Integrated restoration of the High Tatras National Park ecosystems following the wind gale of November 2004 – Water Forest Project

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The wind gale of November 19th 2004, that blew over the Slovakia, caused the ravage of 12.600 hectares of forest ecosystems in the High Tatras National Park (TANAP). Mostly artificially planted forest ecosystems were damaged, the value of which – apart from the economic loss – can only be hardly calculated (e.g. the protective function of forests, erosion-defense and the climatic, biological, recreational functions of forests etc.)

One of its functions that, has been disturbed included the erosion-defense of forests with water regime of the ecosystems. The change of conditions occurred, such as changes in humidity of forest soils and rainwater run-off, together with the change of micro-climatic conditions, while potential risk of the fires, droughts and floods have increased.

In order to restore the ravaged forest ecosystems in the TANAP, the People and Water NGO with partners submitted a concrete project titled „The Water Forest". The Water Forest Project is based on integrated restoration of water resources at the selected 52-hectares area as a pilot model for the ravaged forest ecosystems restoration.

In the preparatory stage of „The Water Forest" project, analyses and syntheses were elaborated for the assessment of presumed changes of water regime including proposals for technical solutions titled „Water Holding" – aimed to support the saturation of the ecosystems with rainwater. Consequently, the Water Holdings were implemented throughout the whole 52 ha location during the year 2005, later followed by re-forestation, carried out in October 2005 and April 2006.

The project was financially supported by the Slovenská sporiteľňa (Slovak Savings Bank) with 10 million Sk contribution for the whole projects implementation - from management and purchase of tree seedlings – up to the new forest planting. The TANAP State Forests decided to provide the new tree seedlings free of the charge, and therefore the project could be extended by one more location – a 12 hectares site left after a forest fire (Fire-prevention Water Holding) that hit the ravaged Tatras nature. During the summer 2005, average 100 volunteers including those from the Slovak Scouts organization, regional and foreign volunteers from 21 countries, practically helped in the project.

After carrying out of Water Holdings, the selected location was re-forested on the basis of the reforestation project elaborated by the Forest Research Institute. The project respects the humidity conditions for selection of tree species composition in the newly modified micro-relief after implementation of Water Holdings. The species differentiation of forest trees that have been spaced at the location, copies the „humidity conditions", what may justify us to presume even today that the Water Forest may bring many answers on how to help the natural restoration of forest ecosystems.

Introduction

The dried out ecosystems in any river basins of the world bring about many risks (Roberts, 1995, Rolland, 1998, Kravcik, 2000). The dried out Earth´s surface contributes to the micro-climatic changes, and it lowers the chemical and biological processes directly in the ecosystems (Robert, 1991). The dried out ecosystems cause further degenerative processes of changes in the global ecosystem (Robert, 1995).

The vital and inevitable condition to maintain the temperature balance between the Planet Earth and the atmosphere, is sufficient water both at the Continents and in the atmosphere (Shiklomanov, 1970). Each water vapor molecule in the atmosphere acts as an absorber, reflector and disperser of ultra-violet radiation, heat and light from the Sun. Sufficiency of water in the atmosphere slows down the processes of heat exchange among the Earth´s surface and the atmosphere, and maintains the temperature balance (greenhouse effect).

The fact is, that the area of the dried out regions has been extending, from which less water has been evaporated in the atmosphere than in the past. The most probable triggering mechanism of the regions´ drying-out and extension, are humans. The current civilization elaborated an „ingenious" system of legislation tools, techniques and technologies how to canalize the rainwater and drain it away from the agricultural and urban landscape by canals, ditches, rainwater drainage grids, and through streams and rivers – to the seas and oceans (Mollinson, 1999, Kravcik, 2000).

This „ingenious“ system of the landscape industrialization, widely elaborated through the 20th century, has been drying out the soil, reduces the underground water supplies, and endangers the renewal of vegetation and biodiversity, reduces the amount of water evaporated in the atmosphere, reduces the water supplies in the hydrological cycle, and changes the rainfalls distribution (Kravcik, 2000). Insufficient exchange of water between the continents and the atmosphere is likely the most serious cause of weather disturbances that consequently cause follow-up degradation of natural ecosystems through wind gales, floods, droughts and fires (Rolland, 1998).

