MINISTRY OF ENVIRONMENT, WATERS AND FORESTS

Iceland Liechtenstein Norway grants

ANNEX 10

GUIDE FOR THE RESTORATION OF DEGRADED PEATLANDS FROM ROMANIA[1]

[1] The guide for the restoration of degraded peatlands in Romania is a document in which are summarized the results of some activities carried out within the Project " *Restoration strategies of the deteriorated peatland ecosystems from Romania (PeatRO)*", supported under the Programme RO02 – "*Biodiversity and ecosystem services*" and financed by an Grant given by Iceland, Liechtenstein and Norway. The Program Operator was the Ministry of Environment and the Project Promoter was the Bucharest Biology Institute of Romanian Academy (IBB)

CONTENT

INTRODUCTION

Globally, peatlands cover an estimated area of 400 million hectares in 180 countries, equivalent to 3% of the Earth's land area (Joosten and Clarke, 2002).

In the last millennia the main anthropic activity of the peatlands has been the extraction of peat, especially for the heating of the houses and for the cooking, but in the last two centuries the activity of extraction it has been added the one of drainage, often followed by the complete destruction of the specific habitats, as a result of urbanization, extension of agricultural areas and pastures (Clark and Reiely, 2010). At European level it is estimated that the functions of the peatland ecosystems are so affected that in 50% of the existing ones no peat is accumulated, while 20% of the secular peatlands have disappeared. (Joosten and Clarke, 2002). The situation is all the more dramatic as these fragile ecosystems recover extremely hard, peat accumulation being an extremely slow process. It is estimated that the peat layer formation rate is 20-60 cm over 1000 years (Couwenberg, 2005).

The functions of peatlands are extremely complex and include the maintaining of biodiversity, the role of carbon and water reserves, regulators of water level and waterways, etc. Being unique acidic ecosystems, peatlands are home to species with special adaptations, mostly relictations, dependent on these habitats, therefore are considered to be among the most valuable biodiversity reservoirs. Also, the peat layers accumulated slowly over thousands of years, are a true museum of natural history, providing valuable information on the dynamics of the fauna, and especially of the vegetation over the time.

Globally, peatlands store about half of the soil's carbon reserve through the ability to absorb and store long-term atmospheric carbon dioxide. That is why they are considered to play a major role in moderating climate change. Peat drainage, followed by the massive release of carbon dioxide and methane gas, can have a major impact on climate warming and climate change. Studies have shown that peat drainage from the temperate zone releases, annually, by peat oxidation, approximately 25 tons of carbon dioxide per hectare (Șotropa, 2010). It is estimated that over the past 10,000 years atmospheric carbon dioxide stored in peatlands has reduced the global temperature by approximately 1.5-2˚C (Holden, 2005). Global estimates show that due to the drainage, 445,696 million tonnes of carbon dioxide were released into the atmosphere, of which 1298 million tonnes only in 2008 (Joosten, 2009). As a result of the anthropogenic impact, Romania, where it is estimated that the areas covered by peatlands have diminished in the last 10 years, has also contributed to this massive release by approximately 4% (Joosten, 2009).

Currently, most peatlands in Romania are included in the European network of protected areas *Natura 2000.* Their inclusion in the network was made mainly based on studies and estimates made and published in 1960 by Emil Pop. Subsequently, studies on peatlands in Romania were few and disparate, not covering the whole territory of the country, and nor the issue of their rehabilitation, restoration and conservation, in all its complexity. Relevant and insufficiently documented data are provided for the assessments made at European level (Minayeva et al., 2009).

From the analysis of the existing data it appears that in Romania there are natural habitats of bogs and peatlands of communitary interest, whose conservation is regulated by the Habitats Directive (HD). Thus, of the 10 types of such habitats listed in Annex 1 of the DH, on the Romanian territory there are 8 types, of which 4 types of acid peatlands (7110, 7120, 7140, 7150) and 4 types of alkaline bogs (7210,7220,7230, 7240) which increases the importance of these habitats by prioritizing them for rehabilitation, reconstruction, conservation and monitoring activities.

This guide aims to synthesize the main techniques and methodologies used in the extensive restoration programs of worldwide degraded peatlands, adapted to the specific and issues of the peatland ecosystems from Romania. This work will be a useful tool in supporting the authorities, local or national, in the process of restoration / reconstruction of degraded peatland ecosystems.

1. PRINCIPLES OF RESTORATION

1.1. Decision on the opportunity of restoration interventions

Before taking any steps regarding the restoration of a peatland habitat, a critical analysis of the opportunity and feasibility of the intervention is required, as well as a correct anticipation of its efficiency. For this, the degradation stage must be assessed very correctly and identify the main factors that led to the destabilization of the habitat. As the most disruptive factors affecting peatland bogs are the decrease of the hydrological regime and the exploitation of the peat, these factors are the first to be evaluated. Usually, it is considered that a peatland can be restored if:

- peat layer thickness measures at least 50 cm
- the specific conditions allow maintaining/restoring the positive hydrological balance.

If these two conditions are met then the most likely restoration option is the correct one and the intervention will be able to reach its goal.

In making the decision it may be useful to build a decision matrix or decision tree (*decision tree*). A decision tree model for peatland bog restoration projects is presented in Figure 1 (Bodescu et al., 2016). In this case, the decision tree comprises the evaluation of the determining factors in the functionality of the site, as well as the evaluation of its particularities (topography, hydrological regime, vegetation, etc.).

1.2. Natural regeneration

The natural regeneration of the sites from which the peat was exploited is a slow process and is recorded with a low frequency if nothing intervenes after the cessation of the exploitation. For example, only 17% of the peatlands where the peat was exploited in blocks were naturally recolonized with *Sphagnum*, while in those where the exploitation was done with the milling machines no cases of natural recolonization were reported (Quinty, 2003). The clear cut surfaces, water deficit, exposure to dehydration, erosion and lack of spores, seeds or any propagules capable of regenerating new plants, are the main causes that limit the natural regeneration. Therefore, interventions are needed to initiate the regeneration of the characteristic vegetation of the habitat, contributing significantly to its reconstruction.

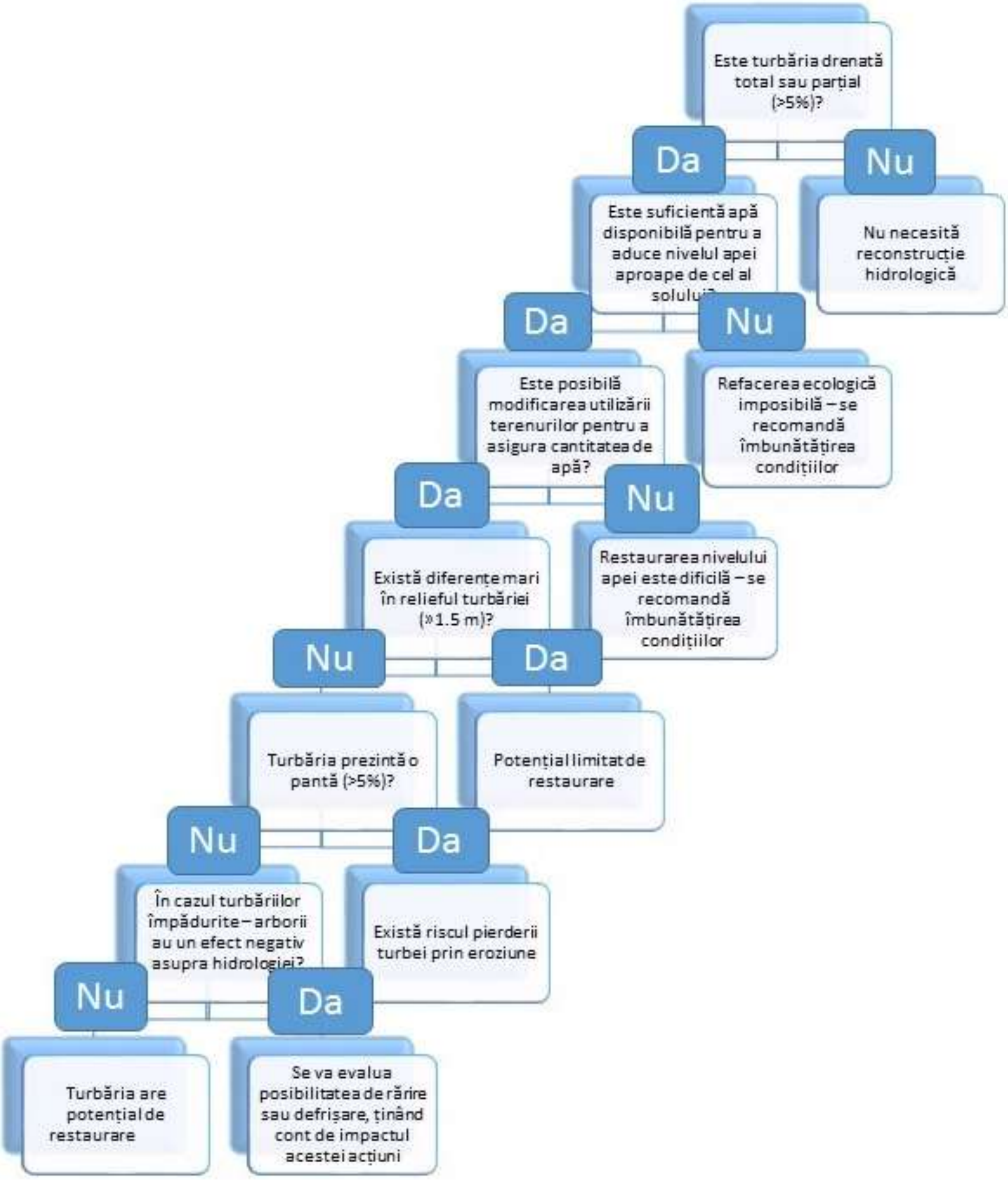

Figure 1. - Decision tree for restoration projects for drained peatlands

1.3. The objective of the restoration

The central objective of a restoration action is to restore the functions within the ecosystem so that it can function autonomously, self-regulate and, consequently, become an active peatland that accumulates peat. The key factors for restoring the functions within the ecosystem are a positive hydrological balance and the restoration of the vegetation associations characteristic of peatlands (usually those with *Sphagnum*).

