ESTONIAN SEMI-NATURAL COMMUNITIES

ALVARS and JUNIPER SHRUBS

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Foreword

Semi-natural communities are valuable and species-rich natural ecosystems that have been passed down to us through millennia as a result of the sustainable use of land by our ancestors. In order for Estonia's semi-natural communities and the biodiversity associated with them to be preserved in the future, we must continue grazing, mowing, and other necessary activities to support biodiversity. So here you are holding a guide that gives you an overview of how to best operate in Estonia's alvar pastures. The guide provides an overview of alvar and juniper shrub habitat types, describes the bases for the development and conservation of their species richness, summarizes general guidelines for the most appropriate management of communities, and provides a theoretical basis for the creation of further area-based management plans. The guide is intended for all people and institutions interested in Estonian semi-natural communities and, above all, could be of help to the caretakers of Estonian semi-natural communities and various institutions dealing with nature conservation, agriculture, and sustainable landscape use.

This publication is an updated version of the guide 'Estonian alvars and juniper shrubs. Guide to the maintenance and restoration of communities', commissioned by the Environmental Board in 2011. The latest version includes up-to-date scientific information on the values, maintenance, and restoration of semi-natural communities and a significant increase in maintenance and recovery experience compared to the 2011 edition, especially thanks to the numerous diligent community engaged in the maintenance and restoration of alvars and the large-scale alvar restoration project "LIFE to Alvars"

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Chapter 1

INTRODUCTION

Alvars – what are they?

Alvar pastures are meadow communities with a thin layer of soil (up to 2030 cm) and a few shrubs on limestone or pebbles (hereinafter simply alvars or alvar grasslands). Alvars are semi-natural communities that have developed over the centuries due to human activity. The special environmental conditions, the large natural species pool, and the long-term moderate human impact have created a very species-rich and unique biota in the alvars. The local plant and lichen species are light-loving, small, and tolerate grazing well but are unable to cope with the competition of lusher plants, the layer of plant litter, and bush. The species-rich vegetation also favors other groups of biota, so there are many species of fungi, insects, spiders, and Myriapoda and bird species in alvars. Alvars have unique environmental conditions. Due to the thin layer of soil directly on the limestone, the soil can either dry out completely or be flooded for a short time at different times of the year. There may be frost heaving in winter.

Chapter 1 provides an overview of the content of the handbook and the topics covered. **Chapter 2** provides an overview of the biota of alvars, the backgrounds of the formation of the species richness of alvars, and the more characteristic environmental conditions.

Alvars are sources of important natural benefits or ecosystem services, as holders of the species richness of soil biodiversity, pollinators, natural enemies of pests and other important groups of organisms, mitigating climate change and contributing to tourism, the preservation of cultural heritage, and the maintenance of the diverse landscapes necessary for wellbeing as part of vibrant rural life.

Chapter 3 provides an overview of the important natural resources associated with alvars and their landscape significance.

Distribution, status, and protection of alvars

Alvars are very limited in distribution around the world. In addition to Estonia, alvars can be mainly found only in Sweden on the islands of Öland and Gotland. One-third of the world's alvars are located in Estonia, which is why they need special protection here.

Alvar pastures have probably been grazed in Estonian areas for thousands of years. Back in the 1930s, alvars were widespread in the western and northern parts of Estonia, but their area has decreased by 80% during the last century. In the second half of the 20th century, attempts were made to make excessively species-poor alvars more profitable by afforestation, and areas with thicker soils were used as arable land. Most of the alvars simply overgrew due to lack of grazing.

Due to their biodiversity and global rarity, alvars are a priority habitat type within the NATURA 2000 network of protected areas, being a priority habitat* 6280 type in Annex I of the Habitats "Directive Nordic alvar and Precambrian calcareous flatrocks." The pavement-like limestone surfaces found in alvars by patches are also of primary importance: Habitat type in Annex I of the Habitats Directive * 8240 Limestone pavement. Estonia has a significant share (28%) of all the world's alvars (Eriksson & Rosén, 2008), which is why we have a duty to ensure the preservation of this rare habitat type. Chapter 3 also deals with issues related to the status and protection of alvars.

Maintenance, restoration, and monitoring

In order to ensure the preservation of species-rich alvars in Estonia, it is necessary to graze the still preserved areas and selectively restore the overgrown or forested areas. While approximately 5,600 hectares of alvars were properly maintained in 2019, 11,000 hectares could be maintained to ensure the safe conservation of the community's biodiversity. Appropriate maintenance and restoration techniques are the basis for the conservation and restoration of species richness

and also for ensuring the availability of important ecosystem services. **Chapters 4 and 5** deal with the maintenance of alvars, the needs of different biota groups, and restoration activities suitable for Estonian conditions.

Juniper shrubs in Estonia

In addition to the alvar habitat type, this guide provides an overview of juniper shrubs belonging to habitat type 5130 (Juniperus communis communities on heaths or grasslands with carbonate soils) in Annex I of the Habitats Directive. These are valuable communities on a European scale, but in Estonia, this habitat type has received a lot of attention alongside alvars and meadows overgrown with junipers. The juniper shrubs widespread in Estonia can be broadly divided into juniper shrubs in the former alvars (alvar juniper shrubs) and juniper shrubs that have arisen during the overgrowing of different meadows (Boreal heaths and dry and fresh grasslands) as well as felling areas or fallow fields with junipers (Paal, 2000). Juniper shrubs of primary origin are found to a small extent only in coastal pebble ridges (Paal, 1997). **Chapter 6** provides an overview of the juniper shrub habitat type and its maintenance and restoration.

CHAPTER 2

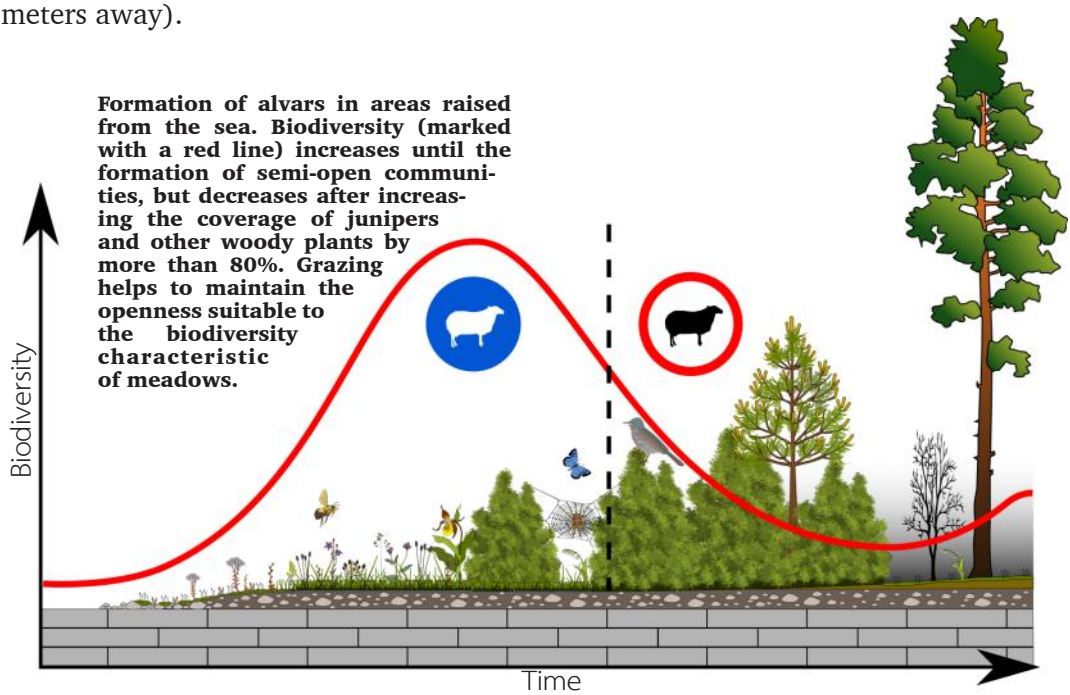
FORMATION, BIOTA, AND ENVIRONMENTAL CONDITIONS OF ALVARS

The alvars, also called juniper pastures, are species-rich biocenosis of a high natural value with a thin layer of soil and limestone tolerant vegetation common in the western and northern part of Estonia. The word 'alvar ' has come to us from Swedish, meaning a limestone substrate without trees, with a thin layer of soil, or completely without a surface covering (Laasimer, 1973). The distribution of alvar plant communities in Estonia is limited to the open areas of the Ordovician or Silurian limestone outcrops, and the thickness of the soil layer is generally less than 20 cm, and more by patches in limestone fissures and pits (Pärtel et al., 1999). In this work, we deal with alvars in the so-called broad sense, and this means that the parent material can be less eroded limestone, calcareous cambisol moraine, as well as gravel and pebbles (Paal, 1997; Zobel, 1984).

The vegetation of alvars in good status is low-growing, unproductive, and diverse, consisting mainly of limestone-tolerant and stress-tolerant plant species. Junipers (*Juniperus communis*) usually grow alone or in groups in the alvars; There are no completely open alvars in Estonia today. In addition to juniper, the shrub layer is also formed by *Frangula alnus*, especially in Muhu and mainland Estonia), *Lonicera xylosteum*, *Rhamnus cathartica*, sometimes also *Viburnum opulus* and others. In wet places, the shrub layer can also be formed of *Dasiphora fruticosa*, which is very common in Öland's alvars, but in Estonia, it occurs only in the alvars of Keila area. The tree layer is mostly absent in grazed alvars or consists of individual specimens or tree groves. The most common trees are *Pinus sylvestris, Sorbus intermedia, Sorbus aucuparia, Betula pendula, Acer platanoides, Quercus robur* and others. On non-grazed alvars with richer soils, the pines are the trees that start growing the fastest, especially if the pine forests or individual trees that are the sources of the seeds are close (approx. up to 100 meters away).

Formation of alvars

There are many ways of formation of alvar. Part of the alvar plant communities are the so-called primary alvar areas; the stunted vegetation characteristic of alvar areas has developed after the ice age on the pebbly and rocky areas that rose from the sea and on exposed limestone slabs, which then remained open due to human influence (grazing) (Lippmaa, 1935; Paal, 1997; Zobel, 1984). There are often only a few centimeters of soil in such alvar areas, if even that.



Formation of alvars in areas raised from the sea. Biodiversity (marked with a red line) increases until the formation of semi-open communities, but decreases after increasing the coverage of junipers and other woody plants by more than 80%. Grazing helps to maintain the openness suitable to the biodiversity characteristic of meadows.

However, most of Estonia's alvars have developed secondarily through the removal of trees and bushes from the forest vegetation and by further grazing. Alvars have also appeared on ancient fields (Laasimer, 1965; Pärtel, 2004). The alvar areas with such formation have thicker soil (up to 2030 cm), and before they could be turned into pastures, there could be quite luminous alvar forests with abundant undergrowth in their place. The old alvar forests with a natural structure, which have survived to this day, are quite bright and sparse due to the varying bedrock (limestone cracks, depressions) and, in some places, a very thin layer of soil, and they contain a large part of the plant species characteristic of open alvars. This history of formation means that the survival of alvars is also closely linked to human activities, especially grazing. Historically, sheep and horses were mostly grazed on the alvars (Laasimer, 1965), but there are also pictures in the archives that show that the alvar areas have also been used for grazing cattle and even as hayfields. For centuries, alvar pastures have been an integral part of the traditional village landscape of the western and northern regions of Estonia.

Alvars and all other Estonian meadow communities are semi-natural communities, which means that their formation and preservation are closely related to human activities in landscapes. However, man is, above all, a shaper of environmental conditions and a contributor to the spread of species - the fauna of alvars and all other

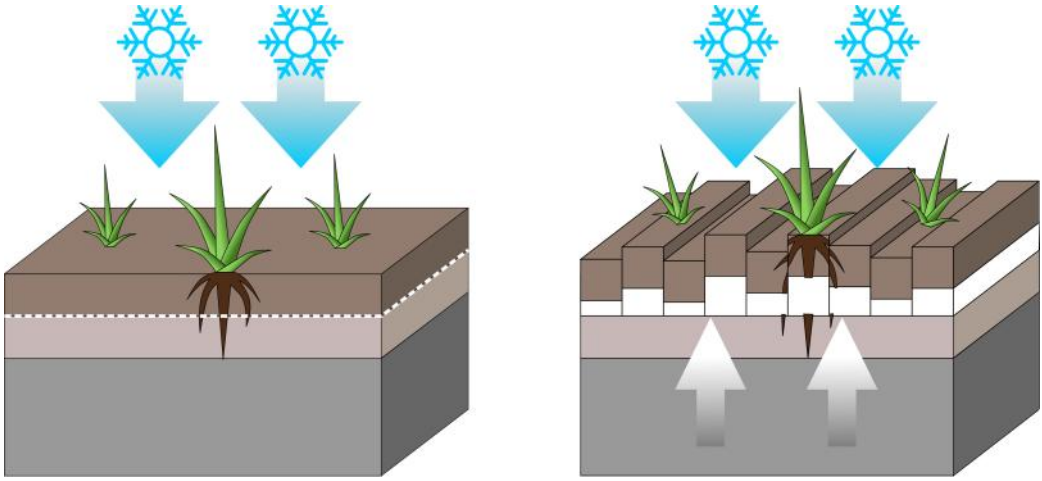
Alvars were mostly grazed in Estonia. Examples from the collections of the Estonian National Museum, the National Archives, and the Saaremaa Museum. ERM Fk 768:1; SMF 4126 132; EFA.554.22721; ERM Fk 214:188.

In some areas, winter hay also had to be collected from alvars. A mowed alvar and a grazed alvar side by side in Kostivere, Northern Estonia, a meadow on the right side of the stone fence, a pasture on the left side. ERM Fk 1523:2587.

semi-natural communities, the plants, and animals there are native European species that were here even before the last ice age and even when there were no humans in Europe (Willerslev et al., 2014). Thus, in the last hundreds of thousands of years, before the wide spread of humans, naturally large herbivores (megaherbivores) were the important shapers of European landscapes; most of them are now extinct, domesticated by humans, or extremely rare (e.g., woolly mammoth, European rhinoceros, European hippopotamus, Eurasian wild horse or tarpan, aurochs, European bison or wisent, giant deer, European buffalo, wildebeest, etc.) (Pärtel et al., 2005; Svenning, 2002). These large herbivores kept many areas open or semi-open and laid the foundations for the high species richness of the meadow communities. Resettling wild herbivores in our landscapes would also benefit alvars.

