Chapter 21. Principal Methods of Ecological Restoration and Creation of Grassland Habitats

21.1 Restorative Mowing and Grazing (S. Rūsiņa)

Restorative mowing and grazing are more intensive than regular mowing and grazing. It is the simplest, but the most time-consuming method if applied as the only measure for the restoration or creation of a semi-natural grassland. It can be applied in a shrubland, arable land, improved grassland, as well as in places where the fertile topsoil has been removed (quarries, sites with removed turf and/or fertile topsoil). The appropriate frequency of mowing and intensity of grazing should be carefully chosen. By using this method, the vegetation is allowed to develop naturally from the local species pool.

Restorative mowing alone is applicable only in places that have been abandoned comparatively recently, where neither shrubs and trees, nor tussocks are interfering with mowing. It must be considered, that during the first year the hay will not be suitable for animal feed, because, along with green grass, it will contain the litter accumulated over the last years. While restoring or creating a grassland, the frequency of mowing and the intensity of grazing must be adapted to the site conditions. Too fertile sites and sites dominated by expansive species must be mown at least twice per season or grazed intensively. In some cases light overgrazing is required. To control shrubs and expansive herb species, the grass must be grazed as low as possible in order to weaken these plants and limit their further growth.

Selective grazing should be limited during restoration. Higher grazing intensity decreases grazing selectivity, thus increasing the efficiency of undesirable species control.

There are two main shortcomings of restorative mowing and grazing as the only measure for restoration. Vegetation development can be arrested by expansive or invasive species. The lack of semi-natural grassland plant seeds and vegetative diaspores can lead to the undesirable development of vegetation. Restorative mowing and grazing can fail in sites which have been intensively fertilised. In arable lands, the soil seed bank may contain a lot of weeds, which delay the establishment of grassland species. If the soil is too fertile, undesirable ruderal or nitrogen-demanding tall grass plant communities may develop.

Grazing has certain advantages over mowing. Pasture animals help in creating micro niches for the germination of seeds, animals spread seeds all over the area of the pasture and beyond it, if they are moved from one paddock to another. However, grazing is only better than mowing in the case of appropriate grazing intensity and control of pasture weeds such as *Cirsium* spp.

Restorative mowing should be continued, by adjusting the frequency of mowing as required, until the grassland has been restored and only requires regular maintenance mowing.

Restorative grazing can be introduced in areas, where shrub cutting and tilling has not been performed. However, in this case the recovery may be slower (Fig. 21.1.1, 221.1.2).

The most efficient method of habitat restoration is winter grazing, without the additional feeding of animals. Of course, the principles of animal welfare must be followed. A sufficient amount of food must be provided to animals and, if required, shelter during bad weather conditions must be ensured. Adoption of the experience of farms where grasslands have been restored by grazing is a significant prerequisite for the successful implementation of restorative grazing. During the first years, while animals explore the new site, they use the pasture only partly. They mostly graze areas with better grass. Modification of the grazing regime might be necessary to reach the results within a desirable time frame. Additional mowing could be required in the areas only partly grazed by animals.

An example of the creation of a semi-natural grassland in Czechia

Two ways of establishment of semi-natural grassland in arable land were compared. One of the fields was left fallow, and mowing and grazing was introduced. In the other field mowing and grazing was introduced after the sowing of mixture of seeds (*Agrostis* tenuis, *Festuca pratensis, Festuca rubra, Lolium multiflorum, L. perenne, Poa pratensis, Trifolium pratense* and *T. repens*). The vegetation in both fields became similar within the first ten years. In 20 years, semi-natural grassland developed in both fields, and their vegetation did not differ significantly (Lencova, Prach 2011). Thus, the addition of seeds may be omitted in the restoration of areas which have viable seed banks containing semi-natural grassland species or where the closest surroundings are rich in seed resources e.g. semi-natural grasslands, species rich forest edges, road verges.

Fig. 21.1.1. A horse and cattle pasture, established in "Engures ezers" Nature Park in 2002, in 2011. Shoots of *Alnus glutinosa* are mown every year. Since *Alnus glutinosa* easily produce stump shoots, but cattle avoid eating them, shoots must be removed annually. To prevent regrowth, *Alnus glutinosa* stumps must be extracted or herbicides must be applied (after careful evaluation of the environmental risk to benefit). Cover of trees and shrubs up to 10–30% does no harm to semi-natural grassland habitat, and even increases the overall biodiversity. Ring barking of trees, instead of felling them at the restoration phase could, possibly, be a better solution. Photo: S. Rūsiņa.

Fig. 21.1.2. A pasture of semi-feral horses. Grazing started when pines were 10–15 years old and over 2 m tall. Therefore the horses cannot destroy all pines completely and most trees still survive. To encourage the restoration of grassland vegetation, it is recommended to remove pines. Photo: S. Rūsiņa.

21.2 Prescribed Burning in Grassland Restoration (S. Rūsiņa)

21.2.1 Experience of Using Fire for Grassland Management in Latvia

The experience in the use of fire for the restoration of semi-natural grassland habitats in Latvia is limited. The results of research on the restoration of bird habitats using fire were published in 2002 (Opermanis 2002; Reinvalds 2002). A single prescribed burning at the end of March resulted in an increased number of bird pairs and overall biodiversity in long-abandoned grasslands. The authors emphasise that burning which is not followed by mowing or grazing has a very short-term effect that lasts for only one breeding season. However, this can significantly contribute to the preservation of rare bird species.

Using fire has been a traditional nature management method in the biome of Northern European coniferous forests (Parviainen 1996). However, in contrast to boreal forests, where wildfire occurs naturally (Brūmelis, Jankovska 2013), it is not a natural part of ecosystem processes in grasslands of this region. Grassland species of Latvia are not adapted to frequent burning. Fire as a natural environmental factor is only significant in regions with grasslands as natural vegetation – steppes (grasslands of temperate continental climate) and savannah (grasslands of tropical climate). In these areas fires are common in the middle of summer after the drought period, when the activity of thunderstorms and lightning is highest; plant and animal species are adapted to fire as a natural factor and it is even necessary for the biodiversity.

Fire has been traditionally used to remove litter in the grasslands of Latvia in early spring. News on the accidents that occurred while burning old grass were common in the newspapers of the 20s – 30s of the 20th century, for instance, news of a burnt barn or a forest fire (*Brīvā Zeme* (Free Land), 1937; *Latvijas Kareivis* (Latvian Soldier), 1929). Serious fire safety measures were introduced in the forest and agricultural lands of Eastern Europe in the territory of the Soviet Union (Goldammer, Furyaev 1996). However, even then the burning of litter was prohibited during the high fire risk period. For instance, the newspaper *Padomju Jaunatne* (The Soviet Youth) of 1972 gives advice on how to correctly burn litter to avoid hazards to forests and buildings. The fire should be started at the sides and directed towards the centre of the grassland. Other advice is given as well (*Padomju Jaunatne* 1972). Alongside other management measures, fire has been used as a routine method of grassland management in Europe (for instance, in Austria, Estonia, Hungary, Poland, Slovakia). In Sweden it was used in early spring to limit the accumulation of litter (Valko et al. 2013). Such practice has been typical also in Latvia.

21.2.2 Use of Fire in the Restoration of Grassland Habitats

After a longer period of abandonment, burning is recommended as a cost-efficient method of grassland restoration. Abandoned grasslands are characterised by a thick layer of litter, anthills overgrown with grass and high tussocks developed by some grass and sedge species (for instance, *Deschampsia cespitosa*, *Carex cespitosa*). It is almost impossible to resume mowing in such grasslands during the first year because of tussocks, litter and anthills. The smoothing of grassland surface is required first. However, if the vegetation and animal species characteristic of the habitat are still present, tilling or harrowing of the entire area is not recommended, as it damages topsoil, can introduce weed species and reduce the chances of successful habitat restoration. In such a case, burning is a good alternative, since it reduces the amount of litter which delays the germination and development of plants (Fig. 21.2.1). Burning in small areas does not leave a long-term effect on invertebrates. The invertebrates of the herb layer are typically burnt, while the fauna of the soil is affected to a comparatively insignificant degree. Burning should be avoided, if protected snail species occur in the grassland.

Early spring burning immediately after the melting of snow and before bird breeding causes no significant harm to typical grassland bird species. It even has a positive effect on some species of waders, especially those which nest in open short-grass grasslands (for instance, *Vanellus vanellus* and *Haematopus ostralegus*), resulting in an increased number of nesting birds and improved feeding environment. Species feeding on invertebrates from the topsoil, for instance, *Gallinago gallinago* and *Gallinago media* also benefit from burning, as access to bare soil improves. The best results are achieved in the grasslands with large amounts of litter.

After burning, the litter does not interfere with mowing, the tussocks and anthills are well visible and can be smoothed by trampling, drag-harrowing or careful tilling of the particular area (instead of the entire grassland) (*see Chapter 21.3*). Thus burning saves both time and financial resources. It also does less harm to the grassland ecosystem and the species diversity by preserving topsoil and turf.

Combination of burning and grazing yields good results in pastures. Patches of taller grass, which are not eaten by animals, develop in partially grazed pastures. Burning of these patches removes the thick layer of litter. Soon after, herbivores readily graze here. A mosaic of burnt and unburnt areas increases the diversity of vegetation. Burning may not be performed in the same places every year.

Fire almost always results in the death of some plants. Regular burning facilitates extinction of fire

Is the using of fire on grasslands permitted?

Burning of litter and groundcover outside the protected nature areas and micro-reserves in Latvia is prohibited (situation in 2016) and punishable by a fine in accordance with the Administrative Violations Code. The actions permitted and prohibited in protected nature areas are regulated by Cabinet Regulation No. 264 *General Regulations on Protection and Use of Specially Protected Nature Territories* of 16 March 2010 or the individual regulations of conservation and use of the particular areas. In most of the protected nature areas a written permit of the Nature Conservation Agency is required to implement prescribed burning of dry grass, reed stands, heaths and forest groundcover, and fire safety services must be notified in writing. In protected nature areas and micro-reserves, prescribed burning is allowed when the required approvals are received.

Uncontrolled burning (usually – illegal burning not approved by the authorities, burning without preparation, without supervision) has become common in European countries over the last decades, which is why nowadays any type of burning – either prescribed or uncontrolled – is prohibited by law in many of them. In some countries – the Netherlands, Slovenia, Germany, France, Spain, Great Britain – prescribed burning is permitted. In others (France, Portugal) burning is permitted for the management of protected nature areas. In Spain and France prescribed burning of pastures was permitted to eliminate uncontrolled burning, which was encouraged by the prohibition (Antonsen, Olsson 2005; Lazaro 2009; Valko et al. 2013). Burning might be useful in the control of fires. Fires that break out in the areas, where large quantities of burning materials accumulate, are the most destructive. For instance, large quantities of litter accumulate in abandoned grasslands. It can easily catch fire in spring and summer and escalate into a disastrous fire. Therefore, prescribed burning is one of the methods for limiting undesirable (uncontrolled) fires, after the elaboration of a burning plan and the provision of preventive measures (fire safety zones, presence of fire fighters).

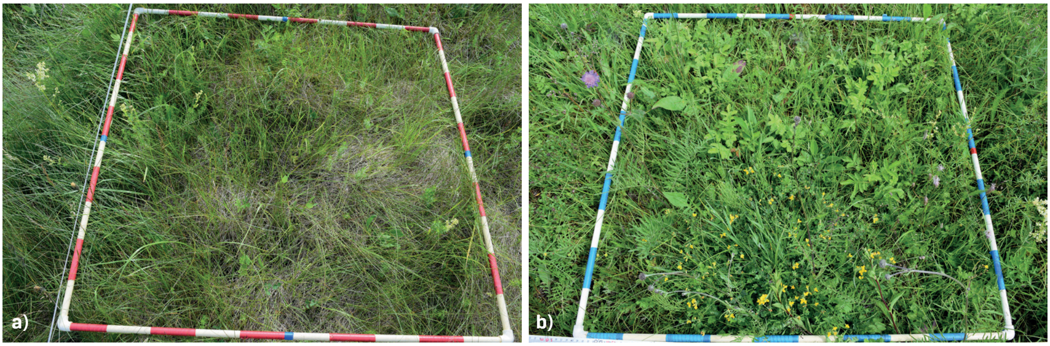

Fig. 21.2.1. (**a**) The litter in the dry grassland hinders the development of vegetation and slows down the restoration of the diversity of species. (**b**) If such grassland is burnt in spring during the first year of restoration, the diversity of species recovers fast. Both photos have been taken in the same grassland on the same day in early July: (**a**) litter accumulated for a long time, not burnt; (**b**) burnt in spring. Photo: S. Rūsiņa.

sensitive plants. On the other hand, it facilitates the spread of some rhizomatous grass species, for instance, *Calamagrostis epigeios* and *Brachypodium pinnatum*. Legumes (nitrogen-fixsing plants), also proliferate after burning.

Maintenance of species-rich grasslands by burning alone is impossible (Milberg et al. 2014). Burning may only be used for grassland maintenance if other options are not available, while keeping a territory free of shrubs is important (for instance, in floodplains in order to maintain bird habitats) and the diversity of vegetation is of secondary concern. But even then burning cannot serve as the only method of management. Annual burning cannot prevent the germination of trees in places free from turf. Other methods must be used for limitation of the dispersal of trees.

Burning is not allowed in wooded grassland landscapes, where it can damage the old trees and junipers. It is also important to burn in early spring when the winter dormancy period of grassland vegetation and invertebrate species has not ended. Late burning can considerably reduce the diversity of species during the current year and harm or even eliminate rare species in the particular area. Burning should be avoided in areas where protected species of plants and animals occur, unless there is evidence that burning will be beneficial to particular species. For instance, *Psophus stridulus* (the species requires areas free from vegetation) can benefit from burning of dry grasslands covered with a thick litter layer in early spring. However, burning after the end of winter dormancy of the species can destroy it.
Grasslands in peat soils may not be burnt when the topsoil has been dried out because the peat can ignite. In such grasslands, time and locality of burning must be selected with care.

21.3 Removal of Litter and Moss and Smoothing of Grass Tussocks, Anthills, Molehills and Wild Boar Rootings (S. Rūsiņa)

Litter is rapidly accumulating in abandoned grasslands. Tussocks of grasses and sedges develop in wet grasslands. In dry grasslands, mounds develop when anthills overgrow with grass (Fig. 21.3.1 – 21.3.2). The grassland must be smoothed to enable mowing. This can be achieved by several methods (Table 21.3.1).

The gathering of litter is mandatory to enhance plant seed germination, prevent microclimate change and eutrophication, thus promoting biodiversity. Prescribed burning is the most efficient method for the removal of litter (in cases when it is permitted by regulatory enactments) (Fig. 21.3.3, 21.3.4). If it is not possible, the litter may be removed by means of light tilling (to prevent considerable damage to the turf), because it shreds the old grass and smooths the tussocks of grasses and sedges. Early grazing is also effective in reducing both the amount of litter and tussocks (Fig. 21.3.5, 21.3.6).

Tussocks and molehills interfere with grassland management, especially in the cases where mowing is the only possibility. They must be removed, even despite their potential contribution to biodiversity by creating micro-niches for plants and animals (Fig. 21.3.7 – 21.3.9).

Digging behaviour of wild boar is a natural behaviour and, in moderate amounts, it benefits the grassland. Small rootings create free niches for the germination of seeds, create turf-free patches which are especially significant for the reproduction of insect species of dry grasslands. For instance, *Psophus stridulus* lay their eggs in bare soil patches,

Fig. 21.3.1. An abandoned dry grassland, where litter and high anthills covered with turf hinder the smoothing. Photo: J. Jātnieks.

Fig. 21.3.2. Sedge tussocks in a wet grassland. Some tussocks must be left to ensure the diversity of invertebrates and birds but haymaking will be impossible if they are left in the entire area. Photo: S. Rūsiņa.

Fig. 21.3.3. A grassland after prescribed burning in a protected nature area. The land can be smoothed easily, because the tussocks have become looser in the absence of litter and are clearly visible. Photo: J. Jātnieks.

Fig. 21.3.4. The grassland from the previous image after smoothing of tussocks. Photo: J. Jātnieks.

Fig. 21.3.5. Early grazing efficiently reduces the amount of litter. Photo: E. Nordmanis.