Paradoxically, the changes of ecosystems that occurred in the agricultural urban lands, result in the domino effect through further degradation of natural ecosystems that goes on out of human interference. The typical example of such a degenerative change is the wind calamity in the High Tatras National Park that in November 19^{th} 2004 rolled out forest on 12.600 hectares area.

The invasion of the cool frontal system from the ocean to the European continent that swept over the High Tatras ridges, had been consequently pulled by warm ascending currents from the open agrarian-urban overheated Poprad basin (three weeks of heats were too extreme for the autumn season – 15-18°C), and caused the rolling-up of cool air to the form of cylinder (the Tatra bora effect). This Tatra story of the most extreme bora incidence, as well as many other weather disturbances show that we need to find tools for prevention from the natural storms and to minimalist the risks caused by the climatic changes. More than in the past, we need today new methodologies and innovative solutions for the ecosystemic and integrated restoration of devastated nature parts – caused either by human activities, or by so called natural storms.

Soon after the Tatra wind storm, the People and Water NGO has offered the partners and donors to solve o concrete example of the ecosystemic restoration of the ravaged parts called The „Water Forest“. For the project, a 40 hectares location situated at the eastern end of Horny Smokovec, over the Way of Liberty and ca 2 km eastern from the Stary Smokovec centre, while the 12 ha Fire-Prevention Water Holding location was situated at the west part of Stary Smokovec, also above the Way of Liberty. The areas were carefully selected after consideration with the SL TANAP management.

Material and methods

The native forest at the selected location included 80-100 years old trees located at the glacial moraine sediments with gravel-boulder blocks. As for the classicification by the Zurrich-Montpellier school, the trees were classified in the *Vaccinio-Piceion* as as. *Vaccinio myrtilli – Piceetum*. In the time of the wind gale storm, the trees have not yet reached the climax stage.

The geomorphologic classification (Luknis 1968) places the affected location to the Fatra-Tatra area, and more closely to the Sub-Tatra basin unit, and sub-unit of the High Tatras Foothills. Typologically, the area relief belongs to the erosion-accumulative, glacial – even glacial-fluvial area, situated at the poly-genetic sediments, ranging from slightly solidified - to crumbly soils, with weak application of lithology. Of the relief forms, the more noticeably found here are the degradated areas at moraines and the glacial-fluvial complexes.

From the climatic view, the affected area belongs to cooler climatic areas with average temperatures in July under 16°C, and to the moderately cool district, with 12-16°C July temperatures. According to the climatic-geographic type classification (Stehlik, 1970), the location´s climate is of the mountainous character with only small inversion of temperatures, ranging from humid to very humid. Sub-type: cool with temperatures in January from – 5 to – 6°C, with the annual total sum of rainfalls amounting to 950-1000 mm.

As for the wind force and direction, the area is regularity affected by specific form of raid winds coming from the north, so called „the Tatra Bora“. Though it occurs irregularity, the historic records confirm its incidence: it occurred 5-times in the 20th century, and also the 2004 November wind storm is regarded by some authors as the impact of the “bora”, being the strongest of all.

The dangerousness of raid winds in the High Tatras may increase significantly, as the weather extremalization and sudden changes of climate through the last decades show that also such weather forms (such as the raid wind, sudden rainfalls) may occur more frequently. Such a trend is confirmed also by analyses of spacial changes in rainfalls distribution not only in the High Tatras area, but also in the whole Slovakia.

The geological substrate of area comprise the rock of crystallinicum and the Inner-Carpathian paleogen. Crystallinicum builds the central part of the High Tatras. It concerns the biotitic granodiorits, and even tonalities (Nemcok, 1994).

Paleogen is the formation characterized by various ratio of claystones to sandstones. The mentioned rocks do not reach the surface in the affected area, and are covered by Quaternary sediments.

More than one half of the affected area´s Quaternary is comprised of glacigennic moraine sediments. They are weathered, gravel-boulder-like with blocks of granitoid rocks. Sediments are part of the oldest, so called „the Smokovec“ moraines of the High Tatras (hanzel, 1984).