Environmental conditions in the alvars

Typical soils of alvar grasslands are arenic cambisols or gley alvars (Paal, 1997). Podzol horizon and illuvial horizon are absent, and the humus layer is immediately followed by parent material. The soil layer with an alkaline reaction in alvars is extremely rich in nutrients, containing significantly more organic matter, total nitrogen, and also macronutrients compared to other ecosystems and fields (Ca, K, Mg, P, see table on page 18). However, the soil is very thin, on average 10.4 (± 4.4) cm in Estonian areas, which is why plants growing in alvar areas tend to suffer from a lack of nutrients (Pärtel, 2004). Thus, the species that are frequent in alvars are shorter and have a significantly lower demand for soil nutrients



In winter, the wind often blows snow off the open alvars, and the cold creates the cold heavings characteristic of the Arctic. Cold heavings occur when ice crystals raise the soil particles when the water in the ground freezes, damaging the plant roots and creating a free soil surface.

than the species that occur on alvars less often. Soil conditions in alvars are heterogeneous - some alvar areas have a very thin layer of soil and are therefore characterized by non-vegetated areas where the subsoil is exposed; in other alvars, the thickness of the soil layer may be more than a few dozens of centimeters. In summer, alvars with thin soil are characterized by complete drying out of the soil by wind and sun. Few precipitations flow from the ground between the cracks in the subsoil, causing long periods of dryness (Rosén, 1982) and forcing many plant species to stop growing until the autumn rains. Such a rest break is characteristic of the steppes to the south of Estonia, where quite a few of the alvar species come from. In winter, the thin layer of soil on alvars often freezes to the bottom and melts again with a thaw. This alternation of freeze-thaw causes the alvar soil to move, and cold heavings occur, which tear the roots of the plants (Akkel, 1967; Pärtel et al., 1999). Moving soil causes local disturbances and free soil surface, which in turn is a favorable ground for seed regeneration. Such harsh conditions also prevail in the tundra and high mountains, from which another set of species

Region	Soil depth (cm)±SD	Number of areas (soil depth)	OA (%) ± SD	Number of areas (OA)	N (%) ± SD	Number of areas (N)	pH±SD	Number of areas (pH)
Saaremaa	10 (±3.4)	103	11.2 (±5.5)	90	0.6 (±0.4)	39	6.7 (±0.4)	82
Muhu	9.5 (±3.4)	37	13.2 (±4.1)	36	0.6 (±0.2)	11	6.9 (±0.1)	34
Hiiumaa	8(±3.7)	16	17.2 (±14.8)	16	1.2	1	6.7 (±0.3)	16
West Estonia	14.5 (±5.8)	18	13.2 (±4.2)	18	0.5 (±0.1)	4	7.1 (±0.2)	18
Pärnu County	12.9 (±3.3)	6	13.7 (±4.3)	7	0.9 (±0.2)	2	6.9 (±0.3)	7
Northwest Estonia	10.4 (±6.3)	15	27 (±1.4)	15	1.6 (±0.5)	7	6.5 (±0.5)	15
North Estonia	15.7 (±5.1)	11	17.1 (±5.5)	11	0.8 (±0.4)	6	6.5 (±0.4)	11
Average	**10.4 (±4.4)**	**206**	**14 (±8.1)**	**193**	**0.7 (±0.5)**	**70**	**6.8 (±0.4)**	**183**

Polygons caused by frost heaving on thin-soiled alvar.

characteristic of alvars originate from (Laasimer, 1965).

On alvars with less eroded and non-eroded bedrock (limestone pavements, (Zobel, 1984)), the limestone does not allow water to pass through, and during periods of more rainfall, temporary excessively wet areas may form on otherwise dry alvars.

Biodiversity in alvars

Moderate grazing pressure, diverse environmental conditions, and a large species pool (i.e., a large number of species for which conditions characteristic to alvars are evolutionarily suitable) have allowed the development of a very species-rich biota on alvars. In terms of the small-scale species richness of vascular plants, open alvar pastures rank second in Estonia after wooded meadows – a maximum of 49 vascular plant species have been found growing together on one square meter of an alvar (described by Meelis Pärtel and Rein Kalamees in 1994 from an area by now completely overgrown in Kahtla alvar of East Saaremaa, approx. 58.4029 N, 22.9885 E) (Helm, 2001). However, 21 species of vascular plants (Väkra alvar in East-Saaremaa, 58.4555 N, 22.84203 E, described in 2013) have been found in a palm-sized patch measuring 10x10 cm, which is quite comparable in size to the world record result in Laelatu wooded meadow, where 25 vascular plants have been found in the area of thee same size. 2012). The vegetation of alvars in good status is low-growing, unproductive, and diverse, consisting mainly of limestone-tolerant and stress-tolerant plant species (Kasari et al., 2013).

The biota of alvars, especially the plant communities of alvars, has now been studied in Estonia quite thoroughly. Knowledge from previous studies on alvar vascular plants (Gazol et al., 2012; Helm et al., 2007; Kasari et al., 2016, 2013; Pärtel et al., 1999a; Pärtel

P (mg/kg) ± SD	Number of areas (P)	K (mg/kg) ± SD	Number of areas (K)	Ca (mg/kg) ± SD	Number of areas (Ca)	Mg (mg/kg) ± SD	Number of areas (Mg)
20.2 (±24.3)	82	163.1 (±84.2)	82	3052 (±1179.4)	82	441.8 (±335.8)	82
24.5 (±14.7)	34	182.2 (±60.6)	34	2996.8 (±604.1)	34	912.5 (±317.5)	34
22.8 (±28.2)	16	107.6 (±93.1)	16	5030.5 (±2295.8)	16	103.8 (±81.4)	16
25.3 (±13.9)	18	180 (±51.5)	9	2790 (±512.1)	9	933 (±135.6)	9
14.3 (±13.6)	7	323.7 (±48.6)	5	3054.6 (±741.3)	5	1141.6 (±211.2)	5
77.2 (±64.1)	15	342 (±155.6)	7	8417.4 (±2333.6)	7	159.5 (±79.8)	7
255.5 (±109.3)	11	275.1 (±147.7)	6	4926.8 (±1639)	6	183.4 (±61.2)	6
40.5 (±68)	**183**	**179.9 (±99.5)**	**159**	**3537.6 (±1790.9)**	**159**	**537.3 (±410)**	**159**

Specialists and generalists

Each species has slightly different habitat requirements, but depending on the conditions to which the species have adapted, a distinction is made between habitat specialists and generalists.

Habitat specialists have only adapted to the environmental conditions of their habitat and are suitable to live with other species-specific to that habitat. However, habitat generalists may live in more habitats and are more widespread in landscapes. Unlike generalists, however, specialists have no other suitable habitat. Often, habitat specialists are associated with other species in the same community through complex relationships. Thus, for example, the large blue in the Estonian alvars requires the presence of both Thymus serpyllum and certain species of ants (mainly the *Myrmica sabuleti*).

A large blue on Thymus serpyllum. Photo: Anu Tiitsaar

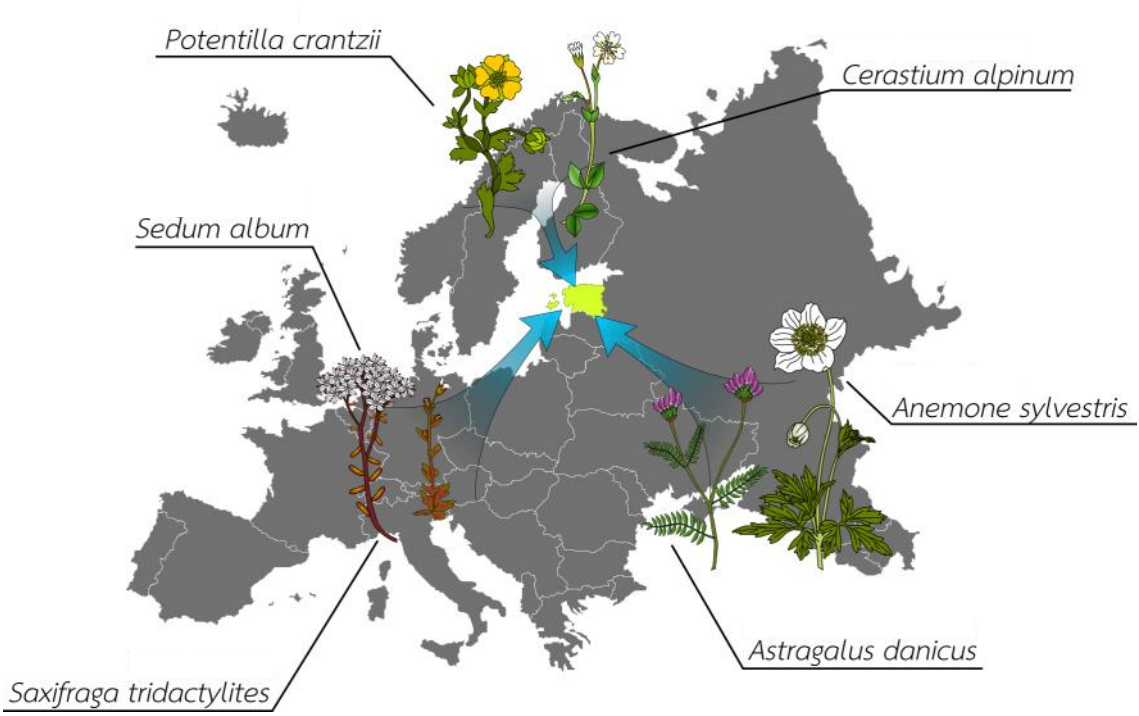
and Helm, 2007; Saar et al., 2012; Takkis et al., 2013 et al.), Bryozoans (Kupper, 2007), lichens (Kolnes, 2006; Leppik et al., 2015, 2013), butterflies (Sang et al., 2010; Tiitsaar and Talgre, 2015), bumblebees (Sõber et al., 2015) and orchid mycorrhizal fungi (Oja et al., 2015). From 2014-2019, a lot of new information about Estonian alvar fauna was gathered from the Estonian alvar restoration project 'LIFE to Alvars' and in the framework of EIC study 'The effect of large-scale restoration of alvars on biodiversity, capturing the status before restoration,' conducted in parallel with it, where, in addition to vascular plants, lichens, mosses, butterflies and bumblebees, the biodiversity of hitherto little-known groups of organisms was examined, including birds, green-eyed flower bees, ground spiders, ground beetles, millipedes, arbuscular mycorrhizal and ectomycorrhizal fungi (Helm, 2018, 2017).

Biota of alvars

Vascular plants

The biota of alvars is a unique mixture of undemanding species from many different areas. Here are plant species from the steppes of southern Siberia and south-eastern Europe

The biota of alvars is a unique mixture of undemanding species from many different areas. For example, there are species from the steppes of south-eastern Europe and south-west Asia, from the mountainous areas of southern Europe, but also from the tundra and mountain meadows of northern Europe.



(*Artemisia rupestris, Potentilla tabernaemontanii, Astragalus danicus, Trifolium montanum, Carlina vulgaris, Asperula tinctoria, Anemone sylvestris*), from the subarctic of Northern Europe (*Cerastium alpinum, Poa alpina, Potentilla crantzii*) and Northwest European maritime climate (*Saxifraga tridactylites, Sedum album* et al.) (Helm, 2001; Laasimer, 1965; Rosén, 1982).

Moss and lichens

Dry alvars with sparse grass layers are especially suitable habitats for mosses and lichens growing on the ground (Randlane, 2004; Kupper, 2007). When grazing in the wild alvars ceases, the grass layer becomes denser, and these species disappear from the communities. There are 142 species of mosses (28% of the Estonian bryoflora) on alvars, 24 of which are listed in the Estonian Red Data Book (Kupper, 2007). Among the protected moss species, the moss species of protection category II, *Porella cordaeana, Brachythecium turgidum, Encalyptamutica*, and *Tortella rigens* have been found on alvars. The latter two are highly dependent on open alvar conditions and are also listed among Annex II species of the EU Habitats Directive. The most common moss species in open alvars are *Ditrichum flexicaule, Hypnum cupressiforme, Homalothecium lutescens*, and *Abietinella abietina*. In the areas overgrown with junipers, *Camptothecium lutescens, Hypnum cupressiforme, Abietinella abietina* are more common, but there are also forest species H*ylocomium splendens*, *Dicranum scoparium*, and *Rhytidiadelphus triquetrus* (Helm, 2017).

263 species of lichens have been registered on alvars, which make up 26% of the Estonian lichen flora (Kolnes, 2006). These also include many rare species and ten protected species.

The thin-soiled areas are characterized by rich moss and lichen flora.

Common ringed plover on a restored alvar in Kassari, Hiiumaa.
Photo by Liis Keerberg.

Birds

Alvars are very pleasant places for bird biota. Alauda arvensis, Lullula arborea, Saxicola rubetra, Emberiza citrinella, Anthus pratensis, Vanellus vanellus, and Numenius arquata find a suitable place for nesting in open alvars, and fresher alvars suitable habitats for Gallinago gallinago and Tringa totanus, among others. Areas more covered in junipers are nesting places for Sylvia curruca, Sylvia communis, Sylvia nisoria, Lanius collurio, Carpodacus erythrinus, Prunella modularis, Phylloscopus trochilus, Hippolais icterina, Carduelis cannabina and Emberiza citrinella, but also Parus major, Fringilla coelebs, Turdus merula, or Carduelis flammea, a more unique nester who prefers coastal juniper shrubs. Based on a bird survey conducted on alvars (Marja & Keerberg 2017), alvar areas are rich in birds, where many protected and less common bird species prefer open areas. Thus, in addition to the aforementioned, other protected bird species, such as the Numenius arquata, Jynx torquilla, Ficedula parva, and Turdus viscivorus, have been found as nesters in the alvars (Marja & Keerberg, 2019).

Invertebrates of alvars

Invertebrates have not been studied much on alvars, but in recent years information on different species groups (butterflies, bumblebees, arachnids, ground beetles) has begun to accumulate. The insect community of the alvars has been compared with the steppe areas to the south of us (Talvi, 2004).