2. METHODS USED IN RESTORATION

The factors that disrupt the proper functioning of the peatland ecosystems in Romania are various and often act synergistically. According to the studies carried out in the field (on site), within the PeatRo project, the main factors that negatively influence the balance of peatland bogs in Romania are: drainage, fragmentation of habitats, presence of invasive species, disappearance of characteristic species, grazing, mowing, tourism, cutting down protection trees, eutrophication, pollution, presence of wastes, transformation into agricultural land, exploitation of peat, collection of berries and mushrooms, arson, presence near human households / settlements, construction of roads and buildings. Images that exemplify these factors, captured in the Romanian peatland ecosystems, are presented in the Annex. Although numerous, the disturbing factors identified have different intensity impact, which is why following the particularities of the Romanian ecosystems, the methods used in the restoration will refer to counteracting the factors that produce the most serious imbalances, namely drainage, the presence of invasive species, habitat fragmentation and characteristic species disappearance.

2.1. Methods of restoring the hydrological regime

Restoring the hydrological balance in the peatland ecosystems is considered to be decisive for the success of any restoration project. Therefore, the site-specific conditions regarding topography, climate, peat layer chemistry, groundwater level, the existence of underground springs, the existence of additional sources of water (springs) in the vicinity of the site, must be evaluated from the beginning. In general, the methods of restoring the water regime can be grouped into two main categories:

- methods to reduce water surplus when the site is overfilled;

- methods to increase the water level in the site and restore a positive hydrological balance regardless of the season.

2.1.1. *Methods to reduce water surplus*

These methods are required when the site is overfilled with water, being almost flooded, which makes it impossible to survive typical vegetation of the peatlands. These are relatively rare cases and the main methods of intervention are:

- upstream dams construction to reduce water supply
- re-directing the watercourse so that it does not accumulate on the site
- execution of water drainage channels from the site
- planting large species consuming water to increase evapotranspiration.

For this type of intervention are recommended Birch species (*Betula sp.*), on which studies have shown that the rate of transpiration is three times higher than other trees such as oak or beech and up to seven times higher than in some conifers, such as pine or spruce (Kozlowski and Pallardy, 1997).

2.1.2. *Methods of increasing the water level in the site and restoring a positive hydrological balance*

This category of methods are the ones that should be used frequently in restoration programs, because drying is one of the most commonly disruptive factors encountered in the Romanian peatland ecosystems. These methods consist either from various works and arrangements that lead directly to increasing the water level in the site or to the indirectly reducing of evapotranspiration. Also in this category are the methods by which is ensured the supply of the site with quality water.

2.1.2.1. Direct methods of increasing the water level in the site, adapted according to the model presented by Schumann and Joosten (2008) are:

- The management of existing drainage systems through:
    - reducing water losses by building locks and stables
    - removal of underground drainage pipes
- Increasing the natural humidity by introducing wood material, stones and other natural obstacles in the streams that pass through the bogs

- Embankment of drainage channels through dams/weirs constructed of suitable materials; it is recommended the use of natural materials (wood logs, wood chips, branches, peat, mineral soil, etc.) which helps to reduce costs and also ensures a natural appearance of the site after the intervention; artificial materials (concrete, plastic or metalic sheet) can be used but only in special cases, when natural materials are not available/ efficient. The dam can be constructed from a single type of material or combinations of natural materials (braided branches, soil and plastic pipes) can be made as shown in the Figure 2. The built structures must be durable and withstand the topographic, climatic and seasonal characteristics of the site. An example of a weir constructed mainly of natural materials (branching, earth, gravel and plastic pipes) is executed to limit the drainage of water through the main drainage channel of the site ROSCI0112 *Mlaca Tătarilor* (Photo 1).

Photo 1 – Mixt weir executed in the site ROSCI0112 *Mlaca Tătarilor*

- The complete filling of a care drainage channels can be done with natural or artificial materials, in similar ways to the famous objective. Peat is a recommended material due to its sealing properties and also because it offers optimum substrate for restoring specific vegetation. In order to use the peat, it is necessary to consider obtaining the permits.

- Embankment with charms applied in the marginal areas of the site. They can be made from peat or other materials such as clay or plastic.
- Creation of water basins by excavating areas of the site; these areas should be restricted to limit erosion by wind and water.
- Diverting the course of some permanent or seasonal water sources towards (into) the site; such an intervention was made on the site ROSCI0112 *Mlaca Tătarilor* (Photo 2).
- The irrigation of the site by pumping the water in the site is possible only on small areas due to the high costs.

Photo 2 - Diverting the flow of a seasonal water source into the site ROSCI0112 *Mlaca Tătarilor*

It is recommended that these techniques be applied gradually, being abble to avoid flooding of the site and to allow the gradual restoration of the characteristic vegetation.

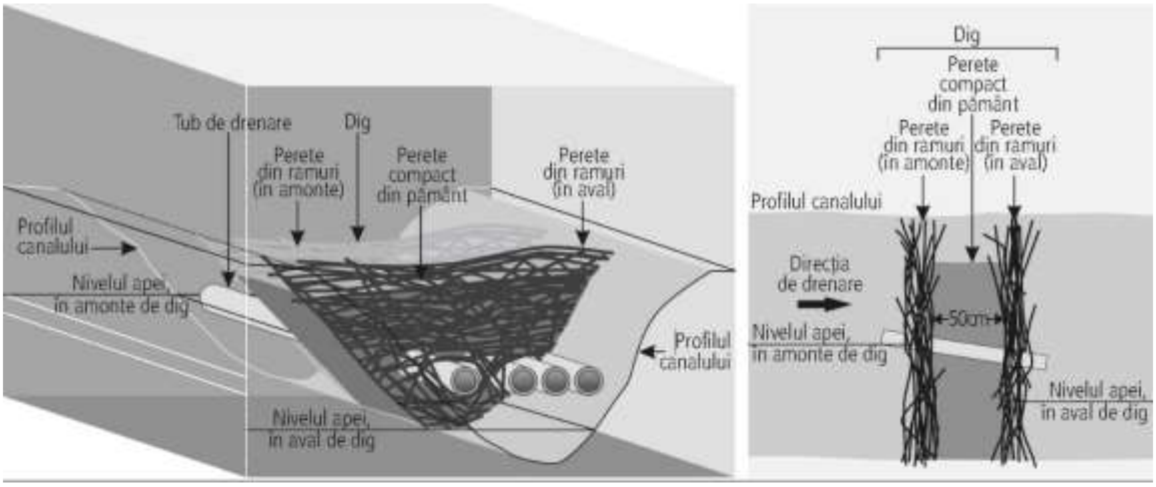

Figure 2. Diagram of a mixed dam constructed from natural and artificial materials (original)

2.1.2.2. Indirect methods of increasing the water level in the site which refer to the reduction of evapotranspiration

Evapotranspiration is a very intense process that can lead to complete drainage of a peatland site over time. In the peatlands colonized with trees, a direct correlation was established between the density of the trees and the water level in the site; the more developed the tree layer, the lower the water level is (Sarkkola et al., 2010). The upper plants, especially the trees, are capable of eliminating significant quantities of water by transpiration, of the order of tens and even hundreds of liters daily, depending on the species, the season, the circulation of air currents, the availability of water, etc. For example, estimates made within the PeatRo project showed that individual birches from the site *Mlaca Tătarilor* eliminates daily, by sweating, an average of about 1440 kg of water, and those of cruxin 1355 kg of water (Bodescu et al., 2016). Furthermore, the trees continue to remove water, even after the trunk has been cut (Photo 3).

Photo 3 - Removal of water through a trunk *Frangula alnus* (cruxin) 24 hours after sectioning

The methods of reducing evapotranspiration consist of:

- Removal of trees from the central peatland areas and removal of wood from the site. Such an intervention was executed on the site ROSCI0112 *Mlaca Tătarilor* (Photo 4 and 5)

Photo 4 – Aerial-photograme with the site *Mlaca Tătarilor* before the intervention

Photo 5 - Aerial-photograme with the site *Mlaca Tătarilor* after the intervention

The efficiency of reducing water loss through evapotranspiration from sites where wood material has been removed is also proven by the estimates made within the PeatRo project, regarding the rate of evapotranspiration before and after the intervention. (Figure 3).