Fig. 21.3.6. Grazing horses in winter and early spring enables the control of litter and tussocks. A sedge tussock, which is nibbled down to the roots by horses, is seen in the figure. Photo: S. Rūsiņa.

and they do not lay eggs on grass or litter. However, wild boar rooting of higher intensity considerably interferes with management. It is a serious obstacle for mowing and harms semi-natural grassland vegetation, especially in places where wild boar return every year. Wild boar especially prefer areas with the presence of oak trees with abundant acorn yield, high quantity of insect larvae in the soil or abundant cover of some herb species in the grassland, for instance, *Aegopodium podagraria*, *Elytrigia repens*, *Filipendula vulgaris* for their nutritious rhizomes. The rooting of the grassland once in several years does not destroy the habitat. However, if it occurs every year, the semi-natural grassland perishes and is replaced by a fallow land vegetation rich in weeds (Fig. 21.3.10). In this situation grassland smoothing (drag-harrowing, harrowing), followed by spreading of hay containing semi-natural grassland plant seeds should be performed (*see Chapter 21.7*). In a wide landscape of semi-natural grasslands, for instance, in a river floodplain with no arable land around, where the grassland has not been ploughed for the last 30–40 years, smoothing is sufficient and semi-natural grassland species will regenerate themselves (Fig. 21.3.11 – 21.3.13).

21.4 Removal of Shrubs and Trees (S. Rūsiņa, A. Auniņš, V. Spuņģis)

The effective regulatory enactments must be studied before the felling – allowed and prohibited activities in a particular area, necessary approvals and permits (*see Chapter 7.2)*. On river banks, the cover of trees and shrubs must be evaluated not only in relation to grassland values, but also concerning the biodiversity of the river (Urtāns (ed.) 2017). Trees and shrubs must be felled only outside the bird breeding season, irrespective of the objective of grassland restoration.

The area and number of trees that need to be felled must be evaluated first. Gradual felling of trees and shrubs over a period of several years is recommended to promote the adaptation of vegetation to new light conditions. Solitary trees and shrubs or their groups should be retained to promote the overall species diversity in the grassland, unless the grasslands are significant for waders or are small (up to 1 ha). When leaving trees and shrubs, the requirements of plants, invertebrates and birds must be taken into consideration. The felled trees and shrubs must be collected and transported away from the grassland. If grinding of tree and shrub roots is planned, they must be cut as low as possible. The ground root mass should also be removed from the grassland as a measure of nutrient removal to prevent the introduction of nitrogen loving species immediately after restoration and thus – to promote the development of semi-natural grassland vegetation. The overall **diversity of plant species** in grasslands that are larger than 1 ha can be promoted by leaving solitary trees and shrubs in up to 10% of the area. This creates diverse light and moisture conditions. Special attention must be paid to forest edges and river banks. Wavy forest edges should be established instead of straight in order to create a mosaic and variability of light and other environmental factors, thus ensuring higher diversity of plant and animal species. For more information on the development of forest boundaries, see the recommendations provided in Chapter 24 and *Demo Farm* project (Anon. 2011). Leaving *Picea abies* is not recommended, since they make shade and increase soil acidity, thus reducing soil suitability for grassland characteristic species. Leaving *Salix* spp. and deciduous trees (*Populus tremula*, *Alnus incana*, *Alnus glutinosa*) should be avoided, because they tend to expand by root and stump shoots, and gradually reduce the open area of grassland. *Alnus incana* in poor soils create symbiotic relations with nitrogen binding bacteria and thus improve the soil, which is not beneficial for the diversity of semi-natural grassland species.

Conservation of the **diversity of bird species** requires the retaining of shrubs and trees in certain areas, which has to be considered, when the felling is planned. This will also promote the structural diversity of the grassland and creation of ecological niches for grassland bird species, since some grassland passerine species (for instance, *Lanius collurio, Carpodacus erythrinus* and *Emberiza schoeniclus*) require shrubs for nesting.

A dense scrub cover should be cleared as much as possible, since it reduces the open area of the grassland. Meanwhile trees and shrubs that exist-

In Latvia, greater attention should be paid to the use of fire for grassland restoration and in some cases also for the management than has been done so far.
Burning may be used for the restoration of semi-natural grasslands that have been abandoned for a long time, to get rid of the thick litter layer, and enable mowing and grazing.

ed in the grassland before it was abandoned must be preserved, unless there are other considerations in favour of their removal (for instance, to reduce fragmentation). Scrubland usually develops in areas where management is difficult due to terrain or other reasons. These areas are likely to be difficult to manage nowadays as well. Leaving the shrubs in a mosaic-like pattern is preferable to create shrub clusters of various size (diameter and height) – from solitary shrubs to small groups. Old, large trees should be left on river banks, especially hollow trees (including the trees that have internal hollows that are not visible from outside).

The quantity of shrubs to be preserved depends on the target species of the grassland:

- shrubs in grasslands intended for the maintenance of meadow wader communities should be kept at a minimum. Care must be taken not to leave them in places where they can be used by corvids in search of wader nests. Shrubs that are

Fig. 21.3.7. Homemade toothless drag-harrow, which enables effective smoothing of molehills. The drag harrow is not suitable for old tussocks that have been overgrown with grass. Photo: D. Sāmīte.

Fig. 21.3.8. Careful grinding of tussocks (the turf is affected around the mound only, the rest of the grassland is not affected). Photo: G. Jubelis.

Fig. 21.3.9. A toothless drag-harrow, which enables smoothing of molehills and wild boar rootings, as well as sedge tussocks, if the harrowing is performed in the autumn in conditions of frost, when the tussocks are fragile. Photo: S. Rūsiņa

Fig. 21.3.10. Semi-natural grassland rooted up by wild boar in autumn. Almost no turf has remained. Photo: S. Rūsiņa.

Fig. 21.3.11. The vegetation characteristic of habitat type 6210 has been totally destroyed by wild boar. Photo: S. Rūsiņa.

Fig. 21.3.12. Fresh rootings can be smoothed with a rake. If grass has grown through them, use of equipment is necessary. Photo: S. Rūsiņa.

Fig. 21.3.13. Restoration of dry grassland on calcareous soil after smoothing of wild boar rootings with a spring-tooth harrow. (**a**) Before harrowing in 2013; (**b**) after harrowing in March 2014. (**c**) In the first year after harrowing (early July 2014) the vegetation is not closed due to a dry summer. However, it was greener than in the areas that were not harrowed and where the plants flowered. In the harrowed areas the plants were mainly spreading vegetatively and very few grasses bloomed. Weeds were not spread, because no seed bank of weeds was available in the vicinity. (**d**) Late June 2015; (**e**) late June 2016. The vegetation has been fully restored and the habitat is in good condition. (**f**) In the fenced, but non-harrowed sampling plots, the vegetation has been preserved, wild boar rootings have been grown over (because rooting up of turf was not repeated), however, management of such areas is very difficult, because the surface of the grassland is very uneven and raking of the grass is almost impossible. Photo: S. Rūsiņa.

Table 21.3.1. Methods of grassland surface smoothing and their efficiency.

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Burning</td><td>The cheapest method. Efficiently removes litter and facilitates smoothing of tussocks, because the turf is also partially burnt. Burning enables some nutrient removal (nitrogen), thus reducing the eutrophication caused by litter.</td><td>Very careful fire control measures are necessary. Burning facilitates tussock smoothing, however, in order to smooth them off completely, additional measures are necessary (toothless drag-harrowing, harrowing, tilling).</td></tr>
<tr><td colspan="3">Only prescribed burning is permissible, with the approvals of the respective institutions. Burning is only permitted in the grassland restoration phase. A single measure in early spring (February – March), when winter dormancy has not yet ended. Burning is permissible in the absence of wind in dry weather only. The area must be ignited from the sides and fire directed towards the centre. The burning area must be delimited with fire safety zones - zones mown and cleared in the previous year or directly before the burning, harrowed zones or belts created by prescribed burning around the area scheduled for burning (Fig. 21.4.3).</td></tr>
<tr><td>Grazing</td><td>Comparatively cheap in the long run – does not require manual work.
Easily controlled by enclosures. Early grazing in spring, when domestic animals are hungry for fresh grass and eat old grass together with the fresh sprouts of grass, is efficient.</td><td>Cannot be used to remove tussocks. Decreases only litter. Cannot be ensured in remote areas. Pasture animals are not always available. If the grazing intensity is insufficient, a sufficient level of litter control is not achieved.
Constant monitoring is required to ensure sufficient grazing intensity for litter removal. Cannot be used in very wet grasslands, due to topsoil damage. The construction and maintenance of enclosures is comparatively expensive.</td></tr>
<tr><td colspan="3">Regulated grazing with mobile enclosures must be organised, to ensure sufficient grazing intensity in areas with a dense layer of litter. Salt licks should be placed in the areas with excessive litter to attract grazing animals. Horse grazing is more efficient in areas with excessive litter, because horses use their hooves to dig it up and afterwards eat it.</td></tr>
<tr><td>Disk harrowing, disk tilling</td><td>Removes both old grass and tussocks at the same time.</td><td>Long-term accumulated nutrients are not removed from the grassland, which reduces the potential to restore semi-natural grassland vegetation.</td></tr>
<tr><td>Mulching</td><td>Smooths the uneven surface of the grassland developed by accumulated vegetation.</td><td>All nutrients that have accumulated over a longer period of time remain in the grassland, reducing natural vegetation recovery potential. Cannot be used to remove high tussocks.</td></tr>
<tr><td>Toothless drag-harrowing</td><td>Simple and cheap method. Effective in sandy light soils and after a period of rain, when the tussocks are wet and loose, or during frosts, when they are more fragile, but are not completely frozen yet. A simple device, which can be assembled from simple and cheap materials.</td><td>Cannot be used for the removal of litter. Only loose tussocks can be effectively smoothed. If they are covered with turf or dry (in clay soils), the efficiency of drag-harrowing is low.</td></tr>
<tr><td>Grinding</td><td>Very effective – removes litter, tussocks, shrubs and reduces their regrowth capacity.</td><td>Expensive method. May only be implemented during the vegetation dormancy period and only if other, more sparing methods cannot be used.</td></tr>
<tr><td colspan="3">Recommendations on grinding. Grinding is recommended in winter. It is especially significant in wet peat soils inaccessible by equipment in spring and autumn. It is recommended to cut the shrubs as low as possible and remove the felled material from the grassland to prevent nutrient accumulation in soil. Mowing is not usually possible before grinding in the places where the litter layer is particularly thick (due to tussocks and lying litter). Therefore the nutrients introduced in the soil by grinding should be removed by mowing the meadow at least twice in the next summer and following grass removal.</td></tr>
</table>

left should not be higher than 1.5 m. Upon the restoration of the overgrown grasslands complete clearing of the lowest and moistest areas is preferable. Shrubs can be preserved in a mosaic-like pattern in the driest areas, where they can serve as nesting places for passerines;

- shrubs do not play a decisive role in the grasslands intended for the conservation of Corncrake *Crex crex*, unless they considerably reduce the total open area; grasslands that are completely void of shrubs are also suitable for Corncrake, however, a mosaic-like pattern of shrubs will increase the overall diversity of passerines;

- the allowed density of the shrub-mosaic in the grasslands, which are significant for the conservation of Great Snipe *Gallinago media* populations, is lower than the density allowed for Corncrake grasslands, but it may be higher than the shrub density in wader grasslands. The spatial distribution of shrubs is not of high significance. It is more significant to ensure that feeding sites suitable for Great Snipe do not become scrubby. These sites are characterised by easy access to very fertile, loose and mineral soil rich in earthworms (in such places, letting an awl fall from a straight arm, it would penetrate the ground up to the handle). Such gently sloping, damp slacks are often overgrown with shrubs, because the soil there is soft and moist and therefore they are bypassed and left unmown;
- it is recommended to maintain the density of shrub mosaic as low as possible in dry, sandy grasslands suitable for the conservation of *Anthus campestris*. They must be kept as open as possible.

When planning the restoration of grassland, it is significant not to fell shrubs during the bird breeding period – from early April until late August. Clearing of shrubs is allowed in August, since only second or third broods of grassland passerines can occur then, however, postponing of the works until September is recommended whenever possible.

In order to preserve **invertebrates**, it is important to leave separate belts or groups of shrubs and trees, thus ensuring a microclimate such as wind protection. Such belts must be established in grasslands with an area of more than 5 ha. The creation of one such belt per every 5 ha of a grassland is recommended. It is advisable to consult an invertebrate species expert, who is able to recommend the optimum arrangement of such belts, and a bird species expert, who is able to advise where such belts may or may not be established. Abundantly blooming woody species such as *Prunus padus*, *Crataegus* spp., *Sorbus* spp., *Rosa* spp., *Rhamnus* spp., *Euonymus* spp., may be left because they will ensure diverse nutrition for invertebrates. If the diversity of invertebrates that inhabit large trees must be promoted, deciduous trees can be left – lime trees *Tilia* spp., oaks *Quercus robur*, however, these trees must reach old age before they are significant for rare species of invertebrates, for instance, invertebrates associated with wood pasture grasslands (*see Chapter 18*).

The methods for the control of trees and shrubs are summarised in Table 21.4.1.

21.5 Loosening of Compacted Soil (S. Rūsiņa)

The restoration of a semi-natural grassland in compacted soil will fail, if the soil is not treated prior to other restoration works. Growth of plant roots and the development of soil fauna, which is necessary to ensure the successful development of grassland vegetation, is disrupted due to reduced air supply. In compacted soils, the moisture in the topsoil of mesic and wet grasslands increases, creating an anaerobic environment.

Soil compaction can be alleviated by loosening. This can be done with a subsoil aerator, which scarifies the soil to a depth of up to 30 cm without turning the upper layer of topsoil over, thus preserving the turf. The working depth of the aerator is adjusted based on the degree of soil compaction, its depth and moisture. Soil structure can also be improved by incorporation of organic material. It is recommended to use solid manure that has been seasoned for several years, thus reducing the amount of nitrogen (Rothero et al. 2016).

If only slight soil compaction occurs, its causes and consequences must be eliminated. Typical causes are the use of heavy tractor equipment and overgrazing. Use of lighter equipment or equipment with less pressure on the ground (for instance, by using double-wheel systems), will prevent compaction and the soil will recover naturally within a few years. The number of livestock per unit of area must also be regulated, and grazing must be avoided during excessively wet periods, when the soil is wet. Increased moisture of topsoil during spring and rainy periods occurs because the infiltration of water into the deeper layers of compacted topsoil is delayed. Therefore, shallow drainage must be performed in mesic and wet grasslands with compacted soil. Shallow ditches (up to 20 cm) must be dug, which help in draining the excessive moisture and facilitate the access of oxygen to plant roots.

21.6 Restoration of Hydrological Regime (S. Rūsiņa, A. Auniņš)

21.6.1 Necessity of Rewetting

Appropriate hydrological regime is one of the main preconditions for the conservation of moist and wet semi-natural grassland habitats. Elimination of the effects of drainage and rewetting to the original condition as it was prior to draining is especially significant to ensure the conservation of Great Snipe *Gallinago media* and diversity of other meadow waders (*see Chapter 23*). Concerning restoring the diversity of birds, it is only worth doing in grasslands that are larger than 10 ha or that are located in a wide open landscape of semi-natural or improved grassland and mires.

Interaction of excessively wet and dry periods, their duration and character very significant for the habitats of mesic and wet semi-natural grasslands, as it determines the diversity of plant and animal communities. There is no eco-hydrological research (requirements of species and habitats for hydrological regime) in Latvia on semi-natural grasslands in Latvia, therefore information from other European countries, especially Great Britain (Wheeler et al. 2004) has been used for the purposes of these guidelines. The characteristics of hydrological regime provided in the guidelines should not be considered as precise criteria, but as indicative parameters, which must be used with caution and supplemented with careful monitoring of the influence of restoration works on the grassland.