Butterflies

Compared to other ecosystems, alvars are home to a remarkably large number of specialized and protected species of butterflies (Tiitsaar & Talgre, 2015). 68 species of butterflies have been registered on alvars (Sang et al., 2010), which makes up almost 70% of the entire permanent butterfly fauna of Estonia. Many species of butterflies are rare or non-existent in other communities, such as *Erynnis tage, Hesperia comma, Phengaris arion, Melitaea aurelia, Melitaea cinxia, Melitaea Argynnis niobe*,

The most numerous bird species on alvars are at different overgrowth levels (Marja & Keerberg, 2017). Open areas and restored areas are characterized by different protected species compared to overgrown or forested areas.

Habitat	The most numerous bird species (more numerous than protected species in parentheses)
Open alvar	yellowhammer, willow warbler, lesser whitethroat, Eurasian skylark, common rosefinch (red-backed shrike, barred warbler)
Restored alvar	willow warbler, yellowhammer, common chaffinch, Eurasian skylark, lesser whitethroat, woodlark (Eurasian curlew, common redshank)
Overgrown alvar (juniper shrub)	lesser whitethroat, yellowhammer, willow warbler, common rosefinch, common whitethroat, dunnock
Pine forest established on the alvar	willow warbler, common chaffinch, common chiffchaff, common blackbird, song thrush
A mixed stand formed on the alvar	willow warbler, common chaffinch, common chiffchaff, song thrush, common blackbird, European robin

ALVAR ORCHIDS

Anacamptis pyramidalis

Cypripedium calceolus

Dactylorhiza fuchsii

(Photo: Triin Reitalu)

Dactylorhiza incarnata

Epipactis atrorubens

Gymnadenia conopsea

Herminium monorchis

Ophrys insectifera

Orchis militaris

Orchis ustulata

Orchis mascula

Platanthera bifolia

Platanthera chlorantha

Orchis morio

(Photo: Triin Reitalu)

Listera ovata

(Photo: Wikimedia Commons)

The rattle grasshopper *Psophus stridulus* is a relative of the grasshoppers, and its name gets a clear meaning when he takes off in front of the walker's feet accompanied by a loud rattle, flashing its bright red hind wings. When it lands, the rattle subsides, the hind wings are folded, and the camouflage of the insect makes it almost imperceptible. Photo by kOchstudiO

The difficult life course of the *Phengaris arion* is closely linked to the food plant Breckland thyme present on alvars and to the species of *Lasius alenius* inhabiting the maintained areas.

Agelenidae, whose funnel-shaped nets are well recognizable on dry alvars.

Hyponephele lycaon and *Hipparchia semele*. According to Tiitsaar and Talgre (2015), these species are also suitable as indicators of the good status of alvars due to their limited distribution and specialization. Fresh alvars are home to the *Coenonympha hero* and the *Phengaris arion*. Isolated cases of *Eemhydryas aurinia, Euphydryas maturna*, and *Lopinga achine* have been reported. All of them are protected species of protection category III in Estonia.

Spiders and insects

The arachnid fauna of alvars was studied by Asta Vilbaste in the 1970s (Vilbaste, 1982) and by Mart Meriste in 2015-2016 (Meriste, 2017) and 2019-2020 (data not published). As regards spiders, alvars are very rich in species. In a two-summer study, Meriste (2017) identified ground spiders in 155 species on alvars, which make up 30% of the Estonian spider fauna. Many of the species found are rare elsewhere and rare across Europe. In addition to the rich spider fauna, the alvar areas are also the habitat for ground beetles (e.g., *Brachynus crepitans*) which are very endangered all over Europe and are specialized in dry, calcareous habitats, as well as Aculeata Hymenoptera (oral information from Norbertas Noreika, Villu Soon, Peeter Tarlap, data published in PlutoFi).

As for bumblebees, probably all Estonian

are represented on alvars. In the study conducted in 2015-2016, 23 species of bumblebees were identified on alvars (see Helm 2017), and the biodiversity and abundance of bumblebees were most closely related to the occurrence of flowers. The most preferred food plants for bumblebees in alvars were Anthyllis, Thymus serpyllum, Veronica spicata, Centaurea jacea, Trifolium medium, Trifolium pratense, Inula salicina, Echium vulgare, Vicia cracca, etc.

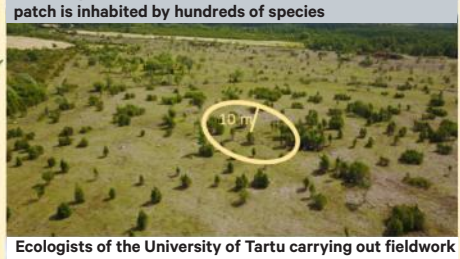
The abundance of alvar species is significant. Over 4,500 species were found in 35 research areas as part of the study "Impact of large-scale restoration of alvars on biodiversity, capturing the state before restoration," carried out with the support of the Environment Investments Center (Helm, 2017)

In one observation area with a radius of 10 m, the following have been found in the open alvars of Estonia:

- **79** species of vascular plants (a total of **335** species in 35 observation areas)
- **30** species of mosses (**121** in total)
- **60** species of lichens (**181** in total)
- **12** species of nesting birds (**43** in total).
- **11** species of bumblebees and **29** species of other hymenoptera (**152** species in total)
- **15** types of butterflies (**68** in total)
- **25** species of spiders (**154** in total)
- **10** species of Carabids (**61** in total)
- **9** species of millipedes (**31** in total)
- **72** virtual taxa of Glomeromycota (**149** in total)
- **570** virtual taxa of other fungi (total **3267**)

A total of **1,101** visually determined species were found in 35 research areas of alvars (including 15 new species for Estonia) and **3416** taxa determined by DNA analysis (including five taxa new to the world) (Helm et al., 2017)

An example of the location of an observation area – this patch is inhabited by hundreds of species



Ecologists of the University of Tartu carrying out fieldwork at alvar observation areas

Different types of al–vars

Based on the species composition of the vegetation cover, alvars are divided into three to seven types, which also differ according to the moisture conditions and the thickness of the soil layer.

Based on the habitat types of the Estonian vegetation (Paal, 1997), the alvars are divided into two habitat types on the basis of moisture conditions: dry alvar grassland and fresh alvar grassland, in which different plant communities are distinguished, the most common of which is the community of Filipendula vulgaris - Trifolium montanum.

In Estonia, a classification of alvars has been compiled on the basis of mathematical analyzes (Pärtel et al., 1999), where broadly, three types of alvars have been distinguished according to moisture conditions and soil thickness. The different types of alvars in Estonia are in good correspondence with the Swedish classification units, and the same names are used: Avenetum, Festucetum, and Molienetum type (Albertson, 1950). These names describe alvars with three different environmental conditions:

The **Avenetum type** is a dry, alvar with richer soil, the Festucetum type is dry and thin-soiled, and the **Molienetum type** is moist or occasionally wet. The types are named after a more characteristic plant species, the Avenetum-type alvar is named after *Helictotrichon pratense*, formerly synonymous with *Avenula pratensis*. The Festucetum-type alvar is named after the sheep's fescue (*Festuca ovina*) common in such alvars, and the Molinietum-type is named after purple moor-grass

Division of alvars into habitat types and plant communities on the basis of Paal 1997 classification of habitat types:

2. Meadow vegetation - Grasslands
    2.1. Type class: Dry and fresh grasslands
        2.1.1. Alvar type group: Alvar grasslands
            2.1.1.1. Dry alvar grassland site type
                1. Thymus serpyllum - Ditrichum flexicaule community
                2. Arrhenatheretum community
                3. Trifolio montani – Filipenduletum vulgaris community
                4. Helictotricho – Callunetum community
            2.1.1.2. Fresh alvar grassland site type
                1. Sesleria- Carex flacca community
                2. Dasiphora fruticosa - Sesleria community
                3. Molinia caerulea- sesleria community
                4. Deschampsia cespitosa community

(*Molinia caerulea*) preferring moister places.

The different types are described in more detail here, as well as recommendations have been provided for maintenance by habitat type. It should be borne in mind that these recommendations are a general guide to the optimal management of alvars. Local conditions and needs (e.g., presence of protected species, etc.) must also be taken into account in each individual area. Read more about maintenance in Chapter 4.

Dry thick soiled, or Avenetum type alvars

This type is named after the characteristic species *Helictotrichon pratense*, synonymous with *Avenula pratensis*. The Avenetum type is further divided into three subtypes: cambisol alvars, heath alvars, and pebble alvars.

Cambisol alvars

Characterization. With the highest species richness and thicker soil (520, rarely up to 30 cm) among alvars, it spreads mainly on cambisol and pebbles in the open areas of the Silurian and Ordovician basins.

According to Paal's (1997) classification of habitat types, this includes alvars of the alvar grassland habitat type (code 2.1.1.1.) And, above all, Trifolio montani – Filipenduletum vulgaris communities).

Distribution. The most widespread in Estonia, present on all islands and in Western Estonia, mostly in East-Saaremaa and Muhu Island. It is also possible to distinguish the Northern Estonian version of the cambisol alvar.

Maintained Avenetum-type alvar. Viita alvar in Matsalu National Park.

The northern Estonian version of Avenetum-type alvars (Võle alvar).

Compared to other cambisol alvars, it is characterized by higher productivity and almost 10x higher phosphorus content in the soil, which may be due to the characteristics of the subsoil (mostly Ordovician deposits in Lasnamäe and Kunda stage) as well as long-term phosphorus pollution from agriculture or industry.

Characteristic species. In addition to the Helictotrichon pratense, cambisol alvars are also characterized by *Filipendula vulgaris, Trifolium montanum, Anthyllis vulneraria, Briza media, Pilosella officinarum, Cirsium acaule, Galium verum, Sesleria caerulea, Astragalus danicus, Potentilla neumanniana, Carlina vulgaris, Festuca ovina, Alchemilla*, on ant hills *Thymus serpyllum*, occasionally *Helianthemum nummularium*, etc.

Northern Estonian cambisol alvars lack several species characteristic of Western Estonian cambisol alvars (for example, Trifolium montanu, Potentilla neumanniana, Carlina, etc.) see Pärtel et al. 1999 Tabel 1), but there is more *Carex spicata, Lathyrus pratensis, Trifolium repens, Veronica chamaedrys, Rumex acetosa*.

The most remarkable areas in Estonia. The most species-rich cambisol alvar is located in Muhu and East-Saaremaa, but there are beautiful examples everywhere in Saaremaa, Hiiumaa, and in the western part of the continent (Hanila, Pivarootsi, Kurese). Significant alvars in Northern Estonia are Lasnamäe, Maardu, Kostivere, Haavakannu, Kiiu, Palmse, Vihula, Kunda, Lüganuse,

Alvars around Toila.

Maintenance-related. It is the highest species richness community type and also the most dependent type depending on careful grazing. With appropriate grazing, such communities become increasingly species-rich; however, when grazing stops, they start to overgrow with junipers quite quickly. In order to maintain/restore the traditional species composition of alvars, the optimal number of sheep is 1.6 to 3.5 sheep per hectare (0.20.5 livestock units per hectare, Saar 1996). As thicker soiled and well-turfed alvars are quite tolerant of grazing, a higher grazing load could be tested on more productive cambisol alvars depending on the characteristics of the area, up to 1 livestock unit per hectare (up to 6 sheep per hectare) (Laasimer 1975, Rosén 1982). Approximately 100300 g/m2 (10003000 kg/ha) of the dry weight of undergrowth biomass production in Avenetum-type alvars has been measured, varying from year to year and in different areas (Saar 1996, Rosén 1982). The productivity of the areas is higher in Northern Estonia than in Western Estonia and the islands.

It is also important to monitor the status of the community during grazing (to avoid long-term over- or under-grazing) and to remove excess juniper and deciduous shrubs and young trees at least every five years. It is very useful to move livestock between different areas and, if possible, to keep different types of livestock at the same time or to vary the species from year to year. With a higher grazing load, annual breaks in grazing (for example, every fourth year) may be taken,

A dry alvar in good status is characterized by a rich and flowering meadow turf.

or one can direct the grazing load within the area with the help of paddocks.

In grazing areas with high production (higher biomass, knee-high grass layer) in Northern Estonia, the grazing load could be about one livestock unit per hectare. If the grazing load is low, mowing can be used to improve the status of the community during the early years of maintenance and certainly the removal of mowed biomass from circulation. It may be useful to combine mowing and grazing and, if necessary, to remove juniper and deciduous shrubs and young trees.

Heath alvar in Saaremaa on the neck of the Eeriksaare peninsula in Vilsandi National Park.

Heath alvar type plant community at Sõrve peninsula on Vesitükimaa limited conservation area. In the foreground Pulsatilla pratensis growing in sandy areas.

Heath alvars

Characterization. Dry sandy areas in the cambisol moraines, often on the sea side sand ridges, waters often mixed with the cambisol. A rare habitat type that is a transitional stage between alvars and heaths.

According to the classification of habitat types Paal (1997), heath alvars belong to the Helictotricho – Callunetum community, which is distinguished under the dry alvar grassland habitat type alvars (code 2.1.1.1.).

Distribution. Western Saaremaa, Hiiumaa, the western part of the continent.

Characteristic species. Characteristic species: *Helictotrichon pratense, Calluna vulgaris, Arenaria serpyllifolia, Ranunculus bulbosus, Carex caryophyllea, Agrostis vinealis*, but also *Festuca ovina, Antennaria dioica, Sedum acre, Anthyllis vulneraria, Thymus serpyllum*. Many different species of moss are fairly rich in mushrooms.

Maintenance-related. The grazing load could be lower than that on cambisol

A community formed on pebble walls in Saaremaa on the Tagamõisa peninsula in the Tagamõisa limited conservation area.

alvars. In the absence of grazing and maintenance, species richness decreases, and areas become overgrown. Due to the thinner turf, grazing of cattle in such communities could be avoided.

Pebble alvars

Characterization. Thin soiled alvar communities form on dry pebbles. Occurs in areas where vegetation has developed on pebbles, often, thin soil and vegetation cannot yet cover the rubble and pebbles. Such a community is thought to be the first stage of succession in the areas emerging from the sea, and they are expected to develop into cambisol alvar type alvars. As a characteristic feature, the soil retains a higher than normal humus content (even more than 20%). In the absence of maintenance, a dense bush cover with juniper, mountain currant or other shrub species can also form. According to the classification of habitat types Paal (1997), this includes the high Arrhenatherum community from under the alvars of dry alvar grassland habitat type.

Distribution. In Vilsandi, on the shores of the Väinameri, in Saaremaa, Hiiumaa, in Western Estonia.

