs to the district of Kežmarok which extends in the north-western part of Prešov County. The cadastral territory of the community is located in the central part of district and it is adjacent to the communities of Spišská Bela, Výborná, Reľov, Vojňany, Bušovce. Its total area is 22.44 square kilometres. It has a north-south elongated shape while almost the entire village area is located in the southern part of the cadastre. The village population is 1787 inhabitants (to 31/12/2004). The population density reaches nearly 79.63 inhabitants/km^2.

Heavy clay soil and clayey-loamy soil in most of area is manifested by lower water saturation. In case of fully saturated soil the landslides are common. Soil cover for various deep weathered flysh rocks is typically composed of mostly unsaturated Cambisol, in the highest altitudes is of podsolic soil and on the landslides gley soil (inceptysols).

Areas contributing to the flood risks

Forest landscape damaged area:

Forest ecosystem is composed of fir and spruce-fir forests (*Abietenion, Vaccinio-Abietenion*) and marginally of spruce blueberry forests (*Eu-Vaccinio Piceenion*). On 19th of November 2004 a major windthrow damaged a large part of the forest landscape. The damaged forest landscape has a lower retention capacity and it is easily subject to water erosion. Below mentioned incidents are in most cases results of human activities in this landscape: heavy machinery operation, the use of machinery in adverse climate conditions, inadequate technical parameters of approach roads and the logging road, lack of forest road maintenance, etc.

Forest roads:

A considerable number of forest roads is badly damaged. The surface of most roads is not equipped with diverters, which leads to the formation of erosion furrows. Another issue of the same importance is the slope of forest roads. Roads transversing slopes are tilted towards the slope and prevent the water from running off into vegetation. This results in the formation of deep erosion furrows reaching dozens of centimetres (Fig. 2, see appendix).

Erosion ravines and furrows in the forest landscape:

Infiltration of rain water into the soil is closely related to the condition of the overlying topsoil layer. If this layer is disrupted by the forest management processes, runoff and erosion soil transport are immediately increased, and thus the flow unstability, too (Minďáš *et al*. 2001). The water running down the surface of the forest roads creates erosion furrows in the forest landscape. In case of multiple roads crossing, synergetic effect can be observed. Water flowing from a maze of roads accumulates and creates erosion ravines with a depth of several meters (Fig. 3, see appendix). The length of logging road or forest roads, relief elements (slope, slope exposure) and the amount and intensity of precipitation are the determinants of the runoff volume and therefore of the erosion ravine formation.

Damaged permanent grasslands:

The existence of grasslands phytocoenoses is subjected to habitat conditions and human economic activities. Phytocoenoses can be coenotaxonomically classified as communities of order of *Arrhenatheretalia* Pawlowski in Pawlowski *et al*. 1928, forming a mosaic and transitions between communities of unions *Arrhenatherion* W. Koch 1926, *Cynosurion* R. Tx. 1947 and polygon-Trisetion Br.-Bl. et R. Tx. ex Marsch 1947. In damaged permanent grasslands erosion furrows are formed.

Damaged parts of arable land:

In the damaged arable land at the time of extreme precipitation erosion grooves are formed. Loam to clay-loam farmland soil on the inner Carpathian flysh bedrock is characterized by a lower retention capacity. Abundant rainfall leads to an over saturation of the soil surface by water. Wet areas remain in the field depressions, where rainwater is accumulated. Such basins present large drainage areas, feeding flows that run down agricultural roads (Fig. 4, see appendix).

Unimproved agricultural roads:

Unimproved agricultural roads reduce water absorption into the ground and are susceptible to water erosion. The use of heavy agricultural machinery especially after extreme rain leads to the formation of deep tracks, often solved by making parallel roads after the original road becomes impassable (Fig. 5, see appendix). This phenomenon seems to be the rule that can be seen almost along all agricultural roads.

Proposed measures for the prevention of floods, drought and revitalization

Two approaches were suggested in this project – improvement by technical measures and improvement by land-ecological measures. We consider that the better solution would be the improvement by land-ecological measures because they increase the ecological stability of the landscape.

Improvement by technical measures

Building waterholding pits, waterholding dikes, diverters

Improvement by land-ecological measures

On the flysch bedrock, there is clayeloam soil with low absorption capacity when being fully saturated. Creation of hydro-ecological complexes, e.g. by planting trees around the seepage pits, restoring sloppy forests along the streams, restoring degraded wetlands and floodplains by withdrawing water from the road surface and grasslands to meadows along the rivers will be the main priority. The transformation of these hydro-ecological complexes from mesotrophic grasslands to hygromorphic up to hydromorphic grasslands is linked to the development of moss layer which has a high retention capacity. The advantage of land-ecological approach is that besides improving drainage conditions this can contribute to the improvement of the ecological stability of the landscape.

