Maintenance plan of wooded meadows and wooded pastures

Tartu 2019

Compiled by E.Roosaluste

Table of contents

Introduction 3
1. Wooded meadows 3
1.1. A brief overview of the formation, distribution, environmental conditions, and values of wooded meadows 3
1.2. Restoration of wooded meadows 8
1.2.1. Principles for the selection of stands suitable for the restoration of wooded meadows 9
1.2.2. Selection and size of groups of non-managed woody plants 11
1.2.3. Principles of designing the species composition and structure of woody plants in restored wooded meadows 12
1.2.4. Selection and preservation of other traditional wooded meadow elements [rocks, lying wood, ants, stumps, water bodies (holes), etc.] 13
1.2.5. Techniques and conditions for the practical restoration of wooded meadows 15
1.2.6. Evaluation of the success of the restoration of wooded meadows 19
1.2.7. Management of newly restored wooded meadows 20
1.3. Management of wooded meadows 21
1.3.1. Mowing 21
1.3.2. Autumn grazing 24
1.4. The main threats to wooded meadows 25
1.5. Favorable condition of wooded meadows 26
1.6. Valuing wooded meadows through nature tourism and nature education 26
2. Wooded pastures 27
2.1. An overview of the concept, origin, distribution, environmental conditions, and biota of wooded pastures 27
2.2. Restoration of wooded pastures 31
2.3. Maintenance of wooded pastures 32
2.4. Main threats to wooded pastures 32
2.5. Favorable condition of wooded pastures 33
Conclusion 34
Acknowledgments 34
Used literature 35
A short guide to the restoration of wooded meadows and pastures 37

1. Basic requirements for the restoration of wooded meadows 38
2. Basic requirements for the restoration of wooded pastures 40

Introduction

This maintenance plan provides an overview of the definition, origin, distribution, communities, biota, the richness of species of wooded meadows and wooded pastures and their causes, and the principles of their restoration and maintenance. The purpose of the maintenance plan is to explain the natural and cultural values of wooded meadows and wooded pastures in Estonia and on a global scale and, based on this, to point out the importance of their restoration and maintenance. In the light of recent research and the changed situation (new restoration techniques, more powerful mowing techniques), the plan provides advice on the restoration and subsequent maintenance of these semi-natural communities. The maintenance plan is intended for use by the land maintenance specialists of the Environmental Board, protection planners, persons organizing nature protection of various institutions, land managers, and all those interested in nature.

Wooded meadows and wooded pastures have been a natural part of Estonian landscapes for centuries. At a time when most of the population lived in the countryside, pastures were needed to graze the animals and meadows to obtain winter fodder. In this way, species-rich semi-natural with sparse woody vegetation developed over a long period of time. At the beginning of the 19th century, such landscapes covered about 20% of Estonia (Kukk, Kull 1997). The change in agricultural models in the middle of the last century, especially with the emergence of collective farms, no longer favored the preservation of natural-looking meadows, as large-scale, ditched, and fertilized meadows and often meadows with additional sowing of species with higher forage value were preferred. Today, the area of wooded meadows and wooded pastures has drastically decreased both in Estonia and throughout Europe. Therefore, the restoration and maintenance of these habitats is one of the most important nature conservation goals for biodiversity conservation.

The draft of this plan was prepared by Elle Roosaluste. The principles of restoration and management in the draft plan were specified by the Environmental Board.

1. Wooded meadows

1.1. A brief overview of the formation, distribution, environmental conditions, and values of wooded meadows

Wooded meadows are defined as sparse natural regularly mowed stands, which are mostly the result of the felling of trees from different forests and subsequent mowing. They are also often called forest meadows. Wooded meadows are characterized by the alternation of meadow patches with different types and ages of trees and shrubs and their groups (Figure 1).
The wooded meadow-like landscapes developed alongside the formation of human settlements when people began to thin the forest, keep livestock and make leafy whisks and hay for them. The introduction of a scythe about 1500-2000 years ago significantly increased the area of wooded meadows, which together with wooded pastures reached about 850,000 ha at the end of the 19th century (Kriiska 2004; Kukk, Kull 1997). Wooded meadows are distributed mainly in Western Estonia, on the islands (Saaremaa, Hiiumaa, Vormsi, Kihnu), Pärnu, and Rapla counties and in Northern Estonia. There are fewer wooded meadows in Central and Southern

Estonia, where they are usually also of a smaller surface area. The exceptions are the floodplain meadows of South-Eastern Estonia and Soomaa. At present, there is about 750 ha of managed wooded meadows in Estonia, and about 450 ha are being restored (Figure 2). In Europe, typical wooded meadows can also be found in Sweden and Finland, and to some extent, there are habitats similar to wooded meadows also in the Czech Republic, Denmark, Norway, Latvia, and Lithuania (Kukk, Kull 1997). As the area of wooded meadows is very small, then, together with wooded pastures, they are among the three most endangered meadow habitats in Europe (Jannsen *et al*. 2016). Wooded meadows are also a priority habitat type of the European Habitats Directive under the code 6530* Fennoscandian wooded meadows (Paal 2007).

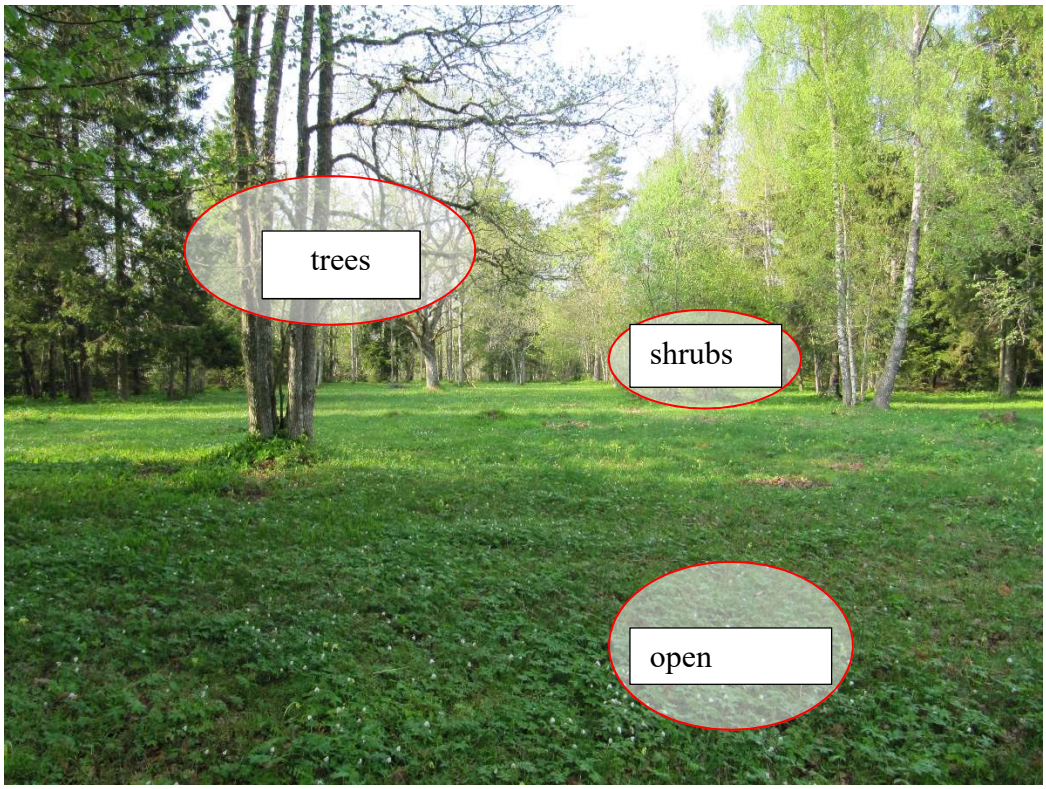

Figure 1. The main elements of the structure of a wooded meadow

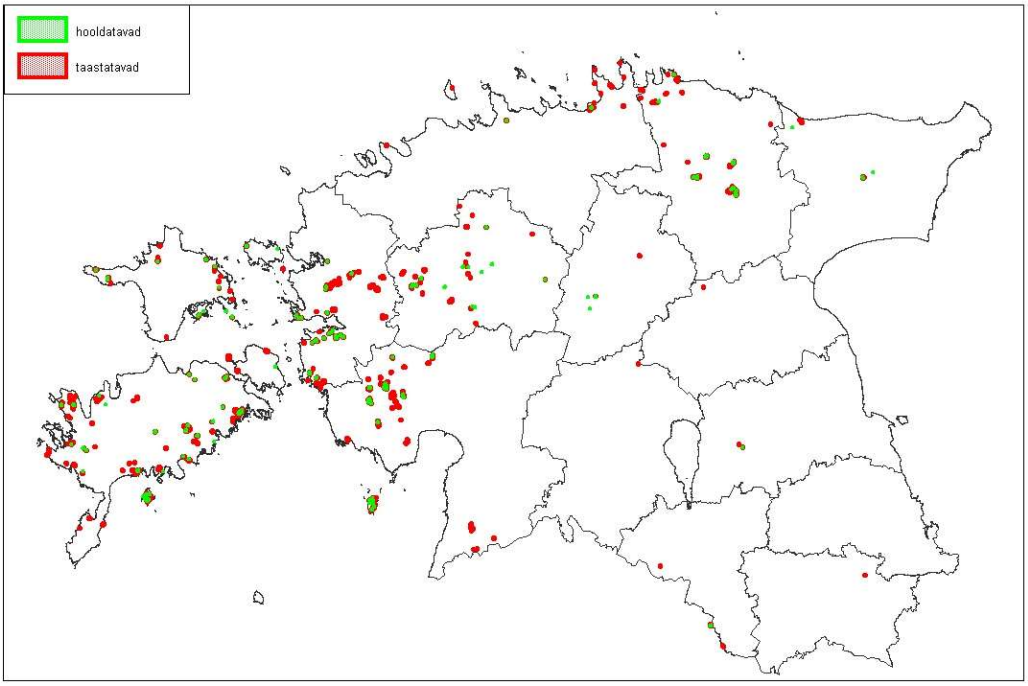

Figure 2. Distribution of maintained and restored wooded meadows in Estonia (https://www.keskkonnaamet.ee/et/eesmargid-tegevused/maahooldus/tegevus-ja-hoolduskavad)

In the course of centuries of development, species-rich communities consisting of different groups of organisms have emerged in the wooded meadows. Depending on the variability of environmental conditions (especially **soil type and soil moisture**), our wooded meadows belong to several habitat types.

Estonia grassland typology, we have mainly **dry boreo-nemoral wooded grasslands**, dry and wet **boreo-nemoral wooded meadows,** dry **boreal wooded grasslands,** species-rich and species-poor **paludified wooded meadows,** species-rich and species-poor and **minerotrophic wooded meadows,** and **floodplain meadows** (formed by floodplain forests on river banks). A total of at least 12 plant communities have been distinguished on wooded meadows and wooded pastures (Krall et al. 1980; Kukk, Kull 1997). According to "Õkoloogialeksikon" (Ecology Lexicon) (Masing 1992), a plant community is defined as a set of plant species growing under the same ecological conditions; different plant communities are distinguished on the basis of species composition, stratification and location.

Dry boreo-nemoral meadows are spread on calcareous cambisols, and typical are dropwort - sesleria, mountain clover - viper's-grass and sesleria - mountain sedge communities. **Boreo-nemoral wooded meadows** are also characterized by cambisol, calcaric cambisol and calcaric luvisol with varying moisture content. Therefore, there are also numerous plant communities in this group: communities of melampyrym, - viper's-grass, dropwort - sesleria, pale sedge - viper's-grass, sesleria - mountain sedge, cnidium- purple - moor-grass. **Boreal wooded grasslands** are mostly characterized by a community of sweet vernal grass-bentgrass, which grows on pseudopodzolic soils. In exceptional cases, wooded meadows formed of alvar forests with thicker soil may also be found. **Paludified meadows and paludified woody meadows** spread on paludified and bog soils, respectively, and can be species-rich or species-poor, depending on the carbonate content of the waters that feed them. The most common are communities of tawny sedge - Davall's sedge, Sesleria - bird's-eye primrose, Sesleria - carnation

sedge, pale sedge - viper's-grass - carnation sedge (Laasimer 1965; Krall et al. 1980; Kukk, Kull 1997). In the case of large-scale wooded meadows, different plant communities form mosaics according to the relief and soil conditions (e.g., Nedrema wooded meadow in Pärnu County). Somewhat different from other wooded meadows are **floodplain meadows**, which are located in flooded areas of rivers and streams. Depending on the position on the terrain, the thickness, and nature of the deposited sediments, they vary in the nutrient and moisture content of the soil. There are more wooded meadows in dry floodplain meadows, the plant communities of which are similar to boreo-nemoral wooded meadows. In wet, sparse floodplain meadows, communities of sesleria - carnation sedge and carnation sedge - carex nigra grow.