Characteristic species. *Arrhenatherium elatius, Galium verum, Linaria vulgaris, Scabiosa columbaria, Sedum acre, Geranium robertianum, Sagina nodosa, Rumex acetosa, Silene nutans, Medicago lupulina, Festuca ovina*

Maintenance-related. It is not necessary to organize grazing in separate areas of this type, nor is it possible due to the scarcity of biomass. However, if the pebble ridges are left next to the grazed area, there is no reason to exclude them from the pasture. Grazing helps to speed up the development of cambisol alvar and the spread of species to the area. Despite the scarce soil, primary (natural) juniper shrubs can also form on pebbly coastal ridges (see Chapter "Juniper shrubs" below).

A pebble alvar was restored from a planted pine forest and dense juniper shrub in 2017 in Kassari, in Kassari landscape protection area of Kassari bay. In the foreground Galium verum, Thymus serpyllum, Campanula rotundifolia.

Dry, thin soiled Festucetum type alvars

A representative of the classical Festucetum type, one of the most representative alvars in Estonia, Lõu alvar in Kaugatoma Lõu landscape protection area on Sõrve peninsula.

Characterization. Very dry and thin-soiled (<5 cm) alvars areas, where there may be vegetation-free but soil-covered patches caused by cold heavings, as well as surfaces of yellowish alvars (patches of yellowish alvar with low vegetation plateau belong to Natura 2000 habitat type 8240 - Limestone pavements). The species richness is lower than that of the Avenetum type, but the Festucetum-type alvar grasslands represent an extremely rare plant community and are a habitat to a number of plant species that are geographically rare and bordering the area and are therefore of great nature conservation importance. This type

A sheep maintaining for a Festucetum-type Sarve alvar in Sarve landscape protection area in Hiiumaa.

is named after a characteristic species *Festuca ovina*. The vegetation has a summer rest period, as the soil dries out all the way to the bottom in summer. Cold heavings occur in the spring. According to Paal (1997) classification of habitat types, this includes the communities of the dry alvar grassland habitat (code 2.1.1.1.) Thymus serpyllum - Ditrichum flexicaule.

Distribution. It occurs in Estonia in the western part of Saaremaa and in Hiiumaa.

Characteristic species. In addition to *Festuca ovina*, the characteristic species are also *Sedum album, Allium schoenoprasum, Crepis tectorum, Artemisia campestris, Artemisia rupestris, Sedum acre, Sagina nodosa, Acinos arvensis* and others. There are many mosses and lichens.

The most remarkable areas in Estonia. Lõu alvar at Sõrve peninsula, Atla region alvars in Saaremaa, Sarve alvar in Hiiumaa.

Maintenance related. Festucetum areas have a very low biomass production, estimated at only 2060 g/m 2(200600 kg/ha) (Krall et al. 1980), and these areas have not been highly valued as pastures. These areas are suitable for low-density grazing of sheep, especially if they are located in a larger landscape with different habitat types. It is believed that maintaining heavier animals can have a negative effect on such areas, leading to the destruction of delicate meadow turf and the invasion of nitrophilic weeds (Krall et al. 1980). However, cattle are quite common on this type alvars on the island of Öland in Sweden, and there is no negative experience there. However, overgrazing must be avoided. As the habitat type is relatively rare, care must be taken to ensure that gathering places of livestock, such as drinking places or shelters, are not located on these. Estonian

Festucetum-type areas are similar to the Great Alvar of Öland; therefore, the grazing load of one sheep per 24 hectares proposed for Öland's alvar areas can be applied. In drier summers, grazing may not be possible at all. The effects of grazing on vascular plants as well as on mosses and lichens could also be monitored annually for this type of alvars. Despite the thin soil, such areas are also overgrowing, so even with little grazing (or no grazing), juniper removal must be carried out every five years, and care must be taken to ensure that juniper coverage does not exceed 30%. Restoration of such areas could rather be carried out during wet weather (autumn-winter), and an attempt should be made to avoid excessive damage to mosses and lichens and vascular plants in areas that are still open during restoration work.

Dry thin-soiled Festucetum-type alvar in Atla village in Saaremaa with exposed limestone pavement. It can be seen from the pictures that despite the thin soil, this type of alvars overgrows gradually.

Occasionally wet or Molinietum–type alvars

Characterization Fresh and occasionally wet alvars with thicker soil. (Paal 1997 code 2112). These types of communities occasionally occur in areas of stagnant upper water and in kettles or flat depressions where the upper water stands for a long time and drains are impeded. The thickness of the soil layer is 520 cm. The species richness is not lower than that of cambisol alvars, but there are often a variety of orchids and other species of declining numbers (e.g., *Primula farinosa*). The proportion of grasses in the vegetation is higher, and the productivity is relatively high compared to other alvar types. The community types dominated by *Sesleria caerulea* and *Molinia caerulea* can be well distinguished. In addition to juniper, depending on the site-specific environmental conditions, they can also overgrow with hazel, frangula, Scandinavian cotoneaster, ash, and mountain currant. In general, however, fresh alvars grow much more slowly than dry thick soiled cambisol alvars, which is why relatively more of them have been preserved. Although overgrowth is slower, upon the cessation of grazing in such areas, an accumulation of biodiversity-depleting layer of plant litter emerges, which will prevent seed regeneration.

A fresh alvar with Ophrys insectifera, Sesleria caerulea, Carex nigra in Sarve landscape protection area in Aruküla, Hiiumaa.

According to the classification of Paal (1997) habitat types, the communities of the fresh meadow habitat type (code 2.1.1.2.) belong here: sesleria - Carex flacca community, Molinia caerulea - sesleria community, Dasiphora fruticosa - sesleria community (only in the area of Harku, Klooga, and Keila).

Distribution. Distributed mainly in temporarily fresh areas in Northern Estonia and the western islands. Near Keila there are fresh alvar communities extremely rare in Estonia, with the dominant shrub species being *Potentilla fruticosa*.

Characteristic species. Typical vascular plant species are *Molinia caerulea*, which has also given the name to the community type, *Sesleria caerulea, Carex panicea,*

Carex flacca, Galium boreale, Potentilla erecta, Carex nigra, Inula salicina etc. *Molinia caerulea*, has also given the community type its name), *Sesleria caerulea, Carex flacca, Carex panicea, Galium boreale, Potentilla erecta, Carex nigra, Inula salicina* etc.

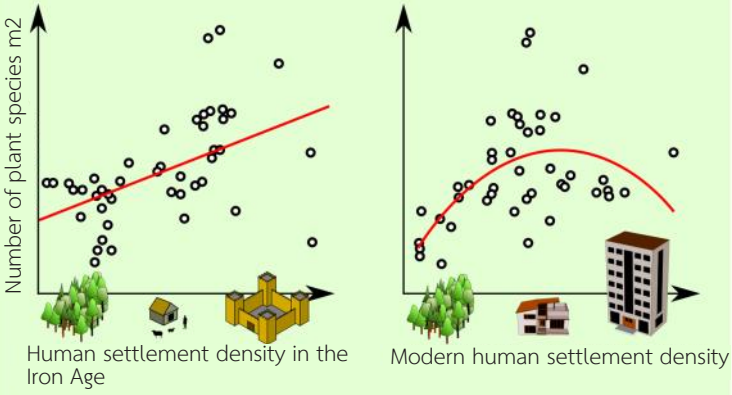
Maintenance related. Suitable for grazing and area maintenance, the same principles apply as for Avenetum type cambisol alvars (see above).

Flooded in spring, or occasionally excessively wet alvar with Primula farinosa and Pinguicula vulgaris near Türju in the Irbe straight limited conservation area at Sõrve peninsula.

Wet Molinietum type alvar in Vahtrepa landscape protection area in Hiiumaa.

Development of species richness of alvars and ensuring its preservation

In terms of the number of vascular plants, alvars are the most species-rich communities in Estonia after wooded meadows (Pärtel et al., 2007a). However, the development of the species composition characteristic of the alvar in good condition and the addition of species to the community is a slow process; reaching high species richness has taken millennia (Pärtel et al., 2007b).



The impact of ancient human settlements

Alvars have evolved together with humans over thousands of years. With grazing and hay transport, people have inadvertently transported seeds between areas. That is why alvars in the vicinity of ancient fortresses and settlements are more species-rich even today.

Behind the current species, the richness of the alvars is the long-term human impact and the wide historical distribution of the alluvial species, and the related network of well-connected areas where vascular plants have spread between the alvar patches. (Helm et al. 2006, Pärtel et al. 2007b). Examining the historical network of Saaremaa alvar areas (Helm et al., 2006), it has become clear that the species diversity of one area depends on the historical number of other alvar grasslands around this meadow. Variations in environmental conditions, too intense human impacts, as well as pure chance, can occasionally lead to the local extinction of some species from the alvar. Historically, the loss of such species on the alvars of Saaremaa has been compensated for by re-spreading from neighboring areas, either with the help of transported hay or livestock moving from area to area: alvars (like wooded coastal meadows) are rich in plant species whose seeds seem to be designed to travel entangled in sheep's wool (Bruun & Fritzbøger 2002). Sheep often moved quite widely, covering very long distances from one area to another or being taken for sale. Although the number of sheep has risen sharply again in our alvars over the last decade, they are now quite stationary, so they are probably no longer contributing much to the wider spread of vascular plants. Meadow communities that have survived to this day are often isolated from each other. The smaller community patches become and the farther away they move from each other

due to habitat fragmentation, the less likely the current spread mechanisms will work. Due to fragmentation and declining area, also populations growing in alvars end up in isolation, leading to their genetic impoverishment (Helm et al., 2009) and extinction. However, today the Saaremaa alvars are still as rich in species as they are historical. This means, however, that our alvars suffer from the so-called extinction debt. Extinction debt includes those species that are able, after fragmentation of the community, to remain viable for a shorter or longer period of time (albeit with reduced abundance) despite the unsuitable environmental circumstances. At the same time, the habitat is no longer very suitable for them, and the final loss is only a matter of time, as many endemic species of alvars need the above-mentioned network for long-term survival. We have identified that in today's landscapes, small, light-demanding plant species and other associated biota are particularly at risk. Due to the extinction debt, the protection and restoration of alluvial and other semi-natural communities must be taken very seriously and systematically. In order to ensure the survival of the species fund, it is crucial not only to create individual well-maintained protected areas but also to maintain and restore seemingly less valuable areas. The species diversity of other groups of organisms - insects, birds, mammals - also largely depends on the species richness of vegetation, which is why the preservation of species-rich communities is extremely important in ensuring the functioning of the entire ecosystem.

The quarries abandoned at different times in the village of Lõetsa in Muhu (left) and in the village of Haavakannu in Harju County show that located in good condition near the alvars, the vegetation characteristic of these alvars is recovering.

Other parts of the landscape supporting the biota of alvars

Alvars and juniper shrubs often form mosaics in landscapes with other valuable habitat types, alongside coastal meadows, calcareous grasslands, or wooded meadows. These habitat types also partially support species characteristic of alvars and thus improve the cohesiveness of the landscape for the alvar species. However, many areas that have historically been alvar pastures but have now shrunk or changed, such as dry calcareous curbs, forest edges, and field edges, as well as the surroundings of houses and gardens in former alvar pastures, also help maintain the landscape cohesiveness required for the biota. Flower-rich areas resembling alvars must be valued by their owners and preserved as habitats supporting Estonia's significant species richness. However, the biota characteristic of alvars can also find refuge in new habitats. Thus, several studies, both domestic and international, have shown that the natural vegetation or active conscious reclamation of old limestone quarries may lead to the emergence of new suitable habitats for meadow species (Krauss et al., 2009; Prach et al., 2015). The master's thesis of the University of Tartu compared the soil conditions of 24 naturally vegetated quarries and the diversity of plants with the alvar soil conditions, plant species composition, and species richness (Uustal, 2011). Although the soil of abandoned quarries was generally significantly less nutrient-rich than that of alvar soils, a total of 314 vascular plant species were found in 24 quarries, including 144 species characteristic of alvars and 12 vascular plant species belonging to the second and third protection categories. The more there were alvars that still survived within a radius of 2 km around the quarries, the more species characteristic of alvars had also spread to the quarries. There were more species characteristic of alvars in such quarries where the historical area of alvars within a radius of 2 km had been higher (Uustal, 2011). A similar result was found in a study in Canada comparing the species composition of vegetation in limestone quarries abandoned 70 years ago with alvars, where it was found that the species composition of the vegetation of former quarries had become similar to alvars as a result of natural regeneration (Tomlinson et al., 2008). Thus, Estonian limestone quarries have the potential to become an important habitat for meadow species spreading from the surrounding area, even without significant active vegetation. However, the appropriate landscape context is of the utmost importance: abandoned quarries can only be inhabited by alvar types if there are still enough alvars surviving in the surrounding landscape.

CHAPTER 3

DISTRIBUTION, IMPORTANCE, PROTECTION, AND RISK FACTORS FOR ALVARS

Distribution in the world and in Estonia

Alvars are very limited in distribution throughout the world, which makes them globally rare and therefore in need of special protection. In addition to Estonia, there are a considerable number of alvars only on the large islands of Sweden, especially on Öland and Gotland (Rosén, 1982). There are also alvars as small isolated areas on the Swedish mainland in Västergötland and near St. Petersburg (Helm & Pärtel, 2002). Plant communities similar to alvars have also been described here and there in other parts of Europe and the Great Lakes region of North America in the Cretaceous and Limestone areas (Catling & Brownell, 1999; Tomlinson et al., 2008). In Estonia, alvars mainly spread in the limestone outcrops in Saaremaa, Muhu and Lääne County and Hiiumaa, as well as in Harju County and East and West Viru Counties.

In the 1950s, there were approximately 55,000 hectares of alvars in Estonia (Laasimer, 1965; Helm & Toussaint, 2020).