Retention potential of the bryophyte layer*:*

Sphagnum species can absorb water in amount reaching up to 26 times its dry weight (http://science.jrank.org/pages/1052/Bryophyte.html). Other bryophytes absorb water in amounts of 5 to 10 times of their dry weight (Dilks and Proctor, 1979). Šoltés *et al* (2010) observed that after constructing water dikes, the cover of the moss layer in the inundation zone of water dikes increased in 80 % in the same year.

The moss surface cover on the alluvial plain of the Slovak creek is about 5%. Approximately 1% of moss growth is composed of *Sphagnum* sp., mainly *Sphagnum capillifolium*. We expect that after draining water from adjacent damaged cropland into this ecosystem the moss species composition will develop to form the community of Phragmito-Magnocaricetea class. The moss cover in these communities can be up to 80% (Oťaheľová *et al*. 2001). We assume that this percentage of moss cover can be reached in 5 years. About half of that coverage will be formed by *Sphagnum* species. Taking into account the retention capacity of bryophytes we expect the retention capacity of this community to reach about 20 $l.m^{-2}$ i.e. 2

mm in the area of 8132 m^2. This volume of water is evaporated by transpiration in less than a day because transpiration intensity of wet meadows is 6.5 - 7.8 $mm.day^{-1}$ (Busch 2000).

a) Proposed measures for the restoration of the damaged approach roads, forest roads and the logging road:

Obliteration of temporary approach roads by digging cross pits. Selected deciduous trees with high retention capacity are planned to be planted next to the pits (Fig. 6, see appendix).

Diverters are constructed on working roads. The number of diverters should depend on the slope angle and local slope angle correction of the road. Local slope correction (carried out by heavy machinery) was chosen for a better water dispersion capability in the areas under the road in terms of retention characteristics ("finer" water dispersion) than the diverters themselves. In fact diverters concentrate the water into series of minor flows, which are less efficient in using the absorption capacity of the area below the road (Fig. 8, see appendix).

b) Proposed improvement measures for the damaged parts of the landscape (erosion grooves, ravines):

One of the measures for the improvement of the damaged parts of the landscape has been the construction of wooden dikes into the erosion ravines up to 1 m high. Construction of dikes alone is not a full flood preventing measure. When the compactness of soil surface is damaged and disrupted by the removal of wood, the soil absorption capacity decreases. The surface runoff is most affected especially in flysh areas where even a small decrease in the forest cover is reflected in significant increase of maximum runoff volumes (Minďáš *et al.* 2001). Therefore the solution we proposed involved planting of trees with high retention capacity (Fig. 7, see appendix).

c) Proposed flood prevention measures for small water flows and periodically drying water flows:

The following three water streams were selected for the implementation of this measure: upper part of Vojňanka, upper part of the Slovak creek and periodically drying water stream in an area called Mokriny. In these locations we have designed the construction of approximately 60 cm high wooden dikes (possibly steps, sills) (Fig. 9, see appendix).

d) Proposed flood prevention measures for damaged permanent grasslands and grass fields:

In this case we proposed constructing wooden dikes or absorption stripes and planting trees (Fig. 10, see appendix).

e) Proposed flood prevention measures for damaged parts of arable land:

This proposal consists of two steps. Building the wooden dikes on sopping agricultural land and planting gray alder tree (*Alnus incana*) (Fig. 11, see appendix). Trees in wet areas transpirate high amounts of water reaching up to 80% of the potential maximum evapotranspiration values. This amount of water comprises about 70% of groundwater reserves and 10% of the atmospheric precipitation (Ewel and Smith 1992, Krtik 2007).

Alder was selected as a suitable tree species for planting this area. According to Tužinský (1999), transpiration of 2-year old alder seedlings in conditions of the capillary water saturation was 4-6 $mm.day^{-1}$. When there was a precipitation deficit causing low level of soil water, the evapotranspiration ranged between 2-4 $mm.day^{-1}$ (Tužinský 1999). The research team of Luby a kol. (1977) observed that during June and July i.e. within 61 days the level of precipitation reached 244 mm (annual transpiration of 2-year old alder seedlings min 4 $mm.day^{-1}$), whereas during the rest of the growing season (May, August, September) i.e. within 92 days 184 mm of precipitation were collected (annual transpiration of 2-year alder seedlings min 2 $mm.day^{-1}$). Transpiration of a 2-year old alder stand can drain 428 mm of precipitation per year. In our study area there are four sites of waterlogged arable land with a total surface area of 14 813 m^2. Transpiration of 2-year old seedlings would withdraw 6 339 m^3 of water per year from this ecosystem. With increasing age of alder stands the transpiration increases, although not very significantly (Fig. 1). For 60-year old alder stand the transpiration value is 538 $mm.year^{-1}$ (Herbst *et al.* 1999). Transpiration would withdraw 7 969 m^3 of water per year from the wetland ecosystem.