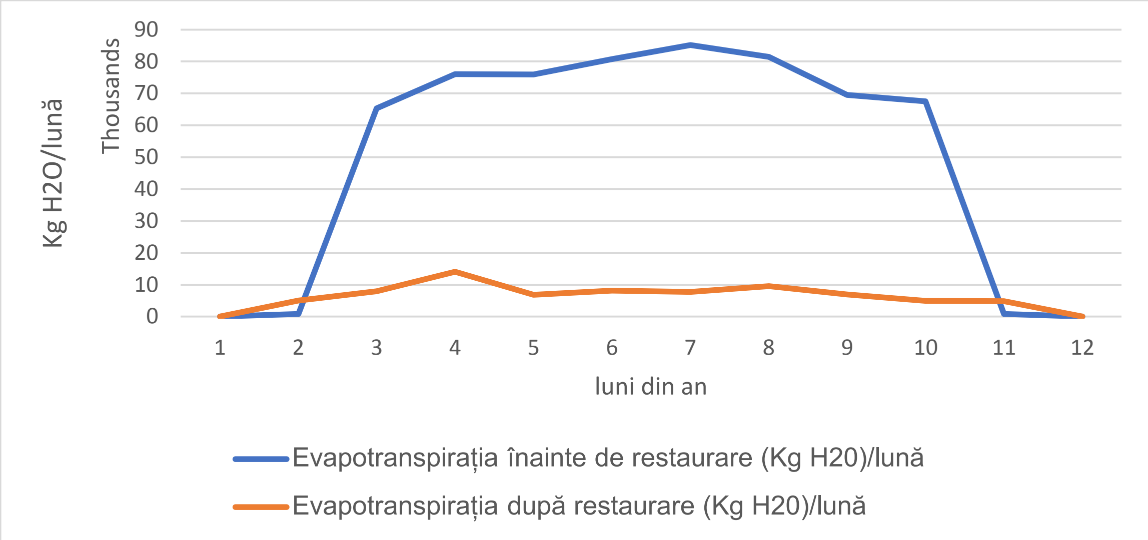

Figure 3 - Dynamics of evapotranspiration in the site *Mlaca Tătarilor*

- Reducing the impact of air currents (which intensifies the evapotranspiration process) by planting trees curtain in the area bordering the site, thus facilitating the creation of a water vapor saturated microclimate. It is appreciated that in an environment saturated with water vapor, even if the water is available in the substrate, the elimination of water through transpiration is very low, sometimes being completely blocked.

2.1.2.3. Methods to improve water quality

- the control of the physico-chemical parameters of the water sources available in the proximity of the site and the use of the sources that have parameters closest to optimal
- avoiding sources near agricultural areas because they can be contaminated with fertilizers, pesticides etc.
- creation of natural filters upstream the site.

2.2. Methods to combat invasive species

Human intervention in bogs to combat invasive species (native or neophyte) is itself impact-generating. As the processes, interactions and species in peatland bogs are complex and in many cases (especially microflora and microfauna) insufficiently known, it is desirable to have an approach based in the first stage on bringing to the optimal trophic and hydrological parameters of the peatland.

Since in most cases the invasion and expansion of invasive species in peatlands is due to eutrophication and decreased humidity, counteracting these disturbances may be sufficient to stop the invasion and eliminate invasive species. Direct intervention on invasive species is recommended only for adventitious species or in situations where the presence and extension of native species that are not specific to peatland obviously affect the conservation status of peatland habitat and the typical species of it. (such as *Sphagnum* sp., *Polytrichum* sp., *Eriophorum* sp., *Drosera rotundifolia, Andromeda polifolia, Empetrum nigrum, Scheuchzeria palustris, Carex pauciflora, Vaccinium oxyccocos, V. uliginosum, Menyanthes trifoliata* etc.).

Also, direct intervention can be justified in cases where, after taking measures to remove trophic and hydrological imbalances, monitoring for the next 2-3 years shows that the expansion of invasive species (objectified by their vigorous growth and the emergence of new plants) keep going.

An individual approach to each disturbance is required and the strategy and measures to combat them must be tailored to their unique characteristics, by a team of specialists, necessarily comprising at least one botanist-ecologist and a hydrologist or hydrogeologist. In some cases, the presence of a forest specialist or a zoologist may also be required (Pawlaczyc et al., 2006).

The purpose and extent of the combat activities must be determined taking into account the local particularities of each disturbance regarding the conservation status and the species of conservative interest. In each case, the conservative advantages obtained by direct human intervention over invasive species must be weighed against the disturbances that can be caused by human activities.

Direct intervention should be carried out only in cases where the conservative benefits are significantly higher than the disturbances caused. Obviously, such an evaluation requires a very good knowledge of the context of the bog, including here the physico-chemical, hydrological parameters, plant and animal species (preferably including the microbiota), processes and interactions between them. In case this data is insufficiently known, interventions for removing trophic and hydrological imbalances, doubled by monitoring and study activities are preferable, and direct intervention will take place, if necessary, after accumulating more information.

The control measures should be applied with the least possible impact on peat moss and the surface of the peatland, and maintaining a high and constant humidity. Also, the control activities must be guided and doubled by monitoring activities designed to evaluate the success of the combat, but also to ensure the absence of the negative effect on the species and habitats that are protected, and to allow the immediate stop of the intervention in such cases.

It is of major importance to differentiate open peatland habitats, where it is appropriate to eliminate woody vegetation from forested peatland habitats, which on their turn are important for conservation, requiring particular strategies too. Since the differentiation between the two types of peatland and the selection of conservation strategy can be difficult to be made, these must be done by specialists.

The presence in the marginal areas of peatlands (or sometimes dispersed, and within them) of some native native species of this habitat can be tolerated in some cases, if the density of the specimens is low and if (especially in the case of woody vegetation) the vigor of the individuals is reduced. These specimens may be important for maintaining a high diversity of invertebrates. It is considered that the negative influence of vascular species on peat moss has three main components:

- Studies have shown that shading of *Sphagnum* pillows by more than 50% by vascular plants reduces their development. For dwarf shrubs (such as in our country those of *Vaccinium myrtillus*) this value corresponds to a coverage of 70%, a value that requires immediate management interventions (Hayward şi Clymo, 1983).
- The organic material (litter) produced by the vascular plants covers the peat muscles and generates the eutrophication of the respective surface.
- The trees, especially the vigorous ones, lose significant quantities of water by evapotranspiration, thus contributing to the water imbalance of the peatland (Schumann and Joosten, 2008, Pawlaczyk et al., 2006). This information must be taken into account

when choosing the method or combination of methods used to combat it. In cases where necessary, the elimination of mature trees, tree seedlings and shrubs is considered a priority. The elimination of grassy plants, if they are adventitious species, may also be a priority.

Published specialized literature presents a number of general methods of combating invasive plants, of which only some are suitable for peatland.

2.2.1. Direct human intervention

2.2.1.1. Mechanical removal methods: manual or specific tool extraction, mowing, mechanized extraction

Methods of this type are most often used to combat invasive plants in bogs. Herbaceous plants as well as young specimens of woody species (up to about 3 cm in diameter), if they have small numbers, can be manually extracted, root and all. It is important to eliminate the root system as much as possible, as some species have the ability to regenerate even from small fragments remained in soil.

However, if *Sphagnum* sprouts (which could be totally destroyed) developed on the basis of the plants which will be extracted, it is preferable that the plant be cut off from the base and the root or any shoots be removed by other methods (Photo 6).

Photo 6- Exemplare de mesteacăn dezvoltate în muşuroaie de *Sphagnum*

Elimination is best done when the water level in the bog is relatively low (in summer, in dry weather or in winter, when the peatland is frozen) to reduce the deterioration of the peatland surface caused by the penetration and circulation through the site and by the removal (Pawlaczyk et al. 2006). To minimize the impact by stepping on sensitive areas and species, it is recommended to work in groups of 6-10 people. Once the plant material is collected, it should be removed outside the bog surface (Photo 7).

Photo 7 - Plant material extracted from the site ROSCI0112 *Mlaca Tătarilor* and stored off-site

If weeds and bushes are abundant, manual mowing can also be applied, repeated at least 2 times during the vegetation period, which decreases the vigor, and reduces the propagation by seeds of invasive plants and in the conditions of restoring the hydrological and trophic balance it can even lead to their elimination. In this case it is also necessary that the vegetal debris be removed outside the bog, and if stored, it must be done in a position and at a distance sufficiently large from the bog that the substances resulting from decomposition do not affect the bog.