Almost 50% of the total area of semi-natural grasslands of Latvia are moist and wet grasslands. Most of them have been adversely affected by

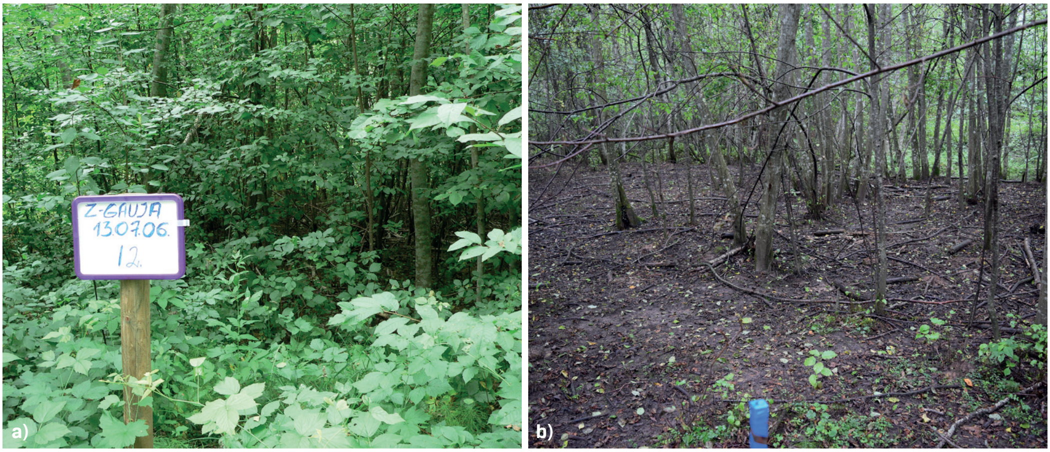

Fig. 21.4.1. *Alnus incana* forest (**a**) before grazing in mid-July 2006 and (**b**) after five years of grazing. Before grazing the trees and shrubs have abundant leaf cover down to the ground, the groundcover (herb vegetation) is rich. After five years of grazing, tree and shrub leaves remain at a height that cannot be reached by grazing animals. However, the openings develop slowly, and the herb layer of the grassland has not developed due to shadow. Photo: S. Rūsiņa.

Fig. 21.4.2. Shoots of *Alnus glutinosa* in a pasture of semi-feral horses. Here the shoots must be controlled by mowing, because grazers avoid grazing *Alnus glutinosa*. Photo: S. Rūsiņa.

Fig. 21.4.3. Burning of the pile of shrubs. Work is started by burning a belt around the pile in order to prevent the fire from spreading over to the dry grass. The branches are ignited on the side opposite to the direction of the wind. Photo: S. Rūsiņa.

Table 21.4.1. Tree and shrub removal methods.

<table>
<tr><th>Method</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Grazing</td><td>Constant control of tree shoots is efficient.
It is cheap, spares manual work of shrub cutting.
Can be easily controlled by enclosures (Fig. 21.4.1)</td><td>Cannot be ensured in remote areas.
Pasture animals are not always available.
If grazing intensity is insufficient, less "tasty" species (for instance, Alnus glutinosa, Rhamnus cathartica, Prunus padus) are not removed by animals and must be controlled by other methods (Fig. 21.4.2).
Constant monitoring is required in order to ensure that the scrubby areas are grazed sufficiently.
It is possible to achieve the result over a longer period of time – several years. Cannot be used in very wet grasslands, because intensive grazing damages the topsoil. Keeping valuable trees undamaged by grazers is difficult.</td></tr>
<tr><td colspan="3">Sufficient grazing intensity in scrubby areas can be ensured with mobile enclosures. Blocks of salt licks may be used to attract animals to scrubby places. In scrubby areas with low shrub vegetation, goat grazing is the most efficient.</td></tr>
<tr><td>Felling, cutting</td><td>Felling can be performed selectively, by preserving the trees and shrubs that you intend to leave.
The felled material can be used for wood chips, firewood or incinerated (Fig. 21.4.3).</td><td>Usually this is manual work and, therefore – a time-consuming and expensive method. Additional work is required after felling to control the regrowth.</td></tr>
<tr><td colspan="3">Shrub felling is best carried out in August, because this will result in weaker regrowth in the following year. It is recommended to fell in the second half of August during the "old moon" lunar phases; then the shrubs will also regrow weaker. During the next two years after felling, the shrub regrowth must be cut at least twice a year. Individual stumps can be bored or cut with a saw in order to damage the wood and open access to fungi for faster stump decomposition. Such stumps will be poorer producers of shoots.</td></tr>
<tr><td>Grinding of stumps and roots (Fig. 21.4.4–21.4.7).</td><td>Very efficient method, almost completely prevents regrowth.
Rather high shrubs can be ground without felling.</td><td>The most expensive method, in wet soils the works must be performed during the frost period. The ground wood is not usually removed, which leads to soil eutrophication, therefore it is recommended to mow and remove the grass twice per season during the first years that follow grinding. If all stumps are not ground, the regrowth could be so vigorous that their control must be continued in following years (Fig. 21.4.8).</td></tr>
<tr><td colspan="3">Grinding is recommended in winter, especially grinding in areas on wet peaty soils, where no entry of equipment is possible in spring and autumn. Grinding in such areas must be performed at a depth of at least 10–15 cm, otherwise in summer, when the drying soil settles, the unground shrub shoots could emerge above the surface and start to grow.</td></tr>
<tr><td>Ring-barking of tree trunks (Fig. 21.4.9).</td><td>An efficient method of avoiding regrowth.</td><td>Time-consuming method. The trees die off slowly therefore the vegetation of the grassland does not develop in the shade under them for several years. Ethical aspect – society perceives it as abuse of trees, therefore, informative measures are recommended before the management.</td></tr>
<tr><td colspan="3">The trees of the species that are prolific shoot producers are usually ring-barked (Populus tremula, Betula spp., common alder Alnus glutinosa). At least a 15 cm wide ring of bark and cambium must be removed. The tree will wither slowly. If the diameter of the tree at breast height is at least 20–30 cm, leaving it as a dead wood in the grassland is preferable, as it will be useful for woodpeckers and invertebrates.</td></tr>
<tr><td>Removal of trees and shrubs with roots</td><td>Pulling out is a rather easy and efficient method in peaty soils.</td><td>It is a slow and labour consuming and, therefore, very expensive method. It does not have advantages over grinding in very scrubby areas and felling in sites where the shrub cover is not dense, except if there are very large stumps. In these cases it must be decided whether to leave the stump as a landscape element and a micro-habitat.</td></tr>
<tr><td>Application of herbicides</td><td>The only effective way to destroy the invasive species, which are capable of fast vegetative reproduction (for instance, beach rose Rosa rugosa in dry grasslands).</td><td>Herbicides adversely affect invertebrates, therefore their use is time and labour intensive – herbicides must be sprayed on individual plants.
Herbicide use is restricted, for example, in water protection zones.
Herbicides cause significant damage to insect and snail species. They cannot be used in places where protected and rare animal and plant species occur.</td></tr>
</table>

Fig. 21.4.4. Grinding of shrub roots in peat soils in the Dviete floodplain meadows in winter, when the ground is frozen. A tracked tractor is used to enable movement on soft ground. Photo: S. Rūsiņa.

Fig. 21.4.5. Shrub root grinding in Krustkalni Nature Reserve. The principle of shredder operation is similar to the shredder provided in Fig. 21.4.4, but it is slightly wider. This type of shredder is more suitable for mineral soils. Photo: A. Namatēva.

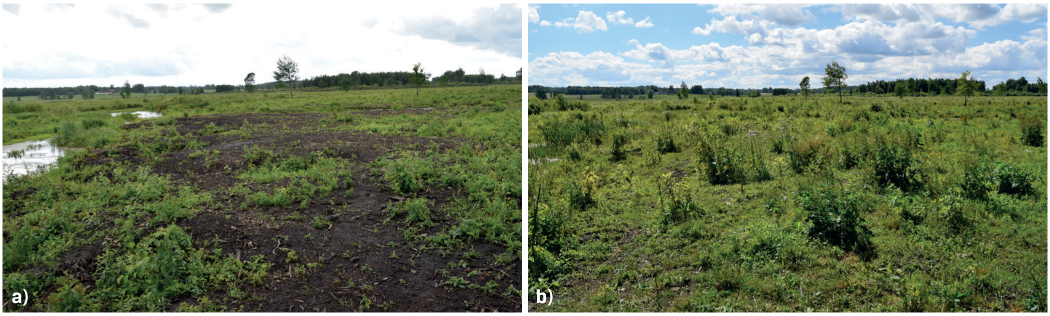

Fig. 21.4.6. Grassland that was ground in February 2014 in the floodplain of the Dviete. (**a**) July 2014, (**b**) July 2015. Floodplain grassland vegetation has been established on open soil. Photo: S. Rūsiņa.

Fig. 21.4.7. A pasture in the Dviete floodplain, where shrub roots have not been ground. Area was grazed from 2006, shrubs were felled in 2011 and shoots were mown with a trimmer in 2013. Photo: S. Rūsiņa.

Fig. 21.4.8. Shrub shoots in wet peaty meadow in the Dviete floodplain before and after grinding (shrubs were cut in winter 2013, roots were ground in January 2015. (**a**) Before grinding in early July 2014, (**b**) after grinding in early July 2015, (**c**) 13 June 2016. Before grinding, mowing was not possible because of abundant tussocks and stumps. After grinding the grassland is more suitable for mowing, however, shrub sprouts keep regrowing vigorously, because the shredder failed to completely crush the stumps. Photo: S. Rūsiņa.

Fig. 21.4.9. A ring-barked *Alnus glutinosa*. Photo: S. Rūsiņa.

drainage (ditches or internal drainage, or both). However, drainage does not necessarily affect the grassland negatively. If the established vegetation is typical for semi-natural grassland (see description at specific habitat types), rewetting is not necessary.

In river floodplains, it has to be decided depending on the character of the river, whether the creation of the grassland is possible and sustainable. Grassland restoration is not easy if the stream gradient is low, river flows through the plain, the soil is dense, its water permeability is low or a high activity of beavers is expected followed by paludification. In such cases it is more practicable either to create a wetland by raising the water table, or to restore the grassland diversity suitable for mesic conditions without rewetting (Rīze et al. 2015).

The presence of nutrient-rich waters during spring flooding may negatively affect the vegetation. If the flood water will enrich the grassland with phosphorus, rewetting is not desired (Leyer 2002; Klaus et al. 2011).

Habitat types negatively affected by drainage are moist and wet variants of 6230* *Species rich Nardus grasslands, on siliceous substrates in mountain areas*, moist subtype of 6270* *Fennoscandian lowland species rich dry to mesic grasslands*, 6410 *Molinia meadows on calcareous, peaty or clayey-silt laden soils (*Molinion caeruleae*)*, 6450 *Northern boreal alluvial meadows*, 6430 *Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels* (Auniņš (ed.) 2013).

An example of unsuccessful rewetting in the Netherlands

Sometimes rewetting can destroy the habitat, instead of restoring it. Raising of the groundwater table on improved grassland, which had been intensively fertilised for a long period of time, resulted in an increase in soil fertility, instead of its reduction as expected (Van Dijk et al. 2004). This was due to the high amount of phosphorus accumulated after the earlier use of mineral fertilisers and soil acidification. The soil pH increased due to the high pH level of the groundwater, which promoted faster decomposition of organic matter, release of phosphorus and overall increase in soil fertility, as a result of which the restoration of biodiversity failed.

Table 21.6.1. Steps for the evaluation of the necessity and possibilities of drained semi-natural grassland restoration.

Has the grassland been drained by using ditches or internal drainage?
Study of map material (for instance, digital land amelioration cadastre www.melioracija.lv, consultation with a rural consultant or municipal land surveyor).

Open drainage with ditches	Internal drainage
Rewetting is possible by means of different methods.	*While the internal drainage is functional, there are no ecological or economic reasons to liquidate it, and the development of grassland in the existing moisture conditions should be assessed. If the functionality of the drain system is poor or it does not function at all, the drainage system should not be restored, and other restoration measures should be planned based on the assessment of how the moisture conditions will develop in the future.*

Does drainage negatively affect the biodiversity of the grassland?	Is any environmental value associated with the ditches?
It should be evaluated if the grassland is semi-natural or improved. If the grassland meets the criteria of a semi-natural grassland, the necessity of rewetting to increase biodiversity of the grassland must be evaluated (see the descriptions of habitat types). If the grassland is improved, the restoration/re-creation of a semi-natural grassland will, most likely, require rewetting (consult a habitat expert). If undrained grasslands are nearby, it is likely that they can contain an abundant species pool that could spread to the restored grassland.	*Consultations and expert examinations of a hydrobiologist and water flora and fauna expert are required.* *If a straightened (dredged) river has protected plant or animal species, the risk-benefit ratio of the relocation or destruction of ditches must be assessed.*

Does the drainage system facilitate the management of the grassland? What management options will be available after the planned rewetting?	Is the drainage system an important cultural and historical heritage or landscape object?
Rewetting to the conditions the grassland had before the drainage may cause a situation, where the existing tractor equipment must be changed to specialised equipment (for instance, only tracked tractors or amphibian type vehicles will be able to enter the grassland), or only manual work will be possible.	*If the drainage system is of cultural or historical significance, for instance, ancient, hand-made shallow ditches, important as cultural and historical landscape elements, then other grassland restoration alternatives that preserve the current drainage system must be sought.*

Who is responsible for the maintenance of a drainage system (amelioration system of national significance or local government amelioration system etc.)? The restrictions specified in the regulatory enactments must be observed.	Will the changes in the drainage system affect neighbouring land properties? Expert opinion, environmental impact assessment.
The drainage system of the grassland may well not be altered due to legislative limitations and therefore the restoration of the grassland can only be planned under the current hydrological conditions.	*Owners of a potentially affected territory must be questioned and informed. Possibly, a consensus may be reached concerning further territory use.*

Decision on changing or elimination of the drainage system. Consultations with habitat expert and hydrologist, elaboration of technical project.

It is important before the start of work!
Any reconstruction, restoration or liquidation of the drainage system must be approved by the responsible national authority. This usually involves a description of the hydrological situation, the drainage system and its characteristics, detailed description of planned construction works, expert reports on the effect of planned works on water and terrestrial ecosystems, fishery resources and agricultural land, etc. The State Environment Bureau may also require an environmental impact assessment.

When assessing the necessity for grassland restoration in drained areas, the current status of the habitat must be evaluated (how suitable it is for semi-natural grassland plant and animal species, especially birds), as well as the type of target habitat in this area. The current and target groundwater table and flood regime, as well as the current and target soil fertility should determine the decisions of whether to start rewetting and what methods to use (Table 21.6.1).

The main methods of rewetting include the restoration of terrain, the creation of wet slacks, change of ditch profile, filling up or damming of ditches and removal of ditch berms, as well as restoration of natural river flows. With rewetting, the effect on water courses must always be evaluated, therefore, the guidelines of water habitat management must be used (Urtāns (ed.) 2017, *Chapter 17*). Restoration of floodplain grasslands that are situated on the banks of catchment watercourses of national significance must be performed in compliance with the requirements for rewetting defined in regulatory enactments – Amelioration Law[1] and Cabinet Regulation No. 631 *Regulations Regarding Latvian Construction Standard LBN 224–05 "Amelioration systems and hydrotechnical constructions"*[2]. Provisions indicated in Part 9 of the construction standard provide that the river bed profile that conforms to a natural river should be created, if the requirements of water transfer are met.

The key to successful rewetting is high quality preliminary research, including observations of the moisture regime for at least 2–3 years before restoration, and a qualitatively developed model of the target hydrological regime.

21.6.2 Maintenance of the Existing Drainage System

Deep drainage with pipes or ditches has usually reduced the biodiversity of semi-natural grassland habitats, therefore the natural hydrological regime must be restored in most cases. However, it is not always possible and the maintenance of existing drainage systems must be considered to be a compromise aimed at the conservation of a grassland. Management of such grasslands must ensure the maximum biodiversity possible.