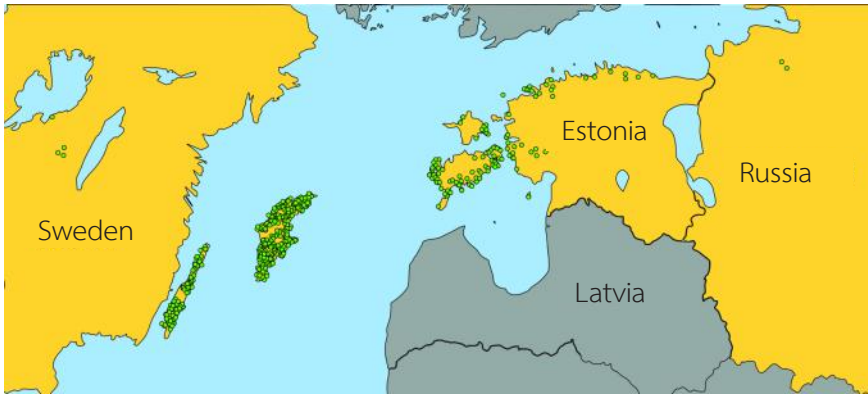
In the 1978 and 1981 inventories, around 16,000 hectares of alvar com-

munities were registered, 25% of which were already more or less overgrown (Aug & Kokk 1983). In 2019, ~ 17,000 hectares of alvar pastures (habitat type * 6280 Nordic alvar and precambrian calcareous flatrocks) have been mapped in Estonia, of which ~ 10,000 are located in protected areas (Helm & Toussaint, 2020). ~ 4800 hectares of Juniper shrubs (habitat type 5130 Juniperus communis formations on heaths or calcareous grasslands have been mapped, of which ~ 3600 are located in protected areas (Helm & Toussaint, 2020). Limestone pavements located on open alvars (habitat type *8240 limestone pavements) have been mapped in a section of about 40 hectares, 30 of them in protected areas.

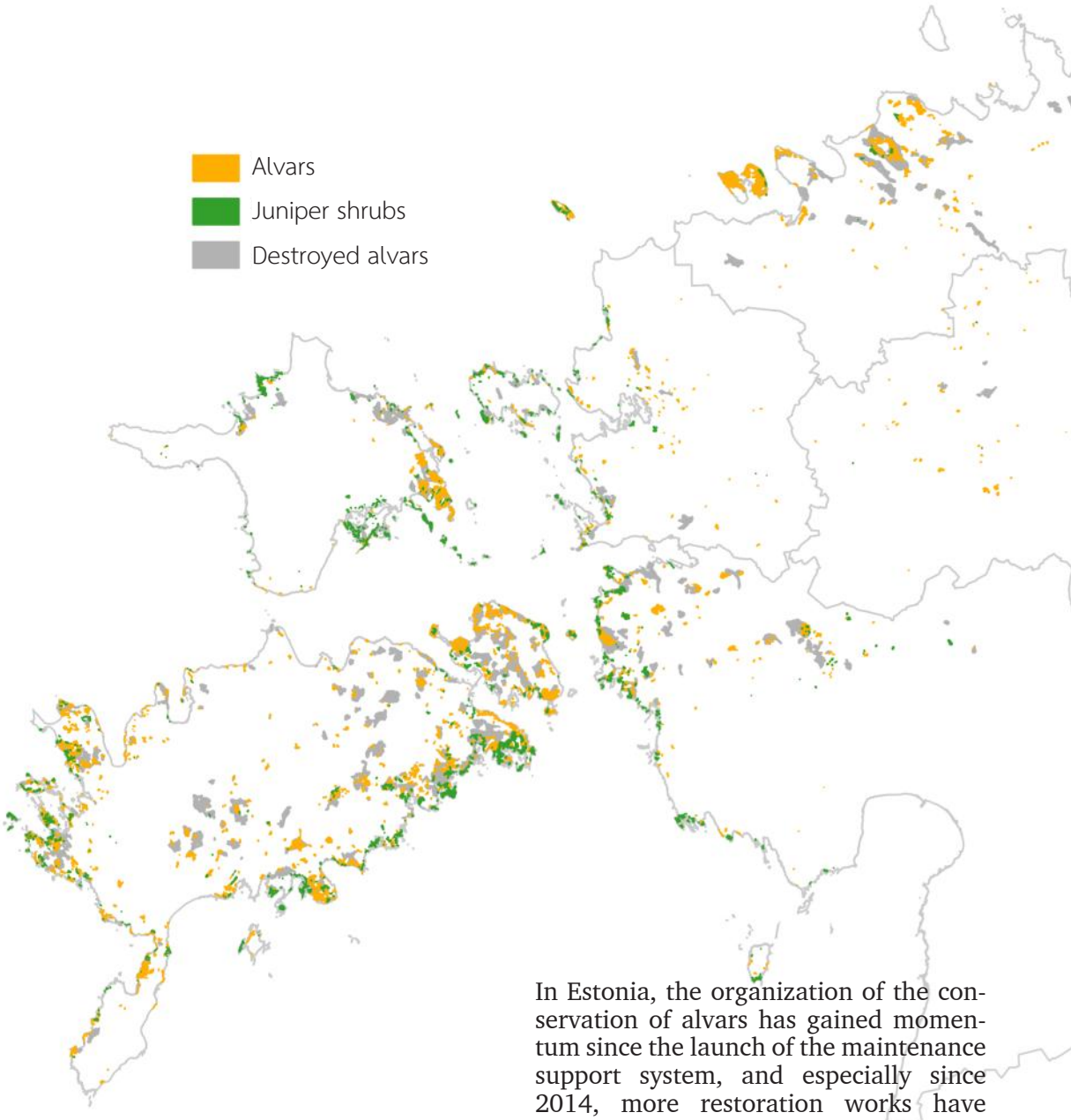
A restored alvar on the island of Öland in Sweden. In Sweden, the European Union's LIFE program restored 7,700 ha of overgrown alvars in 1996-1999, and traditional land use was continued in preserved and restored alvars.

Protection of alvars

Alvars are a priority habitat type in the framework of the European Union Network of Nature Reserves NATURA 2000 (Habitat type in Annex I of the Habitats Directive *6280. The limestone pavements (*8240) found on the alvars are also of primary importance. Estonia has a significant share (28%) of all the world's alvars (Eriksson & Rosén, 2008), which is why we have a duty to ensure the preservation of this rare habitat type. The composition of the regional species fund of Estonian alvar differs from that of the Swedish alvars, containing a larger proportion of species of eastern origin from the Eurasian and Eurosiberian flora elements (Helm, 2001). This shows that we cannot rely on Swedish efforts for the global protection of alvars,

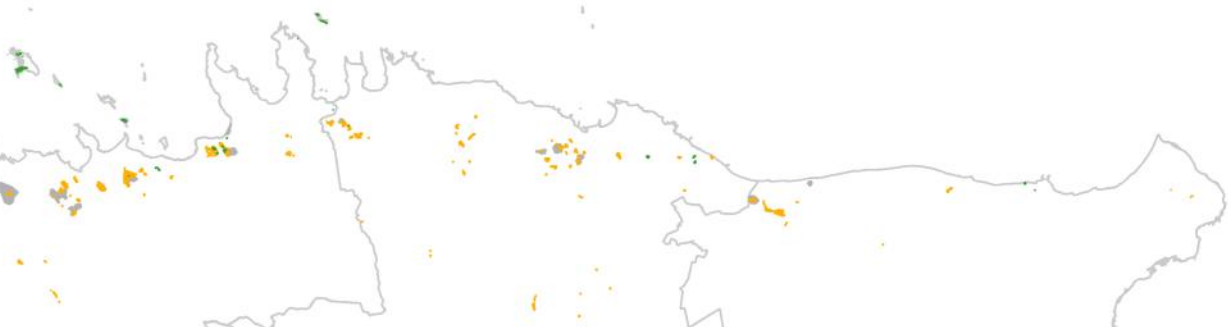


Locations of alvars in Europe. The most alvars in terms of total surface are located in Öland and Gotland in Sweden. The next important area of distribution is Estonia.



but we ourselves must take strong steps to preserve our alvars. 100% of alvars are in Sweden. Europe's largest alvar massif, The Great Alvar (Stora Alvaret, 26,000 hectares) on the island of Öland in Sweden, has been included in UNESCO World Heritage Site.

In Estonia, the organization of the conservation of alvars has gained momentum since the launch of the maintenance support system, and especially since 2014, more restoration works have been carried out, and previously abandoned areas have been added to maintenance. With the support of the European Union's LIFE program, more than 2,500 hectares of alvars were restored between 2014 and 2019 (project Life for the Alvars). During the same period,



Distribution of alvars and juniper shrubs in 2019. The data layer of the Environmental Register's semi-natural communities, the data layer of Natura 2000 habitats, and the inventory database of semi-natural communities of Estonian Seminatural Communities Conservation Association have been used to compile the overview.

alvar areas have also been restored with the help of nature conservation supports and means from the Cohesion Fund, as well as a result of RMK's maintenance work.

In order to preserve species-rich semi-natural communities, it is important to recognize the great value of species-rich meadow communities among the population and decision-makers not only in the local but also in the global context. The importance of alvars in preserving overall biodiversity, as carriers of heritage culture and traditional landscapes, and in ensuring the conservation of many natural assets (including pollination, soil biodiversity, stable carbon storage, and the presence of important biodiversity groups and species) must be understood. The initiatives of landowners and land managers in the management of alvars must be strongly encouraged.

It is a type of community whose semi-natural mode of operation today provides economic benefits through both meadow meat (ecologically pure meat from animals maintaining semi-natural communities) and its upcycling, as well as through other products (wool, juniper-related products, medicinal plants, etc.) (Environmental Board, 2017).

National conservation objectives

There are a total of about 17,000 hectares of alvars in Estonia, of which ~ 10,000 are located in protected areas. In 2019, maintenance support was paid for ~ 5500 hectares of alvar maintenance (mostly grazing) in protected areas. Within the framework of the strategy document "Action Plan for Semi-Natural Communities for 2014-2020", appropriate maintenance of 7700 hectares of alvars was envisaged by 2020. In 2018, 3690 hectares of alvars located in protected areas (habitat type 6280) and 307 hectares of juniper shrubs (habitat type 5130) were under maintenance. Most of the alvars and juniper shrubs were grazed (3627 and 31 hectares, respectively), and only about 70 hectares were mowed (63 and 6 ha, respectively) (Holm et al., 2019). Based on the ecological area requirement of seminatural communities, it is necessary to preserve at least 11,000 hectares of alvars in Estonia in order to ensure the necessary conditions for the existence of species groups related to alvar habitats (Helm & Toussaint, 2020).

Outside the protected areas,

Who organizes the maintenance and restoration of alvars in Estonia

Support for the maintenance of semi-natural communities, including support for the maintenance of alluvial communities, is regulated by a regulation of the Minister of Rural Affairs and administered in Estonia by the Environmental Board and the ARIB. Maintenance support is paid to communities located in Natura 2000 sites (at least until 2020, subject to change in the future) at the request of the maintainer. The Land Management Bureau of the Environmental Board coordinates applications for support for semi-natural communities, sets management conditions, and, if necessary, inspects areas. The ARIB processes applications for maintenance support and organizes the payment of support to applicants. In 2019, the amount of alvar maintenance support was 250 euros per hectare for grazing and 185 euros per hectare for mowing (only with the permission of the Environmental Board). The maintenance of semi-natural communities on state lands is organized by the State Forest Management Center, leasing state lands to the custodians of the areas.

No maintenance support has been paid until at least 2020, but apparently, some areas have been maintained with the help of a single area subsidy. In the future, it is necessary to ensure that the preservation of valuable alvars is ensured both inside and outside protected areas.

Significant benefits of nature and the value of alvar for the well–being of the population and the local economy

Semi-natural communities rich in species, with multiple economic opportunities which increase the tourism potential, can have a very important socio-economic impact on rural areas

The alvar soil biota is very rich in species. Studies of Estonian alvars have shown that 5 grams of alvar soil contain an average of 40, but on some alvar, even more, than 60 taxa of arbuscular mycorrhizal (AM) fungi, or Glomeromycota, which makes up as much as 20% of the species richness of Glomeromycota of the entire world. Glomeromycota is a very important symbiont that help plants (including crops) to better absorb nutrients and make them more resistant to various extreme conditions.

Alvars and climate change

Preserving and restoring species-rich ecosystems is also an essential measure to curb and mitigate climate change and prevent the degradation of landscapes and soils. Biodiversity helps to buffer the threats posed by climate change to our key industries, including agriculture and forestry. Thus, the survival of other species around us can be seen as an insurance policy to adapt to climate change - we do not know which species, species characteristics, or genotypes will be essential in the new conditions. Alvars are home to many species that can withstand drought and other extreme weather conditions in terms of plants, insects, and soil biota. Species that have adapted to difficult conditions may be indispensable in a changing climate. The soil of alvars is also an extremely good carbon sink, containing an average of 10-15% organic carbon (SOC) (for comparison, mineral field soils have a predominantly organic carbon content of less than 3% (Putku, 2016).

that are otherwise beyond the reach of other economic activities. The socio-economic benefits associated with Estonian alvars, including the role of alvars among local communities, have been examined in the study Hog (2017). These are ecosystems that diversify agricultural activities and food production, enabling the promotion of local organic meat production and the upcycling of other products (wool, juniper-related products, medicinal plants, etc.). The areas increase business opportunities for tourism entrepreneurs (excursions, orchid observations, landscape observations) and contribute very positively to Estonia's image as a nature-friendly and ecological European country. When the European Union's plan to implement ecosystem services-based accounting is launched, historic species-rich communities will be an important part of the new system.

Much of Estonia's biodiversity is associated with alvars and other semi-natural communities, which is why their preservation plays a very important role in ensuring the well-being of Estonian nature. Ecosystems with biodiversity must be preserved and restored in every landscape; only in this way can we ensure the preservation of pollinators, beneficial organisms, soil biota, and other important natural assets of agriculturally important biodiversity.

Nature conservation values

The conservation value of alvars is primarily due to their unique and rich biota (see above) and the associated benefits of nature or ecosystem services (see table on page 48). Semi-natural communities can also be seen in landscapes as safe areas necessary for the preservation of Estonia's biodiversity.