These methods can be applied to all terrestrial grass species reported as invasive in peatland bogs in Romania: *Agrostis stolonifera, Amaranthus sp., Ambrosia artemisiifolia, Anthoxanthum odoratum, Arctium lappa, Briza media, Calamagrostis epigejos, Chamerion angustifolium, Cirsium arvense, C. palustre, Conium maculatum, Deschampsia cespitosa, D. flexuosa, Echinocystis lobata, Erechtites hieraciifolius, Erigeron annuus, E. canadensis, Eupatorium cannabinum, Fagopyrum dumetorum, Festuca rubra, F. airoides, Helianthus tuberosus, Impatiens glandulifera, I. parviflora, Juncus conglomeratus, J. tennuis, Leucanthemum vulgare, Nardus stricta, Onopordum acanthium, Pteridium aquilinum, Rudbeckia laciniata, Rumex acetosa, Solidago canadensis, Urtica dioica, Veratrum album, Vicia cracca, Xanthium orientale subsp.*

italicum. Combating reed (*Phragmites australis*) and the papaws (*Typha latifolia*) it can be done by repeated mowing during the vegetation period.

There are several possibilities for combating trees. They can be cut-down and cut into smaller pieces to facilitate transport outside the bog. Ideally, the resulting vegetable debris should also be taken out of the bog.

In some cases it has been proceeded to *in situ* wood burning or shredding and scattering the fragments on the surface of the bog, but the use of fire can endanger the marsh, both methods having the disadvantage of introducing nutrients into the peatland (Schumann & Joosten, 2008). The logs or wood residues can also be used to block the drainage channels of the bog or to arrange bridges or access roads that facilitate the reconstruction activities and minimize the impact by trampling. It is possible that the complete removal of the trees may require repeated pruning of the logs from the remaining trunks, possibly supplemented by the use of herbicides.

Tree removal can also be done by ringing at the base of the trunk (cutting a bark ring, 10-15 cm wide, reaching the Liberian vessels, cutting them to stop the flow of produced sap). Ringing can be coupled with the use of herbicides.

In cases where the shading of the peat has been more intense and longer lasting, it is advisable to ring the trees followed by keeping of dead trees another season to prevent a sudden and radical change in the conditions of light and heat that could adversely affect the peat moss that had been shadowed(Brooks et al. 2014).

These methods can be applied to all woody and semi-woody species reported as invasive, or potentially invasive in peatland bogs from Romania (*Alnus glutinosa, Betula pendula, B. pubescens, Elaeagnus angustifolia, Fagus sylvatica, Frangula alnus, Juniperus communis, Picea abies, Pinus sylvestris, Populus tremula, Rubus idaeus, Salix caprea, S. cinerea, S. silesiaca*, *Sambucus nigra, Sorbus aucuparia*, *Vaccinium myrtillus*) the selection of the method being made, preferably, based on field (in-situ) studies.

In the case of very large bogs, in other countries there has been used the mechanized grinding, which has the disadvantages of higher costs and a stronger impact. The mechanized grinding is not recommended for peatland sites in Romania due to the small surfaces and the negative consequences of entering the site with various machines.

In situations where a thick layer of vegetal debris (usually leaves) has been deposited on the surface of the peatland, which has covered and suffocated peat moss (in areas where there is no longer peat moss), it can be cleaned and removed from the peatland this nutrient rich layer (using various tools, the Pulaski ax being recommended). The land thus released allows the natural restoration or through anthropic intervention, of the characteristic vegetation.

2.2.1.2. Physical methods of control

Hot water or fire is used to combat unwanted grass vegetation, but in the case of peatland they can strongly impact peat moss and are therefore not recommended. Moreover, many sources mention the danger posed by arson to peatland and insist on preventing fires during droughts (Schumann and Joosten , 2008) .

2.2.1.3. Chemical methods of control

These methods are also very effective and widespread in the control of weeds in crops, but in the case of peatlands that are complex systems the effect of using herbicides or other chemicals is difficult to evaluate. Their use is controversial and requires strict precautions, being limited to cases of absolute necessity.

In these cases the herbicide (for example Roundup, with efficiency up to 90%) it is applied by brushing on the surface of each stain remaining after cutting, or on the injured surface after ringing the bark. Herbicides can also be injected into the intact tree trunk (Pawlaczyk et al. 2006).

2.2.2. Biological control

Although in the control of invasive plants biological control is becoming more and more widespread and promising (Myers and Bazely, 2003), for peat this method is not yet used significantly. Targeted woody species each have pathogenic insects or microorganisms, but since peatland bogs are often found near forests, their use implies the risk of spreading these pathogens to neighboring forests as well.

Some control programs use grazing to control grass species and shrubs in eutrophic marches and peatland bogs (Anderson, 2001) with the recommendation to use traditional, less demanding breeds and measures to control the intensity of grazing, with the need to install fences and feeders, and subject to the increased impact risk through ironing and eutrophication. But other sources consider grazing to be an impact better to be avoided, which is why this controversial method is better to be replaced by mechanical methods, which are easier to control.

Other methods, such as invasive plant reproduction interventions, the use of allelopathy, or genetic methods are not yet applicable in the context of pestlands because they are insufficiently studied in this context.

2.2. 3. Change of resort conditions.

These types of measures are of the utmost importance for combating invasive species in peatlands, especially atypical ones for this habitat. They mainly involve counteracting previous human activities with negative impact on the peatland (drainage, willful or accidental eutrophication, etc.), which have altered the natural state of the marsh, thus favoring invasive species, and restoring the marsh, as far as possible, as close to its previous state, prior to the disturbance.

Executed correctly, these measures have the advantage of favoring a natural regeneration of the peatland and have minimal risks of unwanted impact. In many cases these measures may be sufficient to eliminate invasive plants, especially atypical ones for these types of habitats.

2.2.3.1. Optimization of the water regime

It implies, from case to case, (after preliminary studies and with the consultation of a specialist) the blocking or filling of the drainage channels that have been dug in the peatland or at its edge and/or the construction of dams that raise the water level in the peatland. If drainage pipes have been installed, they must be removed. In the situation of peatlands that are near a watercourse, slowing the flow of water may help to raise the humidity of the adjacent area (Schumann and Joosten, 2008).

For blocking the drainage channels can be used both natural materials (tree trunks or planks, wood residues, peat or mineral soil, which reduce costs and retain the natural character of the peatland) as well as artificial materials (concrete, plastic, metal) , which may be necessary in some cases. The drains and structures blocking the drainage channels must be designed to withstand the maximum possible accumulation of water (in case of heavy rain or snow melting). Also, these arrangements should be made during periods of low wetland moisture, to reduce the negative impact on the peatland surface.

2.2.3.2. Optimization of the chemical parameters of the pealand

Eutrophication of peatlands can be caused either by the contribution of nutrients through the water that feeds the bog or by the organic substance that reaches its surface.

Improving the quality of water sources is done by preventing agricultural pollution (through fertilization, amendments, pesticides) or pollution with industrial or domestic wastewater. If the source of polluted water cannot be controlled, it is necessary to re-direct the polluted water so that it does not accumulate in the bog.

In case of an increased influx of mineral or organic particles, sediment traps or filters upstream of the bog can be installed. Also, in some cases it may be necessary to reduce erosion in areas bordering the peatland, if the eroded materials are washed in the peatland (Schumann and Joosten, 2008). The measures to stop the eutrophication caused by the invasive vegetation are correlated with the mechanical measures of its removal.

There are other types of measures that can be applied on a case-by-case basis, depending on the specific conditions of each pratland. Of these the following can be listed:

- modification of some topographic factors
- control of climatic factors through barriers or fences against the wind
- preventing the contribution of seeds of invasive species, by reducing human and animal passing through peatland, cutting animals, etc.

2.3. Methods of restoring connectivity between fragmented peatland habitats

The term **fragmentation of habitats** is an umbrella term that describes a complex process whereby habitat loss results from the division of continuous habitats with a large surface area into a larger number of fragments having a smaller total surface area than the original habitat from which they arrise, isolated from each other by a matrix consisting of different types of habitats. In this context, habitat loss is considered to be correlated with fragmentation.

Habitat fragmentation is a complex phenomenon that takes place at the landscape level. The surface of the habitat fragments, the edge effect, the shape of the fragments, the degree of isolation and the distance between fragments, the structure and composition of the matrix between fragments, the pressures and the anthropic and natural threats a.s.o. are important elements that depend on the severity of habitat fragmentation. (Didham R.K., 2010).

In Romania, due to its geographical position, peatland habitats which occupy quite limited areas are naturally fragmented. The geographic features are also added to the anthropic impact that is visible especially in the depression areas (drainage for the extension of agricultural crops or of the urban areas).

According to Kline (2014), connectivity is the ability to transfer water between different systems. This ability is described as a variable dependent on static and dynamic factors. The static factors reflect the spatial variability in the identification of the hydrological connectivity, the restoration by the topographic modification of the connected lands.

The structural connectivity term represents the connection from the physical point of view of the relief units. The concept of functional connectivity was developed to take into account the way in which the relations between the multiple structural characteristics influence the geomorphological, ecological and hydrological processes. (Wainwright, et al, 2011).

According to Bracken & Croke (2007) connectivity is the ability to transfer water between different relief elements. They describe this ability as a dependent variable, controlled by dynamic and static factors.

The functional connectivity indicates the dispersal capacity of the peatlands characteristic plants and their ways of dispersing, either by water, with the help of wind or on animal fur.