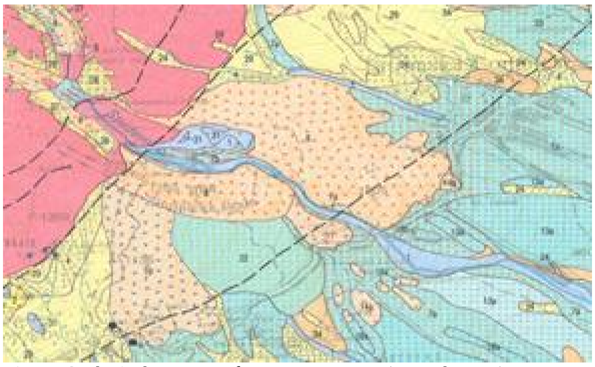

Fig. 1: Geological structure of Water Forest area (Nemcok, 1994)

The glacigennic moraine sediments are, from the eastern part, connected by the glaci-fluvial crumbled gravels that are coarse – even boulder-like, with incidence of blocks (older Pleistocene). The basic component of the sediments are formed by sand, mostly crumbled granodiorits crumbled into sand. It is coarse-grained of 1-4 cm diameter, chocked with silt. The silt (dust-like) clays are strongly kaolinized, and form the cementing component of the sediments. The silt-like and sand-like fractions together form 50-60 % share in the sediments (Linkes, 1980).

The soils found in the affected area are characterized by the mid level of permeability with the transmisivity coefficient $T=1.10^{-4}$ - 1.10^{-3} $m^{-3}s^{-1}$. Due to a very variable content of clay components, their permeability changes significantly both in vertical, and in horizontal direction (coefficient of filtration $k = 10^{-7} – 1.10^{-5}$ $m.s^{-1}$ (Linkes, 1980)

The level of underground water in sediments depends on the morphological position; it is found ca 5-15 m deeply under the ground, and is mostly of loose, locally even of slightly tense character. The level of the underground water fluctuates throughout the year by 3-4 m, with maximum levels in the spring end during the snow melting, and in the summers with abundant rainfalls. The minimum water levels are mainly in the winter months, in December-March period (Luknis, 1968).

In the affected area, there are no surface watercourses, and no springs significant for water management use. The underground water supplies have been supplemented both by rainfall infiltration, and from the hidden transfer from the more highly situated crumbled rocks. The average specific underground outflow from the area amounts to 2-5 $l.s^{-1}km^{-2}$ (Hanzel, 1984).

The elevation gradient, structure of substratum and the diverse vegetation in the affected area called the Uvaliny (80-100-year old trees) formed, prior the November 2004 wind storm gale, good conditions for life of rich zoocenoses of mountaineous character, with incidence of protected, alpine and boreo-alpine animal species, and sub-species.

On the basis of the field research of the affected area, and of the re-construction of its floristic composition, it is possible to detect, what fauna species, mainly representatives of vertebrates, lived here prior to the calamity, and which of them will be able to survive, and what new species will migrate and settle in the area.

The evaluation results of rainwater erosion in the affected location (Midriak, 1977, Saly, Midriak, 1995) show that due to water flowing at the surface, 72 % of the area is prone to the mid-level of erosion – and 25 % up to the strong level of erosion.

The average intensity of possible soil outflow carried away by water erosion due to unconcentrated surface run-off from the whole model area amounts to 1,34 mm annually. According to (Midriak, 2005, Stehlik, 1970), this value should not underestimated, because the intensity of soil creation in similar natural conditions is only several hundredths, at maximum several tenths, per a year; we can presume from this that e.g. in 25 years period of imperfectly protected soil surface could result in average 33,5 mm loss, while the soil creation would be up to 2,5 mm increase.

On the basis of knowledge of the affected location, we proposed small water-holding technical measures that will slow-down the rainwater and snow melting run-off from the area to the gullies and river beds, thus stopping the drying out of the damaged ecosystems and avoiding possible risks of floods, until the restored vegetation starts its water-holding function again (Mollison 1999, Kravcik at al, 2000). We proposed and implemented the mentioned measures from various reasons.