The most typical and well-known are dry boreo-nemoral wooded meadows, where the most common tree species are oak and birch, but all other species also grow there to varying degrees. Hazels, bird cherry, juniper, rosehip and hawthorn species, European crab-apple, and rowan are some of more commonly found shrubs. The tree stratum of paludified meadows and paludified woody meadows is characterized by downy birch, alder, various species of willow, blue honeysuckle and Myrica gale. The main tree species in the floodplain meadows are oak, birch, aspen, linden, alder; the most prominent of the shrubs is the protected common spindle.

Depending on the numerous macro- and micro-habitats in the wooded meadows, there are opportunities for living for many species groups. The flora of **vascular plants** which can be assessed for about 600 species (about 40% of all Estonian species) has been subject to most in-depth studies. Among them are 56 protected species (about 26% of all species protected in Estonia) (Pärtel et al. 2007). The high total and small-scale species richness of vascular plants is more characteristic of the dry boreo-nemoral wooded meadows spreading on the calcareous soils of Western Estonia and the islands, because the properties of these soils promote the growth of more numerous species. Small-scale species richness is usually measured by the number of species per 1 m² and currently 7 wooded meadows (Laelatu, Allika and Vahenurme wooded meadows in Pärnu County, Tagamõisa, Mäebe and Küdema wooded meadows in Saaremaa, Tärkma wooded meadow in Hiiumaa) with more than 60 species per 1 m² are known in Estonia. A maximum of 76 species per 1 m² were counted in Laelatu wooded meadow in 2001 (Sammul, Kukk 2013). The **moss** flora of wooded meadows has been less studied and the total number of these species in all types of wooded meadows is unknown, but given the diversity of substrates suitable for moss growth (soil, tree and shrub trunks, deadwood, rocks, stumps), the number may be quite high. For example, more than 100 species of moss have been found in the well-studied Laelatu wooded meadow, the rarest of which are the streaky feather-moss and the protected antitrichia curtipendula growing on the rocks (Ingerpuu, Vellak 2013). 2018 A brief examination of the moss flora of the Nedrema wooded meadow stones revealed that a total of 22 moss species grew on the seven studied rocks. Moreover, 3 of them grow only on rocks. A maximum of 11 species grew on one rock. Thus, the rocks in the wooded meadow play an important role in ensuring the overall species richness (Niemann 2019). **Lichens** grow on wooded meadows and wooded pastures, especially on old tree trunks; a total of 172 species have been found on this substrate (36% of all epiphytic, i.e., lichens growing on trees). Most species -97- grow in oak trunks under good light conditions, whereas many species disappear in overgrown wooded meadows. Among the lichens of the wooded meadow, there are several endangered and protected species, such as lobaria, sclerophora coniophaea, sclerophora pallida, cyphelium inquinans, megalaria grossa, nephroma parile. In addition to oaks, other deciduous trees such as the ash, maples, and old aspens are also important for the survival of lichen species (Oja, Jüriado 2016). The growth of different groups of the **fungi** of wooded meadows depends on human activity and its intensity. For example, mowing promotes the growth of gilled mushrooms, but can inhibit the development of phytopathogenic fungi parasitizing on

herbaceous plants. Preservation of dead and lying wood promotes the presence of wood-degrading fungi. Humus saprobes (living in the humus horizon of the soil) and saporic protists (living on plant residues on the ground) play a major role in the decomposition of organic matter, biogeochemical cycle, and formation of soil. Mycorrhizal fungi are also very important. The species richness of the fungi of wooded meadows depends largely on soil conditions. There are many more species of fungi on calcareous soils than on meadows with the soil low in lime content. This applies to both drier and wetter meadows. Among the mushrooms of wooded meadows, there are also rare and protected species such as satan's bolete, pseudohygrocybe punicea, lactarius acris, leucopaxillus compactus, etc. The species richness of mushrooms is facilitated by the continuous mowing of wooded meadows, which also affects the seasonality of the mycelium: in summer, when the grass is high, there are few species, in the second half of summer and in autumn after haymaking, there are plenty of mushrooms (Kalamees 2004).

The fauna of wooded meadows has been studied relatively little and in varying detail. As for invertebrates, data on snails, earthworms, and several groups of insects are available. Numerous **snails** live in the patches of wooded meadows of different densities and different maintenance intensities. Thoroughly studied, 35 species of terrestrial snails have been found in the Laelatu wooded meadow, which is about 41% of all species recorded in Estonia (Talvi et al., 2013). The fauna of **earthworms** in the three wooded meadows studied consisted of eight species, the distribution of which in different soil layers depends on the soil moisture. Regularly mowed meadows have more species living inside the soil; newly restored meadows have more species living on the surface of the soil (Ivask *et al*. 2012). Wooded meadows have many habitats for **insects**. The review of the fauna of wooded meadows by T.Kukk and K.Kull (1997) mentions the orders of odonata, orthoptera, true bugs, beetles, hymenopterans, and lepidoptera. Of the latter, several species of the European Habitats Directive are related to wooded meadows, such as scarce fritillary, woodland brown, marsh fritillary, scarce heath (Talvi 2004; Kuusemets 2011). The habitat of these butterflies is a well-maintained (mowed) wooded meadows, but their main time of flight and reproduction is in June-July, and therefore mowing must not be performed before flowering and fruiting of most of the plants, as this destroys the food base of butterflies (Kuusemets *op*. *Cit*.). The species of the European Habitats Directive is also the hermit beetle living only on the oaks of the floodplain meadows and pastures of south-eastern Estonia [Action Plan for the Protection of the hermit beetle (*Osmoderma barnabita*) 2018]. The tree and shrub strata with a complex structure, grassland of suitable height, nest cavities in old trees, and rich insect fauna are prerequisites for **the existence of species-rich wild birds in** the wooded meadows. Unfortunately, there are no modern in-depth studies on the birds of wooded meadows. According to general sources related to birds, wooded meadows are an important habitat for about 50 species. Most birds build their nests in the canopies of trees and shrubs, and many in tree cavities. Some species, e.g., the Eurasian nuthatch and the green woodpecker prefer aspen trees, whereas some species prefer spruce (European goldfinch, European greenfinch, yellowhammer), as well as rotten, broken trees and stumps, are nesting places for many species. There are also species whose nests are on the ground inside the grass (tree pipit, European robin, European nightjar, some species of leaf warblers, and Sylvia warblers) [Kumari 1954; Rootsmäe, Veromann 1974; Elts et al. (comp.) 2018]. **Of the amphibians**, the wooded meadows are characterized by a moor frog, a European newt, and a common frog, and of the reptiles, by a grass snake, a viper, and a viviparous lizard. As for small mammals, the most common are a bank vole and striped field mouse; there are no large mammals unique to wooded meadows (Kukk, Kull 1997).

The reasons for the high species richness of wooded meadows, especially in the case of vascular plants, are the following (Kull, Zobel 1991; Kukk, Kull 1997; 1998, Luhamaa *et al.* 2001):

1) calcareous soil, which promotes the growth of numerous species;
2) the average soil fertility, which is ensured by the removal of hay every year after mowing;
3) regular mowing, which makes the light more accessible to small size species and allows plants with different competitiveness to grow together;
4) variability of the micro-relief (the meadow has lower and higher areas, which differ, for example, in terms of soil moisture and allow plant species with different ecologies to grow and thus promote the formation of community diversity);
5) variability of lighting conditions based on the alternation of trees, shrubs, and open meadow patches;
6) large species pool - the surroundings have a diverse landscape from which species can spread from one community to another. The species richness of vascular plants is also expected to be positively related to the species richness of other groups of organisms.

Wooded meadows are also economically and aesthetically important. The traditional management of wooded meadows can be seen as a model for the sustainable use of nature. Apart from the animal feed, firewood, berries, and mushrooms were obtained from there. Many plants were used for dyeing yarn and in folk medicine. In a former farm, the material of the consumer goods was wood with various properties from different types of wood. As different types of trees and shrubs grew in the wooded meadow, the material of the tools was always available. Vases inside the house were adorned with beautiful flowers, which probably also inspired the creation of colorful handicraft patterns. Using all the gifts of nature wisely, there was no fear that they would run out.

There are not many descriptions of the landscapes of wooded meadows. Yet, these are some of the most complex and diverse landscapes in our nature. Diversity is expressed in horizontal, vertical, and temporal dimensions. The horizontal structure is characterized by the alternation of open meadows, trees, and shrubs and their complexes. The mapping of woody vegetation in the Nedrema wooded meadow to the extent of approx. 1 ha showed that the old, well-established, and constantly managed wooded meadow has fewer trees and shrubs growing individually than those growing in groups. The group richest in species consisted of 6 woody plants, with an average of three trees and shrubs growing together (Niemann 2019). This species and spatial variability in the tree and shrub stratification is an important component of landscape diversity. The latter is complemented by rocks, stumps, and deadwood on the meadow. Vertical diversity is characterized by different heights of landscape components (especially trees and shrubs) as well as variability in relief. Traditionally, the landscapes of wooded meadows are characterized by hay barns, stone fences, and, temporarily also by haystacks and haycocks. Different colors of the wooded meadows prevail in different seasons - light green in spring, deep green, and abundance of flowering plants in summer, the variety of red and yellow leaves and bare dark-toned trees and shrubs in autumn give the wooded meadows a high aesthetic value. The management of wooded meadows is also related to material culture. Different tools, different methods of making haystacks have been used in different parts of Estonia; unfortunately, information on these aspects is still incomplete.

1.2. Restoration of wooded meadows

The main goal of the restoration of wooded meadows is to carry out the restoration in such a way as to create traditional habitats that are diverse in terms of landscape- and species and aesthetically pleasing. Further restoration and maintenance of biodiversity must be achieved during further continuous maintenance, which is ensured by improved lighting conditions, control of soil fertility by mowing, and continuous adjustment of stand density. At the same time, it is necessary to keep in mind the creation of habitats favorable for as many groups of

organisms as possible, which requires the design of several living and non-living elements of nature and their combinations in the meadow.

1.2.1. Principles for the selection of stands suitable for the restoration of wooded meadows

Today, a large part of the former wooded meadows are more or less overgrown and forested. The degree of overgrowth depends mainly on the following factors:

1) from the time of termination of management - the longer the overgrowth has lasted, the more the habitat is similar to a forest;
2) the type of community and environmental conditions - the overgrowth of very dry and very wet habitats is slower compared to habitats with moderately moist soils.

The feasibility of recovery depends on a number of factors that need to be considered when making a final decision.
The most important factors promoting the restoration of wooded meadows are the following:

1) there is an interest and capacity for restoration and subsequent proper management;
2) the observed area has been wooded meadow, which is indicated by the following features:
* the landscape and species structure characteristic of the wooded meadow have been preserved in the habitat - numerous different tree (especially broad-leaved) and shrub species grow scattered or in groups, between which young trees and shrubs have grown after the end of management;
*sparsely grown large old trees with wide crown previously grown in good light conditions, especially oaks;
*multi-stemmed deciduous trees (especially birch and black alder), which have developed from the stump shoots created during the management of the meadow);
* the turf grass (a complex formed by the dense overgrowth of the root system of herbaceous plants, especially grasses and the upper organic horizon of the soil) has been preserved in more exposed places);
* there are objects indicating former maintenance (e.g., stone fences, remains of hay barns);
3) the overgrown wooded meadow is part of a wooded meadow complex under maintenance and/ or restoration or forms a landscape complex with other semi-natural communities under maintenance or restoration (e.g., alvars, open grassland on mineral soil, coastal meadows near the sea). This aspect is especially important for small wooded meadows. In some areas, especially on the islands, there has historically emerged zoning of semi-natural communities, characterized by seaside coastal meadows that turn into either alvars or wet or paludified meadows between the beach ridges and further into wooded meadows;
4) there is access to the area (roads, culverts).

Identification of the existence of a former wooded meadow is also facilitated by earlier map material (historical maps on the Land Board's website).
On a landscape scale, it is possible to combine different habitat types as mosaic - forest, wooded meadow, and other semi-natural communities, which create landscape, habitat, and species diversity and a rich species pool.