According to Good, (1998) ecological corridors are those areas along the fragmented sites that allow the dispersal of plants and the distribution of animals so as to reduce their risk of extinction. The concept of ecological corridor can vary from 5 m path wide along the road to an area of several kilometers width. Ecological corridors that connect areas that extend over several kilometers are called regional corridors, being more complex and costly than local corridors that link certain habitats within a site, or between sites that are close by.

The proposed methods and techniques are aimed at restoring both structural and functional connectivity between fragments comprising peatland habitats. These refer exclusively to peatlands that have been identified as being in the same river basin. One criterion for choosing fragmented peatlands for which reconstruction measures can be proposed for the restoration of structural and functional connectivity is that they are supplied from the same groundwater network, and the one regarding proximity to the supply river, the distance taken into account being of maximum 1 km.

An important step in the process of restoring the structural connectivity of the fragmented peatlands was the identification of the peatlands that were previously connected and of the barriers that prevent the structural and functional communication between them [...].

After these barriers created by human activities were identified, in the second stage were proposed activities (with the indication of methods and techniques) of removing the barriers and restoring the structural connectivity, restoring the water regime and implicitly restoring the functional connectivity, the dispersal ability of specific plants spores and seeds.

To ensure connectivity between peatlands, it is also necessary to discuss the connectivity from the administrative point of view, and to establish a buffer zone for peatlands which will be restored. In some cases, for peatlands valuable from the conservatively point of view, which will be rebuilt and not included in any protected area, it is necessary to make diligencies to declare the area as a protected one.

In cases where the connectivity can no longer be restored due to the fact that the connection areas are completely degraded, the alternative of reconstructing the area and designing the green corridors is considered.

The restoration/reconstruction of a habitat must start from a good knowledge of the current situation/state and the desired situation/state. It should also be taken into account, if it is possible that starting with the current situation, the floristic composition, structure and functions of that habitat or ecosystem to be restored, in what time frame and with what material and human resources.

The main purpose of the restoration/reconstruction is to bring the habitats in their natural state, in the absence of the destructive anthropogenic impact, using as a standard for restoration a reference ecosystem. This may be an area of the concerned site, in a good state of conservation in terms of structure and/or functions, or a similar area.

Compared to other Nordic countries (Canada, Scotland - UK, Norway, Sweden), where peatland habitats make up large and compact areas, peatland habitats in Romania naturally include, due to the geographical location of the country, areas that are quite small and very fragmented.

Thus, if in the Nordic countries, the activity of restoring peatland habitats (degraded especially by the excessive exploitation of peat resources) can be carried out on a large scale, on large areas and with mechanized resources, in Romania, restoration techniques and methodologies for restoration/reconstruction of the areas affected by the fragmentation of peatland habitats will have to be adapted to small areas, most often quite difficult to reached.

All these activities will be carried out taking into account the provisions of the in force legislation, respecting the regime and the right of the land property.

Among the methods used to restore the connectivity of fragmented peatland habitats the most important are:

2.3.1. Restoring hydrological connectivity between peatland fragments by creating water circulation channels between fragments

In the case of many peatland fragments, they come from an initial extended one, existing along or in the immediate vicinity of a watercourse.

The technique of making these channels should be adapted according to the particularities of the area, considering either to the use of mechanized (small excavators handled by qualified personnel) or manual resources (pickers, rollers, etc. and adequate workforce). The technique of making the channels for the hydrological connection of the fragments should also be adapted to the pedological particularities of each area. The tools used and the labor force will be adapted to each particular situation.

Particular attention will be paid to the way in which these works are executed so that their negative/disturbing impact on peatland habitats and habitats from their immediate vicinity to be minimal and reversible. Thus, the storage of materials and tools, parking of machines and personnel will be done only in the areas previously designated and limited as extension.

The canals will be constructed to transport water from the upstream fragments to those situated downstream. The depth of these channels will be, ideally, uniform throughout their length, so that no drainage of the fragment located upstream to be achieved. If necessary, at the starting point of the channel in the upstream fragment, rich in water, an overflow dam should be created, which will allow water to flow into the connecting channel only after there is a sufficient amount of water in the upstream bog.

to ensure that the specific habitats are in a favorable state of conservation. The soil resulting from these channels will be evenly spread in the surrounding areas or will be used for filling the drainage channels in the area, if applicable.

The channels for the hydrological connection of peatland fragments have to be checked periodically (annually or once every two years) to avoid their clogging and to ensure both structural and functional, long-term connection of these fragments.

Examples of peatlands in which it is proposed to apply this measure are: Mlaca Tătarilor –Brașov County; Stăvilarul lui Kovacs and Mlaștina Mucoasa from Covasna County; Tinovul Apa Lină and Movila Nisipoasă from Covasna County.

2.3.2. Feeding the peatland fragments with water from the springs, the neighboring streams, by making some supply channels

The most majority of the peatlands are supplied with water from springs or groundwater. The number of peatlands fed exclusively by rainfall is very small. Decreasing the amount of water entering the peatland leads to drying and fragmentation.

The capture of the springs/streams or their river bed deviation has led, or may lead in time to the modification of the water regime, to the drying of the peatland habitat and to the triggering of the succession to drier habitat types occurance.

In each case, the channel that brings the water to the peatland will be verified, to revent it from being blocked or completely clogged. If this does not allow sufficient water to enter into the peatland, it should be cleaned of stones, sediments, widened, or a new channel should be made, as the case may be. This method will ensure the necessary water supply to maintain the structural and functional integrity of these peatland bogs, favoring/triggering the process of reconnecting the neighboring fragments.

The technique of blurring/enlarging/making these channels will be adapted according to the particularities of the area, using either the mechanized resources (small excavators handled by qualified personnel) or manual ones (pickers, spades, etc. and adequate work force). The technique of making the channels for the hydrological connection of the fragments will also be adapted to the pedological particularities of each area. The tools used and the labor force will be adapted to each particular situation.

Particular attention should be paid to the way these works are executed, so that their negative/disruptive impact on peatland habitats and habitats situated in the immediate vicinity is minimal and reversible. Thus, the storage of materials and tools, parking of machines and personnel will be done only in the areas previously designated and limited in scope.

In more particular cases, for sites with high conservative value, threatened by drying, pipes (of plastic or metal) with a diameter of min 20 cm can be mounted, to bring an excess of water from the springs situated in the neighboring area, depending on of the particularities of the land.

The channels for water supply of the peatland fragments will have to be verified periodically (annually or every two years) to avoid their clogging and to ensure both structural and functional, long-term connection of these fragments.

Examples of peatlands in which it is proposed to apply this measure are: Mlaca Tătarilor –Brașov County; Stăvilarul lui Kovacs and Mlaștina Mucoasa from Covasna County; Tinovul Apa Lină and Movila Nisipoasă from Covasna County.

2.3.3. Realization of networks of water supply channels, between fragments, to restore the structural and functional connectivity

In order to restore the structural and functional connectivity between the peatland fragments, in some cases (after the construction/unclogging of the supply channels and/or of the link between the fragments, and the drainage channel occlusions), channel networks can be realized. The realization of these networks is prior to the restoration of soil moisture and, subsequently, of the structure and composition of the vegetation in the degraded areas situated between fragments.

Depending on the dimensions and particularities of the areas between fragments and the distance between them, these areas may be fully restored and incorporated into the peatland, or they may function only as ecological corridors, achieving the structural and functional link between fragments.

The technique of making these channels of the networks, should be adapted according to the particularities of the area, using either mechanized resources (excavators and trucks of small dimensions handled by qualified personnel) or manual ones (pickaxes, spades, etc. and adequate work force). The technique of making the channels for the hydrological connection of the fragments will also be adapted to the pedological particularities of each area. The tools used and the labor force will be adapted to each particular situation.

Particular attention should be paid to the way these works are executed, so that their negative/disruptive impact on peatland habitats and habitats situated in the immediate vicinity is minimal and reversible. Thus, the storage of materials and tools, parking of machines and personnel will be done only in the areas previously designated and limited in scope.

If the water from the springs/brooks that feed the peatland is collected for household use (cottages or households) or for the watering of animals from the sheepfold, a servitute flow must be established and maintained that runs directly into the peatland.

Examples of peatlands in which it is proposed to apply this measure are: Mlaca Tătarilor –Brașov County; Stăvilarul lui Kovacs and Mlaștina Mucoasa from Covasna County; Tinovul Apa Lină and Movila Nisipoasă from Covasna County.

2.3.4. Closing/clogging of the drainage channels, in order to restore/maintain the water regime necessary for the structural and functional connectivity of the peatland fragments

Due to the fact that peatlands were formed in areas where, initially, rainfall was abundant enough, in order to reduce the area of the surrounding agricultural lands or to protect the roads, drainage channels were created. In some cases, these channels have been built to include in the agricultural circuit the surfaces of the former peatlands (Stupini - Brașov) or to increase the areas of hay or grassland.

Considering that many of these channels are under the administration of ANIF (National Agency for Land Improvements), the approval of the authorized institutions must be obtained in the case of drainage channels closure, and the potential impact that this activity will have on the neighboring lands must be evaluated.