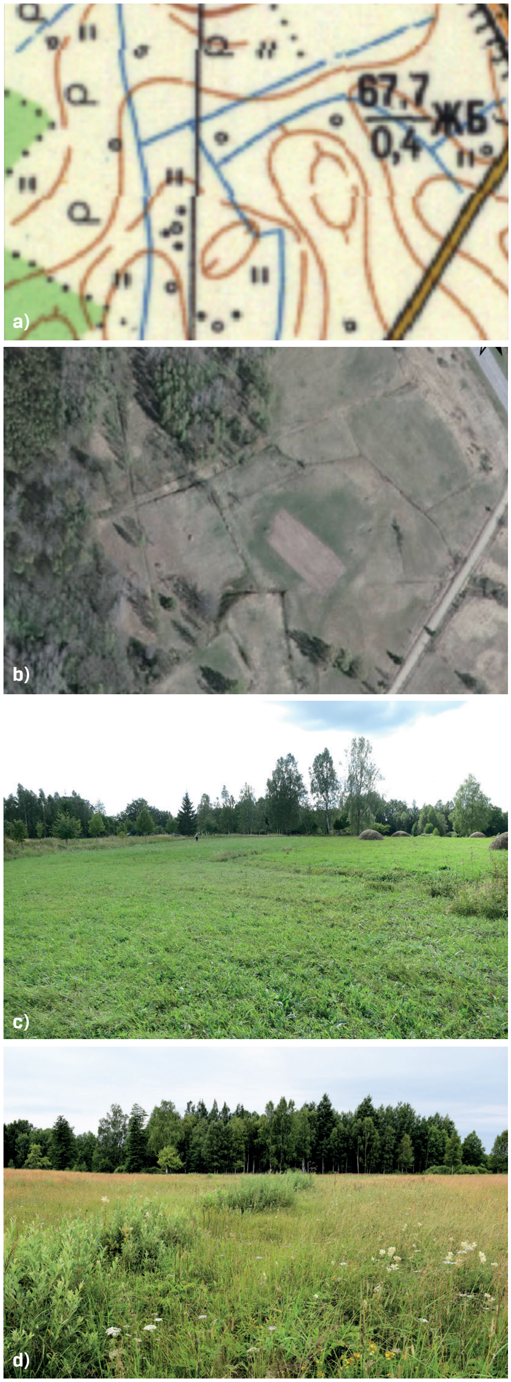

Fig. 21.6.1. A system of shallow ditches in semi-natural grassland in Dundaga. (**a**) The system of ditches is indicated on the topographical map (blue lines); (**b**) the ditches are almost indistinguishable on the orthophoto map, because they are shallow and narrow, as can be seen in (**c**) and (**d**). Photo: S. Rūsiņa. Maps: TOPO 10K USSR; orthophoto map in the scale of 1 : 10,000 © Latvian Geospatial Information Agency (ORTHOPHOTO 4).

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1 Version of 1 January 2015.

2 Version of 23 August 2005.

Fig. 21.6.2. The system of shallow ditches in semi-natural grassland in Sīkrags. (**a**) The system of ditches on the topographical map (blue lines), (**b**) the system of ditches on the orthophoto map, (**c**) and (**d**) – the ditches are shallow and flat, therefore the grass is mown. Photo: S. Rūsiņa. Maps: TOPO 10K USSR; orthophoto map in the scale of 1 : 10,000 © Latvian Geospatial Information Agency (ORTHOPHOTO 4).

Fig. 21.6.3. Shallow ditches in a horse pasture in Vaiņode, 30s of the 20th century. Solitary shrubs, which could be suitable for breeding passerines, are seen in the distance. Photo: Digital library collection *Lost Latvia* of the National Library of Latvia. An image from the collection of the Lettonica collection and Baltic Central Library Collection of the National Library of Latvia.

21.6.3 Maintenance of Shallow Ditch Systems

The ditches dug in semi-natural grasslands in the early 20th century must be preserved. Their ecological significance is based on complete adaptation of the grassland to the new moisture conditions over a period of several decades, resulting in a semi-natural grassland with a high diversity of species. They are also valuable as cultural and historical heritage objects, because these shallow ditches were dug in a way that did not reduce the area of the meadow, but enable mowing on the slopes and bed of the ditch as well (Fig. 21.6.1–21.6.3). Such ditches should not be deepened. Chapter 14.5 describes the cleaning of a shallow ditch, while restoring the grassland in Slītere National Park.

21.6.4 Ditch Profile Change

Ditch profile change is a significant restoration technique that has not been used in Latvia to date, but it is widely used in other countries of Europe with good results. Ditch profile can be changed in two ways. One involves the creation of a low angle wall, the other – creation of two-level ditches to ensure that water stays longer in these ditches during both the flood and summer rain periods (Fig. 21.6.4, 21.6.5). The expansion of the profile and creation of low angle inclination of ditch banks increases the diversity of both plants and animals, it is also beneficial for water flows (Urtāns (ed.) 2017).

21.6.5 Damming and Filling up of Ditches

Damming of ditches is a comparatively cheap method. However, afterwards the costs may unexpectedly rise. The dams must be maintained and repaired to counter potential leaching, beaver damage, as well as damage by humans. Therefore, if possible, it is better to fill up ditches completely.

Various types of dams that differ by sustainability and costs can be constructed (wooden, peat, plastic, metal, straw). The durability of the dam will determine how frequently it must be repaired and, consequently, what the long-term costs will be. A cheap method of damming of a ditch is filling it up at its entry into the river using a bulldozer.

A more efficient, but more expensive drainage elimination method is the complete filling up of ditches. It stops artificial runoff from the grassland and does away with the necessity to perform repeated regular dam monitoring and damage repairs. Full or partial (single phase) filling up of a ditch may be performed, the choice of the method depends on both the specific site conditions and financial resources. Partial filling up can be useful to create wader scrapes (Fig. 21.6.14).

21.6.6 Removal of Ditch Berms and Dikes

In many places of Latvia, drainage systems are poor in quality. Ditch bank berms created while digging ditches are not smoothed. Sometimes this was done on purpose, to protect the area from flooding (Fig. 21.6.6). They block spring flood waters from entering the grassland, while, at other times, they prevent the outflow of water from the grassland into the river or ditch.

As a result, the hydrological regime is unsuitable either for improved or for semi-natural grassland. The most preferable option in these cases would be rewetting by filling up the ditches using the soil from berms. If this is not possible, berms should be fragmented, in order to prevent obstacles to the flood water. The excavated soil must be removed from the grassland if smoothing can destroy localities of protected species or a habitat in a favourable conservation status. In other cases, the soil can be smoothed on the grassland. After smoothing, it is recommended to spread hay from a semi-natural grassland or to sow seeds, which prevents the excessive spread of weeds or expansive plant species in the smoothed area. The weeds could delay the development of semi-natural grassland vegetation.

More on the practical experience of grassland rewetting

Before selecting the most appropriate methods, the characteristics of the particular area must be carefully examined and practical grassland restoration experience must be reviewed, taking into account not only the success stories, but also the failures. To date the restoration experience in Latvia has dealt with flood plain grasslands only. The experience on other mesic and wet grassland habitats, which were drained in depressions between hills or damp plains is absent. Detailed descriptions of experience regarding the restoration of the hydrological conditions in the floodplains of the River Slampe (Ķuze, et al. 2008), the restoration of the hydrological conditions in Lubāna Wetland floodplain meadows (Bergmanis 2008) and the restoration of a natural section of the River Dviete (Priedniece, Račinskis (ed.) 2015 are available. The ideas of dam construction in peat grasslands could be found in the Latvian Bog rewetting experience (Priede (ed.) 2017).

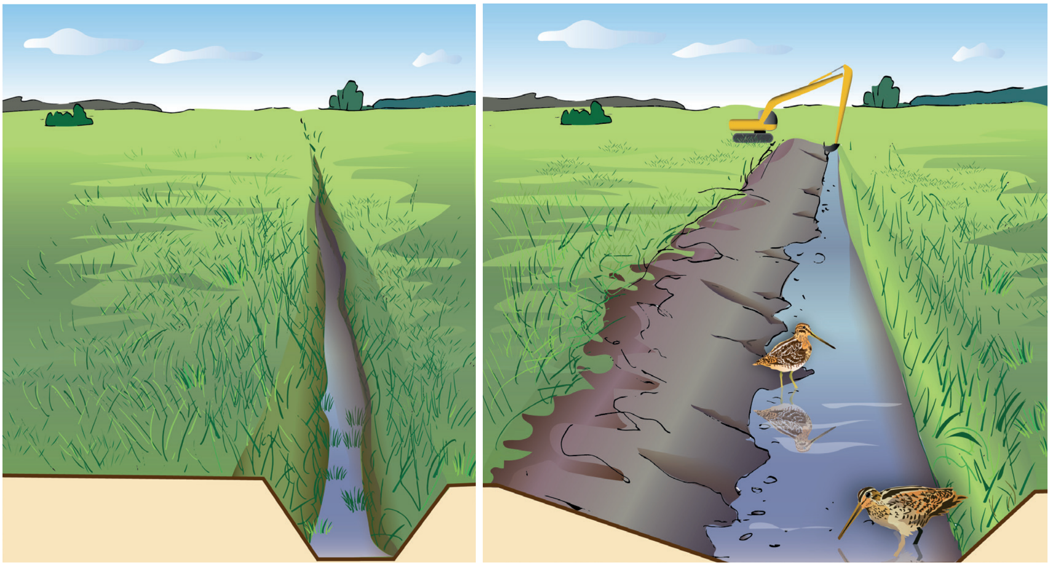

Fig. 21.6.4. A ditch with a changed profile. Drawing by D. Segliņa

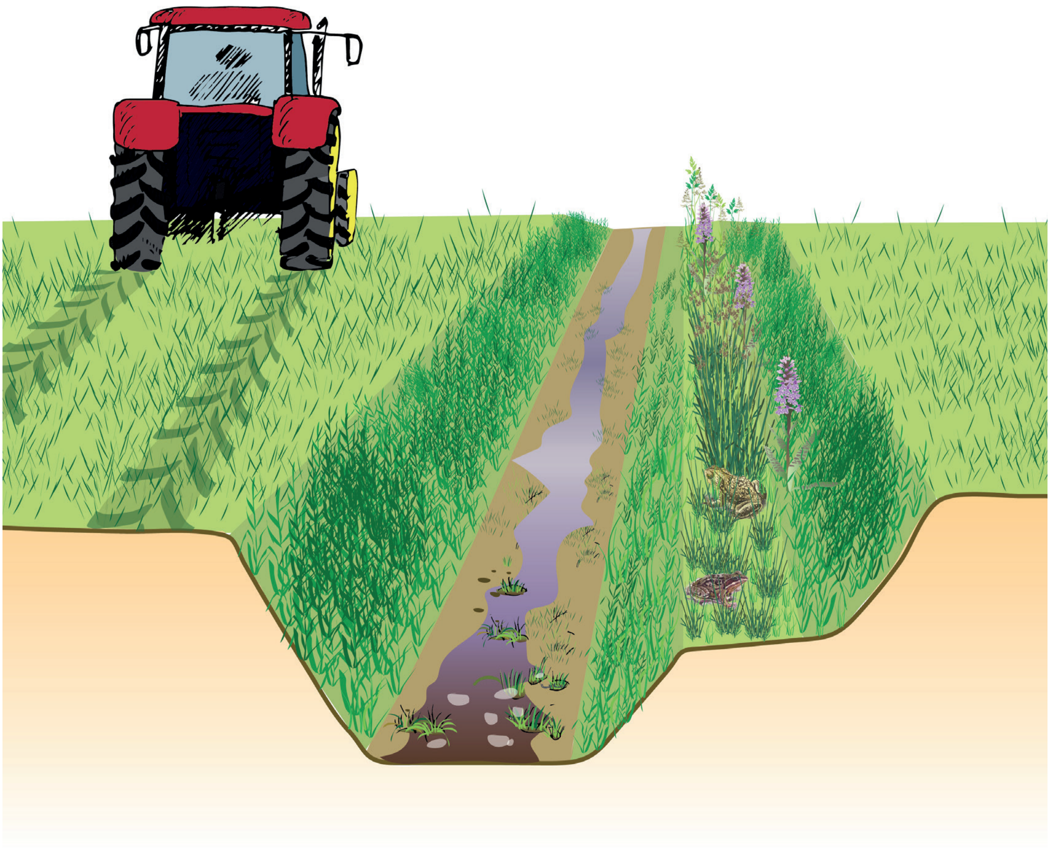

Fig. 21.6.5. Two-stage ditch design. Drawing by D. Segliņa

21.6.7 Regulation of Beaver Activity

Beaver dams raise the water level, which can be both favourable and unfavourable to the grassland. If the water level gets excessively high, rapid paludification can occur, which may be favourable for birds in the short term (if the area of grassland is wide). In the longer run, such habitat will lose its importance for birds, as the peat will accumulate and anaerobic conditions will develop, resulting in a species-poor and excessively eutrophic water body (Priede et al. 2015). If excessively wet areas with sedge vegetation develop as a result of beaver activity, excessive moisture and difficulty of management will cause the grassland vegetation to perish, although such habitat could be favourable for bird diversity (Fig. 21.6.7). Beavers cannot be "negotiated with" regarding specific parameters of a dam or maintenance of a permanent number of dams, therefore beaver activity cannot be relied on in the long run.

Fig. 21.6.6. A dike created with the purpose of limiting floods in the floodplain of the River Lielupe. Photo: A. Priede.

21.6.8 Installation of Sluices and Weirs

Hydrological regime can be changed by constructing weirs on the ditch, which raise the water level (Fig. 21.6.8), or sluices that allow the water level to be adjusted. It must be mentioned that sluices frequently require surveillance or restricted access, to prevent arbitrary damage to them. Additional costs may also be caused by automated control support of the sluices and electricity supply.

Fig. 21.6.7. A meadow paludified due to long-term flooding caused because of beavers. Photo: S. Rūsiņa.

21.6.9 Shallow Wader Scrapes, Diversification or Restoration of Terrain

Original floodplain terrain can be restored in places where natural floodplain grassland has once been smoothed by filling the slacks created by natural spring flood activity (Fig. 21.6.9, 21.6.10). Restoration involves imitation of the terrain, which was characteristic of the particular river floodplain before smoothing. The original terrain can be reconstructed based on topographical maps or aerial photographs taken before smoothing, as well as other remote sensing methods. The diversification of the terrain is only useful if the flood activity is restored as well. Vegetation composition and structure should also be restored. Otherwise the activities described above can even limit the biological diversity of the grassland, since the exposing of bare soil contributes to the introduction of annual weed species.

The terrain is diversified with an excavator. The excavated soil can be smoothed around the wader

Fig. 21.6.8. A weir on the River Slampe to raise the water level. Photo: G. Pāvils.

Fig. 21.6.9. Semi-natural grassland in a floodplain, where the slacks have been smoothed. Slack locations are marked only by slightly more humid conditions with *Deschampsia caespitosa* tussocks. Photo: S. Rūsiņa.

Fig. 21.6.10. Semi-natural grassland, where slacks have not been smoothed. They are characterised by distinct plant and invertebrate communities. Photo: S. Rūsiņa.

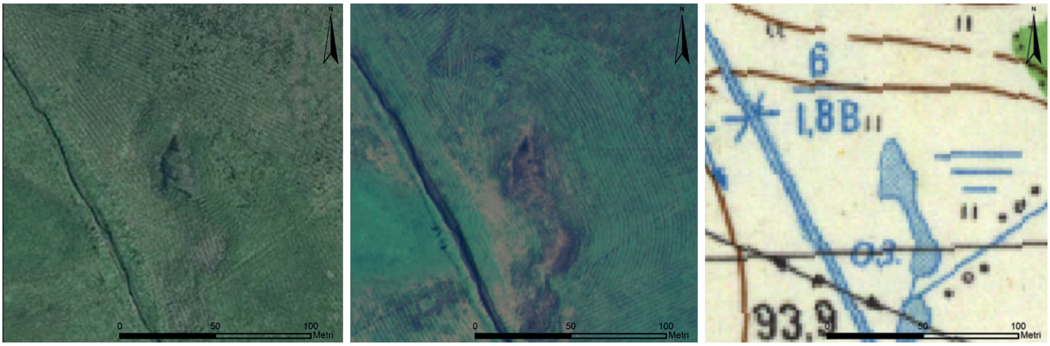

Fig. 21.6.11. A natural shallow slack in the meadow of "Lubāna Mitrājs" Nature Reserve in the downstream of the River Pededze. The meadow is flooded in spring. Afterwards, the water remains in the slack and gradually dries out. Thanks to this slack the meadow is used for lekking of Great Snipe, which uses wet and loose feeding sites throughout the nesting season. Maps: orthophoto map in the scale of 1 : 10,000 © Latvian Geospatial Information Agency (ORTHOPHOTO 2, 4); TOPO 10K USSR.

scrape, or small elevations can be created, but not too close to the scrape in order to avoid predators hiding here. If semi-natural grassland is located around the smoothed slack, the vegetation will recover in the smoothed area as well, although its quality will be lower (it will improve with time, if the management is appropriate). If very fertile soil has been removed or peat has accumulated, the excavated substrate must be transported away from the grassland. Smoothing of such soil on the grassland may harm the existing diversity of the grassland and delay its recovery.