Restoration is not practical if

1) viable populations of rare shade-loving species (protected species and species belonging to the endangered categories of the Red List) which cannot tolerate changes in lighting conditions have settled down in the stand;
2) the ground is very rocky, which makes mowing difficult, and the removal of stones would damage the area evenly; in that case, it makes sense to use the area as wooded pasture.

In some cases, overgrown wooded meadows may be designated as key habitats (KH for short). According to the Forest Act, a key habitat is an area where the probability of the occurrence of narrowly adapted, endangered, vulnerable, or rare species is high.
The characteristics of a key habitat are:

1) an ancient or rare forest community grows in the area (low human impact, naturally developed forest, etc.);
2) oresence of biological (gaps, trees of different ages, abundant deadwood, old or hollow trees, etc.) and landscape related (different areas affected by water, cliffs, fires, etc.) indicators referring to special living conditions and landscape indicators;
3) presence of indicator species refers to special living conditions (species that need special conditions for growing, which often do not exist in managed forests).

Valuable habitats and wooded meadows already in maintenance, as well as potentially worth restauration, overlap to some extent. The regulation of the Minister of the Environment of 18.10.2017 stipulates that key habitats are divided into types related to the forest type group and the landscape element.

Key habitats associated with landscape features that may overlap with wooded meadows are:
1) shore slopes of natural water bodies;
2) shallows and floodplains near water bodies;
3) spring areas.

Key habitats of wooded grasslands, which include overgrown wooded grasslands, wooded meadows, and wooded pastures, are listed separately.

Characteristics of key habitats in addition to the direct forest structure are **cut gaps** (alvar forests, spruce forests, and mixed spruce forests), **old trees** (alvar forests, spruce forests, and mixed spruce forests), **slow-growing trees, often with curved stems** (alvar forests), **standing dead trees** (alvar forests, spruce forests and mixed spruce forests), **lying wood of stage of decay (**alvar forests, spruce forests and mixed spruce forests, sharp **tree** stumps, (spruce forests and mixed spruce forests), **trees with holes and hollows** (spruce forests and mixed spruce forests), **windfall and windthrow** (spruce forests and mixed spruce forests). **The presence of wood fungi, hanging mosses, epiphytic mosses, old hazels, and shrubs with nectar-rich flowers** has been considered important (Classification of key habitats, selection guidelines, organization of protection, and conclusion of a contract for the protection of key habitats and specified bases for calculating the fee for the right to use 2017).
In conclusion, it can be said that many species and features characteristic of key habitats can be preserved in wooded meadows as sparse stands.

If a KH has also been designated in the area selected for the restoration of wooded meadows, the following activities and opportunities are available to resolve the conflicts:
1) the expert shall verify whether the key habitat has been preserved;

2) in case of the presence of KH values, they must be maintained when restoring a wooded meadow if KH
(a) is located on the edge of a meadow,
(b) is located inside the meadow as a non-managed entity.

If it is not possible to find a solution in this way, the problem areas must be inspected with semi-natural communities and KH specialists.

1.2.2. Selection and size of groups of non-managed woody plants

In traditional old wooded meadows, larger groups of trees and shrubs can be seen that are not thinned and under which no mowing is performed (Figure 3).

Figure 3. An unmanaged group of trees on Tagamõisa wooded meadow (photo by E.Roosaluste)

Such denser islets of woody plants diversify the landscape and species composition of the wooded meadow (forest species growing in the shade), provide a habitat and food base for birds and other animal species. Such patches may also be left on restorable wooded meadows, but their area should not exceed 10% of the total area of the meadow, and the size of one patch could be up to 0.05 ha.
When selecting such patches, the following is preferred:

1) clearly recognizable groups of woody plants from the denser structure of the old wooded meadow, in which:
several more valuable tree and shrub species grow together, e.g., oak, linden, willow, common hazel, European crab-apple, rowan, Swedish whitebeam, common barberry, hawthorn, and rosehip species;
2) groups of woody plants where species that often do not reach the first stratum (for example, linden of the undergrowth) or groups of trees with remaining (dwarf) canopy forms grow;
3) difficult to manage, e.g., excessively moist depressions and rocky places.

1.2.3. Principles of designing the species composition and structure of woody plants in restored wooded meadows

When restoring wooded meadows, it is very important, from the very beginning, to design the species-related and spatial structure of trees and shrubs typical of the habitat. To achieve this goal, the following principles should be guided by:

1) the design of the structure should be based on the appearance of old wooded meadows historically characteristic to the region so as to create a scattered, irregular pattern of trees, shrubs, tree and shrub complexes alternating with patches of open meadows (it is recommended to leave fewer single trees and more small groups of trees and shrubs, as individual trees are threatened by being thrown by wind) (Figure 4);

Figure 4. Group of trees and shrubs wooded meadow in Tagamõisa (photo by E.Roosaluste)

Figure 5. Thick-barked old birch on Raespa wooded meadow (photo by E.Roosaluste)

2) first and foremost, to leave old trees of the wooded meadow [thick, with a broad crown, multi-stemmed, with a strong bark (micro-habitat for mosses and lichens) growing (Figure 5), especially oak, birch, linden, maple, spruce], including damaged or dead trees (Figure 6), but younger specimens of different age categories must also be retained to ensure intergenerational continuity;
3) in the choice of trees to be preserved, preference shall be given to trees with thicknesses of more than 30 cm or to trees with a special canopy or trunk shape and diverse looking trees; it is essential to preserve trees and groups of trees associated with local heritage or other local heritage traditions;
4) to keep trees with hollows in which birds find nesting places;
5) depending on the peculiarities of wooded meadows (often related to regionalism), also to keep pines (Figure 7), thick old aspens, willows, common alders, - the goal is maximum species diversity; with the preference to the trees with the well-developed canopy;
6) of the shrubs, hazel, Swedish whitebeam, rowan, common barberry, European crab-apple, and hawthorn species shall be preferred, but other shrub species should also be retained; shrubs as large as possible could be maintained if individual specimens were to be allowed to grow

(7) Rare and protected plant species growing in the area should be identified prior to restoration in order to maintain their populations during restoration in accordance with the ecological requirements of the species.

In summary, the total area of the stand of boreo-nemoral wooded meadows should be 0.4-0.5 (0.6), with the recommended proportion of shrubs being 0.1-0.2. The lower limit for the crown cover of flooded meadows, paludified meadows, and paludified woody meadows could be 0.2.

Figure 6. Dead tree on an old wooded meadow in Mullutu
(photo by E.Roosaluste)

Figure 7. Pines on a wooded meadow in Võrsna
(photo by E.Roosaluste)

1.2.4. Selection and preservation of other traditional wooded meadow elements [rocks, lying wood, ants, stumps, water bodies (holes), etc.]

In addition to trees and shrubs, the landscapes of wooded meadows are characterized by inanimate nature objects and dried trees in many forms. All of these elements are home to many small organisms, often difficult to detect and distinguish. There are also anthills in the wooded meadows. In the case of restoration, one of the objectives is to preserve as many habitats as possible for different groups of organisms in order to ensure maximum species richness. This requires:

1) preserving **lying wood** (Figure 8), preferably with a diameter of at least 30 cm (habitat for fungi, mosses, lichens, insects), especially on non-managed woody plant patches, under trees and shrubs and their complexes;
2) preserving **anthills** and the trees and shrubs and stones around them (Figure 9);
3) preserving **stones** (for example, Figure 10 **)** that do not interfere with mowing and are a substrate for many species of lichens and mosses, as well as preserving stones that are under trees and shrubs. Species-rich micro-communities in which vascular plants and several invertebrates settle (the latter is also a refuge for the winter) are formed on the rocks, which have been standing undisturbed for a long time;

4) it is recommended to leave some thicker **stumps** in the restored area (Figure 11), as they are a substrate for fungal, lichen, and moss species;
5) not to clear the immediate surroundings of the **stone fences** in the wooded meadow, but to preserve the trees and shrubs (Figure 12);
6) when restoring and maintaining, to preserve **bodies of water** found in wooded meadows; filling bodies of water with stones, wood, grass, and other materials is not allowed.

Figure 8. Lying wood with lichens in Nedrema Figure 9. Anthill under a tree in Ristiku wooded meadow in Kihnu island (photo by E.Roosaluste) wooded meadow (photo by E.Roosaluste

Figure 10. A low stone (photo by E.Roosaluste) Figure 11. Species-rich stump (photo by E.Roosaluste

Figure 12. A stone fence on Kõrgelaiu wooded meadow (photo by E.Roosaluste)

1.2.5. Techniques and conditions for the practical restoration of wooded meadows

The practical restoration of wooded meadows requires a great sense of responsibility and awareness, as it will shape the landscape structure of the habitat for a very long time. Restorers are therefore required first to undergo theoretical and practical training. Restoration of wooded meadows nowadays takes place in both small and large areas. In smaller areas, this is done by traditional means and over several years. The structure of the stand is better visible during the time of bare trees, whereas the preservation and composition of the meadow vegetation are better visible during the summer. Felling is usually started from the better-preserved meadows by gradually expanding them. In the first place, the bush is cut, then a better overview is created for shaping the tree stratum. By thinning the tree and shrub strata over several years, it is possible to better choose the trees to be removed. Longer-term felling also prevents the simultaneous release of a large number of nutrients into the soil and thus the extensive growth of ruderals (Hellström, http://kingpool.hak.edu.ee/materjalid/puisniit4/index.html;Talvi 2010). During a longer restoration, girdling of trees has been used to prevent stumps and root shoots (the bark of the lower part of the tree trunk is cut off in a strip of about 10 cm, after which the tree dries and no longer gives off shoots) (Jürgens, Sammul 2004b). In today's large-scale restorations, all work is done with efficient technology in a short period of time (usually one year). Therefore, the principles and methods of restoration need to be carefully thought out in advance.

The following principles must be observed during restoration:

1) in the case of restoration, clear marking of the trees and shrubs and other elements to be preserved or removed is necessary; the best time is when the trees are bare, and the stand structure is more visible;

2) it is expedient to first remove most of the bushes and then to start selecting and marking the remaining trees and shrubs;
3) if possible, especially in the case of smaller and less overgrown areas, felling shall be started from the edge of the area or by expanding the better-preserved meadow patches;
4) it is recommended to design the transition areas of the restored meadow and the neighboring community in a sinuous way - this way, the landscape is more beautiful to look at, and the habitat area of the transition area increases;
5) felling is most optimal on top of frozen soil or in dry weather (after melting of the snow) or in late autumn to avoid soil damage as much as possible;
6) restoration felling shall not be carried out during the active period of nesting of birds, the deadlines of felling peace established as a statement of goodwill (15 April - 15 July) shall be followed, nor shall stacked chipping material be removed during the nesting period of birds;
7) a group of trees growing from one root turf must be removed or preserved as a whole, instead of cutting off individual branches;
8) trees and shrubs to be felled must be cut as close to the ground as possible (parallel to the ground); no sharp stumps should be left;
(9) preservation of trees with one-sided and sparse crowns should be avoided; if this is necessary for the design of the structure of a wooded meadow (few suitable trees), the group of trees should be preserved if possible;
10) in the course of the work, the trees and shrubs and other landscape elements that are to be preserved must not be damaged by the equipment;
11) during restoration, the complexes of living and non-living nature must be preserved as much as possible, i.e., small groups of trees and shrubs should be left to grow together, with single rocks, anthills, etc., under them;
12) tree trimmings with a diameter of more than 5 cm and a length of more than 50 cm shall not be left behind;
13) tree trimmings shall not be left in the meadow, and all felled timber shall be removed immediately or at the latest by the beginning of the vegetation period following the felling operations;
14) tree trimmings may be temporarily stored in a restored area; after removal of the tree trimmings, the storage place must be tidied up;
15) the roads necessary for restoration and maintenance as well as the locations for storage of tree trimmings must be planned on dry and hard ground in places where it does not damage the typical meadow vegetation and habitats of rare species;
16) equipment that does not leave rails (machines with belts preferred) must be used for restoration;
17) in the event of the formation of rails, they must be leveled immediately after the completion of the restoration work;
18) if the formation of rails cannot be avoided, it is required to drive along with one pair of rails in order to avoid damaging a larger area;
19) the stumps of trees and shrubs must be milled level with the ground after felling (except for individual stumps which are left as a substrate for lichens and mosses); if necessary, the stump must also be milled from the ground (particularly applicable in case of wet meadows where there is a risk of the stumps rising after felling due to the changes in and subsidence of the soil).
20) superficial surface milling is permitted in areas where the wooded meadow is densely overgrown, there is no turf grass, and the ground is covered with the roots and stumps of trees.
21) in the case of removal of tree stumps, the holes must be leveled;
22) if tree trimmings are burned, this must be done in the places where the existing vegetation is least damaged (in places with no turf, on stumps);

23) the burning of tree trimmings is prohibited during times with an increased risk of fire; the requirements for fire safety must be observed during burning;
(24) Prior to restoration, sites should be selected that are preferably not restored due to the presence of stones interfering with mowing. The surroundings of larger rocks and groups of rocks consisting of several rocks should not be restored. This is especially the case if the rocks are covered in moss and various trees and shrubs grow around them, which also function as signs of the rocks and valuable micro-habitats during the further maintenance of the area. The rocks that interfere with mowing can be removed during restoration. In general, mowing is not disturbed by stones that are significantly higher than the grass stratum and clearly visible or flush with the ground or protrude so little from the ground that are below the cutting mowing. Preferably, the removed stones should be collected in places unsuitable for mowing, under trees and shrubs, stored at the edge of the meadow, built into a stone fence or used to repair old stone fences. If it is not possible to place the stones individually in the meadow area, they can be grouped into small and scattered piles, preserving as much of the traditional landscape as possible. The resulting holes must be leveled. If during the removal of stones it turns out that these are very large stones (boulders) or that they leave a hole in the ground that needs additional aggregate, the stones must not be removed, and the stone must be marked when mowing (Figure 12a). If the area contains stones to the extent that removal of them is not practical and would damage the habitat, the area must be maintained as wooded pasture.
25) trees and shrubs are grown around or on stones shall not be felled but shall be preserved as elements of the landscape.