The technique of clogging the drainage channels should be adapted according to the particularities of the area, using either the mechanized resources (excavators and trucks of small dimensions handled by qualified personnel) or manual ones (pickaxes, spades, wheelbarrows etc. and adequate work force). The realization technique will also be adapted to the pedological particularities of each area. The tools used and the labor force will be adapted to each particular situation.

The drainage channels can be closed by filling them with soil from the surrounding areas or with soil resulting from the creation of channels for hydrological connection of the fragments, depending on the location of the concerned site and the characteristics of the land. The soil will be transported with the help of wheelbarrows, or, where the area is quite large and dry, with the help of small trucks.

If necessary, we can opt for completely filling the channels with earth, along their entire length, or you can choose the option of making dams, from place to place, along the length of the channel.

If the required amount of soil cannot be obtained from the areas immediately adjacent to the channel, will be brought soil from the nearby areas. When bringing soil from other areas, particular attention will be paid to the texture and structure of the soil and the composition of the vegetation in that area. The vegetation of the sector from which the soil is taken must not contain alien species with invasive potential, which will degrade the peatland that is intended to be rehabilitated.

Particular attention should be paid to the way these works are executed, so that their negative/disturbing impact on peatland habitats and habitats situated in the immediate vicinity is minimal and reversible. Thus, the storage of materials and tools, parking of machines and personnel will be done only in the areas previously designated and limited in scope.

Clogging the drainage channels will lead to the raising of the water level in the peatland and to the initiation of the process of restoring the structural and functional connectivity between fragments.

However, attention should be paid that a large amount of stagnant water completely covering the peatland have the same harmful degree as the drainage, ultimately leading to habitat degradation.

In this case, the natural or artificial drainage channels that remove the water from the peatland, should not have to be completely closed. An overflow level should be established and dams will be made for obtaining the set-up level. When the peatland water rises above the desired level (in case of heavy rains or floods), the excess water will be discharged from the peatland over the overflow dam.

The dams can be made of woven braids of twigs and/or gravel and/or boulders, among which can be introduced earth or furrows of grass with local species. This activity will be carried out using manual means (making braids) and manual resources (using spades, wheelbarrows, etc.) and/or mechanized means (excavators, trucks for soil transport), depending on the particularities of the area.

Examples of peatlands in which it is proposed to apply this measure are: Muscoasa – Covasna County, Movila nisipoasa – Covasna County, Luc, Ruc – Fantana brazilor – Harghita County, Mlaca Tătarilor – Brașov County.

2.3.5. Elimination of invasive woody species (trees, shrubs) in peatland habitats that affect structural and functional connectivity between fragments

The most common woody species identified in peatland habitats are: birch (Betula pendula), wild pine (*Pinus sylvestis*), alder buckthorn (*Rhamnus frangula*), poplar (*Populus alba*), black anin (*Alnus glutinosa*) a.s.o. These species are precursors of peatland fragmentation, producing and emphasizing their drainage.

The propagation of these woody species in the peatland habitats leads to the degradation of the habitat by drainage, due to the accentuated evapo-tanspiration from the foliar level, and the excessive shading of the soil. The reduction of humidity and the shading are unfavorable to the species characteristic of the peatland habitats, these being gradually replaced by species from the drier neighboring areas habitats of grass or forest. Thus "enclaves" consisting of invasive woody and grassy species appear, which gradually fragment the peatland into portions with specific habitat. The portions with specific habitat of peatland, will be gradually reduced, being replaced by the habitat built by the invasive species, against the background of the drying of the area.

The technique used for the removal of wood species causing fragmentation will be adapted to the small and fragmented surfaces occupied by peatland habitats. Thus, it is recommended that the woody species seedlings removal to be carried out manually or with a device for removing weeds of the Light (Fiscars) type. The larger diameter specimens will be eliminated by cutting with scissors/garden pliers (professional nippers for branch cutting, 93 cm), hand saws or saws, or they can even be uprooted using barrels (as the case may be). Regardless of the technique chosen for their elimination, the least disturbed habitat disturbance will be considered.

Wood species must be cut as close to the ground as possible, so that the remaining portions of the stems are covered with water and the shoots are greatly diminished (especially in the case of birch and buckthorn).

In some cases, it is possible to root out the specimens, but paying greater attention to minimizing the impact on the habitat.

The removal of woody material from the peatland will be done manually, being stored outside the peatland habitat. From here the plant material will be transported by cars, in areas specially intended for the storage of plant waste or it will be used locally (for heating, making braids, etc.).

Examples of disturbances in which it is proposed to apply the measure: Mlaca Tătarilor – Brașov County, Tinovul Câmpeilor Grădinița Tinovul Tesna Împuțită Grădinița (Natura 2000 Larion site) - Bistrița-Năsăud County, Pilugani – Suceava County.

2.3.6. Elimination of invasive grass species in peatland habitats that affect structural and functional connectivity between fragments

It is recommended in extreme cases, where these species, due to drainage, have become excessively propagated.

These are some species of spontaneous flora, for example *Deschampsia cespitosa* or invasive alien species - *Erigeron anuus, Solidago canadensis* etc.

Especially the *Deschampsia cespitosa* species it forms dense bushes, which turn into mussels on which are then installed other species that contribute to the accentuation of the drying of the area and to the appearance and advancement of fragmentation within the peatland habitat, initially affected by drainage.

The technique used to remove grass species that accentuate the phenomenon of fragmentation, will be adapted to the small and fragmented surfaces occupied by peatland habitats and for each particular case.

It is recommended to cut/mow them, either uprooting, prior to the restoration of the water regime.

Their cutting can be done using wire or disc mowers or even scythe (which are quiet, useful in areas with wildlife shelters).

The rooting can be carried out, as the case may be, by manual removal, with a device for removing weeds of the Light (Fiscars) type or using spades.

In the case of uprooting, special attention will be paid to protecting the roots of peat species in the vicinity of the specimens that want to be removed from the habitat.

In both cases, the remaining stumps will be removed using spades. The soil will be spread evenly, at the same level as the rest of the peatland, so that the entire surface is covered by water during periods of high water. The purpose is to eliminate the terrain level discrepancies (slopes; higher ground), drier portions compared to the surrounding peatland, these being a focus of installation and expansion of invasive species that accentuate the fragmentation of the habitat, against the backdrop of the water level in the peatland.

Removal from peatland of the resulting plant material will be carried out with wheels or in bags, which will be stored outside the peatland habitat. From here the plant material will be transported by cas, in areas specially intended for the storage of plant waste.

Examples of peatlands in which it is proposed to apply the measure: Lacul Sec – Buzău County.

2.3.7. Limitation of groundwater withdrawals from residential or industrial areas near peatlands that affect structural and functional connectivity between fragments

In many cases, peatland areas from valleys, meadows and depressions (Hărman, Prejmer, Stupini –Brașov County) have become very attractive in real estate, developing numerous residential neighborhoods here.

In this situation there are two distinct cases. In the first case, where the peatland was drained and on the site of the former peatland there are already constructions, we can consider, under the current legislative conditions, the peatland as permanently lost for conservation/restoration.

If peatland enclaves are located in the vicinity of expanding residential neighborhoods, these areas should be excluded from drainage and construction. In this case, the peatland can be saved by regulating/reducing the amount of water collected from the groundwater and the waste water discharged into the soil through insufficiently isolated septic tanks.

The methods recommended in this case are of a legislative nature with the involvement of the competent authorities in this field.

Examples of peatlands in which the measure is proposed to be applied: bogs from Stupini, Prejmer, Hărman –Brașov County.

2.3.8. Construction of fences, obstacles and braids to maintain the functional and structural connectivity of peatlands

The vast majority of peatlands are located in subalpine and mountain areas where grazing has been constant for hundreds of years.

In the case of peat with a high degree of drying, the animals enter the habitat, destroying the characteristic species and bringing an unwanted contribution of organic substance into the system and thus quite fragile.

In these cases, for the protection of the habitat it is recommended to make fences/ braids made of local materials (wood) that prevent the access of the animals in the peatland.

In many cases, in order not to affect the landscape, in cooperation with the mountain masters and shepherds, electric fences can be installed, during the summer, permanently or only temporarily during the dry period. They are effective in preventing animals from entering the habitat. The costs of setting up and maintaining them are quite low, and can be used for several years, under the conditions of proper maintenance and storage.

Examples of peatlands in which it is proposed to apply the measure: Muscoasa – Covasna County, Movila nisipoasa – Covasna County, Lacul Sec – Buzău County, Lacul Manta – Buzău County.

2.3.9. Establishing and complying with prohibitions in peatland areas to maintain the functional and structural connectivity of peatlands and limit fragmentation

Compliance strictly with the provisions of the in force legislation (including the provisions of the management plans of the protected areas that include peatlands) regarding grazing. The recommended method in this case requires the involvement of the guardians of the protected areas and of the authorities with competence in this area.

Thus, sheepfolds shall not be located less than 200 m from the peatland boundaries.

The sheepfolds will not be located on or near the peatland feeding channel, but at a distance of at least 200 m.