The most important reason is stopping of the drying out of the ravaged forest ecosystems, and avoiding the risk for the newly planted and naturally renewed trees threatened by lack of humidity (Mollison, 1999, Rolland, 1998) for their optimal growth, and paralelly, to sustain the conditions for underground water protection and flood-prevention also after the project end. All these measures are here also to stop the micro-climatic changes and the ecosystems´ tendency to erode.

Through the water-holding measures, we wanted to achieve the stability of the restored location, conservation of water resources, prevention from floods and fires, and to create conditions for smooth natural restoration of trees (Kravcik at al, 2000). The project aims to point out to the simplicity of innovative solutions for conservation of the Slovakia´s waters, biodiversity, climate and jobs creation. By the project, we have implemented the Water Holding model solutions (model of rainwater retention in calamity-ravaged forest ecosystems) by means of small waterholding technical steps including preparation of ravaged areas for reforestation.

This solution will prevent the affected location´s temperature from rising, it will keep, and most likely also improve the current microclimatic conditions. Besides, it will stop the drying out, and protect the water resources quality; the risk of floods and fires will be mitigated. This concrete solution of the Water Holding model projects will create favorable conditions for the planted trees growth, and for smooth restoration of the Tatras forest ecosystems.

Through their long-year effort, the People and Water NGO have been promoting this solution in Slovakia by means of projects called The Blue Alternative since 1994 (Kravcik, 2000).

The Water Holding typology for Water Forest

The individual dykes, their type, water-holding capacity, dimensions and possible combinations of types, were proposed according to the micro-basin´s area (basically it is a catchments area between the proposed dyke and the closest dykes above it), field conditions and according to the kind of local material for their construction (Mollison, 1999).

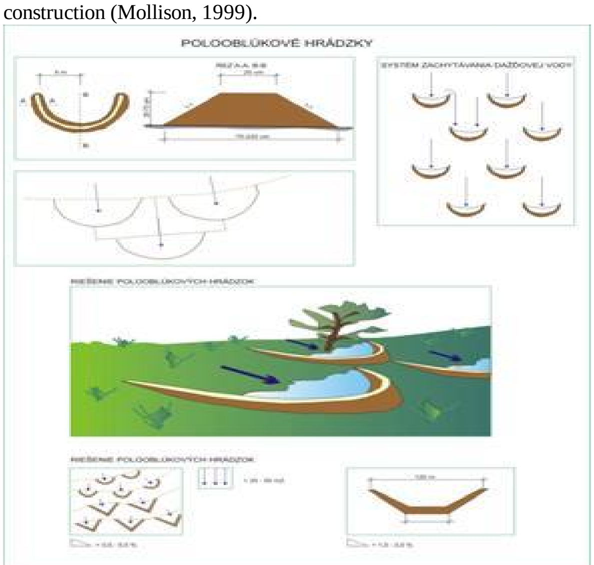

Fig. 3: Schematic drawing of semi-arc dikes (Haber, 2005)

The concrete solutions and types of dykes depended on particular conditions of the relief structure, local material and needed proposed parameters. For the Water Forest, 9 types of typological solutions of Water Holdings were elaborated:

1. Contour-line dykes
2. Terraces
3. Semi-circular dykes
4. Triangular dykes
5. Eye terraces
6. Gully micro basins
7. Small-hollow structures
8. Cassette structures
9. Checkerboard structures

The Contour line and Semicircular dykes came in useful best of all. Therefore, we present them as a typical example of calculation of individual micro-basins´ structures and special arrangement.

Earth dike: Constructed from the local soil digger out from the catchments yard of the dyke, and from the furrow, for the aeral foot of the dyke including using it for the dyke body building ; the stones obtained from digging were used for strengthening of foots of lower parts of the dyke earthworks.

Fig. 2: Contour line dike implemented by Tencin University volunteers

Dike made from windfalls: The windfalls that are situated in right angle to the contour lines, following the valley line, were used for the dikes construction. We used the hollow left by the fallen tree roots, as a catchments yard for dykes, and the „ root cake" as the dikes body. The hollow left after the roots was usually modified – enlarged by digging, while the soil from the digging was used for building of the dyke (made of earth or stone), connected with the root cake.