Figure 12a. Too big stones to be removed (photos by Ants Animägi)

As a result of the restoration of the wooded meadow, a habitat must be created in which the characteristic structure of the wooded meadow with the crown cover of woody vegetation 0.4-0.5 (0.6) has been formed and where trees and shrubs and their groups alternate with open meadow patches rich in light (Figure 13). Restored wooded meadows should be dominated by older trees and shrubs, but woody plants from younger age groups should definitely be preserved to ensure offspring. In the wooded meadows restored in one year, it will be necessary to regulate the density of trees and shrubs for at least a few years. The species composition of the trees and shrubs must be as rich as possible, but with an emphasis on the species typical of the traditional wooded meadows in the area. The presence of lying wood,
dead standing trees, single stumps, and stones in the meadow is very important. The conservation of all these elements and their complexes is important for the recovery and preservation of as many biotas as possible. Figure 14 gives an overview of the structural elements of a wooded meadow.

Both after restoration and during further maintenance, it may be necessary to assess the **crown cover of the woody plants** of the wooded meadow. There are several ways to do this, the most convenient of which today are:

1) visual assessment of the crown cover;
2) measurement of the area of the canopy of trees and shrubs on an observation plot of 1000 m² - the projection d or r of the canopy on the ground is measured, their total area is calculated, which divided by 1000 shows the % coverage of canopy (does not take into account canopy openings);
3) calculation of the crown cover from the so-called "fisheye photographs";
4) calculation of crown cover from drone images.

Identifying the best method requires additional fieldwork and data analysis.

Figure 13. Properly restored wooded meadow in Saaremaa (photo by E.Roosaluste)

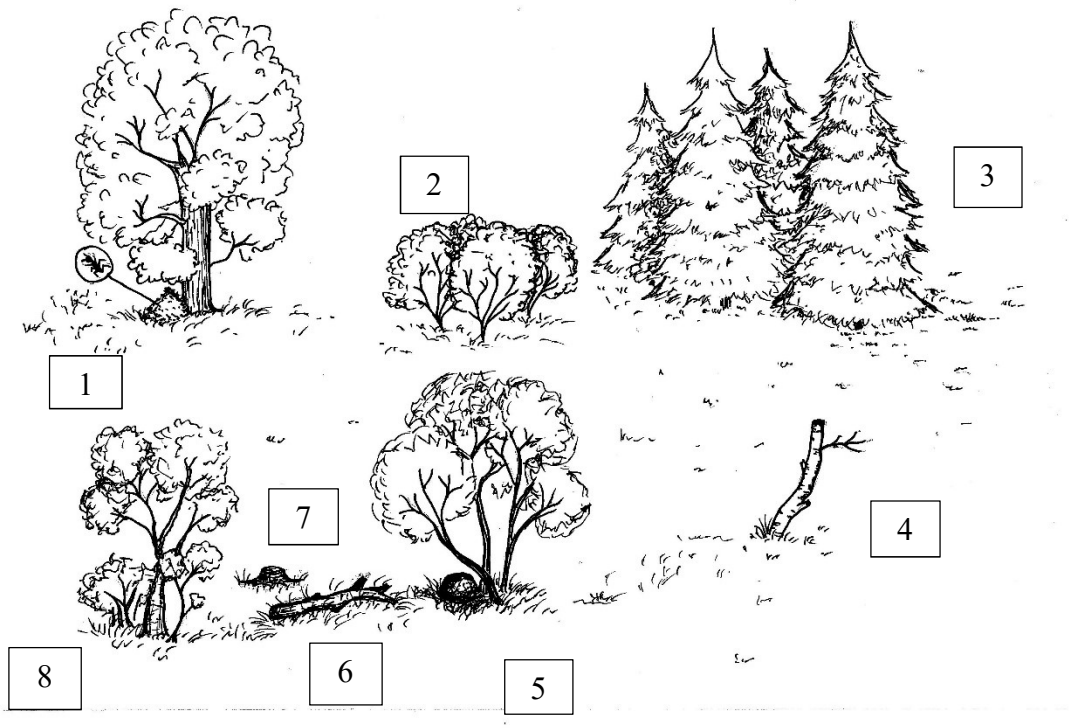

Figure 14. Structural elements of a wooded meadow: 1 - an old wide crowned tree with an anthill, 2 - a group of shrubs, 3 - a non-managed group of trees, 4 - a dead standing tree, 5 - a multi-crowned tree with a stone, 6 - lying deadwood, 7 - a stump, 8 - a group of trees and shrubs (Figure T.Kasepalu).

1.2.6. Evaluation of the success of the restoration of wooded meadows

The biota of wooded meadows has developed over a long period of time, and its restoration is a process that depends on
(a) the type of wooded meadow;
(b) the degree of overgrowth;
(c) the methods and quality of restoration;
(c) the methods and quality of maintenance;
(e) the seed bank and the species fund.

The characteristics of a successfully restored wooded meadow are as follows:

1) a dense and massive turf;
2) the restoration of the landscape structure characteristic of traditional wooded meadows and the species composition of woody plants, which is reflected in the existence of a landscape image and tree and shrub species corresponding to the type of wooded meadow and the specifics of the area. Depending on the effects of the flood, the floodplain meadows are thinner than the boreo-nemoral wooded meadows, the same is true for paludified meadows and paludified woody meadows;
3) recovery of large- and small-scale species richness, which must be monitored continuously for up to 10 years under appropriate monitoring conditions - it is recommended to apply the current meadow monitoring methodology (50 x 50 m permanent observation areas with 20 1-m^2 analysis squares) (Kukk 2018);
4) the presence of complexes of vascular plant species characteristic of wooded meadows.

It must also be borne in mind that the species richness of wooded meadows has developed over a very long period of time under traditional management conditions and, depending on the degree of habitat degradation, it may take a long time for all biodiversity to recover. Therefore, a long-term sustainable action plan needs to be established to monitor these processes.

The vegetation of wooded meadows is formed by species with different light requirements: shade-loving plants grow under trees and shrubs, plants with an intermediate light need to grow in semi-shade, and light-loving plants grow in open meadow patches. As the soil conditions are more or less average due to pH and other chemical properties, there are no plant species characteristic only of wooded meadows. Therefore, the vegetation of a wooded meadow in good condition can be characterized by a complex of typical meadow species.

The following species grow more frequently in **boreo-nemoral wooded meadows:**

Graminoids (grasses, sedges, rushes):
sweet vernal grass, quaking-grass, sheep's fescue, and red fescue, meadow oat-grass, sesleria, common bent, common woodrush and field wood-rush, blue sedge, pale sedge, bird's foot sedge, carnation sedge, Carex caryophyllea;
herbs:
Alchemilla species, bellflower with large-flowers and round leaves, common mouse-ear chickweed, dropwort, wild strawberry, northern bedstraw, meadow vetchling, rough hawkbit, oxeye daisy, melampyrum nemorosum, mouse-ear-hawkweed, ribwort plantain, dwarf milkwort, potentilla erecta, common cowslip, common self-heal, ranunculus polyanthemos, meadow buttercup, viper's-grass, red clover, mountain clover, common dog-violet.

The vegetation of paludified meadows and paludified woody meadows has not been studied in detail, but the characteristic species include the bird's-eye primrose, the viper's-grass, the globeflower, the Succisa, the milk-parsley, the marsh helleborine, the Davall's sedge, the tawny sedge, the carnation sedge, the blue sedge, the Buxbaum's sedge, the Carex hartmanii, and the sesleria.

Good indicators of successful recovery are the introduction of meadow ungulates and other protected and rare species into the meadow. Good quality wooded meadows are characterized by numerous bird species nesting in the crowns of trees and shrubs and in tree hollows. There are also many butterflies and other insects in the meadows with many flowering plants.

1.2.7. Management of newly restored wooded meadows

Management of restored wooded meadows must start immediately, otherwise they will be very quickly covered with the bush, as the light conditions have changed and nutrients are released from the roots of dead trees, which will encourage the growth of large species. Mowing, grazing, and combinations thereof can be used for management.

If the restored area has been unmanaged for a long time and the number of meadow species in the community and in the seed bank is small, the meadow can be grazed with a suitable load in the first few years. Livestock spread the species with both their coat and manure, and the spread of the species is particularly effective when the animals are also grazed on neighboring meadows, from where they spread propagules to the restored meadow. From now on, regular mowing of the meadow should start. Grazing could take place with different species of animals, as they eat different plant species, which helps to diversify the flora (e.g., combining grazing with sheep, goats, horses, and cattle). No additional feed may be given to the animals during

grazing. Less overgrown restored meadows, where the meadow species and the turf grass have been preserved to some extent, should be mowed immediately. Initially, mowing could take place several times during the summer, especially where there is an abundance of bushes, meadowsweet, and dewberries. In this case, it would be optimal to mow in spring, mid-summer, and late summer (Sammul, Jürgens 2004b).

If there is no turf grass in the restored area or it is present only in patches, the meadows often overlap with ruderal species in the first year (e.g., thistles). To get rid of them faster, the meadow can be mowed before the seeds ripen, and the mowing must be removed immediately. This management technique should last until the disappearance of the ruderals.

1.3. Management of wooded meadows

Traditional techniques have been developed for the long-term management of wooded meadows. The first activities began in the spring with the raking and burning of dead grass, leaves, and twigs, and in some areas, the gathered grass, leaves, and twigs were taken to the lairage as litter for animals when it ran out in the spring. In addition, stones and stumps disturbing with mowing were marked, the ground, e.g., digging traces of wild boar and molehills, was leveled, broken trees were removed, and branches disturbing mowing were cut. These traditional activities were widespread in Sweden, Finland, and Estonia (Hæggström 1981**;** Kukk, Kull 1997; Hansson & Fogelfors 2000). Caretakers of smaller wooded meadows still follow these rules today.

Haymaking usually began when the hay in the open meadows was made, so time was allocated for the hay growing in the shade to ripen. In the wooded meadows of Sweden and Åland, mowing started in the second half of July, in dry summers also earlier. In general, the onset of haying time was determined by the phenology of the plants, e.g., the flowering of the timothy and the fall of the seeds of the rhinantus heralded the beginning of the haying time (Hæggström 1981; Mitlacher *et al.* 2002). The oldest mowing tool was a blacksmith's scythe, followed by horse mowers. After mowing, the hay was dried and raked, which helped the seeds of the plants to after-ripen and spread. The dry hay was placed in haystacks and haycocks, which were later transferred to hay barns. All these activities were environmentally friendly, did not damage the soil, trees, and shrubs, and promoted the creation and preservation of all-encompassing species richness. Of particular importance was the multiple soil disturbance during both spring preparation and tedding and raking of hay, which resulted in small patches of bare soil where new plants could settle. The current covering of wooded meadows with mosses and the decline in species richness may be partly due to the absence of such long-term disturbance. After the hay was harvested, aftergrass grew on the meadow, and in the autumn, the wooded meadows were grazed with cattle for a short time.