Prohibition of grazing inside the peatland (especially the drained ones) and in the immediate vicinity.

Examples of peatlands in which it is proposed to apply the measure: Muscoasa – Covasna County, Movila nisipoasa – Covasna County, Lacul Sec – Buzău County, Lacul Manta – Buzău County.

2.3.10. Restoration of soil from exploited / degraded peatlands to restore functional and structural connectivity of peatlands and limit fragmentation

It is a complex method, which involves the preparation of the land so that it is suitable for the restoration of the water regime and the creation of ecological niches for the species of turbogenetic plants to be transplanted and allowing the union of the small peatland fragments that still remain in the field.

Surface preparation involves leveling it and filling the pits made for drainage water from the peatland, to favor the exploitation. In some cases it is necessary to make small basins for water retention within the site to be restored.

These activities are usually carried out with mechanized means (excavators and small trucks handled by qualified personnel). Supplementary will also be used manual equipments (pickers, paper clips, wheelbarrows, etc. and adequate workforce). The realization technique will also be adapted to the pedological particularities of each area. The tools used and the labor force will be adapted to each particular situation.

If necessary, it might been choose for the complete filling of the channels with earth, along their entire length, or you can choose the option of making dams, from place to place, along the length of the channel.

Because the area to be rebuilt, most of the time is depleted of nutrients following the exploitation of the peat, it is recommended to apply organic fertilizers to allow colonization of the surface by plants from transplantation or fragments. However, the fertilizer should be used with caution to avoid eutrophication of the habitat.

Examples of peatlands in which it is proposed to apply the measure: Pilugani – Suceava County, Mândra – Brașov County.

2.3.11. Creation and maintenance of ecological corridors in the field, to restore and maintain the structural and functional connectivity between the peatland fragments

The methods and techniques presented previously for restoration / reconstruction of the areas affected by the fragmentation of peatland habitats can be carried out along or within areas designated as "ecological corridors", which connect the fragments with characteristic peat habitats.

The size of the ecological corridors is variable, depending on each specific case.

All necessary legal steps will be taken to declare these areas of connectivity as protected areas (connection from an administrative point of view).

2.4. Methods of restoring vegetation

In case of carrying out works of extended ecological reconstruction, for example in the exploited peatlands or severely degraded peatlands, complex activities will be carried out to recover the composition and structure of the vegetal floor. These will be preceded, necessarily by activities to restore the water regime and/or the characteristic substrate.

Detailed studies (including physico-chemical) are required for each site and the establishment of stages and methods appropriate to each case.

Ideally, plant sources should be located near the site where the restoration is done, to minimize the impact of transportation and conservation of plant viability, as well as to maintain the local genetic background. The choice of the site from which the transplant is made is particularly important. It must have a phytocenotic composition similar to the one of the site planned to be reconstructed. It is recommended that moss species (*Sphagnum sp., Polytrichim sp*. ș.a) and plants (*Carex sp., Eriophorum sp., Juncus sp.* ș.a.) dominated and/or characteristic to be the firstly transplanted. It is very important for the plants to be transplanted into furrows, or with peat pieces. Peat is a source of diaspores of *Sphagnum sp*., An essential species, in most cases, for restoring a peatland.

From the sampling areas, the vegetation will be removed in "mesh" or strips that also contain a portion of soil. If the vegetation is properly collected, it will recover fairly quickly at the site where the collection was made.

The plants, together with the soil taken, are transplanted in the niches created on the site that will be restored or spread relatively evenly, on the soil with an adequate and necessarily constant humidity.

For plants that appear sporadically or less rarely in the composition of phytocenoses, compared to the surface of a peatland, plants from seeds sown outside the site can be obtained, the plants thus obtained will then be transplanted. If some rare species cannot be obtained from seeds they can be obtained by micro-multiplication *in vitro*. Their provenance must also be from similar areas and avoid impurification of the area with species from geographically and genetically remote areas.

Because the area to be rebuilt is most often depleted of nutrients (for example after peat exploitation), it is recommended to apply organic fertilizers to allow colonization of the surface by transplanted species.

In the first phase it is recommended to create ecological niches, with properties of soil and water carefully monitored and controlled, from which the dominant species and characteristic of the habitat will colonize the rest of the peatland.

Although the restoration of the peatlands from which the peat was exploited for its subsequent production and exploitation is feasible, at the global level no such project has yet been undertaken. The restoration of the peatland for a future commercial operation involves an extremely long waiting time, until the accumulation of a layer thick enough to be used considering the fact that a peat layer of 20-60 cm accumulates within 1000 years (Couwenberg, 2005).

The application of organic or artificial fertilization should be done carefully, to prevent the emergence of unwanted species, which are not characteristic of peatland habitats. As they begin to multiply, actions will be taken to remove them, without affecting the habitat and species of transplant plants, which are still very vulnerable.

3. RESTORATION PLANNING

3. 1. The restoration project

The development of a restoration project is a complex step that involves going through several stages, of which the essential ones are:

3.1.1. Identification and understanding of dysfunctions within the ecosystem

During this stage, as much data as possible on the site that is the subject of the project must be accumulated, both historical and field data. Thorough documentation is the basis of correctly identifying the problems, but also of estimating the success rate in eradicating them. Qualified persons with expertise in the field should be involved in this action. If the project is a large one, national agencies and organizations with experize in this field must be involved. The documentation on site (in the field) must be an extremely detailed one and must contain both data on the current state of the site (characteristic species, invasive species, water level in the site, etc.), identified problems (drainage channels, intensive peat exploitation, pasture, etc.) as well as suggestions for interventions (drainage channel blocking, elimination of invasive species, the possibility of using the vegetation near the site for repopulation, etc.). Extremely useful for centralizing this complex information are the templates for on-site (field) visits. [....]

3.1.2. Identification of project objectives

Following the identification and understanding of the mechanisms that caused the major dysfunctions that led to the degradation of the ecosystem, the major objectives of the reconstruction project can be established. The central objective of such a project cannot be other than restoring the functions of the ecosystem and regaining its autonomy. In other words, the peatland should become an active one and accumulate peat again. Sometimes this desire cannot be achieved, so the immediate next goal should be to stop the degradation of the ecosystem.

3.1.3. Establishing the project budget

By establishing a proper restoration plan that contains all the project activities, a budget can be calculated for each activity and by summing their allocated amounts, can be established the project budget. This budget is an estimative one and variables such as fluctuations in the exchange rate, fuel prices, etc. must be taken into account.

3.1.4. Establishing the legal framework

Prior to any intervention in the field, must be obtained the approval of the local, regional or national authorities which manages the site. The approval is requested by presenting the restoration plan and any additional information requested by the authorities.

3.1.5. Identification of institutions interested in project implementation

An important step in carrying out the project is to identify the potential beneficiaries, but also of those interested, without having a direct benefit, in the implementation of the project.These can be both state and private institutions that have interests or concerns about biodiversity conservation, reducing the effects of climate change, ecological education, etc.

3.1.6. Risk evaluation

The risks involved in carrying out a reconstruction project are various and must be objectively anticipated. Among the most common types of risks are:

- the risk of failure to meet the deadlines for carrying out the plan activities
- the risk of failure to meet some objectives, incorrectly set
- financial risks caused by incorrect estimation of costs
- fiscal policy risks caused by unforeseen changes in fiscal policy
- physical risks caused by illness or injury of some members of the project team
- social risks caused by the demotivation of some team members

3.1.7. Establish measurable indicators for evaluating the efficiency of actions

For a correct estimation of the project results and the achievement of the proposed objectives, a series of measurable indicators should be established from the beginning. For example, if the restoration measures had as their main purpose the restoration of the hydrological regime of the site then the setting of piezometers and the water level monitoring using them is an example of establishing a measurable indicator (Photo 8).

3.1.8. Implementation of restoration measures according to the restoration plan

In order to avoid delays in the development of the project, the restoration actions must be implemented as far as possible according to the schedule provided in the restoration plan. Any delay or deviation from the initial plan may have consequences on the efficiency of the actions taken and may affect the final result of the restoration project.

Photo 8- Piezometer installed in the site ROSCI0112 *Mlaca Tătarilor*

3.1.9. Resolving unforeseen problems and changing objectives that cannot be achieved

The correct and objective assessment of the risks, from the beginning of the project, greatly simplifies the efficient solution of the problems arising during the activities implementation. The correct analysis of the field data will confirm if the objectives initially proposed are feasible. For example, an objective such as restoring a positive hydrological balance is feasible only if the site has a constant water supply or other nearby water sources can be captured.

3.1.10. Analysis of the ecological, social and economic benefits resulting from the implementation of the project

The benefits of a project successfully implementation aimed to restore peatland ecosystems are diverse and complex and must be evaluated not only from an ecological perspective but also from a social and economic perspective. The social benefit lies in the creation of a recreational area, for study for the passionate, a space for education regarding the protection of nature, etc. The economic benefit could consist of the rational exploitation of the products delivered by the restored ecosystem.