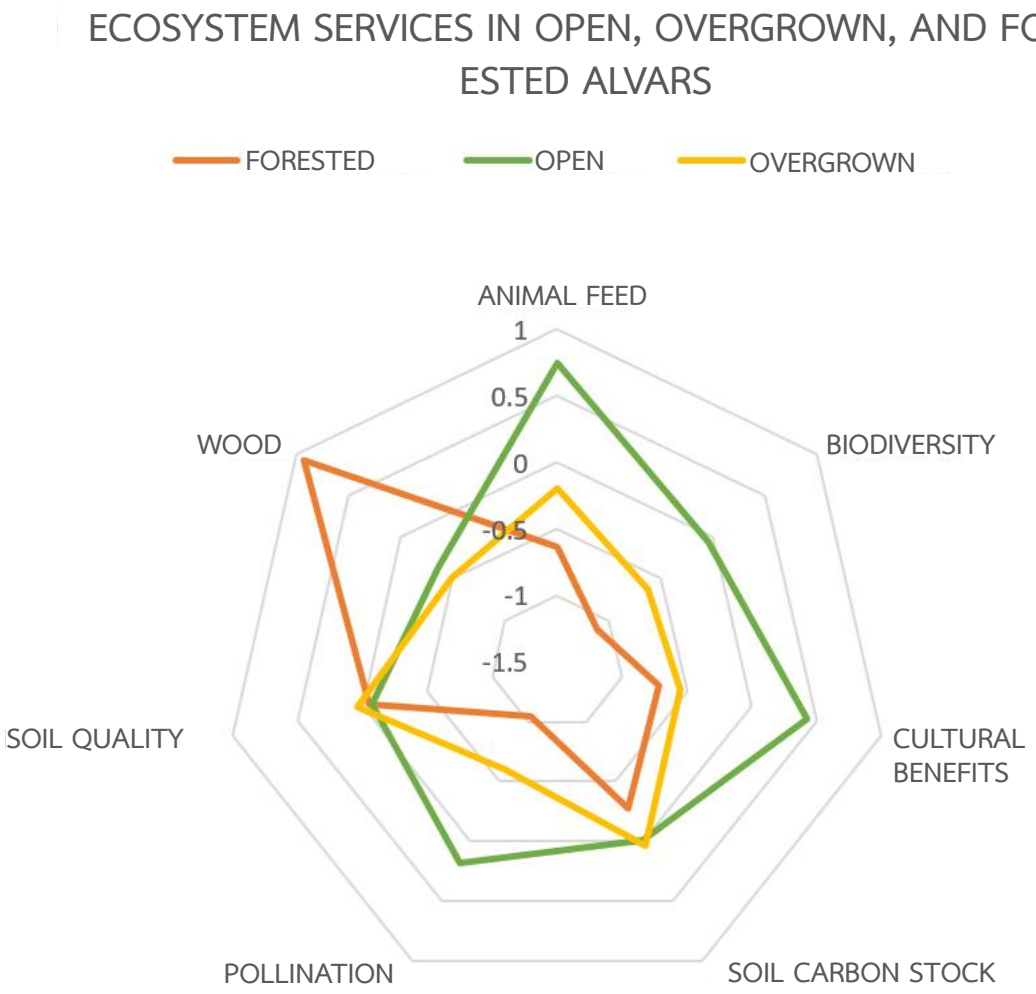
ECOSYSTEM SERVICES ASSOCIATED WITH ALVARS OR BENEFITS OF NATURE

	BENEFITS	SIGNIFICANCE	EFFECTS OF OVERGROWTH OF ALVARS
REGULATORY BENEFITS	Pollination	Maintenance of genetical diversity in the landscape; Supplying nearby agricultural landscapes in need of pollination with pollinators (canola fields, strawberry, and apple orchards	↓
	Natural pest control	Reduction of herbivorous plant pests in the landscape - a reduction of plant damage and less need to use insecticides	↓
	Maintenance of soil quality	Preservation of the community in its original form thanks to the stable state of soil conditions and fertility	→
	Carbon sequestration in soil	Climate regulation - binding of CO_2 from the atmosphere to biomass and soil, which forms a stable carbon reserve there and prevents excess carbon from returning to the atmosphere	→
	Maintenance of ecosystem functioning and genetic diversity	The functioning of ecosystems related to biodiversity, the functioning of biochemical cycles, and the preservation of genetic diversity. Resistance to global changes	↓
PROVIDING BENEFITS	Livestock and animal feed	Livestock production and plant biomass for animal feed	↓
	Other animal products	Meat, wool, and local products made from it	↓
	Wood production	Wood obtained as a result of the overgrowth of alvars (including juniper wood)	↑
	Berries, herbs, other plant products	Wild strawberries, mulberries, juniper berries, medicinal plants (Breckland thyme, common cowslip, St. John's wort, oregano, common yarrow, hoary plantain, dropwort, glaucous dog rose, viper's bugloss, Polygala comosa, dwarf milkwort, burnet-saxifrage, Lady's bedstraw, etc.). Traditional plants and mushrooms used for dyeing (northern bedstraw, dyer's woodruff, Lady's bedstraw, St. John's wort, Anthemis tinctoria, slimy spike-cap, brown slimecap, etc.)	↓
	Edible mushrooms	Morels, slippery jack, weeping bolete, slimy spike-cap, brown slimecap, St. George's mushroom, Tricholoma myomyces, Lepista personata, sweetbread mushroom, saffron milk cap, false saffron milkcap, gooseberry russula	↑
CULTURAL BENEFITS	Recreation and tourism	Use of alvars for hiking, walking, horseback riding, etc.	↓
	Nature conservation value	Preservation of flora and fauna characteristic of alvars, preservation of biodiversity, preservation of protected species.	↓
	Preservation of heritage culture, preservation of the characteristic landscape appearance	Preservation of historical, cultural history, and farming practices in the landscape and enabling it to be seen	↓
	Providing inspiration	Providing inspiration for various works (paintings, folk songs, photography, film shoots)	↓
	Educational and scientific value	Study tours (educational materials on information boards on alvars for getting to know the community), provision of information necessary for research	↓

↓ On overgrowing, the availability of the benefit decreases

→ Overgrowing has no impact on the availability of the benefit

↑ On overgrowing, the availability | of the benefit increases



Providing essential ecosystem services to open, overgrown and forested alvars. The higher the value of the respective service, the better the provision of the given service. Open alvars are significantly better sources of biodiversity, cultural goods, pollination, and animal feed than overgrown and forested areas. Soil quality (a combined index that includes both soil geochemical parameters and soil biota) and soil carbon stock did not differ between open and overgrown alvars (Prangel, 2017).

<<< **Important benefits of nature in alvars and their change during the overgrowth of alvars. Review by Elisabeth Prangel.**

Threats to alvars

Overgrowth

Overgrowing woody plants greatly reduce the biodiversity of alvars. Based on research conducted in Estonia, the number and species richness of vascular plants, mosses, lichens, bumblebees, butterflies, Chelostoma rapunculi, bumblebees, arachnids, ground beetles, and arbuscular mycorrhizal fungi (mostly living in symbiosis with herbaceous plants) decrease upon overgrowth (Helm, 2017). Upon overgrowth, the biodiversity and abundance of ectomycorrhizal fungi (mostly fungi living in symbiosis with trees) increase.

Overgrown alvar in Muhu. Such an area is in urgent need of restoration in order to save the biota characteristic of open alvars.

From the 1930s onwards, and throughout the Soviet period, the traditional management of all semi-natural communities declined due to the spread of intensive agriculture, which led to the abandonment of less productive areas. On alvars, the cessation of grazing leads to their overgrowing with shrubs (mainly juniper) and trees (mostly pine) and to an invasion of large grazing-sensitive herbaceous plants. Alvar types (Avenetum type, see the chapter, Different types of Alvars) thicker soil layer and a higher degree of erosion of the subsoil where there is an environment suitable for forest species and trees (Zobel 1984) and which are widespread in Estonia, are particularly vulnerable to forest invasion. However, even thin-soiled and even platy alvars are not protected from overgrowth - at first, when the grazing ceases, the woody plants take root in limestone cracks and patches with thicker soil, then each individual shrub forms a so-called colonization center. At the center of colonization, locally suitable environmental conditions are created for forest species (shady, accelerated soil formation with mosses and old thorns), which leads to further invasion of shrubs and trees or shade-tolerant herbs.

Thin soil is not enough to prevent overgrowing yet. A rapidly overgrowing Festucetum-type alvar on Tagamõisa peninsula in Saaremaa.

In temperate climates, trees with a broader root system prefer soil that is more heterogeneous in terms of nutrients and soil depth than herbaceous plants with a smaller root system (Pärtel et al., 2005b). Examining the invasion of pines in Estonian alvars, we have found that rooting of trees in an open meadow is more likely if there are a few places with deeper soil in the area. Then, as a result of their life activities, the trees make the soil even more spotty and thereby promote further invasion of woody plants (Pärtel & Helm, 2007). Underground processes cannot be taken into account very well in practical nature conservation, but it should be borne in mind that the appearance of individual pines in alvars is a worrying sign, as it indicates a shift in soil conditions in a direction suitable for woody plants. In this case, urgent restoration work must be undertaken.

Afforestation

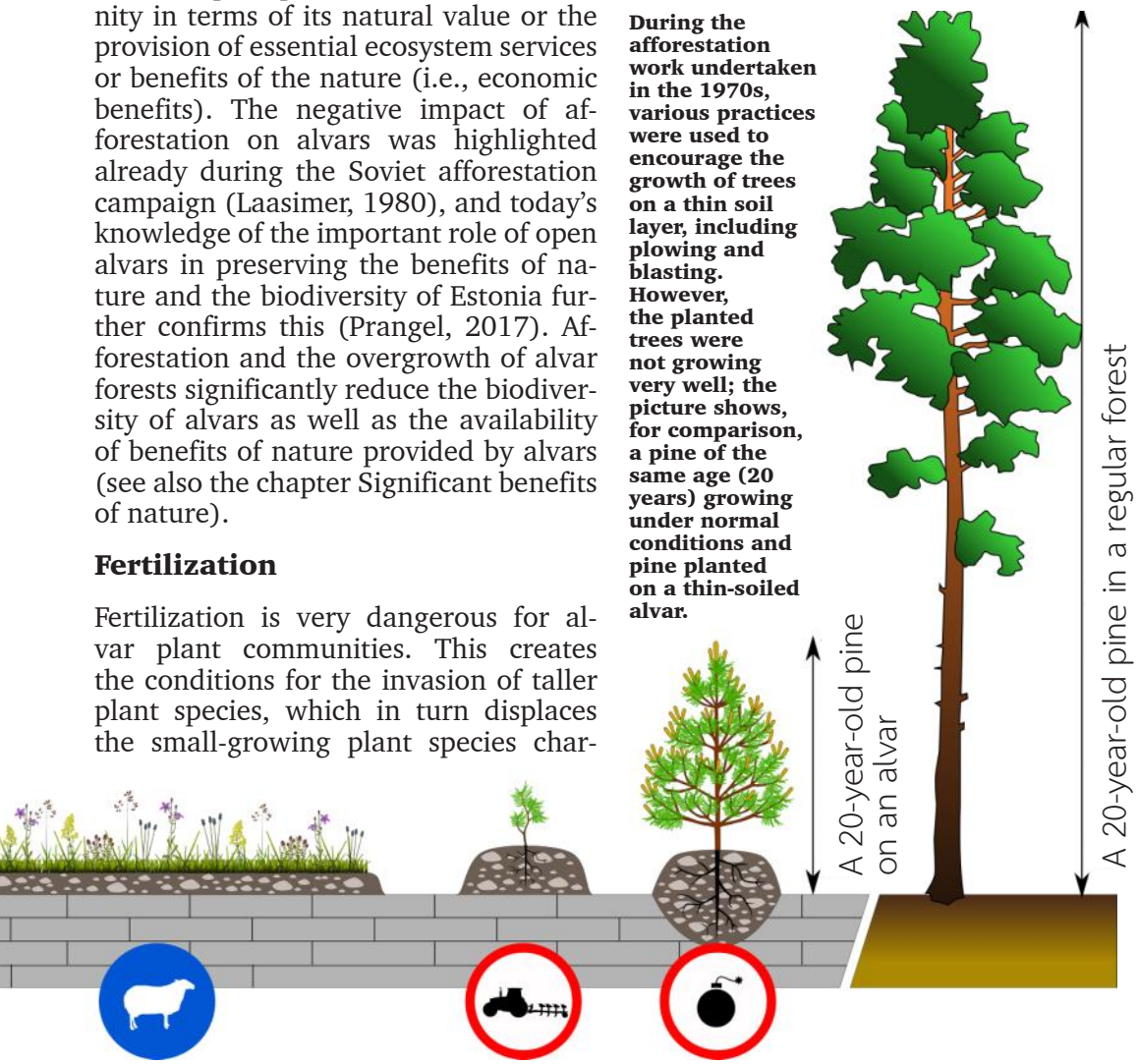
From the 1950s to the end of the 1970s, afforestation work was carried out in Estonian alvar areas. It was an attempt to increase the profitability of low-productivity areas. Whereas in previous years, experimental patches were established, in the seventies, more than 25,000 hectares of alvar pastures were transferred to the Saaremaa forest industry for afforestation (Laasimer, 1973; Kaar, 1986). In order to collect the soil needed for the trees, deep furrows were plowed, the bogs were turned aside by hand, or even blasting was carried out. Although there were many failures, trees took root on the thicker soiled alvars using appropriate techniques (soil preparation, increasing the thickness of the soil layer by turning bogs, etc.), which is why we have a large number of monocultural alvar pine forests that are about 50-60 years old today. Overall, however, works were successful on only a quarter of the sites. At the same time, on many of the thinner soiled, and open alvars, one can still notice shallow ridges scraped together from a small amount of soil or holes blasted in the limestone surface. Subsequent analysis of the experimental cultures in Saaremaa showed that some of the alvar areas are not suitable for afforestation at all, and the rest are difficult to afforest (Örd, 2000). There is nothing to do with the holes and ridges made as a result of the unsuccessful and successful afforestation experiments that have survived to this day - they probably also offer more diverse growing places today, creating a micro-relief. If the holes are very disturbing in management, then in the case of alvars in good status

they can also be leveled as sustainably as possible, but not more than 20% of the area at a time, allowing the vegetation to recover in the meantime.

We have not escaped the threat of afforestation and the continued overgrowth of alvars even today. Although history has shown the infertility of these works, attempts are being made to establish forests in thin-soil alvars over and over again. However, it must be borne in mind that even if tree planting is successful, the monoculture stand established in this way is not comparable to the lost open species-rich alvar community in terms of its natural value or the provision of essential ecosystem services or benefits of the nature (i.e., economic benefits). The negative impact of afforestation on alvars was highlighted already during the Soviet afforestation campaign (Laasimer, 1980), and today's knowledge of the important role of open alvars in preserving the benefits of nature and the biodiversity of Estonia further confirms this (Prangel, 2017). Afforestation and the overgrowth of alvar forests significantly reduce the biodiversity of alvars as well as the availability of benefits of nature provided by alvars (see also the chapter Significant benefits of nature).