1.3.1. Mowing

Today, the area of wooded meadows to be managed varies greatly (from a few hectares to 100 hectares), and therefore the methods of management have become more diverse than before. The following schemes can now be distinguished:

1) the traditional old maintenance method: the managers of mostly small wooded meadows still work traditionally - they arrange the meadow in the spring as described above, mow it with a scythe, dry and ted the hay, put it in stacks, and finally remove it from the meadow. This also includes the maintenance of a wooded meadow with a horse mower and a horse rake, which has also been largely forgotten today. Smaller mowers are also mowed with the motoblock;

2) mowing with a tractor in the traditional way: hay is mown, dried-tedded-swathed, raked (haycocks, haystacks, hay barns) or baled;

positive side:

(a) small machines with good maneuverability can also be mowed under trees and shrubs;
b) lower trampling load;
c) under the conditions of drying and swathing, the seeds ripen and spread - promotes the preservation (growth) of the species richness of the meadow;
negative side:

(a) the meadow must be visited at least three times (mowing, tedding, gathering);
b) time and labor-intensive;
(c) high dependence on the weather;

3) mowing with a tractor and immediate collection of the mowing (baling)

positive side:

(a) only one machine is required;
(b) the meadow is trampled only once;
(c) saving of time, fuel, labor;

negative side:

(a) heavy machinery may damage the porosity of the soil, the turf grass, and the vegetation;
(b) machinery is usually large, is unable to mow under trees or shrubs, and additional work is required;
(c) the seeds of the plants are likely not to ripen and spread, resulting in the depletion of the species composition;
(d) fauna operating in grass fauna is also collected and removed from the meadow.

If the mowing is collected and baled immediately, the following measures must be taken in order for the seeds to ripen and spread:

1) in large meadows, start mowing from different ends of the meadow in different years;
2) skip one year of mowing;
3) mow by strips or leave unmown patches of other shapes. Such management has been successfully applied to natural grasslands in Switzerland for the protection of the populations of butterflies and orthoptera. The area of unmown patches could be 10% of the meadow area, and unmown patches should vary from year to year (Buri *et al.,* 2013; Bruppacher *et al.,* 2016). The width of unmown strips could be about 10 m, and the distance between them max. 30 m (Humbert *et al.* 2012);
4) in order to save the fauna inside the hay, an "apart from the middle" or "from edge to edge" mowing scheme could be applied to larger open meadow patches.

Selection of suitable equipment for maintenance:

1) smaller wooded meadows, including those with more difficult access (e.g., small islands), are recommended to be managed in the traditional way, by mowing either with a scythe or a motoblock, drying, tedding, and gathering the hay on the meadow and then removing it from the meadow;

2) larger wooded meadows are mowed with a tractor, the width of the mower of which must be suitable for mowing of a meadow that is in good condition and has a structure characteristic to a wooded meadow; a bar mower is more beneficial to biota than a rotary mower;
3) mowing and other maintenance equipment must be selected so that the special pressure is low and does not damage the meadow turf;
4) Rubber bands should be used for mowing paludified meadows and paludified woody meadows; in the case of very wet summers, a break year for mowing might be considered.

The main recommendations for the maintenance of wooded meadows:

1) wooded meadows must be mowed regularly and mowed to prevent the emergence of the layer of dead grass and leaves as well as brush. Depending on the condition of the wooded meadow and the weather (peculiarities of vegetation and mowing), the meadow may be left unmown in one summer per 5 years;
2) mowing must also be performed under trees and shrubs, around stumps, sharp dried tree stumps, lying wood, rocks, anthills, small lakes, etc.(with a scythe or a trimmer);
3) chopping as a maintenance technique for wooded meadows is not permitted, as one of the bases for the species richness of wooded meadows is to keep the soil nutrient content low in order to prevent the dominance of tall species, whereas hay left over on the ground after chopping increases soil fertility, forms a layer of dry and rotten hay that prevents seeds from germinating and growing;
4) Despite the established uniform start date for mowing on 10 July, the species richness of insects and plants has decreased over time, so leaving the start date arbitrary in wooded meadows encourages inter-area mosaicity at the landscape level and encourages the diversification of plant and insect communities. At the same time, it is necessary to leave 10% -30% of the area unmown every year to increase biodiversity. The unmown area must rotate from year to year (the area is left unmown at different places each year). Depending on the specific protection values, a specified mowing start date may be required.
5) after mowing and collecting the mowing, the areas may be grazed on the aftergrass. Areas can also be grazed after restoration until meadow vegetation is created that can be mowed and collected.

Later mowing is beneficial for the following:

(a) Traditionally, haymaking time began after Midsummer, but open grasslands were first mowed, followed by wooded meadows. An important reason was the slower growth of hay in wooded meadows due to the shade of trees and shrubs. In such management conditions, the species richness of today's wooded meadows has developed;
(b) many important species of wooded meadows have not usually managed yet to flower and grow fruit before July. According to the orchid flowering schedule compiled by R.Kurbel and T.Hirse (2017), the main flowering time of red helleborine, lesser butterfly-orchid and greater butterfly-orchid, several species of marsh orchids, fragrant orchid, the burnt-tip orchid is in late June and the first half of July; according to phenological studies carried out on the Laelatu wooded meadow, the species in the dry boreo-nemoral wooded meadows are most in full bloom in the first weeks of July (Hein 1970);
c) early mowing is unfavorable for birds nesting in the ground (e.g., leaf warblers and Sylvia warblers, European nightjar, tree pipit, European robin, whose chicks are still nesting even in early July); in the meadows bordering the marshes and paludified areas, young birds nesting there, e.g., common crane, end up in wooded meadows;
(d) as wooded meadows are home to many insects, including rare and protected species, flowering plants are an important food source for them. Adequate food allows insects to reproduce and prepare for winter (Kuusemets 2011; Bruppacher *et al.* 2016). The same results

have been obtained in the study of orthoptera (Buri *et al.,* 2013). Thus, the coordination of mowing and flowering times are very important for maintaining all-around species richness. Very late mowing (from the second half of August) is also not recommended, as in this case, proper aftergrass necessary for the insects to feed and prepare for winter (Talvi 2010) will not grow;
So as of today, starting mowing in early July is a compromise between different arguments. If the phenology of the meadows changes in the future as global warming continues, it will be possible to reconsider the current deadlines;
5) some small patches (collections) of outstandingly ornamental plants (e.g., St. John's wort, large bellflowers, Inula salicina, etc.) could be left unmown;
6) sharp stumps and trunks of dried thick trees must be preserved on the wooded meadow; fallen trunks interfering with mowing may be cut into long pieces and stored at the edge of the meadow;
7) the storage places for mown hay and hay bales must be changed, and places poorer in species must be chosen for storage places;
8) The density of trees and shrubs in the meadow should be adjusted from time to time, preferably in autumn or winter, and the branches and part of fallen trees should be removed.
9) in the spring, the traces of digging by wild boars and molehills must be leveled on wooded meadows, either manually or by machine;
10) Traditionally, old grass, leaves, and thinner branches have been raked together and removed harvested in the wooded meadows in the spring, and this is also recommended today, as digging the soil promotes plant growth and repels moss.

The species of flora and fauna of wooded meadows vary from meadow to meadow. In wooded meadows, where rare and protected species grow and live, the so-called **target species** must be taken into account when organizing maintenance. These include a number of ungulates (especially the lady's-slipper orchid, narrow-leaved helleborine and red helleborine, the burnt-tip orchid), the moor-king lousewort, the Turkish marsh gladiolus, the Siberian Iris, the Viola elatior, the dyer's plumeless saw-wort, as well as large communities of some other rare and protected species. Of butterflies, such species include the scarce fritillary, the woodland brown, the marsh fritillary, the scarce heath. The presence of these species in wooded meadows must be identified and maintained in accordance with the requirements of the species.

1.3.2. Autumn grazing

Grazing in the second half of the summer and an after graze in the autumn is one of the traditional ways of managing wooded meadows. In addition to the need for practical pasture, grazing has a positive effect on the wooded meadow itself. The animals eat young woody plants, prune trees and shrubs, by treading create small patches of bare soil in the turf grass where the plants can settle, as well as spread the propagules of the plants. Apparently, grazing also prevented the mossing of meadows (Troska 2004). Investigations in Åland revealed that on wooded meadows, the sheep ate predominantly species with large leaves (ungulates, several Apiaceae, meadowsweet, tall fescue, cock's-foot, field meadow foxtail); as for woody plants, they preferred ash, guelder-rose, rowan, maple. The longer the grazing period, the more plant species the sheep began to eat. Bovine animals were less selective in terms of edible species. As for the trees and shrubs, they preferred the same species as the sheep. However, they mostly ate grasses; the first choice also included zigzag clover, autumn hawkbit, brown knapweed, spring vetchling, and nettle-leaved bellflower. Both species of grazing stock avoided species with sharp plant parts (spruce, juniper), but cattle also liked to eat poisonous plants such as St. John's wort, Ranunculus polyanthemos, and lily of the valley. In general, moderate-load

autumn grazing is useful for regulating the growth of tree shrubs and some large herbaceous plants (Hæggström 1990). It could also be a good way to control mosses.

The following principles should be applied to autumn grazing:

1) graze only in case of sufficient grass growth;
2) grazing must be short-term, not exceeding one month;
3) grazing should be carried out with a low load (not more than 0.5 LU/ha);
4) no additional feed may be given to the animals during grazing.

Livestock unit values:
1) bovine animals over 24 months of age, incl. suckler cow - 1 LU
2) bovine animals aged 6-24 months - 0.6 LU
3) bovine animals up to 6 months of age - 0.2 LU
4) horses over 6 months of age - 1 LU
5) horses up to 6 months of age - 0.35 LU
6) goats or sheep over 12 months of age - 0.15 LU
7) goats or sheep aged 6-12 months - 0.05 lU

1.4. The main threats to wooded meadows

The drastically reduced area of wooded meadows and the time-consuming restoration give reason to name the threats. The most important of these is the continued overgrowth of formerly wooded meadows, and the longer it lasts, the more difficult it is to restore the meadow and the more time-consuming it will be to restore biodiversity. In many cases, it no longer makes sense to restore the wooded meadow but to allow the forest to grow.

During the restoration and subsequent maintenance, wooded meadows may also be compromised by the following factors:

1) trees and shrubs characteristic of a wooded meadow are not left growing during restoration, i.e., a typical species composition, age structure is not ensured;

2) the stratum of trees and shrubs is made too sparse;

3) elements important for the species richness of a wooded meadow are removed - stones, stumps, lying wood, semi-dried and dried standing trees;

4) inappropriate equipment is used for both restoration and maintenance that damage the turf grass and damage trees and shrubs;

5) hay is abandoned or shredded, as a result of which the soil is enriched with nutrients and large species benefit;

6) hay is continuously collected and removed during mowing so that the seeds of plants cannot ripen or spread; in addition, most insects and other invertebrates are removed together with hay.

The above requirements and recommendations must be observed to prevent such errors and damage.

One of the indirect threats to the species richness and plant communities of wooded meadows is the addition of nutrients by way of precipitation, especially nitrogen compounds, whereas

acid rain changes the soil's reaction over time, both of which make the communities poorer. The changes due to these factors are characterized by studies in permanent observation plots of Swedish meadows, where analysis of vegetation descriptions made at 25-year intervals revealed an increase in plant biomass, an increase in the proportion of grasses, and a decrease in the proportion of herbs. During the same period, the addition of nitrogen compounds to the soil increased 2-3 times (Berlin *et al.* 2000). The lack or decline of a network of wooded meadows and other species-rich semi-natural communities is also a negative factor that has had an effect for a long time, as it hinders the spread of species and leads to the emergence of an extinction debt.

1.5. Favorable condition of wooded meadows

The characteristics of the well-restored and regularly maintained wooded meadows are as follows:

1) the wooded meadow has a typical landscape, which is characterized by irregularly located trees and shrubs of different ages characteristic of the given area and ecological conditions, between which are light-filled meadow patches to be mowed, the optimal connection of the stand is 0.4-0.5;

2) the meadow is mowed regularly, the hay is removed, the result is a grassland rich in species characteristic of wooded meadows without tall dominants; in addition, rare and protected species grow on the meadow;

3) old trees with wide canopy, especially oaks, as well as multi-stemmed trees, grow on the meadow; the bases of those trees are also mowed;

4) the meadow has complexes of living and non-living natural objects consisting of trees, shrubs, rocks under them, stumps, anthills;

5) the meadow contains a few large rocks protruding from the grass, as well as low stones and stumps that do not disturb mowing, lying wood, semi-dried and standing dead trees as key micro-habitats for many groups of organisms;

6) there is no layer of dry and rotten leaves on the ground.