3.1.11. Monitoring the restoration performed actions

A restoration project cannot be complete unless after the measures provided for in the project activities are implemented, monitoring of their efficiency is carried out. To this end, a monitoring plan will be developed in which the specific actions will aim to measure indicators of restoring ecosystem functions. The types of indicators and the way the monitoring is carried out are developed in Chapter 4. *Monitoring the restoration.*

3.2. National restoration projects

If the restoration project targets large territories with many sites that require restoration actions, very important becomes the prioritization of the proposed sites to be restored. In this regard herewith is proposed an original methodology for evaluation and prioritization. The methodology involved the assessment of the marshes inventoried according to the types of pressure and threat on the habitats, based on the evaluations carried out by experts on the site. Depending on the *Intensity*, *Trend* and *Forecasts* related to pressures and threats the expert evaluations will be noted, as shown in the tables below (Tables 1 and 2):

Table 1. Metodology for rating the pressures

Crt. No.	Pressure intensity	Score (*NIP*)	Pressure trend	Score (*NTP*)	Pressure forecasts	Score (*NPP*)
1.	Unknown	1	Unknown	0	Unknown; Favorable; Good	0
2.	Low	1	Decreasing	1	Stationary	1
3.	Medium; Moderate	2	Stable; Stationary	2	Poor; Moderate	2
4.	High	3	Increasing; pronounced	3	Bad	3
5.	Very high	4	-	-	Total destruction	4

Table 2. Rating methodology for threat assessment

Crt. No.	Pressure intensity	Score (*NIA*)	Threat tendency	Score (*NTA*)	Threat forecasts	Score (*NPA*)
1.	Unknown	1	Unknown	0	Unknown	0
2.	Low	1	Decreasing	1	Favorable Good	1
3.	Medium; Moderate	2	Stable; Stationary	2	Poor Moderate	2
4.	High	3	Increasing accelerate	3	Increasing	3
5.	Very high	4	-	-	Bad Unfavorable	4

For each evaluated site a total score will be calculated according to the formula:

Total_impact = *NIP* + *NTP* + *NPP* + *NIA* + *NTA* + *NPA* + *ND* + *NS*

Of which:

NIP – Score for **Pressure intensity**

NTP – Score for **Pressure trend**

NPP – Score for **Pressure forecasts**

NIA – Score for **Threat intensity**

NTA – Score for **Threat tendency**

NPA – Score for **Threat forecasts**

ND – Score for **the presence of drainage (YES = 10, NO = 0)**

NS – Score for **the presence of invasive species (YES = 10, NO = 0)**

As a general observation any factor that causes an imbalance in the proper functioning of the ecosystem can be considered pressure or threat. The difference between them is that pressures are considered the factors that have exerted their action in the past and continue to affect the present and the threats are the factors that is anticipated to affect the ecosystem in the future. It might be possible that the same impact to be both, pressure and threat, if it occurs in present but exist a high likelihood it manifest in the future.

On the column ”Tendency (trend)...” from both tables, will be appreciate how the pressure / threat will evolve. Also, in the column ”Forecasts on....” will be noted the perspective for habitat evolution under the impact of the respective threat/pressure.

In the scoring system it is observed that although drainage and the presence of invasive species are treated and noted each as threats / pressures, the sites where they are reported receive additional scores, because these factors are the ones that decisively contribute to the degradation of the peatland ecosystems, unlike the other identified factors.

Such an evaluation system will allow the correct ranking of sites in a national restoration plan. The sites with the highest scores will have priority for reconstruction and will be included as first ones in the national short-term plans (to be rehabilitated within 5 years at most), the ones with the average score will be included in the national medium-term plans (following be rehabilitated within a maximum of 10 years) and those with the lowest scores will be included in the national long-term plans (to be rehabilitated within a maximum of 20 years).

3.3. Restoration plan

The restoration project is based on the development of a restoration plan in which all the actions to be taken as well as their succession in time must be specified. The restoration plan is also necessary to estimate the costs of the restoration project.

A proper restoration plan should contain at least the information from the model presented in the table 3.

Table 3 - Model of restoration plan

The action	The date on which it takes place	The location where it takes place (coordinates)	Methods of work	People involved	Duration of the action	Expected results	Costs estimated

4. MONITORING THE RESTORATION

The monitoring of the restoration must be carried out consecutively with the restoration actions and is carried out according to a monitoring plan. The monitoring plan contains specific activities aimed at tracking measurable indicators, established according to the objectives of the restoration. If the major objective of the restoration project was to restore the hydrological balance, then the periodic measurement of the water level using piezometers strategically installed throughout the site is an example of monitoring the efficiency of the measures taken.

Depending on the complexity of the restoration project, the monitoring plan may be:

- realized in the short term (3-5 years) when the restoration project aimed at simple activities, such as removing invasive species
- achieved in the medium term (6 -10 years) - when the restoration project was a more complex one, with extensive activities to restore the hydrological regime and the vegetation characteristic for the ecosystem
- realized in the long term (11 - 20 years, or more as the case may be) - when the project was an extremely complex one, with the objective of ecological reconstruction of a completely modified ecosystem, in which the elements characteristic of the peatland ecosystem had to be restored or integral reintroduced

Regarding the monitored indicators, they can be grouped into several main categories as follows:

4.1. Biodiversity indicators

They are represented primarily by the indicator species and the key species in the ecosystem. In peatland ecosystems, the genera most richest in plant species used as indicator are *Sphagnum, Polytrichim, Carex, Eriophorum și Juncus*. Moreover, the presence on site of rare, protected or endangered species is a valuable indication of biodiversity restoration.

4.2. Habitat indicators

Plant and animal species represent valuable indicators in assessing habitat quality. The species of plants, being fixed, reflect faithfully the changes of the habitat through the presence, temporary absence or disappearance from the habitat of certain species. Also, the monitoring of some animal species such as some species of *odonata, lepidopterans* or *amphibians* provides information on the specific conditions offered by the habitat.

4.3. Hydrological indicators

Monitoring of hydrological indicators is essential and must not be missing from any restoration monitoring plan. The level of water in the site and its fluctuations play a determined role in the good functioning of the ecosystem. Monitoring of the water level in the site is made in the simplest way by installing piezometers (Photo 9).

Photo 9 - Aerophotogram with the location of piezometers in the site ROSCI0112 *Mlaca Tătarilor*

4.4. Chemistry indicators

It refers to parameters that provide information on water quality, such as : pH, nutrients load and their accessibility, the presence of toxic substances, etc. Usually, water samples for analysis are collected from piezometers.

CONCLUSIONS

From the evaluations made on the site within the **PeatRo** project approximative 190 peatland sites from Romania requires interventions to restore the balance within the ecosystem. The most intense pressures that produce the most serious imbalances are desiccation, invasive plant penetration and habitat fragmentation.

The reconstruction of a degraded peatland ecosystem is a complex process that involves diverse activities and expertise in domains such as Biology, Chemistry, Geography, Geology, Environmental Science, Geological Engineering, Environmental Engineering, and the list remains open. Although it involves mobilizing significant resources, restoration projects bring multiple benefits:

- environmental benefits - conservation of species and habitats, reduction of carbon dioxide emissions, flood control, reduction of fire risk, conservation of water resources, etc.

- economic benefits - can contribute to the development of tourism in the area by generating income, collecting berries, etc.

- social benefits - projects can offer jobs to the local population, recreational and for ecological education areas, etc.

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ANNEX

Images illustrating the main types of pressures and threats identified in the Romanian peatland ecosystems during the period 2015-2016 in the **PeatRo** project.

Drainage channel (Tinovul Ortoaia, Suceava County) - Photo Ciprian Mânzu, PhD

Drainage channel (Tinovul Hotelul Comunal- Poiana Stampei, Suceava County)
Photo Ciprian Mânzu, PhD

Grazed inside the site (Marsh Camionca Lucina, Suceava County)
Photo Ciprian Mânzu, PhD

Grazed in the marsh Tinovul Sângeorzanei (Suceava County) - Photo Ciprian Mânzu, PhD

Constructions near the site Tinovul, Hotelul Comunal -Poiana Stampei (Suceava County) - Photo Ciprian Mânzu, PhD

Storage of household waste (Tinovul Balhui-Coșna, Suceava County) - Photo Ciprian Mânzu, PhD

Catchment in Tinovul cel mare, from Coșna (Suceava County) - Photo Ciprian Mânzu, PhD

Replacement of characteristic species of *Carex* with species of grasses (graminee) Tinovul Teșna (Suceava County) - Photo Ciprian Mânzu, PhD

Spring excavated in the marsh Fântâna Brazilor (Harghita County) - Photo Anna Szabo, PhD


Eutrophic marsh (Colăcel, Suceava County) - Photo Ciprian Mânzu, PhD


Exploitation of peat in Tinovul Pilugani-Poiana Stampei (Suceava County) - Photo Ciprian Mânzu, PhD

Adjacent access road to Tinovul Jinului (Suceava County) - Photo Ciprian Mânzu, PhD

Photo invazive species *Pteridium aquilinum* in the marsh *Tăul fără fund* from Obârşia Cloşani, Mehedinţi County - Photo Sorina Fărcaș, PhD

Invasive species *Solidago canadensis* in the marsh from Hărman, Braşov County Photo Sorin Ștefănuț, PhD