If the restoration of the flood regime in ditched semi-natural grasslands is not possible, the improvement of moisture regime and feeding sites for waders, as well as raising the diversity of plant species is possible by creating wader scrapes. They are shallow depressions with gently sloping edges which create obvious water features in grassland.

Wader scrapes are dug, attempting to imitate a natural slack (Fig. 21.6.11–21.6.13). Their banks must be as shallow as possible, and they must not possess the function of grassland drainage. Water depths in the wader scrape in early spring should be between 0–25 cm over half of the area and 25–50 cm in the second half. Wader scrapes must be cleaned or re-created after a few years. The excavated soil, when digging and cleaning wader scrapes, must be removed from the grassland. Wader scrapes can also be created from deep ditches, by partially filling them (Acreman et al. 2007; Acreman et al. 2010) (Fig. 21.6.14).

If the grasslands are drained by means of an internal drainage system, where the drain system is not functioning well due to clogging of drain collector wells, wet depressions develop around them.

These pools suit waders perfectly and should be preserved, while preventing them from overgrowing with shrubs (Fig. 21.6.15).

In Latvia, neither terrain diversification or restoration, nor the creation of wader scrapes has been performed so far. Only, when the River Slampe was straightened, a water body was created in a site where the soil was taken for the filling of a river. It is too deep to be used by waders, but it has increased the overall biodiversity in the landscape (Fig. 21.6.16).

21.6.10 Restoration of Polder Grasslands

Large areas of wet and damp semi-natural grassland have disappeared in Latvia as a result of the drainage and establishment of polders. Polders are drained areas in floodplains, which have been delimited by dykes (protective dams) and where an artificially regulated hydrological system has been created (water run-off is controlled by pumping). The biggest polders are situated in the floodplains along the River Lielupe between the towns of Jelgava and Jūrmala, in the vicinity of Lake Babīte, in the Lubāns wetland, in the vicinity of Lake Burtnieks (Fig. 21.6.17, 21.6.18).

Not all of the polders can be rewetted. Many of the polders are included in the list of agricultural objects of national importance. Residential buildings have been constructed in some of them. When planning the restoration of grasslands, the entire system of polder territories must be reviewed. Before the polders were established, wetlands (mainly fens) and wet grasslands (remote meadows), were situated in these territories. They were mainly used for manual haymaking in late July, when the groundwater table has fallen and mowing becomes possible, although sometimes it was still difficult due to excessive moisture (Zariņa et al. 2013; Zariņa et al. 2017). Complete restoration of the previous hydrological regime of polder territory could only be sustainable if it was recreated as a self-sustaining wetland, which does not require regular grazing and mowing, or if a plan for the long-term management of restored mesic and wet grasslands with real financial support would be implemented.

Polder grasslands are typically characterised by low biodiversity. Regulation of hydrological regime – raising of groundwater table and/or renewal of flood regime is significant for the restoration of such grasslands. There is no such experience in Latvia, however, nature conservation plans of protected nature areas contain descriptions of areas, where such actions would be necessary. For instance, the

Fig. 21.6.12. A natural shallow slack in spring, late April. The slack remains water-filled until June. Water accumulates in the slack in rainy periods of summer as well. Photo: S. Rūsiņa.

Fig. 21.6.13. Natural shallow depression in early June in the Lielupe floodplain in Jelgava "Pilssala". Photo: S.Rūsiņa.

Fig. 21.6.14. A wader scrape has been created by filling the ditch with ground. Drawing by D. Segliņa.

Fig. 21.6.15. A clogged drainage well, with a wet slack and a layer of surface water around it in spring. The shrubs next to the drainage well should be felled. Photo: S. Rūsiņa.

Fig. 21.6.16. Swans use the water body dug in order to fill up a span of the River Slampe. The unfilled span (ditch) of the straightened bed of the River Slampe is seen in the left part of the picture; on the right – the dug water body. Photo: A. Priede.

Fig. 21.6.17. Managed polder grassland of Lake Burtnieks. Photo: S. Rūsiņa.

Fig. 21.6.18. A polder grassland of Lake Liepāja, which is overgrowing with reeds *Phragmites australis*. Photo: S. Rūsiņa.

nature conservation plan of "Svētes Paliene" Nature Park (River Svēte floodplain) recommends rewetting of floodplains, including polder territories, as one of the measures for the restoration of migratory bird habitats (Anon. 2007b).

Partial destruction of polder dykes (by reducing their height) may be used for polder rewetting (Mauchamp et al. 2002). Water table regulation with pumps is also applicable. Changes of water level during the bird breeding season must be avoided, if the water level is regulated artificially, because such changes would severely affect the feeding conditions of birds and food availability.

There are situations, where grassland has become semi-natural due to long-term extensive management under new moisture conditions. An example of this is the polder of Lake Pape, where natural grazing has been performed since 2004, thus creating and maintaining semi-natural grassland diversity (Nikmane (ed.) 2007). No rewetting is required to restore the initial situation in such areas, unless it is crucial for the restoration or conservation of meadow wader populations.

21.6.11 Restoration of Natural River Beds

Restoration of natural river flow is an effective way of restoring a flood regime. Note that in areas with intensive agriculture the river beds must usually also be cleaned after restoration. It is necessary because of high amounts of agricultural fertiliser residues in the water, which facilitates the proliferation of aquatic plants and development of submerged and floating plant vegetation. The restoration of natural river beds and flooding regime is not desirable in areas, where the river is intensively enriched with waters rich in nutrients that enter the grassland during floods and fertilise it (Leyer 2002; Klaus et al. 2011). For more information on the restoration of natural river beds see the guidelines for river management (Urtāns (ed.) 2017).

When planning such restorative measures, the previous experience must be analysed in detail to adopt the best solutions and avoid mistakes. This type of experience in Latvia has been accumulated in three projects. The flooding regime was restored and river meanders were restored in a section of the River Slampe within the LIFE Nature project *Conservation of wetlands in* Ķemeri *National Park* LIFE02 NAT/LV/008496 (2002–2006); river meanders were restored in a short section of the straightened River Dviete within the LIFE Nature project *Restoration of Corncrake habitats in Dviete floodplain Natura 2000 site* LIFE09 NAT/LV/000237 (2010–2015); a section of the straightened River Skudrupīte has been scheduled for restoration in 2017 within the framework of the LIFE+ project *Restoring the hydrological regime of* Ķemeri *National Park* LIFE10 NAT/LV/000160 (2011–2018).

The longest restoration experience is associated with the River Slampe. An absolutely new river bed with river meanders has been recreated, because the old river bed was not preserved and could not be restored due to a completely altered hydrological situation. A dam was created to raise the water level in the river by one metre, which would ensure the restoration of the flood regime (Ķuze et al. 2008; Priede et al. 2015). A large portion of the grassland has been exposed to floods since 2006, which had not been observed here since the 70s of the 20th century. Over a period of seven years, from 2006 to 2012, the vegetation changed from nitrophilous vegetation with *Dactylis glomerata, Anthriscus sylvestris*, *Urtica dioica,* to vegetation characteristic of natural floodplains with tall tall sedge and grass communities dominated by *Carex disticha, C. acutiformis, Alopecurus pratensis, Phalaroides arundinacea* in wet places, and mesic grassland communities with *Centaurea jacea, Galium album, G. boreale, Deschampsia cespitosa, Geranium palustre, Valeriana officinalis* in mesic sites. (Fig. 21.6.19). However, the grassland still had very few indicator species of semi-natural grasslands, suggesting that the return of plant species diversity to restored intensively drained and improved floodplains is a very slow process, especially in sites with low initial grassland species pool and isolation from other grasslands.

The restoration of bird species diversity was much more successful. The restored meanders of the river served as good feeding places for *Ciconia nigra* and high concentrations of migratory waterbird species have been observed during the first spring floods. No occurrences of migratory waterbirds have been spotted in this grassland earlier (Ķuze et al. 2008; Priede et al. 2015).

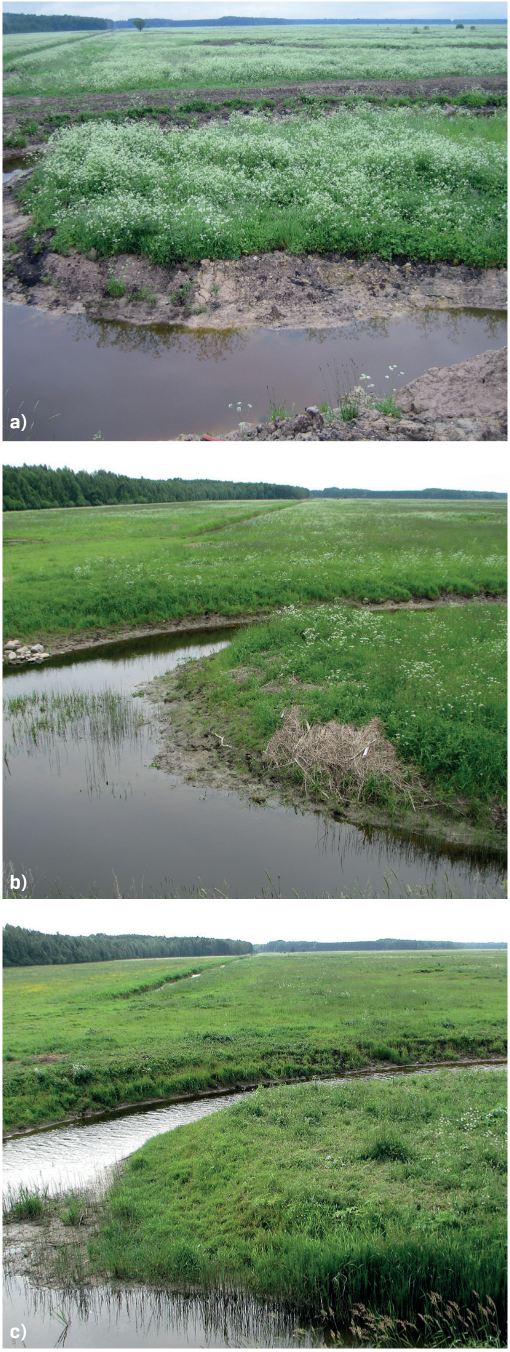

Fig. 21.6.19. Dundurpļavas (Dunduri meadows) in Ķemeri National Park, where the spring flood regime was restored by restoring the natural bed of the River Slampe. (**a**) The grassland on 11 June 2005 – immediately after the works. It was still dominated by the expansive species *Anthriscus sylvestris*; (**b**) the same site on 7 June 2010; (**c**) the same site on 12 June 2013. The vegetation has become almost semi-natural, the proportion of expansive species is much lower, species diversity has increased. Photo: A. Liepa (a), A. Priede (b, c).

Table 21.7.1. Classification of soils by their mobile phosphorus content (according to Anon. 2014c).

Soil fertility by phosphorus content	**Amount of organic matter in soil**			
	Content of mobile phosphorus in soil (P_2O_5, mg kg^{-1} according to the Egner-Riehm method)			
	<5,1	**5,1–20,0**	**20,1–50,0**	**>50,0**
Very low	<25–40*	<40–60	<80	<100
Low	26–80	41–121	81–160	101–200
Medium	100–160	160–240	161–305	201–365
High	121–270	161–410	305–520	366–620
Very high	>155–270	>255–410	>520	>620

* Lower values in soils of light granulometric composition, higher values – in soils of heavy granulometric composition

Table 21.7.2. Phosphorus content in soil and the possibilities of semi-natural grassland restoration (according to Janssen et al. 1998).

Phosphorus, according to Olsen method (ml l^{-1}) (Natural England 2008a)	**Phosphorus, according to Egner-Riehm method (mg kg^{-1}) (Horta et al. 2010)**	**Restoration potential**
0–15	0–22	Such phosphorus content is detected in most of the semi-natural grasslands that are in favourable biodiversity status. The restoration of the grassland could be very successful.
16–25	23–44	Species diversity decreases considerably. The restoration of the grassland could be more complicated or require more time, however, it can still be successful.
25–45	45–87	Reduction of phosphorus content in the soil is recommended before restoration works (for example, supplementary sowing of semi-natural grassland seeds). Grassland restoration success could be average, restoration could require a comparatively long time.
46–70	>87	Very expensive and labour-intensive methods are necessary – removal of turf, deep ploughing, chemical immobilisation of phosphorus. Restoration by using only mowing or grazing may be unsuccessful, or the result can only manifest in a few decades.

21.7 Reduction of Soil Fertility (S. Rūsiņa)

21.7.1 Options and Methods of Soil Fertility Reduction

Soil fertility in arable fields, sown grasslands and intensive pastures is often too high for the restoration of semi-natural grassland. Special soil fertility reduction measures are required in such cases. Improvement of agricultural lands in Latvia was implemented on a large scale in the second half of the 20^{th} century. According to the evaluation of agronomists, only 18% of Latvian arable lands had a medium or high concentration of phosphorus in 1964, while in 1990 – already 62% of arable land was rich in phosphorus (Skromanis et al. 1994). Soil fertility by the content of phosphorus can be divided into several groups (Table 21.7.1).

Restoration success mainly depends on the content of phosphorus in the soil (Table 21.7.2). Based on the data published in scientific literature we can conclude that: if the content of phosphorus in the soil exceeds 80 mg kg^{-1} according to the Egner-Riehm method or 50 mg kg^{-1} according to the Olsen method (more commonly used in western and northern Europe (Janssen et al. 1998; Vucāns et al. 2008; Horta et al. 2010)), a sharp reduction in soil fertility is necessary before the implementation of any other restoration measures. So the content of phosphorus, which is considered low in agriculture, is still very high for semi-natural grassland species.

Table 21.7.3. Methods of soil fertility reduction (according to Janssen et al. 1998; Walker et al. 2004).

Method	Advantages	Disadvantages
Frequent mowing with removal of grass	Cheap method.	Effective only when soil fertility is slightly increased. One instance of mowing can reduce the content of phosphorus by one percent point.
Mowing with the removal of grass and fertilisation with nitrogen and potassium	More effective than mowing without fertilising.	None.
Removal of turf and topsoil	Very good result within a short period of time. The removed fertile topsoil can be sold, thus reducing the costs.	It is a very expensive and labour consuming method.
Growing of cereals and fertilisation with nitrogen and potassium	The result can be reached relatively quickly. The costs are medium.	If semi-natural grassland species occur in the grassland, they will be eliminated.
Deep ploughing	Good results within a short period of time.	When carrying the deeper soil layers to the surface, there may be a risk that the soil on the top is too nutrient-poor lacking established communities of invertebrates and micro-organisms. This may interfere with the restoration of the grassland.
Introduction of phosphorus-immobilising chemicals into soil, for instance Fe(OH)3	None.	Expensive and insufficiently tested method.
Introduction of *Rhinanthus* spp. (see Chapter 21.8.6)	Effective method; substantial changes in soil conditions are not required	Seed germination can fail due to inappropriate weather conditions or insufficient germination microniches.

The success of mowing for soil nutrient decrease

In the Netherlands, previously intensively fertilised meadow for 25 years was managed by mowing with the purpose of restoring matgrass *Nardus stricta* communities. However, after this time, soil fertility still twice exceeded the desired fertility for this habitat. Annual mowing reduced the amount of nutrients more significantly than mowing once every two years, however, the restoration of target vegetation was still not fully reached. The authors of the study believe that this effect was caused by airborne nitrogen deposition (Bakker 2005).

Annual mowing of previously drained and intensively fertilised meadow (with *Junco–Molinietum* plant community before drainage) resulted in a reduction of hay biomass from 11 to 6–7 t ha^{-1} over a period of nine years. Within five more years it decreased to 5–6 t ha^{-1}, however, the optimal hay yield would be under 4 t ha^{-1} (Oomes et al. 1996). Nutrient removal from sandy soils was faster compared to loamy and peaty soils: in a sandy soil the productivity of a meadow decreased from 12 to 5 t ha^{-1} of hay over a period of 10 years, while in peaty and loamy soil the decline was only from 12 t ha^{-1} to 8 t ha^{-1} (Berendse et al. 1992). In dry calcareous soils the highest diversity of species is observed in the meadows with a yield that does not exceed 3.3 t ha^{-1} of hay (Willems, Nieuwstadt 1996). Sometimes restoration by mowing fails to reach the expected results. For instance, an attempt to restore a wet *Molinia caerulea* meadow after a long period as a cultivated pasture failed, due to high nutrient content in soil. Finally, a 15–20 cm thick topsoil layer was removed, as a result of which the yield of hay dropped by 50% and the content of phosphorus dropped by 85%. Only after topsoil removal did the species richness gradually return (Tallowin, Smith 2001).