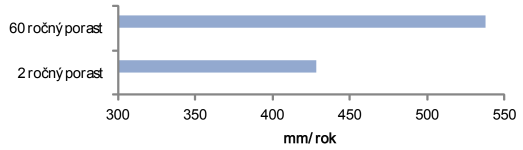

Fig. 1. Comparison of transpiration of 2-year old seedlings and 60-year old stand of *Alnus glutinosa*

f) Proposed flood prevention measures for unimproved roads in the agricultural landscape:

Landscape and water management consist of creating a complex of waterholding absorption ditches connected to the water diverters on agricultural land road and their outlets into the meanders of the Slovak creek and finally construction of dikes in the stream. Our goal was not only to design the mechanical measures but especially to make the best use of the landscape's retention potential (Fig. 12, see appendix).

1st stage - building the absorption ditches in the optimal direction according to the presumed water direction during an extreme rainfall as well as in the areas far from the stream

2nd stage - building the diverters on the road connected to the absorption ditches and then conveying the water to the meadow section of the meander in order to capture as much rainfall as possible using the biotic potential of the landscape

3rd stage - building dikes on the Slovak creek with height of up to 60 cm, assuming that the succession of measures will lead to a more balanced flow rate in the stream, thus increasing its retention capacity

Conclusion

In the present paper we have described solutions of the project Program for landscape revitalization and Slovak Republic 2011 river basin integrated management that has been worked out for the municipality Slovenská Ves. The specific hydrological regime of our study area was our main vantage point when planning the restoration of the landscape. In our study we proposed two variants: improvement by technical measures and improvement by land-ecological measures.

The technical measures consisted in building dikes, waterholding dams, absorption ditches, diverters etc. Heavy machinery and construction material were used when applying these measures. Although this type of measure is a commonly used approach to landscape restoration, we assume that it is only a temporary flood solution.

The second improvement we considered involved landscape-ecological measures. Tree planting was an essential strategy especially in this area with extremely unfavourable infiltration conditions affected by geological substrate, as Central Carpathian flysh is. We have assumed that moss layer spreading should not only increase the area's water retention capacity but also increase the species diversity. We believe that the landscape-ecological measures are a more effective way of solving flooding problems. The forest itself may not prevent the rise of floods but to a large extent can affect the intensity of surface runoff. This effect is caused by crown rainfall interception as well as by transpiration of trees and ground vegetation layer.

Taking into account the active function of the forest ecosystem water management of the landscape and forest management is most needed especially in the flood sensitive catchment areas (Minďáš *et al.* 2001).

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Appendix

Fig. 2. Erosion groove caused by runoff (April 20, 2011, photo: J. Slivinský)

Fig. 3. Erosion ravine, depth of 1.5 m formed by accumulation of surface water runoff from several forest roads in the village of Slovenská Ves (April 20, 2011, photo: J. Slivinský)

Fig. 4. Erosion groove resulting from surface runoff caused by waterlogged areas in the midfield (April 20, 2011, photo: J. Slivinský)

Fig. 5. New parallel field road along original field road in the village Slovenská Ves (April 20, 2011, photo: J. Slivinský)

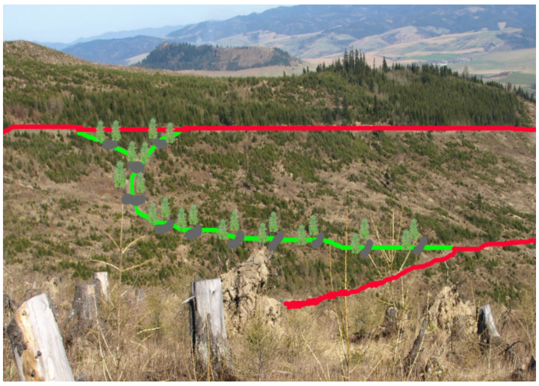

Fig. 6. Forest roads above Slovak creek (April 20, 2011, photo: J. Slivinský)
forest road - Green - obliteration - cross pits with planting alder (*Alnus incana*)
forest road - Red - restoration - diverters, local slope correction

Fig. 7. The proposed model of water dikes in forest erosion groove (left - the current state; April 20, 2011, photo: J. Slivinský, right - suggestion flood measures)

Fig.8. Working forest road - diverters, local slope correction (left – present state; April 20, 2011, photo: J. Slivinský, right - suggestion flood measures)

Fig. 9. Slovak creek (17 dikes) – sills, steps, dikes (April 15, 2011, photo: M. Janiga, simulation of waterholding measures)

Fig. 10. The absoprtion ditch with retention area (left – present state April 20, 2011, photo: J. Slivinský, right - suggestion flood measures)

Fig. 11. The sloppy parts above the Jewish cemetery. Construction of waterholding measures on waterlogged farmland – dikes, tree planting (April 20, 2011, photo: J. Slivinský).

Fig. 12. Proposed measures on unused unimproved agricultural road above theJewish cemetery – absorption ditch and hoeing of road surface (April 20, 2011, photo: M. Janiga)