Fertilization

Fertilization is very dangerous for alvar plant communities. This creates the conditions for the invasion of taller plant species, which in turn displaces the small-growing plant species characteristic of alvars and other groups of organisms related to them. Fertilization of alvars may have been carried out all over Estonia during the Soviet era, but even today, North-Estonian alvars stand out in terms of higher



During the afforestation work undertaken in the 1970s, various practices were used to encourage the growth of trees on a thin soil layer, including plowing and blasting. However, the planted trees were not growing very well; the picture shows, for comparison, a pine of the same age (20 years) growing under normal conditions and pine planted on a thin-soiled alvar.

productivity. The reason may be direct fertilization (so-called surface fertilization), but in some cases, also nitrogen pollution probably spreads through the air (Pärtel et al., 2004; Saar et al., 2012). Today, fertilization with mineral fertilizers in preserved semi-natural communities must no longer be acceptable; the best fertilizer for the preservation of biota is manure from the livestock in the area.

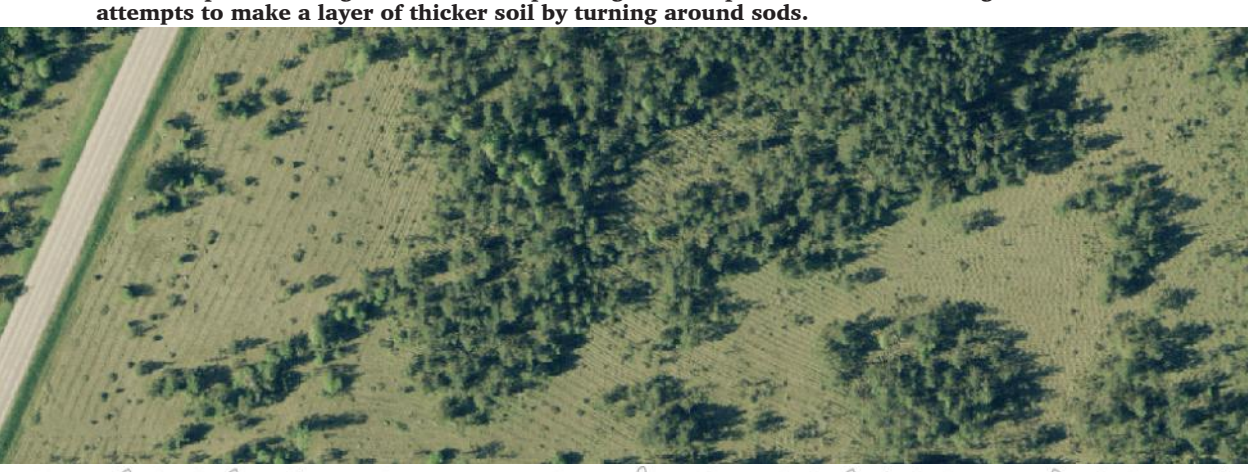
Result of afforestation experiment in Lõo alvar in Saaremaa.

Direct destruction

A large part of the historically common alvar pastures has also been directly destroyed, as they ended up under the city or infrastructure. For example, a large part of the eastern part of Harju County is a former alvar area, where the Lasnamäe district and several new residential areas today cover former species-rich alvar areas. Today, when creating new facilities, it is important to take into account the remaining habitat patches and try to preserve them as much as possible. There is no way we can get back historical habitats that have formed over a long period of time, which is why their preservation in the landscape is

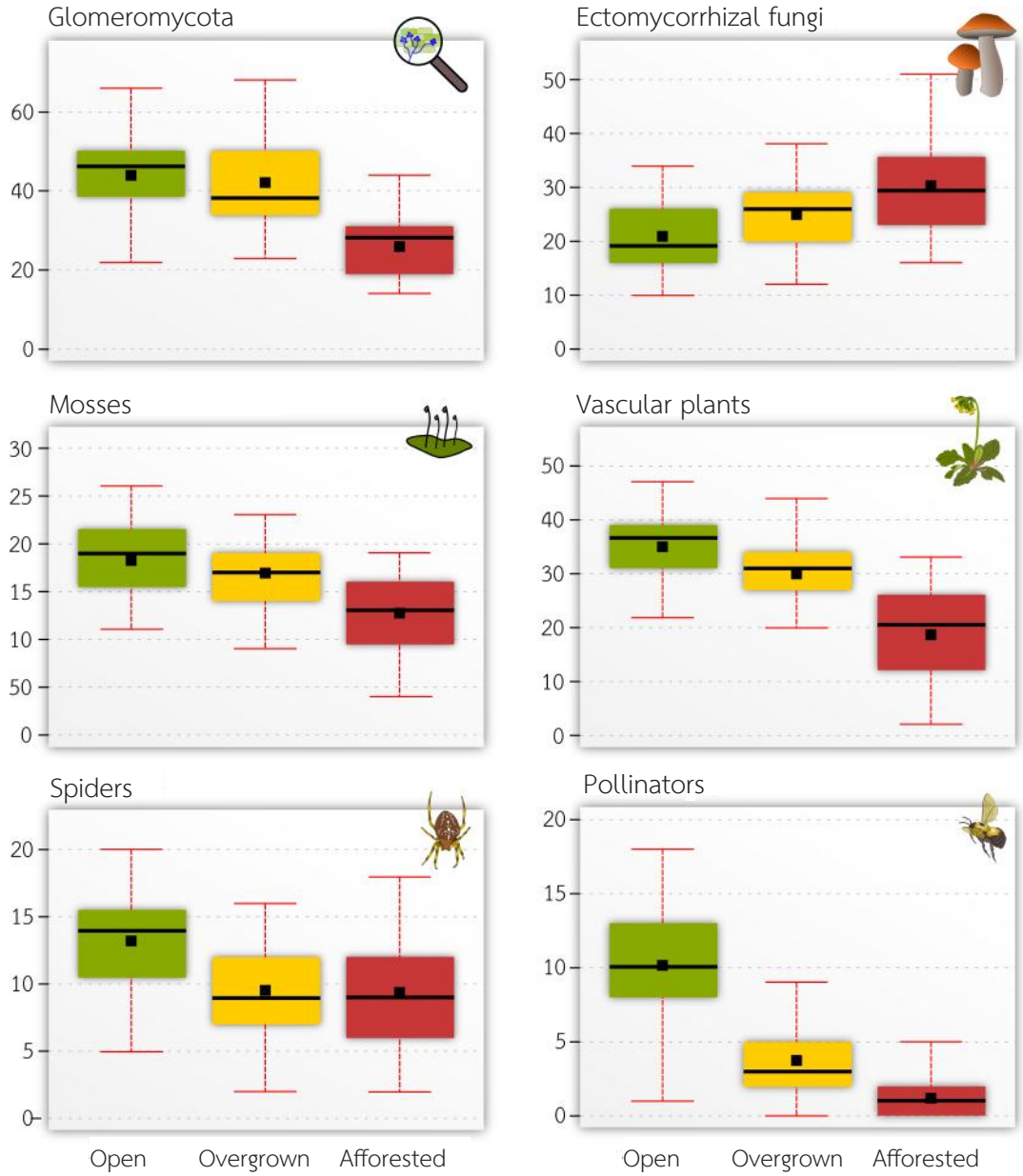
A dense pine forest was planted during the afforestation campaign in the 1970s on Tagamõisa peninsula near Kõruse. The "plow strips" built into the pebbly soil allowed pine crops to grow despite the thin layer of soil, but the result is not very productive forests. The ground was prepared for production crops mostly in the form of plow furrows (furrow spacing up to 1.5 m).

Traces of the ground preparation works used for afforestation of the alvars on Võrsna-Sagariste alvar in Saaremaa by the Kuressaare-Kuivastu road can still be seen even today. The orthophoto distinguishes between planting furrows plowed into limestone ground and attempts to make a layer of thicker soil by turning around sods.



of paramount importance. If damage to the habitat cannot be prevented, the habitat must be preserved as much as possible during the construction of the facilities, for example, by incorporating it into the surrounding greenery or in parts of the building/infrastructure facility. In this case, innovative solutions must be considered, such as complete or partial relocation of the habitat (relevant experience exists in Estonia) and/or its integration

Overgrowth or afforestation of alvars not only reduces the number of plant species but also the species richness of many other important species groups. Thus, overgrown and forested alvars have significantly fewer species of bumblebees and butterflies, as well as ground spiders and Glomeromycota (Helm, 2017; Prangel, 2017).



into buildings (courtyards, roofs). It is important to understand that such activity is also a major disturbance of the original habitat but a much more desirable solution than the complete destruction of the habitat.

The still preserved alvar and a habitat of category I plant species in Lasnamäe, Tallinn, in Paevälja urban region, where the construction of Tallinn Hospital is planned. In cases where nature conservation and national interests collide in this way, the most practical layouts for maximum habitat conservation should be considered.

Chapter 4
MAINTENANCE

General principles of maintenance

Three factors, in particular, need to be taken into account when maintaining alvars.

1. Grazing is the first and foremost way of maintenance of an alvar. These are semi-natural communities that require moderate human impact in order to survive as an open community for a long time. Human impact means, above all, grazing on algae and, if necessary, removing woody plants from time to time. Targeted action by landowners interested in grazing should always be encouraged.

If there is no possibility of grazing, the removal of trees and shrubs as required (but not less frequently than every five years) and mowing if necessary/possible also keeps the alvar open.

2. Diverse management ensures long-term success. Whereas historically, the diverse biota of alvars was ensured by the large area of traditionally maintained alvars and other semi-natural communities, then today, in order to preserve the regional species fund and to organize maximally effective protection, it is good to apply the so-called principle of diversified management. This means that it is not reasonable to apply similar management techniques in all areas (eg

intensive grazing with the same type of livestock year in-year-out). It is useful if the types of herds (sheep/cattle/horses/goats) and grazing loads (periods and areas of more intensive and moderate grazing alternating) vary in both time and space. Keeping small mixed herds (such as horse-sheep-cattle), creating ungrazed areas from time to time, etc., works well. In the case of a normal grazing load, a couple of grazing-free years (rest years) in five years has a rather good impact in an open area. At that time, the same herd could be grazed in neighboring semi-natural communities. Alternating the type of herd makes it possible for species with very different needs to find habitats in the areas, as different animals prefer different food plants (selective grazing; see also instructions for grazing orchid-rich alvars below). Alternating grazing load also allows vascular plant species that are more sensitive to grazing to spread, and the species richness and abundance of many invertebrate groups also depend on grazing intensity (Pöyry et al., 2004; Horv□th et al., 2009; Tiitsaar & Talgre, 2015).

Grazing with a suitable grazing load ensures the preservation of alvars. When grazing ceases, larger grasses start to proliferate, followed by overgrowth with junipers. (Photo: Meelis Pärtel)

Even within the same type of community, conditions can vary greatly from area to area. Also, depending on the weather conditions, biomass production in the same area can be very different in different years. Therefore, it is good to implement both temporally and spatially diverse management, which buffers possible errors in determining the optimal grazing load of the area. In order to assess the effectiveness of management techniques in each specific area, the maintainer could monitor changes in vegetation on an annual basis and consult with a land management specialist if necessary to plan subsequent activities. If, as a result of the inventories, the presence of rare and protected species is known in a specific area, this must be taken into account when applying maintenance techniques.

When taking into account the recommendation for diversified management, it is important to ensure that this does not lead to the emergence of additional bureaucracy and present new demands on maintainers of alvars. Rather, it is simply worth introducing landowners to the pros of diversified management and the ecological processes behind the recommendation. By trying to take into account the spatial distribution of semi-natural communities in the region,

neighboring landowners could be introduced to each other and encouraged to share pastures.

3. Attention to the distribution of species in the landscape scale. Due to the occurrence of extinction debt, it is very important to ensure the spread of both plant and animal species between habitat patches, i.e., to maintain a network of habitat patches. For this purpose, it is necessary to review similar communities (including wooded meadows and grasslands) in the surrounding landscape during the management/restoration of the alvar and, if possible, to start managing them even if they seem less valuable at first sight. In an ideal case, the livestock rotation recommended in the previous clause could be carried out precisely with the help of these so-called network support areas, and herds could be alternated between different habitat patches in different years - in addition to the movement of the population of vascular plants between habitat patches, this practice enriches the diet of animals and prevents the loss of plant species through years of selective eating.

Principles for formation of maintenance support

The maintenance support system should be user-friendly and easy for the state to administer. The study "Analysis of Ensuring the Sustainable Management of Semi-Natural Communities" (Holm et al, 2019) has provided a comprehensive overview of the needs for the design of the maintenance support scheme.

At the same time, it is important to ensure the interest and desire of landowners and maintenance to participate in the maintenance scheme and the preservation and improvement of important natural values and benefits. In addition to large maintainers, who often have the capacity to provide maintenance for larger areas, small landowners and local people whose individual approach to their areas to be maintained and the bond to the surrounding landscape are necessary for the achievement of good results should also be involved in land management. A maintenance support system based at least in part on the results achieved (the so-called performance-based support measure) could be considered. The performance-based component of maintenance support should encourage:

- the addition of indicator species and the well-being of protected species;
- mixed grazing;
- coordinated maintenance of different types of meadow communities in the same landscape to achieve temporal and spatial diversification of maintenance (rest years every year in different areas in the same landscape, in draught years rather graze in more productive/moist areas in the same landscape, variation of different maintenance measures (mowing, grazing, brush removal, rest year, different livestock);
- the inclusion of isolated residual areas which are less attractive to larger maintainers in the care scheme by motivating small maintainers;
- Extension of maintenance to the areas that are still

outside of maintenance, including outside protected areas.

Purposes of maintenance

• **Purpose of maintenance:** a species-rich, flower-rich community with a diverse structure.

• **Trees and shrubs:** the coverage of woody plants does not exceed 50%, but it is recommended that junipers cover at least 20% of the area in dry alvar types to provide a nesting place for birds and shelter for butterflies and other invertebrates. However, fresh alvars are often also quite open characteristically to them.

• **Vegetation:** no domination of a few individual species, but the community is made up of many species characteristic of them.

• **The plant litter layer** is scarce, covering less than 30% of the area.