Mowing twice a year was the most appropriate method for the restoration of a calcareous grassland overgrown with *Brachypodium pinnatum* (Bobbink, Willems 1991). Also in floodplain grassland, mowing twice a year was more efficient than mowing once a year, proving that such management reduces the competition for light and micro niches, which allows lower species to enter in plant communities (Bissel et al. 2006). In a similar study in Sweden mowing twice a year facilitated the increase in the number of annual species with low competitive ability, because the second mowing decreased the biomass and prevented the development of litter (which delays seed germination in spring), as well as created free niches in the sward. Mowing for the second time in the season is especially important in the places, where aftermath grazing does not occur (Svensson, Carlsson, 2005).

Even in the countries around the Baltic Sea, various methods are used to determine the content of phosphorus in soil. It means that the phosphorus content, which is determined by means of different methods, can differ considerably (Eriksson et al. 2013). Therefore, caution is needed while interpreting and comparing soil phosphorus results and restoration possibilities.

Phosphorus is a persistent element in the soil because it is bound to soil clay particles, as well as with iron and aluminium oxides, and therefore the content of phosphorus declines slowly, if fertilisation is ceased. A small amount of phosphorus (10–20 kg ha^{-1}) is removed with the mown grass (Janssen et al. 1998). 13.7 kg of N, 3.8 kg of P_2O_5 and 16.2 kg of K_2O are removed with one tonne of hay from a meadow. Removal of one tonne of green mass removes 6.1 kg N, 1.7 kg P_2O_5 and 4.9 kg K_2O from the pastures (Kārkliņš, Ruža 2013).

There can also be exceptions, when semi-natural grassland can develop in soil with a relatively high content of phosphorus, for instance, in dry grasslands, where vegetation is exposed to periods of drought (Natural England 2009c).

Vegetation could provide an initial insight into soil fertility condition, if the results of soil analysis are not available. If the vegetation of the grassland is tall (> 1.0 m), thick and dominated by *Dactylis glomerata*, *Phleum pratense*, *Festuca pratensis*, *Arrhenatherum elatius, Alopecurus pratensis* or tall forbs – *Anthriscus sylvestris, Aegopodium podagraria, Cirsium arvense, Urtica dioica, Chaerophyllum aromaticum, Taraxacum officinale,* the fertility of the soil is likely to be too high. Therefore in order to create semi-natural grassland in this area, the fertility of soil needs to be reduced. There are several methods of reducing soil phosphorus content before the restoration of grassland – frequent mowing, removal of turf and topsoil, growing of cereals, deep ploughing etc. (Table 21.7.3).

21.7.2 Frequent Mowing with Removal of Grass

Frequent mowing with the removal of grass is effective if the fertility of soil is only slightly higher and expansive species in the grassland are not abundant. If the grassland is not fertilised, and grass is removed once per year, the content of phosphorus and potassium is reduced by 1%, the content of nitrogen – by 2.5% (Bakker 1987). Therefore annual mowing after the cessation of fertilisation can reduce the amount of nutrients in soil. However, sometimes this process can take much longer than expected. It depends on both the duration of fertiliser use and the composition of the fertilisers, as well as other factors (Willems, Nieuwstad 1996). If large quantities of phosphorus fertilisers have been used, then the delayed influence is longer than the influence of using nitrogen fertilisers alone. In order to achieve the desired results, mowing must be performed at least twice per year and the grass must be removed within two weeks. Mowing more than three times a year is not recommended, because only a few species resistant to frequent mowing will remain and these species may later interfere with the establishment of semi-natural grassland species.

21.7.3 Frequent Mowing with the Removal of Grass Complemented with Fertilisation with Nitrogen and Potassium

Fertilisation of grassland with nitrogen, without adding phosphorus fertiliser, activates the growth of plants and the uptake of phosphorus from the soil (Vitousek et al. 2010). By mowing the grass twice a year, the phosphorus accumulated in the aboveground parts of the plant is removed from the ecosystem, so reducing the amount of soil phosphorus. This type of fertilisation and mowing twice per season must be continued for several years. In a study that was conducted in Great Britain, it

Fig. 21.7.1. Turf removed from fertile improved grassland. Photo: A. Priede.

Fig. 21.7.2. Removal of turf with an excavator. Photo: A. Priede.

was calculated that mowing and grass removal in a grassland that has been fertilised for a long period of time reduces the content of phosphorus in the soil to the level of a semi-natural grassland within 25 years, while additional fertilisation with nitrogen and potassium reduces that period to as few as 12 years (Tallowin et al. 2002).

21.7.4 Removal of Turf and Topsoil

Removal of turf and topsoil affects the ecosystem more than just mowing and grazing. It is usually used when mowing and/or grazing fails to ensure the desired result (or it is not expected that it will happen). It is used in the restoration of semi-natural grasslands in highly fertilised grasslands or arable lands, as well as in floodplains, which have received nutrient-rich flood waters for long periods of time. These activities must be approved by the responsible authorities, because the removal of turf is only permissible if it is necessary to improve the conservation status of a habitat.

It is important to take the removed soil away from the grassland (Fig. 21.7.1, 21.7.2). In areas where the soil is left, nitrogen-demanding or mono-dominant communities with a few species of grasses will develop (often *Agrostis tenuis* and *Holcus lanatus*) (Bakker 2005). This method is widely used in western Europe, where traditional mowing and grazing fails to provide expected results due to high phosphorus levels and nitrogen deposition (Berendse et al. 1992).

The removal of turf and topsoil to a depth of up to 15–25 (50) cm is usually recommended. In order to precisely determine the depth up to which the turf and topsoil must be removed, the content of phosphorus at different depths with an interval of 5 cm must be measured.

Topsoil should be removed to the depth where phosphorus does not exceed 15 mg kg^{-1} according to Olsen. The removal of turf not only removes nutrients, but also significantly reduces or even destroys the seed bank of weeds and highly competitive grasses. As a result, colonisation by semi-natural grassland species is more successful.

On the other hand, if a too thick layer of topsoil is removed, there is a risk that grassland will recover more slowly due to impoverished biological properties and fauna of the soil. The composition and proportion of bacteria, fungi and nematodes is im-

Table 21.8.1. Methods of targeted establishment of species composition (according to Kiehl et al. 2010; Natural England 2010a; Török et al. 2011; Blaksley, Buckley 2016).

Method	Advantages	Disadvantages
Sowing of low-diversity (up to 10 species) seed mixtures (commercial mixtures for improved grasslands) in previously prepared soil (arable land)	Appropriate for large areas.	The development of semi-natural grassland is a slow process, commercial varieties of gramineous plants can outcompete wild species.
Sowing of high-diversity (up to 60 species) seed mixtures in prepared soil (arable land)	The optimal method of admixture sowing, because the composition of species meets the requirements of the restored habitat best; the prepared soil ensures better chances of seed germination than sowing in the grassland.	The seed market is underdeveloped, the seed material is not available or is very expensive. The collection of seeds is complicated.
Sowing of high-diversity (seeds obtained from semi-natural grasslands) seed mixtures in partially prepared soil (grassland)	This composition of species best meets the requirements of the target habitat, however, admixture sowing into the grassland may fail to be productive, if the competition of the species pre-existing in the grassland is too high.	The seed market is underdeveloped, the seed material is not available or is very expensive. The collection of seeds is complicated.
Spreading of seed-rich grass, hay, or hay litter obtained in semi-natural grassland	This method is most effective, if the soil has been well prepared (poor in nutrients and without weed seeds).	Costs of hay transport to the restoration site are too high if the transportation distance exceeds 30–40 km.
Turf inoculation and spreading of seed-containing soil	Effective method, especially in small areas.	Expensive and labour intensive method, destroys the semi-natural grassland or its parts in the site where the turf is taken.
Sowing seeds of *Rhinanthus* spp.	An effective method for increasing biodiversity.	Before sowing the soil must be prepared, preferably by grazing which is not always possible.

portant for the successful development of semi-natural grassland and they occur in smaller quantities deeper in the soil (Blaksley, Buckley 2016).

In drained grasslands the removal of turf results in groundwater table change up to the ground surface, thus also improving the hydrological conditions and promoting more successful restoration. This method is not recommended on steep slopes, where water erosion can begin, or in large flat open areas, where wind erosion may develop. The removed turf can be composted, transported to arable lands as a fertiliser or used otherwise.

After turf removal: 1) restoration can be continued by using a natural method of restoration (grazing, mowing, expecting spontaneous establishment of grassland species) or 2) any method for the targeted establishment of species composition can be used.

21.7.5 Cultivation of Cereals to Reduce Fertility

Cultivation of cereals can be used for soil nutrient removal before grassland species are sown. The cultivation of cereals, complemented with nitrogen and potassium fertilising without the addition of phosphorus, reduced the bioavailable phosphorus at double the rate in comparison with cereal cultivation without the use of fertilisers (Tallowin et al. 2002). It is recommended to grow cereals for one or two consecutive years.

21.7.6 Deep Ploughing

Ploughing of the fertile upper layer of topsoil into deeper layers and raising the less fertile soil layer to the top is an effective method for soil nutrient removal in the zone of plant roots (Pywell et al. 2002). It is recommended to plough the soil at least 50 cm deep.

Furthermore, deep ploughing helps in reducing the seed bank of undesirable plant species (for instance, annual and perennial weeds, highly competitive tall grasses, for instance, *Calamagrostis epigeios*, and forbs) (Jones et al. 2010). Amount of organic matter, available phosphorus and C:N ratio in the soil profile must be determined before ploughing. The depth of ploughing must ensure that chemical properties of soil (substrate) raised to the top are suitable for the target grassland habitat species (approximately less than 15 mg kg^{-1} of phosphorus, Olsen method) and the fertile soil layer is not accessible for plant roots.

21.7.7 Other Methods

Effective method to decrease the production of the aboveground plant biomass is to introduce hemiparasitic plants *Rhinanthus* spp. Grasses are their host plants. *Rhinanthus* spp. weaken the grasses thus decreasing their productivity (Mudrák et al. 2014) (for detailed description *see Chapter 21.8.6*). Phosphorus bioavailability can be changed by raising or reducing the soil pH (binding soil phosphorus in compounds inaccessible to plants). Soil pH can be raised by liming or adding calcareous materials (ground bricks, dolomite, concrete, ash, etc.). Restoration of grassland habitats that require acid soil is difficult in arable lands that have been fertilised and limed for years. Soil acidity must be raised in these cases. This can be done by adding coniferous tree needles or sawdust, as well as *Pteridium aquilinum* and *Calluna vulgaris* hay (mulch) or sulphur, for instance, in the form of iron or aluminium sulphate (Blaksley, Buckley 2016).

21.8 Creation of Species-rich Sward (S. Rūsiņa)

21.8.1 Methods for the Creation of Species-rich Swards

If the restoration of semi-natural grassland is planned in an area covered by vegetation that is not characteristic to the desired grassland habitat, the target vegetation must be created intentionally (Table 21.8.1). The same is necessary if the grassland is established in arable or ex-arable land.

The soil seed bank of semi-natural grassland species is short-lived, it gets depleted fast and therefore the seeds that could re-create the vegetation are absent in the soil. The exception might be habitat type 6120 * *Xeric sand calcareous grasslands*, because the seed germination capacity is preserved for a relatively long time in these habitats (Gilhaus et al. 2015). The seeds can introduce naturally from the closest surroundings, but nowadays species dispersal is restricted because of landscape fragmentation, a lack of dispersal routes and agents – transportation of uncovered hay, spring floods or movement of herds does not occur any more. Poor ability to travel long distances is usually characteristic for semi-natural grassland species (Öster et al. 2009). Mowing and grazing alone is not considered to be a method of targeted restoration of species composition, since it changes the composition of plant species very slowly, and the change depends on the species pool and landscape where the restored area is situated.

21.8.2 Where and How to Collect Seeds and Seed-containing Material

Experience of seed collection has not been accumulated in Latvia, therefore the recommendations are based on the experience in other countries (Kiehl et al. 2010; Natural England 2008b; Török et al. 2011; Blaksley, Buckley 2016). There are two types of seeds or seed-containing material – commercially produced grassland seeds and self-harvested seeds from semi-natural grassland. The volume of this book does not allow to describe the production of native seeds in details. For detailed guidelines see Kirmer et al. (2012), Kiehl et al. (2014), and Espeland et al. (2016).

The commercially available seeds, which have been grown from grass varieties, are not suitable for the restoration of semi-natural grasslands, because they outcompete local varieties and genotypes, thus reducing the genetic diversity of the species. Often these seed mixtures are produced outside Latvia and therefore they contain foreign ecotypes, subspecies and even invasive species that threaten the local genetic diversity. Hybridisation of native and foreign genotypes result in decreased stability of the species population in the next generations, since it reduces the survival ability of species.

Commercial seeds of grasses and legumes should only be used where the obtaining of semi-natural grassland seed mixtures is impossible. Only seeds grown or obtained in Latvia are recommended for use. Use of tall, productive grasses such as *Dactylis glomerata*, *Phleum pratense*, *Arrhenatherum elatius*, *Alopecurus pratensis* should be avoided. *Festuca rubra*, *Festuca pratensis*, *Agrostis tenuis*, *Anthoxanthum odoratum*, *Festuca ovina* can be used in dry to mesic areas, while *Poa palustris* and *Festuca rubra* can be used in moist and wet areas. These seed mixtures can be used in places where the grassland is restored on former arable land or scrubland and the semi-natural grassland species have not survived either in the vegetation or seed bank. The restoration of the semi-natural grassland will be slower and less successful than in the case where a semi-natural grassland seed material is used.

The following principles must be followed when selecting the donor site for the gathering of semi-natural grassland seeds or seed-containing hay:

- The donor areas should be of the same semi-natural grassland habitat type as the target habitat (both territories must have similar soil fertility, pH and moisture conditions);
- the donor areas must be close to the restored area, they may not be situated in a different phytogeographic district (only seeds obtained in the same phytogeographic district must be used, transportation of seeds from western Latvia to eastern Latvia and vice versa should also be avoided);
- the donor areas must not contain invasive species or highly abundant expansive species;
- the donor area must not be a sown grassland improved in the near past and it must not contain varieties of sown grasses and legumes;
- seed collection in protected nature areas, micro-reserves and populations of protected plant species must be approved by the responsible national authority, and vegetation monitoring must be performed to ensure that the seed collection does not contradict with the nature conservation plan of the respective site or regulatory enactments that govern the management of the site.

The vegetation of semi-natural grassland gradually changes, if seeds are gathered every year. In order to retain the favourable conservation status of grassland, the following management recommendations must be complied with:

- seeds may be collected in 1/4 to 1/5 of the total area of the grassland, while the rest of the territory is traditionally managed, favourable for the preservation of species diversity;
- to ensure the maximum preservation of invertebrate populations, the area of seed collection must be scattered throughout the entire meadow, instead of using only one part (for instance, one mown belt for seed gathering, four mown belts for hay);
- select the area used for seed collection in another place of the grassland every year. This ensures that the part that was mown late in the season to collect seeds, is mown at a traditional time next year.

Seed harvesting period is usually very short – for grasses it lasts only 3–4 days from seed maturation (Tērauds 1955). Seed harvesting time may change every year. It depends on weather conditions, as well as the time and type of grassland management. The maturation of seeds in semi-natural grasslands occurs gradually, however, the largest number of unshed seeds is from mid-July to mid-August. Seeds mature earlier (in late June already) in dry grasslands and later in wet grasslands, for instance, *Succisa pratensis* only matures in the second half of August. The best results are achieved, if seed collection is organised several times during the summer/

autumn, then the seed material will represent both early and late flowering species.

Seeds may be collected manually, by using scissors or by roughly wiping inflorescences by hand. Seeds can be gathered mechanically by devices or combine harvesters that are constructed according to the principle of a vacuum cleaner. The devices based on the principle of a vacuum cleaner can also be used later, after maturation and shedding of seeds. The advantages of the method include the possibility of collecting seeds of low plants, which are usually difficult to obtain by other means. This method is most efficient in grasslands with low vegetation, for instance, habitat types 6120* *Xeric sand calcareous grasslands*, 6230* *Species-rich Nardus grasslands*.