1.6. Valuing wooded meadows through nature tourism and nature education

The rich biota of the wooded meadows, the beautiful and colorful landscape at any time of the year are appreciable objects for the activities of introducing natural values, the connections existing in nature, the sustainable use, and appreciation of natural resources. Unfortunately, these opportunities have so far been relatively little used. The following measures could be taken to remedy the situation:

1) equip representative wooded meadows with infrastructure and information boards (there must be someone who maintains and renews them);
2) enter the objects to tourist maps;
3) promote the products of wooded meadows (birch sap, maple juice, medicinal plants, ornamental plants), the use of different types of wood in handicrafts (e.g., handicraft classes for boys at school);
4) make excursions for different interest groups (schools, adult education, *a la* Nature's omnibus);
5) look for opportunities for the marketing of wooded meadow grass to smaller livestock keepers, pets, and zoos;

6) involve local residents in the restoration, maintenance, and introduction of meadows and wooded meadows close to cities and settlements in order to popularize the natural values of their domicile ("the idea of nature protection for everyone").

2. Wooded pastures

2.1. An overview of the concept, origin, distribution, environmental conditions, and biota of wooded pastures

A wooded pasture is a wooded meadow-like ecosystem; the meadow turf was created and preserved as a result of long-term grazing (Kukk, Kull 1997). The names forest pastures and forest paddocks are also common. According to the handbook of the European Habitats Directive (Paal 2007), wooded pasture is a vegetation complex with a very variable tree stratum density, similar to a sparse forest or consisting of only small stands alternating with shrubs and patches of open meadows (Figures 15 and 16).

Figure 15. Wooded pasture with a sparse tree stratum Figure 16. Wooded pasture with a denser tree stratum

However, wooded pastures must be distinguished from forests used for grazing. The criteria here are the nature of the vegetation and habitat:

(a) the tree stratum of the grazed forest is denser and similar to the type of forest from which it originates, and the grassland is characteristic of the type of the growing site of the forest concerned; more meadow species grow on wooded pastures, as well as specific pasture species such as spear thistle, tufted hair grass, nettle. Turf grass has also developed on wooded pastures (Kukk 2004; Kukk, Sammul 2006);
b) According to the criterion used in Finland, the coverage of meadow vegetation in forests used for grazing is usually up to 5%; in wooded pastures, it is over 50% (Pykälä 2001).

Wooded pastures formed about 2000-3000 years ago due to the combined effect of deforestation and grazing and are historically probably the oldest semi-natural community in our country (Kriiska 2004). Prior to the grazing of domestic animals, there were habitats similar to wooded pastures in forests due to the activities of numerous large herbivores (wild horses, bison, aurochs, etc.). Nowadays, more wooded pastures are created by stopping the mowing of wooded meadows and subsequent grazing, restoration of pastures, and sometimes creating new pastures from forests.

Wooded pastures are widespread throughout Estonia; more are found in Western Estonia and on the islands (Figure 17).

The area of wooded pastures in good condition has constantly been decreasing, similarly to wooded meadows. According to T.Kukk and M.Sammul (2006), the area of wooded pastures that were remained about 15 years ago was 4,000 ha; in 2010, 1500 ha were under maintenance (Talvi 2010). Currently, there is about 860 ha of wooded pastures under maintenance, about 260 ha under restoration; the goal is to double the current area. Elsewhere in the world, the distribution of wooded pastures is largely limited to the southern and central parts of Finland, whereas in Sweden, they are found throughout the country. There is also a small number of wooded pastures in other European countries. Due to the scarce geographical distribution and the significant decrease in the area in the recent past, wooded pastures are a key habitat type 9070 Fennoscandian wooded pastures by the European Habitats Directive (Paal 2007). The main threats to wooded pastures are similar to wooded meadows - abandonment or cultivation of natural pastures as a result of the introduction of cultivated pastures. The abandonment of pastures is followed by their overgrowing and afforestation. The result is the disappearance of the characteristic landscape and pasture-specific species (Talvi 2010).

In terms of landscape, wooded pastures are quite similar to wooded meadows (in many cases, the meadows are alternately grazed and mowed), but their structure and species composition are different depending on various factors. Typical tree species are oak, ash, linden, and often spruce and pine. Wetter habitats may be dominated by black alder and birch.

The proportion of shrubs is usually small because the animals damage them in different ways (they eat the leaves and shoots, scratch themselves against them), as a result of which the shrubs dry out. On the one hand, the environmental conditions of wooded pastures are similar to wooded meadows (alternation of woody plants and their groups with light meadow patches); on the other hand, the effects of grazing in terms of biodiversity and habitat diversity are different from mowing.

The effect of grazing depends on:

1) the type of habitat and its vegetation;
2) soil;
3) the species, sex, age, and breed of livestock;
4) food preferences of animals;
5) the grazing load;
6) the length of the grazing season;
7) the weather.

As a result of the study of Finnish wooded pastures, J.Pykälä (2001) has pointed out the following effects of grazing:

1) with a suitable grazing load, the vegetation is low and dense throughout the grazing period;
2) vegetation kept low affects the microclimate of the meadow - makes it warmer in spring and summer, cooler in winter;
3) grazing favors dry-loving species in drier growing areas and moisture-loving species in wetter growing areas;
4) as a result of grazing, the circulation of substances accelerates, the amount of nutrients in the soil decreases over time;
5) as a result of trampling, the soil thickens, and the movement of water and gases in the soil deteriorates;

6) manure fertilizes the soil, especially in places where animals accumulate, where the nitrogen content of the soil increases, which promotes the proliferation of nitrophilic species (nettle, spear thistle, etc.);
7) animals eat plants selectively - some species are "favorites," others are left behind;
8) animals distribute plant seeds and other propagule both intracorporeally (with manure) and extracorporeally (in the coat);
9) grazing increases the diversity of habitats and makes the land turfy.

The following effects may be added:

1) livestock prune trees and shrubs;
2) the animals tread the grass and cause minor disturbances in the form of patches of bare soil where new plants can begin to grow;
3) different livestock affect the vegetation differently, e.g., **sheep** eat more grass and avoid graminoids and rough plants; **goats, horses, and sheep** also chew the leaves and bark of trees and shrubs; **bovine animals** are less selective but prefer grassy, medium-height, and tall succulents;
4) as a result of grazing, convergence (becoming more similar) of plant communities takes place, during which the communities become poorer in species and medium-sized grasses (common bent, festuca rubra, sheep's fescue, Kentucky bluegrass), sedges (pale sedge, finger sedge, carnation sedge), dandelions, yarrow, white clover, caraway, sickle medick, meadow buttercup) start dominating. Due to poor edibility, tussocks of tufted hairgrass are common in pastures (Krall et al. 1980; Hæggström 1990; Pykälä 2001; Jürgens, Sammul 2004a);
5) the grassland of wooded pastures is usually poorer in species than that of wooded meadows, one of the reasons is considered to be the constant pruning of plants by animals, which prevents them from flowering and reproducing by seed;
6) wooded pastures have few protected and rare plant species because the animals like to eat them (e.g., ungulates).

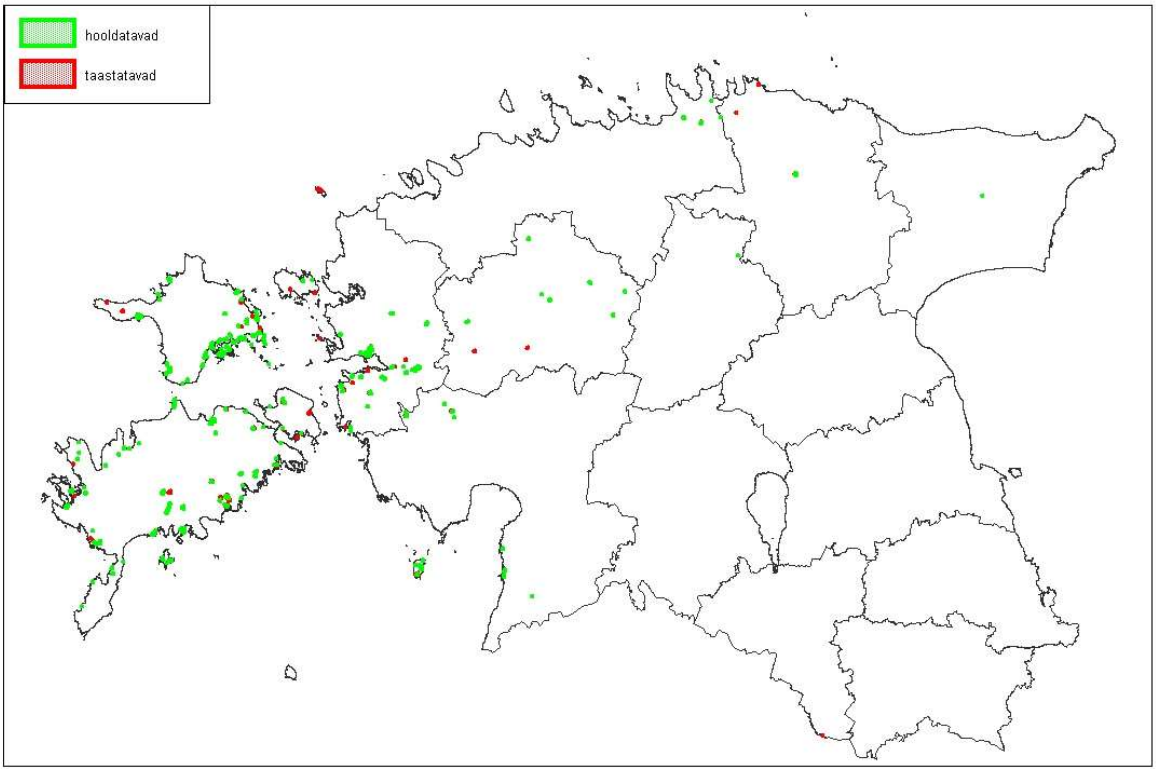

Figure 17. Distribution of maintained and restored wooded meadows in Estonia (https://www.keskkonnaamet.ee/et/eesmargid-tegevused/maahooldus/tegevus-ja-hoolduskavad)

Grazing creates new habitats (especially manure) for various organisms (e.g., fungi, mosses). The abundance of manure saprobes is characteristic. These include the following mushroom species: yellow fieldcap, petticoat mottlegill, liberty cap, ascobolus stercorarius, as well as the often coprinus, stropharia, and agaricus bisporus (Kalamees 2004). A number of beetles (carabus, scarabs), dicotyledons, odonata are associated with manure as a habitat, some of which (e.g., asilidae and geotrupes stercorarius) have become rare species in northern Europe due to the loss of wooded pastures. Old, semi-dead, and damaged trees in wooded pastures are also home to many insects and other organisms. For example, the old oaks in Koiva and Mustjõgi wooded meadows and wooded pastures are inhabited by a rare hermit beetle [Action Plan for the Protection of the *hermit beetle (Osmoderma barnabita) 2018]*. The canopy of trees and shrubs, grass of suitable height, and rich insect fauna create suitable living conditions for numerous birds, including very rare species such as European roller and European green woodpecker. Rare species of small snails have also been found in wooded pastures (Talvi 2004; Talvi 2010; Garbarino, Bergmeier 2014). In conclusion, the mosaicity of wooded pastures, the appropriate grazing period and grazing with different animal species are very important for the well-being of different biota groups.

The plant communities of wooded pastures and their typology have been little studied. It is known that many plant communities of wooded pastures are emergent types of plant communities otherwise characteristic of mowed meadows. As a result of grazing, e.g., sesleria - carnation sedge and buttercup - tufted hair grass communities have formed. According to the Habitats Directive's classification of habitat types (Paal 2007), wooded pastures belong to the same habitat types as wooded meadows, a typical group of alvar forests and shrubs is added.

K. Hellström (http://kingpool.hak.edu.ee/materjalid/puisniit4/index.html) has divided the wooded pastures of Hiiumaa in terms of species composition and general appearance as follows:

1) former wooded meadow dominated by hardwood, usually quite overgrown and dense;
2) 40-60 years old thinned pine forest, with numerous deciduous shrubs, juniper usually withered;
3) a juniper shrubland overgrowing with pines with young deciduous trees and shrubs;
4) sparse birch forest on alvar with a species-rich shrub stratum;
5) black alder forest in the vicinity of coastal meadows;
(6) grazed fairly dense unthinned mixed forest).

This distribution gives a certain picture of the diversity of wooded pastures but also clearly indicates the need for a more in-depth study of their landscapes and communities.