Dike with timber wall: On places with plenty of wood debris (pole timber), we built timber wall dykes. Thus we achieved several ecological effects: all wooden mass will remain in the local area, and will later serve for creation of nutritious forest soil. The timber wall dykes were constructed from the wooden poles 2,0-4,0 m long and of 8-20 cm thick.

Fig. 4:Dike with timber wall implemnted by Slovak Scouting

Dikes from stones. A number of dykes were built from the stones, as the local soil is sometimes rich of them. The needed „carrier" stones for building of such a dyke were of minimum 20 cm in average, and were properly combined with the tinier stones and compact clay.

Earth dyke anchored by branches: This type of dyke has favorable ecological effects, similar to those of the timber wall dyke. Part of wooden debris remained in the earth, and will later serve for creation of nutritious forest soil. The technical advantage of this dyke type construction dwells in anchoring the dikes body by means of thicker branches to the ground, thus stabilizing the dyke.

Fig. 5: Semi-arc dike implemented by Diplomatic High School, Bratislava

Possibilities of the five mentioned dyke types combination: Very changeable, mainly geological and pedological, conditions, required various combinations of dyke types. These combinations did not lessen the construction quality, but vice versa – by adjusting to the given natural conditions – they fitted better in the relief microstructures. The combinations were random, as the local conditions and local material quality allowed.

Guide – methodology of works progression

The Water Holding construction works were coordinated according to the following progression of works:

- clearing the area and removing the impurity from the area
- thorough removal of humus layer from the area
- digging out of the furrow/trench for the foot of aerial earthwork of dyke,
- digging out of the catchments /water-holding/ gutter,
- making the earthwork of the dikes body from the digger out soils/rocks/, either cohesive or non-cohesive, alternately composed soils /rocks/
- the digger out stones were used for strengthening of foots and lower parts of dikes earthworks
- adaptation of the dykes with adding humus that was previously piled in stocks,
- strengthening of dykes´ parts by stones,
- adjustment of the surrounding area, possibly using it as the filtration material at the bottom of the catchments yard,

Discussion

The water-holding elements of 35.692 m3 overall volume are currently found at locations both at the Water Forest, and at the Fire-Prevention Water Holding. Of this volume, 19.864 m3 represent the hollows left after fallen trees, and 15.828 m3 are built by Water Holdings. Our work was based on precondition of need to catch the whole volume of one-off downpour rainfall of 88 mm richness. It is questionable whether it is enough or not. As for the given soil characteristics, we came to conclusion that it is vital to catch 52,8 mm rainwater (27.456 m3), i.e. of water that could potentially run off the area. According to estimation, 382 m3 volume of hollows left after fallen trees are found at one hectare area, what equals 19.864 m3. Therefore, we decided to build 15.828 m3 Water Holdings more necessary for catching the overall 88 mm one-off downpour rainfall, increased by 30% volume of Water Holdings as a forfeit for low quality and poorly fitting Water Holdings. That means, the given surveyed locations should be able to hold a 88 mm one-off extreme downpour rainfall. Such restored Water Forest and Fire-Prevention Water Holding should function, from the water regimes view, as the original forest that grew there prior the wind calamity.

Therefore, it is OK to ask many questions: whether it will happen like that and whether the preconditions will be fulfilled, or whether they were too overblown, or underestimated. However, one thing is for sure, i.e. that during the first downpour rainfalls, the system started to work, and the rainwater did not flow down the slopes, but instead, it was held in the hollows after fallen trees, and in the built Water Holdings, and consequently it was soaking.

It is possible to presume that the built system will affect the increase of underground water supplies, and we may also expect creation of tiny spring areas. We also presume that the rainwater that will be left in the implemented areas ecosystems, will influence the increase of the water transpiration into the atmosphere. This effect could become the subject of interest of the integrated soil conservation research studies.

It is likely that the shallowness of the impermeable layer under the substratum of the western part of the implemented area was the reason that some tiny springs started to arise. We suppose that the implemented restoration project should become the subject of a research to study the restoration impacts on the underground waters supplementation, on the evaporated water balance, chemical and biological processes and quickness of the trees restoration. The achieved knowledge could be used in other restoration programs in river basins.

Acknowledgements

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