The following methods may be selected to gather seed-containing material:

- transportation of freshly mown grass containing deflorated plants;
- transportation of dry hay;
- sowing of the hay litter from hay-barn floors;
- transportation of material raked from an unmown meadow (in dry grasslands this method, along with the collection of seeds with the vacuum cleaner method, is more efficient, because mowing of low vegetation is difficult and seed losses are high, furthermore, it enables the transfer of moss and lichens, which are also the target species of dry grasslands. The method is also easier if the donor area is inaccessible to tractor equipment, for instance, steep terraced slopes of river banks). Upon the collection of seed material with a rake, all plant material must be collected as much as possible. It is preferable to perform raking during humid weather, when the lichens are not fragile. Plant seeds caught up by moss and lichens will then supplement the collected material. However, it is recommended to complement this with other methods to improve restoration success.

21.8.3 Seed Sowing and Admixture Sowing of Semi-natural Grassland

Description of the methods of semi-natural grassland sowing is based on the experience in other countries (Kiehl et al. 2010; Natural England 2010a; Török et al. 2011; Blakesley, Buckley 2016; Valkó et al. 2016).

Seeds are sown in arable land, where weed control measures by using herbicides or agrotechnical measures have been implemented. Otherwise they can significantly impede or even arrest the germination of seeds and the development of semi-natural grassland. Successful development of a grassland occurs also in sites where turf or, additionally, topsoil, has been removed or deep ploughing has been performed (by turning the infertile soil to the top and fertile soil into deeper layers) prior to sowing.

To enhance species diversity, admixture sowing can be performed. Admixture sowing is used in ex-arable lands and sown grasslands that have not been improved for longer periods of time, and in grasslands previously restored by low-diversity seed mixtures. The grassland must be mown and harrowed first, to uncover at least half of the soil surface. Admixture sowing can also be used while restoring grasslands overgrown with shrubs, after the grinding of shrub roots. Soil preparation, for example, harrowing or disc-harrowing the grassland, can considerably improve the survival of target species. The best results are achieved, if admixture sowing is performed in autumn after aftermath grazing. Admixture sowing can be performed in establishment patches. Patches are created by harrowing or rotary hoeing, and should be at least 4 x 4m of the size (Mitchley et al. 2010, Valkó et al. 2016).

Seeds are sown in late summer or early autumn. Seeds of some species take a long time to germinate, sometimes even as long as two months, therefore sufficient time before the first frost must be ensured. Good results in semi-natural grasslands are achieved if 10–50 kg ha^{-1} of seeds are sown, provided that species that are ecologically suitable for the target site are selected. Seeds must be sown very close to the surface of the soil or even on top of it, because in most cases the seeds are tiny. Seeds can be mixed with sand or fine sawdust for convenience. After sowing the soil must be rolled.

This method results in 80–100% germination rate of the sown species, and after 3–21 years the vegetation retains 32–96% of the sown species on average (Kiehl et al. 2010). A much higher seed density is usually recommended for improved grasslands – 200 kg of seed per ha^{-1} (20 000 seeds per one square metre). In semi-natural grasslands this causes strong competition among plants for space, nutrients and water and many seedlings die. A good method for large areas is sowing in belts, combining sowing of low-diversity seed mixtures (1–4 species) and sowing high-diversity seed mixtures. The low-diversity seed mixture is sown with a density of 20–25 kg ha^{-1}. The high-diversity seed mixture is sown with a density of 40–100 kg ha^{-1} in narrow belts or patches (Török et al. 2011).

Sowing of too small a number of species in the seed mixture is not efficient, but a too large number of species fails to produce the desired results, since strong competition between species occurs during germination and many species perish. Most commonly they are the species that are not ecologically perfectly suited to the new site, as well as rare species, where a few specimens fail to create a stable coenopopulation and gradually disappear. The best results are achieved with a seed mixture of approximately 15–30 plant species that are well adapted to the environmental conditions of the target site.

If semi-natural grassland is established in arable land, the sequence of works is as follows (Blakesley, Buckley 2016):

Late June of the 1st year – treatment of the weeds in the field with herbicides;

Late July of the 1st year – ploughing, harrowing and rolling of the soil;

August of the 1st year – weeds are allowed to germinate; treatment with herbicides;

September or October of the 1st year – if required, one more treatment with herbicides is performed, semi-natural grassland seeds are sown, the soil is rolled (rolling is not required, if seeds are shallowly worked into the soil during sowing);

October of the 1st year to March of the 2nd year – keeping the sward low, if required, mowing and removing;

April to June/July of the 2nd year – control of annual weeds by mowing high and weeding. Perennial weeds are weeded or locally treated with herbicides. If the sward contains *Rhinanthus spp.*, mowing lower than 10 cm should be avoided (to enable the development of seeds by annual rattles);

July to September of the 2nd year – mowing or low-intensity grazing to the height of 5–10 cm;

3rd year and later – mowing or grazing. Monitoring should be performed in order to ensure that the plants sown during the first years manage to ripen and spread seeds. Mowing in late July or early August with aftermath grazing in meadows. In pastures, grazing in early spring and late summer, after seeds have been shed.

21.8.4 Spreading of Seed-containing Green Hay or Hay

Spreading of hay or green hay (freshly mown grass) that contains seeds is an alternative to seed sowing. The cost of the obtained seeds is lower and the spread hay serves as a covering material that facilitates the survival of seedlings. Spreading of hay is more effective than sowing low-diversity seed mixtures, because it can introduce more target species, while introducing less species with wide ecology, which usually compete with target species. Research shows that spreading of hay, at least in one half of cases, resulted in the introduction of more than 40 target species, while sowing usually introduced less than 30 species (Kiehl et al. 2010). Spreading of hay is also cheaper, because obtaining seeds from wild populations is a very time consuming procedure that usually involves manual work, because several wild species cannot be easily cultivated with the purpose of obtaining seeds.

Spreading of seed-containing material has not been tested in Latvia; however, it has been described in detail in several publications from other countries (Tikka et al. 2001; Kiehl et al. 2010; Natural England 2010b; Scotton et al. 2012; SALVERE *without date*).

The most effective way is the spreading of freshly mown grass. Hay chaff is less suitable, because a lot of seeds perish as a result of insect and rodent activity. Hay drying results in a high rate of seed loss, because seeds have been partially shed during the turning, drying and transportation of hay. Mowing and spreading of fresh grass is also the cheapest method.

Before the spreading of seed-containing material, the soil in the target territory must be prepared. If the place scheduled for restoration has many undesirable species, for instance, expansive species like *Aegopodium podagraria* or *Calamagrostis epigeios*, the turf needs to be removed, otherwise the introduced species will not survive. The best results are achieved if seed-containing grass is spread in arable land, or if the turf has been removed first. If this method is used in grasslands, the soil must be prepared to ensure at least 50% of open soil (by means of a harrow or a cultivator, while more intense grazing is sufficient in pastures) before the spreading of seed containing material.

The grass mown in the donor area must be immediately transported to the site scheduled for restoration to prevent heating-up of grass and seed death. If the donor area contains large quantities of seeds of target species and no erosion occurs in the target site, a 3–5 cm thick layer of mown grass may be spread (0.5–1 kg m^2). If the site is subject to erosion or quick drying, or if the material contains a smaller quantity of target species seeds, a 10–15 cm thick layer has to be spread (1–2 kg m^2). The area of the donor site should usually be four times larger than the restoration area. It is significant to avoid spreading of a too thick layer, because it suppresses seed germination and changes the microclimate conditions on the soil surface, which additionally reduces the seed germination capacity. Widespread

Fig. 21.8.1. Yellow rattle *Rhinanthus minor*. The mowing time in semi-natural grasslands of Latvia in earlier times was frequently determined based on the observation of rattles – if they started to "rattle" (seeds were mature), the mowing time had come. *Rhinanthus* spp. also serve as an excellent source of pollen for bumblebees. Photo: S. Rūsiņa.

Fig. 21.8.2. Early spring grazing, followed by late mowing, have contributed to the spread of *Rhinanthus* spp. and restoration of semi-natural vegetation in previously cultivated grasslands in Jaunpiebalga, farm Lielkrūzes. The grass, mown at the time of *Rhinanthus* spp. seed maturation, is highly suitable for spreading in the territory scheduled for restoration. At Lielkrūzes, this hay is especially spread in the places with a low diversity of species, when pasture animals are fed. Photo: S. Rūsiņa.

Fig. 21.8.3. A wide natural distribution of *Rhinanthus* spp. (without sowing) in semi-feral horse and cattle pasture near Lake Pape. The composition of species has considerably changed as cultivated grassland species (for instance, *Dactylis glomerata, Phleum pratense)* have been replaced with semi-natural grassland vegetation. Photo: S. Rūsiņa.

species usually get rooted better than rare species, therefore selective collection of the plant material should be preferred.

In dry grasslands 3–6 t ha^{-1} is sufficient for restoration. This is approximately equal to a 2:1 or 3:1 ratio of donor to target site area. If grass cover is denser, the germination capacity is reduced due to shading. For the restoration of mesic and moist grasslands the sufficient ratio of donor to target site area is 1:1 or 2:1.

After the spreading of seed-containing material, the field must be rolled or grazing animals must be introduced to stimulate seed-soil contact and better germination conditions. The territory must either be grazed or mown (followed by hay removal) during the first autumn after the spreading of seeds in order to prevent the weeds (also the competitive grasses in the grassland) from outcompeting the germinating plants. During the next two years mowing is recommended after the plants have flowered and shed seeds. This is promoted by drying hay on the field, by turning it several times. Grazing is not recommended because it reduces the opportunities of plants to flower and shed seeds. Grazing is preferable in the aftermath because it promotes seed-soil contact. If only grazing is possible, grazing should only started after the majority of plants have shed seeds (starting with late July). Late start of grazing is recommended during the first years of restoration until the vegetation is stabilised.

21.8.5 Turf Inoculation and Spreading of Seed-containing Soil

An expensive method that requires complex coordination effort and must not be performed in areas that contain habitats valuable for nature conservation. Turf removal or topsoil bulldozing destroys the habitat. Removal of turf is recommended in small patches only, avoiding turf harvesting on large continuous areas to ensure better recovery of the donor area. The sites of turf collection must be approved by the responsible authorities.

Turf can be removed in various ways – by hand, with a spade or specialised tractors. Commonly, large patches of turf are used (at least 0.5 × 0.5 m and 0.3–0.5 m thick). Alternatively, the soil surface may be collected together with the turf (during the collection process the turf is mechanically fragmented and mixed with soil and therefore it is not replanted, but spread). The soil is collected to the depth of up to 50 cm from the area of the same size as the area, where it is spread for restoration (ratio 1:1). The research has shown that after 3–7 years an average of 50–90% of the species that were introduced with turf or soil are preserved in the restored territory.

The biggest problem of this method is soil eutrophication in the restored area, which is often too fertile to ensure successful establishment of the transferred species. Therefore it is generally recommended to remove turf in the target area up to 20–30 cm deep and use up to a 10 cm thick layer of soil from the donor area.

Transportation of soil is cheaper (even four times) than the transportation of turf and, although less efficient (smaller number of species gets established in the new site), its economic feasibility is higher. Use of transplanting stock is slow and labour-intensive, it has no advantages over other methods and it is usually only possible in small areas (Natural England 2009a).

21.8.6 Use of *Rhinanthus* spp. in the Restoration of Grasslands

Sometimes, apart from the creation of a typical species pool, species are introduced in grasslands to improve environmental conditions. The introduction of *Rhinanthus* spp. (Fig. 21.8.1) into a meadow helps other less competitive species to establish in vegetation. This is possible because *Rhinanthus* spp. are hemiparasite on grasses and legumes. They suppress the vitality of grasses and legumes and create additional opportunities for less competitive plants. The introduction of a large proportion of hemiparasites into a plant community proved to be economically feasible if compared to the labour intensive and costly removal of topsoil (Bullock, Pywell 2005; Natural England 2009b; Mudrák et al. 2014).

Rhinanthus spp. seeds are obtained from semi-natural grasslands by mowing them. *Rhinanthus* spp. seeds are only shed when they are completely dry. In earlier times, when hay was fully dried on site, seeds could be shed during the drying of hay (turning, raking). Changing of mowing time every year is very significant for rattles, because the period of seed maturation varies every year. *Rhinanthus* spp. are annuals retaining seed germination capacity for a short time of 1–2 years only. The seeds germinate in spring and require cold stratification in order to germinate. If the grass is mown too early, the seeds fail to mature (Swenson, Carlsson, 2005).

Sowing of *Rhinanthus spp.* is suitable for mesic grasslands, especially in the places that require nutrient removal. If semi-natural grassland is restored in a previously improved grassland or ex-arable land, where the introduction of other semi-natural grassland species are required, *Rhinanthus* spp. are sown first, followed by other wild species in 2–3 years after the stabilisation of *Rhinanthus* spp. Germination of *Rhinanthus* spp. may be impaired in very dense vegetation due to high competition for light, therefore nutrient removal is recommended even before the introduction of *Rhinanthus* spp.

Rhinanthus spp. seeds must be sown in late summer or early autumn with a sowing rate of 0.5–2.5 kg ha^{-1} The sward must be mown or grazed prior to sowing (the sward must be shorter than 5 cm). Creation of bare soil patches is also recommended (the grassland can be harrowed lightly). The positive effect of *Rhinanthus* spp. on the development of vegetation will only be observed if the abundance of *Rhinanthus* spp. is at least 100–200 individuals per 1 m^2 (Natural England 2009a). The seeds of *Rhinanthus* spp. may be introduced to the grassland with grass or hay. Grazing or light rolling is recommended after sowing to ensure seed-soil contact. In the first years after sowing the grassland must only be mown after the maturation and shedding of *Rhinanthus* spp. seeds. Mowing at the seed shedding time facilitates dispersal of *Rhinanthus* spp. – seeds are moved about 10 m from the mother plant. Aftermath grazing is recommended. Grazing must only be started after the *Rhinanthus* spp. seeds have been shed (Mudrák et al. 2014).

Field observations in Latvia confirm the positive effect of *Rhinanthus* spp. on the increase in biodiversity in previously cultivated grasslands (Fig. 21.8.2, 21.8.3).

21.9 Control of Expansive and Invasive Plant Species (S. Rūsiņa)

21.9.1 Defining Expansive and Invasive Plant Species

Local wild species of plants that start dominating the vegetation and outcompete habitat characteristic species, thus impairing the conservation status of the habitat, are called expansive species. This process can occur either in abandoned grasslands or in well-managed grasslands, especially in pastures, where species that are not consumed by pasture animals can spread excessively. Expansive species can include either species characteristic of a particular habitat or species that do not belong in the habitat. Invasive species differ from expansive species in their origin only. They are non-native species that came to Latvia as a result of human assistance. Without human assistance they would not have crossed natural barriers and spread here.

Both expansive and invasive species are not desired in grasslands due to their ecological flexibility. They easily adapt to the conditions and outcompete lower species (Fig. 21.9.1, 21.9.2). They usually reach high abundance in cases when semi-natural grassland is inappropriately managed, abandoned or managed too intensively. For instance, *Filipendula ulmaria* spreads in abandoned moist semi-natural grasslands, *Cirsium vulgare* may invade overgrazed pastures, taking over the entire pasture and outcompeting pasture characteristic vegetation.

Some expansive species may be typical for the habitat, but they excessively spread and start dominating due to incorrect management (Fig. 21.9.3–21.9.6). *Filipendula ulmaria* is a typical species for EU protected mesic grassland habitat types 6410 *Molinia meadows on calcareous, peaty or clayey-silt laden soils (Molinion caeruleae)*, 6270* *Fennoscandian lowland species-rich dry to mesic grasslands* (moist subtype) and 6450 *Northern boreal alluvial meadows*. However, their dominance in the sward indicates the decline in grassland quality caused by late mowing, grass mulching or abandonment. This species never dominates in a well-managed grassland. If it is common but not dominant in a moist grassland (does not cover more than 25%), the species does not require control.

The most common expansive species in semi-natural grasslands are *Calamagrostis epigeios*, *Anthriscus sylvestris*, *Aegopodium podagraria*, *Filipendula ulmaria*, *Phragmites australis*. Their control is described in Annex 3.

Fig. 21.9.1. In the foreground stand of *Calamagrostis epigeios* in a long unmanaged grassland. The species expands at a rate of 1–2 m per year. The sward almost does not contain other species, as *Calamagrostis epigeios* outcompetes and suppresses them. Mowing once a year with the collection of grass will only give a positive result in controlling this stand in approximately 8 years. Faster control of the species is possible by means of mowing at least twice a year and removal of hay or intensive grazing. Photo: S. Rūsiņa.