The wooded pastures of Saaremaa have also been described to a small extent (Roellig, Sammul 2014). The authors state that depending on the time of abandonment of pastures, restoration, grazing intensity, and ecological conditions, they are very diverse in terms of stand density and species composition. The most common tree species are birch, oak, aspen, and ash, but there are also meadows dominated by pines. The dominating shrubs are hazel and juniper. Wooded pastures often form complexes with alvars and coastal meadows. The study also emphasizes the species richness of insects, snails, fungi, mosses, and birds in Saaremaa's wooded pastures.

2.2. Restoration of wooded pastures

The principles of the restoration of wooded pastures are similar to wooded meadows. The aim is to create a diverse landscape that is suitable for the successful grazing of animals, and that has a large number of landscape elements as habitats for different groups of organisms. To do this, it is recommended:

1) to reduce the source community so that as many different species of woody plants as possible remain;
2) to allow woody plants to grow irregularly, either individually or in groups, to form open areas between them;
3) to retain dead standing trees and lying wood (substrate for fungi, mosses, lichens, tree cavities as a nesting place for birds);
4) to preserve natural and anthropogenic landscape elements such as rocks and piles of rocks, stone fences, small bodies of water, the sites of former farm buildings, and to clear their surroundings of bushes;
5) to establish proper barnyards for the welfare of animals (either to install in electric herds or to build strong and tall wooden fences against predators);
6) to provide drinking water to animals either by (artificial) water bodies or by drinking vessels;
7) to provide shelters for animals, especially on pastures with a very sparse tree stratum;
8) to involve in the restoration activities livestock which will immediately destroy the bushes, in addition, the animals shall indicate their preferred movement routes, resting places, areas where they do not want to go. It helps the restorer to shape the structure of the pasture.

2.3. Maintenance of wooded pastures

Grazing is the main way of maintaining wooded **pastures**. If the pasture has not yet recovered properly or the grazing load is low, and the animals have eaten the plants selectively, which means that taller species (meadowsweet, tufted hair grass, thistles, etc.) have remained growing, the pasture must be **mowed** again in autumn. If the amount of mowed grass is large, it must be removed.

The main recommendations and conditions for the maintenance of wooded pastures are:

1) depending on the nature of the meadow, grazing must take place at the load of 0.3-1.0 LU/ha;
2) the grazing load depends on the following factors:
(a) the type of community;
(b) the nature of the soil (determines trampling tolerance);
(c) the species, breed, age of the livestock;
(d) the time and duration of grazing (at the beginning of the grazing period, the load may be higher, later
smaller);
7) the weather.
3) both over-grazing and under-grazing must be avoided (in case of under-grazing, the uneaten species will dominate, whereas overgrazing will result in the destruction of the turf grass and damage to trees);
4) in the case of a suitable grazing load, approx. half of the pasture has low grass (recommended grass height at the end of the grazing period on dry meadows up to 3 cm, on wet meadows up to 5 cm);
5) if necessary, the load must be regulated with barnyards;
6) as different livestock eat different plant species (bovine animals prefer larger and juicier plants, sheep eat grasses and less coarse species, sheep, goats, and horses also eat the leaves and bark of trees), it is recommended to graze different animal species together or alternately;
7) pastures must not be in contact with cultivated grasslands;
8) animals may not be given supplementary feed;
9) additional facilities - shelters, drinking places - must be set up in a less valuable area of the pasture, thus causing as little damage as possible to the turf grass (Jürgens, Sammul 2004a).
10) The drinking places of animals must be changed to prevent extensive soil damage to their surroundings.

Similarly to wooded meadows, the density and condition of woody vegetation must be monitored on wooded pastures. From the point of view of the species richness of insects, birds, and fungi-mosses, it is important to preserve old trees even after they have already been semi-dried. In the interest of the continuity of the tree stratum, young trees must be allowed to grow when the stand is thinned so that they can replace dead specimens over time (Bergmeier *et al.,* 2010).

2.4. Main threats to wooded pastures

The most important of the factors endangering wooded pastures is the **cessation of** their management, which causes the meadows to become overgrown and afforested. The reason is either the cessation of animal husbandry or the deployment of cultivated pastures. **Undergrazing** also has a negative effect, as it promotes overgrowth because the animals do not eat or prune woody plants to the required extent (Talvi 2010). Undergrazing prevents seed multiplication of plants due to low trampling, as there are no longer enough bare soil spots for

the seeds to germinate (Berlin *et al.,* 2000). **Overgrazing** is also harmful because, as a result of it, the soil is trampled too densely (the moisture and gas regime deteriorates), the plants are eaten before flowering and ripening of the seeds, the turf grass is damaged, and the trees can dry out. From the point of view of general biodiversity, the removal of all lying wood from wooded pastures, as well as the removal of old semi-dried or dried standing trees, is detrimental. As with all semi-natural communities, wooded pastures are at risk of species impoverishment if meadows are located singly or in a fragmented way.

2.5. Favorable condition of wooded pastures

Wooded pastures in good condition are characterized by:

1) tree and shrub strata of varying density (although the share of shrubs can sometimes be quite small);
2) low grass to the extent of at least 50%;
3) absence of large patches of ground without vegetation;
4) landscape diversity;
5) diverse and species-rich biota, including the presence of fungi and coprophagic (manure-feeding) insects from manure aprobes is characteristic of wooded pasture;

Conclusion

Wooded pastures, and especially wooded meadows, are one of the most complex and relatively poorly studied semi-natural ecosystems due to the diversity of their landscape, habitat, and biota. The vegetation and plant communities of wooded meadows are better known, but only regarding wooded meadows with drier soil, the so-called typical wooded meadows. There is a lack of knowledge about wooded meadows in northern Estonia, as well as in those prevailing in Devonian sandstone areas. Data on paludified meadows and paludified woody meadows, as well as floodplain meadows, are rather scarce. However, there is a complete lack of knowledge about other biota groups, not to mention the relationships between them.
The restoration and maintenance of wooded meadows have changed significantly compared to traditional methods due to the introduction of new technical means. The impact of such practices on the biodiversity of wooded meadows is unknown; moreover, no information is available from other countries either.
Therefore, there is a great need for such studies. Some important topics could be:

1. Differences in the biota of different types of wooded meadows and wooded pastures in different regions of Estonia and the reasons thereof.
2. Impact of different restoration and management methods on the biodiversity of wooded meadows (need for immediate monitoring after restoration, impact of different mowing regimes)
3. Response of some rarer meadow species (the fringed pink, Betonica, dyer's plumeless saw-wort, etc.) to different mowing times and regimes.
4. Identification of rare and protected species living in wooded meadows and wooded pastures and planning of meadow management depending on the ecology of these species.

Acknowledgments

Many thanks to everyone who have been thinking along, making corrections and additions, helping with fieldwork: Kaidi Silm, Gunnar Sein, Kaie Kattai, Piret Sepp, Johannes Kõdar, Anneli Holm, Bert Holm, Heikki Luhamaa, Toomas Kukk, Ott Luuk, Peedu Saar, Ants Animägi, Meeli Mesipuu, Aveliina Helm, Rein Kalamees, Silvia Lotman, Renno Nellis, Anneli Palo, Tiina Talvi, Tõnu Talvi, Sven Valler, Rein Lember, Riivo Liin, Urmas Vahur, Tiina Orav, Leo Filippov, Mart Lang, Peeter Hermik, Peeter Pärn, Mario Talvist, Teele Kasepalu, Toomas Hirse, Rainar Kurbel, Tiina Elvisto, Eerik Leibak, Jaanus Elts, Virve Sõber, Kaie Sarv.

Used literature

Bergmeier, E., Petermann, J., Schröder, E. 2010. Geobotanical survey of wood-pasture habitat in Europe: diversity, threats and conservation. Biol Conserv. 19:2995-3014.

Berlin, G.A.I., Linusson, A-C., Olsson G.A. 2000. Vegetation changes in semi-natural meadows with unchanged management in southern Sweden, 1965-1990. Acta Oecologica 21:125-138.

Bruppacher, L., Pellet, J., Arlettaz, R., Humbert,J-I. 2016. Simple modifications of mowing regime promote butterflies in extensively managed meadows: evidence from field-scale experiments. Biol. Conserv.196:196-2012.

Buri, P., Arlettaz, R., Humbert, J-I. 2013. Delaying mowing and leaving uncut refuges boosts orthopterans in extensively managed meadows: Evidence drawn from field-scale experimentation. Agriculture, Ecosystems and Environment 181: 22-30.

Elts, J., Kuus, A., Leibak, E. (koost.). 2108. Linnuatlas. Eesti haudelindude levik ja arvukus. Tartu.

Garbarino, M, Bergmeier E. 2014. Plant and vegetation diversity in European woodpastures. In: Hartel, T., Plieninger, T. (Eds.) European Wood-pastures in Transition. Taylor &Francis, London, pp. 113-130.

Hansson, M & Fogelfors, H. 2000. Management of a semi-natural grassland: results from a 15-year-experiment in southern Sweden. J. Veg Sci. 11:31-38.

Hæggström, C.-A. 1981.Vegetation and soil of the wooded meadows in Nåtö, Åland. Acta Bot. Fennica 120:1-66.

Hæggström, C.-A. 1990. The influence of sheep and cattle grazing in wooded meadows in Åland, SW Finland. Acta Bot. Fennica 141:1-28.

Hein, V. 1970. Andmeid Laelatu puisniidu fenoloogiast. Book: Lääne-Eesti rannikualade loodus. Tallinn, pp. 129-135.

Humbert, J-Y., Ghazoul, J., Richner, N, Walter, T. 2012. Uncut grass refuges mitigate the impact of mechanical meadow harvesting on orthopterans. Biol, Conserv. 152:96-101.

Ingerpuu, N., Vellak, K. 2013. Laelatu puisniidu sammalde nimestik. Estonia Maritima 9: 123-127.

Ivask, M., Kuu, A., Truu, M., Kutti, S., Meriste, M., Peda, J. 2012. Earthworm communities in soils of Estonian wooded meadows. Baltic Forestry 18:111-118.

Jannsen, J.A.M., Rodwell, J.S., Garcia Criado, M., M., Gubbay, S., Haynes, T., Nieto, A., Sanders, N., Landucci, F., Loidi, J., (...) & Valachovič, M. 2016. European Red List of Habitats. Part 2. Terrestrian and Freshwater habitats. European Union, Luxembourg, LU.
Jürgens, K. Sammul, M. 2004a. Kuidas pärandit hooldada ? Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, p. 103-110.
Jürgens, K. Sammul, M. 2004b. Pärandkoosluste taastamine. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 95-102.
Kalamees, K. 2004. Seenestik. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 136-142.
Krall, H., Pork, K., Aug, H., Püss, Õ., Rome, I., Teras, T. 1980. Eesti NSV looduslike rohumaade tüübid ja tähtsamad taimekooslused. Eesti NSV Põllumajandusministeeriumi Informatsiooni ja Juurutamise Valitsus. Tallinn.
Kriiska, A. 2004. Inimene ja loodus esiajal. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 13-47.
Kukk, T. 2004. Aru- ja puisniidud. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 215-222.
Kukk, T. 2018. Aru- ja puisniitude seire aruanne 2018. Pärandkoosluste kaitse ühing, Tartu.
Kukk, T., Kull. K. 1997. Puisniidud. Estonia Maritima 2:1-249.
Kukk, T., Kull. K. 1998. Liigirikkad puisniidud Eestis. Book: Eesti looduse mitmekesisus ja selle kaitse. TA Kirjastus, Tartu-Tallinn, pp. 69-80.
Kukk, T, Sammul, M. 2006. Loodusdirektiivi poollooduslikud kooslused ja nende pindala Eestis. ELUS-i Aastaraamat 84, pp. 114-158. Tartu ELUS.
Kull, K., Zobel, M. 1991. High species richness in an Estonian wooded meadow. J. Veg. Sci. 2:711-714.
Kumari, E. 1954. Eesti NSV linnud. Eesti Riiklik Kirjastus, Tallinn.
Kurbel, R., Hirse, T. 2017. Eesti orhideede käsiraamat. MTÜ Käoraamat, Tallinn.
Kuusemets, V. 2011. Pärandkoosluste ökoloogilised ja maastikulised nõudlused ning nende säästlik majandamine. Riikliku programmi „Põllumajanduslikud rakendusuuringud ja arendustegevus aastatel 2009-2014“ lisa 4. Projekti aruanne. Eesti Maaülikool, Tartu.
Laasimer, L. 1965. Eesti NSV taimkate. Valgus, Tallinn.
Luhamaa, H., Ikonen, I., Kukk, T. 2001. Läänemaa pärandkooslused. Seminatural communities of Läänemaa County, Estonia. PKÜ, Tartu-Turku.
Masing, V. 1992. Ökoloogia leksikon. Eesti Entsüklopeediakirjastus, Tallinn.
Mitlacher, K., Poschlod, P, Rosen, E. & Bakker, J.P. 2002. Restoration of wooded meadows - a comparative analysis along a chronosequence on Öland (Sweden). Appl. Veg. Sci. 5: 63-67.
Oja, E., Jüriado, I. 2016. Puisniidusamblikud vajavad valgust. Samblikud Eesti poollooduslikes kooslustes 1. Eesti Loodus 6-7: 24-27.
Paal, J. 2007. Loodusdirektiivi elupaigatüüpide käsiraamat. Teine, parandatud ja täiendatud trükk. Auratrükk., Tallinn.
Pärtel, M., Helm, A., Roosaluste, E. & Zobel, M. 2007. Bioloogiline mitmekesisus Eesti pool-looduslikes ökosüsteemides. Book: Punning, J. M. (toim.). Keskkonnauuringute nüüdisprobleeme. Tallinna Ülikooli Ökoloogia Instituut, Tallinn: 223-302.
Pykälä, J. 2001. Perinteinen karjatalous luonnon monimuotoisuuden ylläpitäjänä. Suomen ympäristö 495:1-205.
Roellig, M., Sammul, M. 2014. Wood-pasture profile: wood-pastures of Saaremaa, Estonia. In: Hartel, T., Plieninger, T. (Eds.). European wood-pastures in transition: a social-ecological approach. Routledge Taylor&Frances Ltd., London, New York:pp.125-127.
Rootsmäe, L., Veromann, H. 1974. Eesti laululinnud. Valgus, Tallinn..