Fig. 21.9.2. The stand of *Calamagrostis epigeios* seen in the previous picture in spring – the litter of *Calamagrostis epigeios* has densely covered the soil in a 20 cm thick layer, preventing the germination of grassland plant species. Photo: S. Rūsiņa.

21.9.2 General Principles of Expansive and Invasive Plant Species Control

The principal methods of expansive and invasive species control include mechanical (frequent mowing, grazing, felling, uprooting, ploughing, burying, covering with black film), biological (introduction of species specific pests) and chemical (herbicides) methods.

General principles to be observed, while controlling expansive and invasive plant species:

- preventive measures that do not permit the introduction of invasive and expansive species are always more efficient and sustainable than measures aimed at control of the already spread species;
- methods that ensure the complete elimination of invasive species must be preferred over methods that only limit the species, without completely eliminating it; only measures aimed at limiting the species are usually required for the

Fig. 21.9.3. *Filipendula ulmaria* in white flower. It is not expansive here – as a species characteristic of moist grasslands it usually occurs in such habitats, but in small quantities. Photo: S. Rūsiņa.

Fig. 21.9.4. In this situation *Filipendula ulmaria* is an expansive species, and it has spread after the grassland was abandoned. Photo: S. Rūsiņa.

Fig. 21.9.5. *Anthriscus sylvestris* is a characteristic species of mesic semi-natural grasslands, where it occurs in small quantities (the plant with white flowers in the photo). Photo: S. Rūsiņa.

Fig. 21.9.6. *Anthriscus sylvestris* has become expansive and spread over the entire meadow, which was mown with mulching for several years. Photo: S. Rūsiņa.

control of expansive species, since they are native representatives of the local flora and do not endanger it;
- chemical methods (use of herbicides) must only be selected when other methods have failed or their use is objectively impossible due to site-specific conditions;
- the control of species must be continued persistently for several consecutive years. If the implementation of control measures is ceased before reaching the complete result, the species recover rapidly and regain the previous state in the sward;
- preventive measures must be implemented after species elimination, to prevent this or any other invasive species from invading the free ni-

che. In places, where vegetation has perished, its restoration is necessary, preferably – sowing of semi-natural grassland species (Chapter 21.8).

21.9.3 Control of Invasive and Expansive Trees and Shrubs

Mechanical control of invasive tree and shrub vegetation must be performed in August, because then woody species are the most sensitive – shoots regrow slower and less abundantly. Use of a single method is usually less efficient than a combination of several methods (*Chapter 21.4, Annex 3*). Combination of felling with the application of herbicides is the most efficient (next chapter). Herbicides should be used in the form of capsuled granules that are inserted in the stump of a tree or shrub that has been freshly felled, or no more than two weeks from felling, or in the trunk of a growing tree by drilling a hole in it and inserting the capsule. Several capsules must be inserted in one trunk, depending on its girth and the dose of the herbicide included in the capsule.

21.9.4 Control of Invasive and Expansive Herbaceous Plants

Expansive and invasive species that most commonly occur in semi-natural grasslands and methods of their control are described in Annex 3. Herb species should be combated (by mowing, hand pulling, at a time when they are in full flower, but the maturation

Fig. 21.9.7. *Rhytidiadelphys squarrosus* is the most common expansive moss species in mesic and dry grasslands. Photo: S. Rūsiņa.

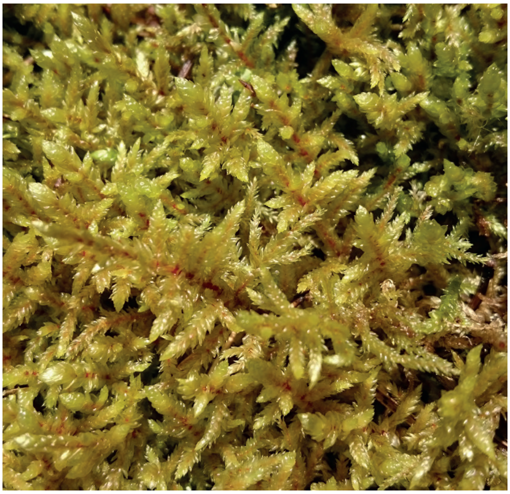

Fig. 21.9.8. *Pleurozium schreberi* is the moss of dry pine forests, which is usually expanding in dry abandoned grasslands. Photo: S. Rūsiņa.

Fig. 21.9.9. *Dicranum polysetum* is an expansive species in dry grasslands. Photo: S. Rūsiņa.

Fig. 21.9.10. *Hylocomium splendens* is an expansive species in dry grasslands. Photo: S. Rūsiņa.

Fig. 21.9.11. Expansion of mosses in a dry sandy grassland. (**a**) Mosses have completely overtaken dry sandy pasture within a period of 15 years, since it was abandoned. Raking (removal) of moss is required for habitat restoration to make space for the germination of herb seeds and vegetative propagation: (**b**) before raking, (**c**) after raking. Photo: S. Rūsiņa.

of seeds has not started. During this time the plant uses all its energy for flowering and seed production and therefore mowing, followed by the removal of plants during this period, will weaken the plant and its recovery will be slower. Covering of vegetation for one to three seasons with thick, black film, the margins of which are tightly fixed, is efficient for the control of all expansive plant species in small areas.

Eradication of expansive grasses (*Elytrigia repens*, *Calamagrostis epigeios*) is more successful with shallow ploughing, thus enhancing the sprouting of shoots. Once they have sprouted, the field is ploughed again much deeper, thus "suffocating" the shoots.

Chemical methods may not be used in floodplains or elsewhere close to water bodies, where waters can be polluted, as well as at sites where protected species of plants or animals occur together with undesirable species. The herbicides must be used in accordance with the requirements defined by legislation. The work must be carried out in windless, dry weather, when rain is not expected. Spraying should be applied in early summer, when the plants are fully leaved. It should not be done when fruits are maturing to avoid poisoning animals that feed on fruit. Measures must be repeated in the following years, until all individuals of the species are exterminated.

21.9.5 Control of Expansive Mosses

Mosses spread in soils of varying moisture, where the upper layer of soil has become acidic or, where

Fig. 21.10.1. A feeder of forest animals in semi-natural grassland. Trampling around the feeder has destroyed vegetation. To restore the semi-natural grassland, the feeder must be removed and semi-natural grassland plant seeds must be sown in the trampled area. If the soil around the feeders is over-fertilised by animal dung, the topsoil must be removed. Photo: A. Priede.

Fig. 21.10.2. Smoothing of the soil (clay) excavated from the pond destroyed the semi-natural grassland. To restore semi-natural grassland, the excavated material must be removed and the grassland must be restored in a similar manner as it is done in arable land. Photo: A. Priede.

the aeration of soil is poor due to compacting. The most common species of expansive mosses are *Rhytidiadelphys squarrosus*, *Hylocomium splendens, Pleurozium schreberii, Dicranum polysetum* (Fig. 21.9.7–21.9.10), in moist grasslands also *Calliergonella cuspidata*, *Aulacomnium palustre* and *Sphagnum* spp.

Rhytidiadelphys squarrosus can expand if the amount of nitrogen increases (for instance by means of atmospheric deposition) both because this moss, possibly, is more efficient at nitrogen uptake, and because nitrogen sediments raise soil acidity. Moss covers the soil, thus inhibiting plant species germination and vegetative growth (Bakker et al. 2002). In moist and wet semi-natural grasslands a continuous layer of moss may indicate paludification. The removal of mosses is usually required during the phase of grassland restoration, in order to promote plant diversity. Moss is removed by harrowing in early spring, when the soil is still frozen. In small areas this could also be done with a rake (Fig. 21.9.11). Liming the soil after harrowing or raking is recommended (fertilising with mineral fertilisers must be avoided), followed by sowing of semi-nat-

Fig. 21.10.3. Construction waste and residues of wooden materials change the soil conditions in a wider area, thus destroying the semi-natural grassland. In order to restore the grassland all earthfilled material must be removed. If the sward has been covered for several years, the surface of the soil must also be removed and seeds of semi-natural grassland species must be sown. Photo: A. Priede.

Fig. 21.10.4. Turf and upper soil has been removed, thus destroying the semi-natural grassland. In this situation, mowing with hay removal of the destroyed grassland and the adjacent grassland can lead to grassland recovery within 10–20 years. Photo: A. Priede.

Table 21.10.1. Restoration of a semi-natural grassland habitat after damage.

Possibilities of restoration	Damage	Restoration
Beaver activity		
Good	Recently flooded grassland, vegetation has remained, there are no indications of paludification. Increased moisture can even benefit a grassland, if it is flooded grassland that has been drained by means of ditches. The habitat is not damaged or the effect is reversible.	Beaver dams must be destroyed and the previous hydrological regime must be restored, or, if the increased moisture is favourable to the grassland, no restoration is necessary.
Medium	Grassland that has been flooded for a longer period of time (one or two years). Grassland habitat is damaged. In places with increased moisture (stagnant above ground water) the grassland vegetation can be completely destroyed. The species composition is changed due to excessive moisture, several species have gone extinct, however, in general the grassland has not been transformed into another ecosystem (water body, fen).	Restoration of hydrological regime is necessary. If tussocks have developed, they must be smoothed off, mowing or grazing must be started. If species composition is very poor, then admixture sowing of habitat characteristic plant seeds or spreading of seed-containing hay is necessary.
Poor	Grassland that has been flooded for a longer period of time (more than two vegetation seasons). The grassland habitat is completely destroyed, a shallow water body or fen has developed. Even if the beaver swamp has been eliminated, the grassland cannot recover by itself.	Financial and ecological options of restoration must be evaluated. If a new habitat important for biodiversity has already developed (a water body significant for bird species, or fen), the grassland should not be restored. If there are no semi-natural grasslands around, the restoration of the hydrological regime (draining of the beaver swamp) alone will be insufficient. Topsoil removal (if peat accumulation has started and there is a risk of eutrophication) and sowing the seeds of grassland species will be necessary.
Wild boar rootings. Control of wild boar digging activity is only possible as a result of tripartite cooperation between the responsible institutions, hunter teams and land owners.		
Good	The turf is damaged in single patches once every 3–5 years or the turf is damaged in the entire territory, but as a single event (once every 5–10 years). After smoothing fragments of turf are visible on the soil surface, or only a few centimetres deep (vegetation recovery is possible from vegetative parts of plants and from the seed bank because, it is not destroyed by deep overturning or ploughing of the turf).	No special measures are required. The habitat is severely damaged on a local scale, some of the plants perish. However, in the longer term the habitat is not affected, because the vegetation recovers from the remained turf.
Medium	Turf is damaged in up to 50% of the area, and the damage recurs every year or every other year. Locally, the damage is severe, because semi-natural grassland species gradually disappear and are replaced by annual and perennial weeds.	After smoothing the land, the bare areas must be covered with grass or hay material rich in seeds, obtained from a similar grassland habitat with favourable conservation status (without wild boar rootings and other damage).
Poor	The turf has been damaged in the entire area of the grassland (less than 10% of the area has been remained), and the damage recurs every year. Habitat is destroyed, since annual damage to the soil surface creates a ploughing effect – the turf is incapable of recovering by itself, the habitat specific plant species disappear, they are replaced by weeds and ecologically flexible grasses or forbs.	Restoration of the entire grassland area is necessary. Grass or hay material rich in seeds, obtained from a similar grassland habitat (not damaged by wild boar or other) must be spread after surface smoothing. Complete recovery is expected after several years or decades, depending on the landscape.
Land smoothing in grassland (after digging or cleaning of ditches and ponds); bulldozing of topsoil; pouring material of foreign origin (sawdust, construction waste)		
Good to poor	Usually the applied substrate is so thick that the previous vegetation is completely destroyed and weed vegetation develops. Habitat is completely destroyed in the poured and smoothed area.	The restoration measures are similar to the creation of semi-natural grassland in arable land. The accumulated eutrophic topsoil and foreign material must be removed.

(continued)

Table 21.10.1 (continued)

Possibilities of restoration	Damage	Restoration
Feeder for game animals		
Medium to poor	In the case of an open feeder, a part of the grassland is covered with the food delivered for the animals at various phases of decomposition, creating a nitrogen-rich environment and causing the replacement of semi-natural grassland species with weeds. A high risk of introduction of invasive plant species. The amount of additional nutrients dispersed around closed or "barrel type" feeders is lower. However, the groundcover is severely trampled, which usually completely destroys habitat characteristic plant species and causes soil eutrophication. The habitat at the feeder or in its vicinity is partially or completely destroyed.	The feeder, as well as all animal food must be removed, including the food that has accumulated and started to decompose. If grassland vegetation has been partially retained, mowing with grass removal could be sufficient to strip nutrients, however, in most affected areas the removal of the eutrophic topsoil and sowing of semi-natural grassland seeds or spreading of hay is necessary.
Ploughing		
Good	Initial ploughing, without further cultivation. Fallow after ploughing. Habitat is destroyed however, a viable seed bank allows its restoration. Restoration is more successful, if the grassland is located in a region rich in grasslands, with no sources of weed seeds around (fields, ex-arable lands, residential areas).	Restoration occurs in the first year after ploughing, if mowing and grass removal or grazing is started immediately. Additional measures are not required, except in cases where the habitat was in unfavourable conservation status before ploughing.
Medium	Ploughing followed by cultivation, fertilisation and sowing of agricultural crops for 1–2 years. Habitat is destroyed, however, it can be restored if soil modification is insignificant and the seed bank remains on grassland margins. Restoration is more successful, if the grassland is situated in a region rich in grasslands, with no sources of weed seeds around (fields, ex-arable lands).	Sowing of habitat specific plant species is required, after processing of the soil – by nutrient removal and weed control. Grassland habitat specific vegetation must be restored in the prepared soil. Habitat restoration is expected no earlier than after 5–10 years. Full restoration will occur after several decades.
Poor	Ploughing followed by cultivation, fertilisation and sowing of agricultural crops for a period that is longer than two years. Habitat is destroyed.	Radical restoration measures must be carried out. Full recovery is expected after several decades.
Fertilisation		
Good	Fertilisation with manure once every 5–10 years, no more than 15–100 kg ha^{-1} of nitrogen depending on habitat type. Habitat is damaged, the cover and abundance of species and total species richness can decrease. However, the fertilisation effect will be short-lasting and the recovery will be successful. In some cases, the deterioration of habitat condition will not occur, even an increase in the diversity of species can be observed, especially in acid poor grasslands that have been extensively managed for decades.	No special measures are required. If appropriate management is implemented, the habitat will recover within a few years.
Medium	Fertilization with manure or fertilisers every year up to 100 kg ha-1 of nitrogen. The habitat is damaged, its conservation status is constantly deteriorating.	Recovery of soil nutrient status by more intensive mowing without fertilisation, introduction of habitat characteristic species is needed. Restoration is expected in several years, or a few decades.
Poor	Fertilisation with mineral fertilisers every year, more than 100 kg ha^{-1} of nitrogen. Habitat is destroyed.	Radical restoration measures are necessary. Full recovery is expected after several decades.

ural grassland species or spreading the previous year's hay from species-rich meadows. The hay contains seeds, which will germinate in the places freed from moss and hamper the further expansion of moss. Commercial grassland seeds should not be sown after harrowing.

21.10 Habitat Restoration and Recreation Immediately After It Has Been Damaged or Destroyed (S. Rūsiņa)

Semi-natural grassland habitat can be destroyed or damaged either by actions that are not directly linked to the management of the grassland (such as building, ploughing, creation of quarries, digging of ponds, construction of forest animal feeders) and incorrect methods of grassland management and use – improvement by fertilisation or drainage, too frequent mowing leading to the development of a lawn vegetation, tourism influences (trampling, fire places, camp sites) (Fig. 21.10.1–21.10.4). In many cases, the habitat of grassland can be restored in the short term (up to five years), however the speed of restoration depends on the intensity of the adverse impact (Table 21.10.1).

The habitat of semi-natural grassland is destroyed when all components of this habitat are lost – vegetation, fauna, soil, necessary environmental conditions and processes. If at least a part of the vegetation or soil in the area is preserved, the habitat can be restored.

Since all semi-natural grassland habitats in Latvia are protected, the destruction of every habitat site must be compensated either by restoring it, or by creating a habitat elsewhere (compensation measures) in order to ensure favourable conservation status of the habitat type.