Sammul, M., Kukk, T. 2013. Liigirikkaimad taimkatteanalüüsid Laelatu puisniidul. Estonia Maritima 9:108-122.
Talvi, T. 2004. Putukad pärandkooslustel. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 149-162.
Talvi, T. 2010**.** Eesti puisniidud ja puiskarjamaad. Hooldamiskava. Viidumäe.
Talvi, Tiina, Mänd, R., Talvi, Tõnu. 2013. Laelatu puisniidu maismaateod. Estonia Maritima 9:128-148.
Troska, G. 2004. Külaelu ja pärandkoosluste majandamine Teise maailmasõja lõpuni. Rmt.:Kukk, T.(ed.). Pärandkooslused. Õpik-käsiraamat. Tartu, pp. 48-64.
Key habitat classification, selection guide, organization of protection, and conclusion of a contract for the protection of key habitat and the specified bases for calculating the fee for the right of use. 2017

Internet sources:

Action plan for the protection of the hermit beetle (Osmoderma barnabita). https://www.keskkonnaamet.ee/sites/default/files/liigikaitse/eremiitpornikas_tk_avalik.pdf. 12.05.2019.
Hellström, K. Puisniidud ja puiskarjamaad. Study material. http://kingpool.hak.edu.ee/materjalid/puisniit4/index.html.12.02.2019 .
https://www.keskkonnaamet.ee/et/eesmargid-tegevused/maahooldus/tegevus-ja-hoolduskavad).02.08.2019.
https://akadeemiake.ee/wp-content/uploads/2019/10/06_Henry_Niemann.pdf

A short guide to the restoration of wooded meadows and pastures

The aim of the restoration of wooded meadows and wooded pastures is to carry out the restoration in such a way as to create traditional, aesthetically attractive habitats with a diverse landscape. In the course of further continuous maintenance (mowing and grazing), the biodiversity corresponding to the ecological conditions of the habitat must be restored and maintained. During restoration, account must be taken, therefore of the creation of habitats favorable to as many groups of organisms as possible, which presupposes the formation of numerous elements of living and non-living nature and their combinations in the meadow.
The following general requirements must be met when restoring both habitats:

1) restoration work may not be performed during the period of active nesting of birds. It is recommended to adhere to the so-called bird peace (15.04-15.07) period;
2) restoration work must not damage the soil; therefore, the best time for restoration is either in the period of frozen ground or during a very dry period. The technique used should be as light as possible, with belt machines being preferred, especially on wetter soils. When creating rails, only one pair of rails must be used to move to avoid damaging a larger surface. The rails must be leveled after the restoration work;
3) whereas the storage sites for tree trimmings created during restoration work, as well as the location of roads required for restoration and maintenance, must be selected on as dry and hard ground as possible before felling, the edge of the area to be restored or the former area with dense woody vegetation where the risk of damage to the meadow turf, meadow vegetation and habitats of rare species is minimal is preferred. The tree trimmings must be removed from the area at the end of the restoration work;
4) tree trimmings with a diameter of more than 5 cm and a length of more than 50 cm shall not be left behind;

5) if tree trimmings are burned, this must be done in the places where the existing vegetation is least damaged (in places with no turf, on stumps);
6) the burning of tree trimmings is prohibited during times with an increased risk of fire; the requirements for fire safety must be observed during burning;
7) stumps higher than 10 cm must not be left in the restoration area, except for some thicker ones in order to preserve biodiversity; it is expedient to mill them flush to the ground in order to get rid of the stumps;
8) surface milling of the ground is not permitted during restoration, as this destroys the preserved turf and promotes the growth of ruderals;

1. Basic requirements for the restoration of wooded meadows

The aim of restoring wooded meadows is to create a landscape where a sparse tree and shrub strata alternate with open meadow patches and with individual elements carrying general biodiversity, such as anthills, lying wood, semi-dried or dead standing trees, larger rocks, stumps either individually or in combination with each other and with trees and shrubs.
The following requirements must be observed during restoration:

1) it is recommended to design the structure of a wooded meadow by cutting woody plants gradually over several years. This prevents the simultaneous release of a large number of nutrients into the soil, the proliferation of root and stump shoots, and ruderals. If the felling is carried out within one year, the area must be managed immediately and the resulting shrub removed;
2) it is expedient to first remove most of the bushes and then to start selecting and marking the remaining trees and shrubs;
3) it is important to clearly mark the trees and shrubs and other elements that are to be retained or removed; the best time is when the trees are bare, and the stand structure is better visible;
4) the design of the structure should be based on the appearance of old wooded meadows historically characteristic to the region so as to create a scattered, irregular pattern of trees, shrubs, tree and shrub complexes alternating with patches of open meadows (it is recommended to leave fewer single trees and more small groups of trees and shrubs, as individual trees are threatened by being thrown by wind);
5) leave **old trees in the wooded meadow** (thick, with a broad crown, multi-stemmed, with a developed strong bark, especially oak, birch, linden, maple, spruce) growing, including damaged trees with a semi-dead canopy, but specimens of younger age groups must also be preserved (preferably in places less suitable for mowing, such as around rocks, stumps, uneven areas, the edge of water bodies) to ensure intergenerational continuity;
6) in the selection of trees to be preserved, trees with a thickness of more than 30 cm or with a special crown or trunk shape trees with a diverse look shall be preferred; it is essential to preserve trees and groups of trees associated with local lore or other local heritage traditions;
7) it is important to leave **trees with hollows** in which birds find nesting sites;
8) based on the peculiarities of wooded meadows (often related to regionalism), to leave a smaller percentage of pines, ashes, aspens, willows, alders grow - the goal being maximum species diversity;
9) of the shrubs, hazel, Swedish whitebeam, rowan, European crab-apple and hawthorn species are preferred, but other shrub species should also be retained; shrubs as large as possible could be retained if individual specimens were to be left growing;
10) if possible, especially in the case of smaller and less overgrown areas, felling shall be started from the edge of the area or by expanding the better-preserved meadow patches;

11) it is recommended to design the transition areas of the restored meadow and the neighboring community in a sinuous way - this way, the landscape is more beautiful to look at, and the habitat area of the transition area increases;
12) the recommended **crown cover of the stand** affiliation is 0.4-0.5 (0.6), of which the shrub stratum could be 10-20%. The lower limit for the crown cover of flooded meadows, paludified meadows, and paludified woody meadows could be 0.2;
13) a group of trees growing from one root turf must be removed or preserved as a whole, instead of cutting off individual branches;
14) preservation of trees with one-sided and sparse crowns should be avoided; if this is necessary for the design of the structure of a wooded meadow (few suitable trees), the group of trees should be preserved if possible;
15) trees and shrubs to be felled must be cut as close to the ground as possible, parallel to the ground (sharp stumps cut at an angle may injure the legs of animals);
16) in the course of the work, the trees and shrubs and other landscape elements that are to be preserved must not be damaged by the equipment;
17) during restoration, the complexes of living and non-living nature must be preserved as much as possible, i.e., small groups of trees and shrubs should be left to grow together, with single rocks, anthills, etc. under them;
18) in the case of removal of tree stumps, the holes must be leveled;
19) denser groups of non-managed woody plants may be left in the restored area, the total area of which may not exceed 10% of the total area of the meadow and the size of a single tree group being 0.05 ha.
When selecting such patches, the following is preferred:
a) clearly identifiable spots from the denser structure of the old wooded meadow;
(b) groups of woody plants in which several more valuable tree and shrub species grow closely together, e.g., oak, linden, willow, hazel, crab-apple, rowan, Swedish whitebeam, hawthorn, and rosehip species;
(c) groups of woody plants in which species often do not reach the first stratum (such as undergrowth linden) or groups of trees with remaining (dwarf) canopy forms;
3) difficult to manage, e.g., excessively moist depressions and rocky places.
2) it is recommended to preserve a) lying wood (at least 30 cm in diameter) in the area to be restored; (b) dead stranding trees;
21) **anthills** and the trees and shrubs and stones around them must be retained;
22) Prior to restoration, sites should be selected that are preferably not restored due to the presence of stones interfering with mowing. The surroundings of larger rocks and groups of rocks consisting of several rocks should not be restored. This is especially the case if the rocks are covered in moss and various trees and shrubs grow around them, which also function as signs of the rocks and valuable micro-habitats during the further maintenance of the area. The rocks that interfere with mowing can be removed during restoration. In general, mowing is not disturbed by stones that are significantly higher than the grass stratum and clearly visible or flush with the ground or protrude so little from the ground that is below the mowing. From the point of view of maintenance equipment, individual stones hidden in the grass are more dangerous. Preferably, the removed stones should be collected in places unsuitable for mowing, under trees and shrubs, stored at the edge of the meadow, built into a stone fence, or used to repair old stone fences. If it is not possible to place the stones individually in the meadow area, they can be grouped into small and scattered piles, preserving as much of the traditional landscape as possible. The resulting holes must be leveled. If during the removal of stones it turns out that these are very large stones (boulders) or that they leave a hole in the ground that needs additional aggregate, the stones must not be removed, and the stone must be marked when

mowing (Figure 12a). If the area contains stones to the extent that removal of them is not practical and would damage the habitat, the area must be maintained as wooded pasture.
23) it is recommended to leave some thicker **stumps** in the restored area, as they are a substrate for fungal, lichen, and moss species;
24) not to clear the immediate surroundings **of stone walls** located on wooded meadows;
25) when restoring and maintaining, to preserve **bodies of water** found in wooded meadows; filling bodies of water with stones, wood, grass, and other materials is unacceptable.
26) in the course of restoration, animals may be grazed on the wooded meadow.

As a result of the restoration, a characteristic wooded meadow landscape must be created, which can be mowed with suitable equipment and where opportunities have been created for the recovery and preservation of the species richness of different biota groups.

2. Basic requirements for the restoration of wooded pastures

The principles of the restoration of wooded pastures are similar to wooded meadows. The aim is to create a diverse landscape that is suitable for the successful grazing of animals, and that has a large number of landscape elements as habitats for different groups of organisms. This requires:

1) to reduce the source community so that as many different species of woody plants as possible remain;
2) to allow woody plants to grow irregularly, either individually or in groups, to form open areas between them;
3) to retain dead standing trees and lying wood (substrate for fungi, mosses, lichens, tree cavities as a nesting place for birds);
4) to preserve natural and anthropogenic landscape elements such as rocks and piles of rocks, stone fences, small bodies of water, the sites of former farm buildings, and to clear their surroundings of bushes;
5) to establish proper barnyards for the welfare of animals (either to install in electric herds or to build strong and tall wooden fences against predators);
6) to provide drinking water to animals either by (artificial) water bodies or by drinking vessels;
7) to provide shelters for animals, especially on pastures with a very sparse tree stratum;
8) to involve in the restoration activities livestock which will immediately destroy the bushes; in addition, the animals shall indicate preferred movement routes, resting places, areas where they do not want to go. It helps the restorer to shape the structure of the pasture.