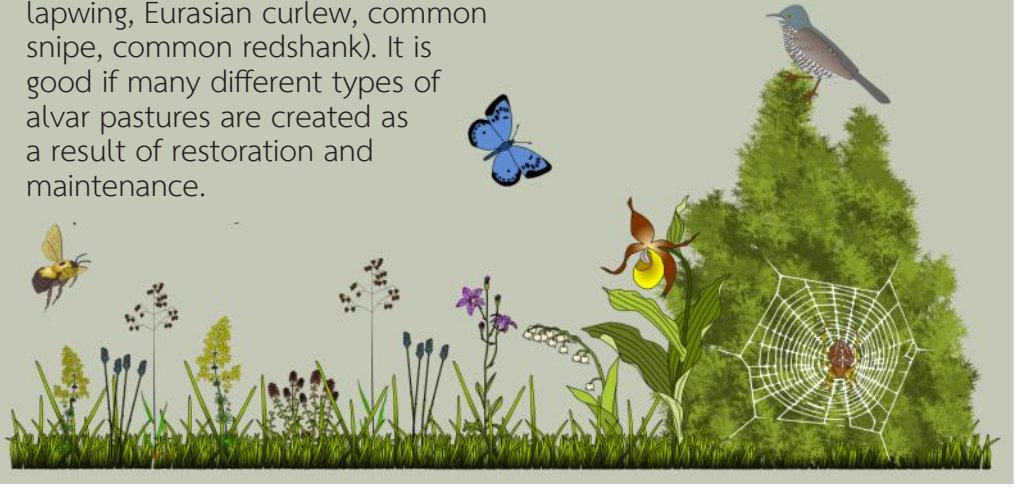
• **Vegetation structure:**

Full of flowers from June to August, the proportion of grasses is at least 40% (except in fresh alvars, which is characterized by a higher proportion of grasses)

Diverse heights; when long-term grazing is applied, the area has both low grass areas (less than 7 cm) and

Juniper increases biodiversity

Although overgrowing with junipers and other woody plants has a negative impact on the biodiversity of alvars, moderate coverage of junipers up to 50% favors the occurrence of many species. Areas partially covered with junipers have more lush vegetation, shade tolerant and light-demanding species can exist together, butterflies prefer such areas for wind shelter and mosaic environment and for shrub-nesting birds, juniper stands located in semi-open landscapes are a good nesting place. On the other hand, some species prefer totally open areas, for example ground-nesting waders (northern lapwing, Eurasian curlew, common snipe, common redshank). It is good if many different types of alvar pastures are created as a result of restoration and maintenance.



also areas with taller plants (over 15 cm). If batch grazing is used, the plants are eaten from almost the entire area immediately after grazing, but the vegetation recovers within a month or two.

• **Indicators of suitable grazing load**: during the grazing period, low grassland is about 20% of the total pasture, and dry meadows have at least 25% of the area covered in flowering plants. By applying the paddock system, 1/3 of the area is grazed at a time if the area is larger than 10 hectares, and in the case of batch grazing, the animals are kept in one paddock for a maximum of 5 days.

• **Positive indicator species** - mowing specialists, low-growing and flowering species.

• **Negative indicator species** - tall grasses, species indicating overgrazing, nutrient overload, alien species

The use of fertilizers and biocides and the introduction of non-habitat-specific animal and plant species are strictly prohibited in alvars and all semi-natural communities. The so-called invasive alien species and so-called blacklisted specimens must be removed. Avoid activities that damage the grass turf, the most harmful of which are plowing, milling, and afforestation!

Alvars are very suitable for various recreational activities - camping, hiking, walking, and school trips. Alvars and other semi-natural communities are

The dry alvars are very rich in flowers. The moderate grazing load allows the flowering plants to go through their life cycle, but it is also not bad for the area to apply a higher grazing load from time to time to prevent overgrowing and the formation of a layer of old grass.

a legacy from our ancestors, and they carry thousands of years of history. It is necessary that this knowledge reaches the heart of every Estonian. It must be possible to visit the alvars and create beautiful views of the stone fences and the sea. The most frequented alvars must have appropriate places for the disposal of rubbish and for making fires. It would be a good idea to ensure that less than 1% of the meadow community is left under the facilities, and if there are any sods with a meadow turf left, then plant them in restored areas.

Located in the limestone areas, alvars are in danger of being mined. If it is necessary to build a mine, prefer the areas adjacent to the open alvars and ensure that a meadow community can develop in the abandoned area after the completion of the excavations. It has become customary to build wind farms and solar parks on open alvars. It should be emphasized here that the Natura 2000 habitat must not be a place for wind farms, but also in other areas, more degraded areas should be found, and the construction of wind farms should be linked to the maintenance of the area through grazing. In general, both mines and wind farms should be established in areas of no nature conservation or landscape value.

A fresh wet alluvial pasture in good condition and with a suitable grazing load in the Rajametsa limited conservation area.

Alvar in a good status

A dry alvar in good status and rich in species (Avenetum and Festucetum types) is characterized by the following

features:

• there are many different flowering types of grass; flowering species cover at least 20% of the area;

• herbaceous vegetation is low, halfway up the calf, inflorescences of grasses and sods in wetter places may be higher in some places;

• the plant litter layer is missing or is very scarce; • on a small scale, the community is species dense: there are many different species, and for example, on a 10x10 cm-scale, it is common to find 3-9 plant species;

• there are no large collections of Brachypodium pinnatum;

• the coverage of shrubs and trees does not exceed 30-50%.

A fresh alvar in good status and rich in species (Molienietum types) is characterized by the following features:

• vegetation is generally low (below

The conservation of alvars and their species richness is ensured by grazing with a moderate load.

knee), dominated by Molinia caerulea or Sesleria, but there are also orchids (e.g., Ophrys insectifera, Dactylorhiza incarnata, Herminium, Epipactis palustris, Gymnadenia conopsea);

• the vegetation is poorer than in dry meadows but still diverse and with flowering herbs growing between grasses;

• the plant litter layer is scarce;

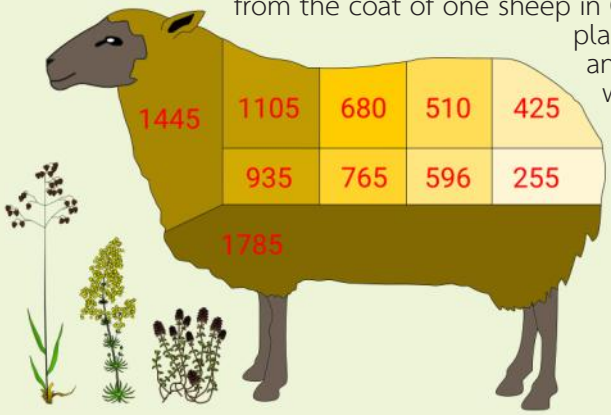
• junipers cover less than 30% of the area, there are no deciduous shrubs, or they exist on less than 20% of the area in small patches.

The main maintenance techniques – grazing

The conservation of alvars and their species richness is ensured by grazing with a moderate load. Alvars may be grazed with sheep, cattle, goats, or horses. Sheep are considered to be the most suitable, but other animals also work effectively. Mixed grazing is especially good. Livestock manure helps to spread "good"

Animals as seed dispersers

Animals play an important role in shaping the species richness of meadows as they are very good seed dispersers. The seeds attach to the animal's fur or pass through their digestive tract and thus move from one area to another. For example, 30 seeds from 85 different species have been counted from the coat of one sheep in Germany. In addition to plants, it appeared that smaller animals also travel in sheep's wool, including spiders, grasshoppers, other different insects, and even frogs.



8500 seeds

85 plant species

meadow species, i.e., the ones we expect to grow on the alvar: low, light-loving, with small and persistent seeds (Auffret et al., 2012). As animals move between habitat patches during the grazing period, the manure becomes increasingly more 'species rich'! Meadow species need grazing and the movement of livestock between areas!

• Grazing helps prevent overgrowth and keeps alvars open.

• Grazing keeps the competition between plants low, allowing even small plants to grow and species richness to increase.

• Cattle spread seeds between different areas through manure as well as wool and hair.

• Livestock cause soil disturbance with claws and hooves. Open patches are habitats for many plant species, contribute to the seed regeneration of alvar species, and support other soil disturbances and species that need open soil (some mosses, lichens, insects, arachnids, Crustaceans, e.g., Isopoda).

• Many insects, insect larvae, and soil biota are linked to livestock manure.

When determining the grazing load, the energy content of the meadow grass and the energy needs of the grazed animals must be taken into account. It should be borne in mind that biomass production varies from area to area and from year to year, so there should be flexibility in setting grazing loads. See box grazing loads.

Recommendations for grazing

• If possible, mixed grazing should be applied

• Good spatio-temporal diversity in grazing - in some years, the grazing load may be higher, and in other years it may be lower. Species abundance is also favored by the diversity of grazing (in loads, etc.) in adjacent areas.

• Maintenance could be flexible based on animal welfare, weather, plant growth, etc, depending on the year.

• Overgrazing over several years should be avoided.

• Paddock system could be applied when grazing.

• Moving animals between different areas (helping to spread seeds) is beneficial.

In summer, so supplementary feed should be given on alvars, particularly dangerous is feeding the livestock hay from cultivated pastures due to the seeds of cultivated plants spreading from there. When grazing in winter, make sure that the load on an area is not too great (that the livestock would not trample the ground until it turns into mud). Modern animal breeds are usually heavier, larger, and more demanding than those that have traditionally maintained the semi-natural communities in our country. If possible, local or otherwise less demanding breeds should be preferred (for example, Estonian native cattle, and Estonian sheep). In the case of cattle, also medium and smaller beef cattle breeds could be preferred (e.g., Aberdeen Angus, Scottish Highland cattle, Hereford). A growing trend is keeping so-called rental sheep, where the owners of smaller semi-natural communities can rent a small number of animals from the keepers of larger herds

only for the grazing period or instead to place their sheep in the care of a larger producer during the winter.

Overgrazing does not favor alvar invertebrates, including butterflies. Tiitsaar and Talgre (2015) found that maintained alvars were almost completely devoid of butterflies from pastures where most of the area was covered in low grass, and there were no patches of high hay. From the point of view of butterflies and other insect fauna as well, it should be ensured that there are always flowering plants in the managed areas and that there are areas with both higher hay and low grasslands. However, temporary overgrazing should not necessarily be feared because if a good landscape cohesion of alvars is ensured and there is an abundance of other landscape elements that potentially support invertebrates (road edges, clearings, areas under overhead power lines) in the area, temporary overgrazing does not threaten any biome group, but rather creates structural diversity and a plurality of environmental conditions, which in turn benefit some other biome groups or species (e.g., many plant species). Temporary overgrazing should always be followed by a rest year.

Tiitsaar and Talgre (2015) suggested the following possibilities as grazing practices favoring butterflies:

1) Permanent grazing in favor of butterflies

Suitable for areas in good condition. In case of this

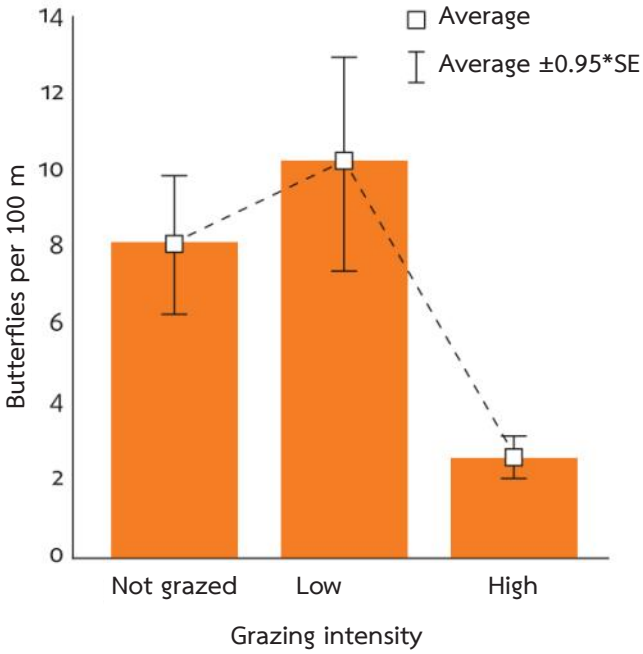
Cattle of less demanding breeds do a good job in the restored area to speed up the recovery of the community. Scottish mountain cattle in Türju alvar on the Sõrve peninsula.

grazing scheme, the stocking density is kept at a level that maintains the heterogeneity of the area, i.e., the area has both places with low grass and places with high hay. Up to 50% of the area is low grassland. As such a scheme may have too low of a grazing load to keep the area open, overgrowing shrubs and junipers should be removed from there as necessary.

2) Rotational grazing with gap years favoring butterflies

In this option, grazing is carried out for some time with the maximum possible load so that the entire area is low grassland, followed by 1-3 gap years. The gap year(s) allow the area to rest and the butterflies to go through one life cycle without interruption. Such a scheme will enable management to be more diversified. At the same time, it is important that the gap year lasts for an entire year so that all butterfly species can go through their life cycle without interruption.

It is suitable for a permanent management scheme, for example, on pebbly alvars with a thin layer of soil, where grazing may not be possible during dry years. It may be the optimal scheme if there are fewer animals and larger areas are to be maintained.



Abundance of butterflies in the alvars of Saaremaa and Muhu depends on the grazing load. Moderate grazing has a good effect on the abundance of butterflies, but intensive grazing reduced the number of butterflies in the year under review. Figure: Tiitsaar and Talgre 2015.

Grazing of thin-soiled areas (Festucetum-type alvars and limestone pavements)

In order to survive, this type of alvar area needs a special sustainable protection regime, i.e., a very low grazing load. Estonian Festucetum-type areas are similar to the Great Alvar of Öland; therefore, the grazing load of 1 sheep per 24 hectares proposed for Öland's alvar areas can be applied. In drier summers, grazing may not be possible at all. Care must be taken to ensure that these areas do not happen to be livestock gathering places, such as drinking places or shelters.

Grazing of orchid-rich areas

In the case of the presence of rich orchid flora or rarer orchids, steps should be taken to favor the status of the orchids. Many orchids need moderate habitat management and open communities to survive, but heavy grazing of sheep can reduce populations in the long run. With this in mind, there are four ways to manage orchid-rich areas:

1) apply a lower grazing load and keep woody plants under control by cleaning work carried out every five years;

2) graze horses (who allegedly do not eat orchids, Ekstam & Forshed 2002) with a moderate grazing load;

3) limit particularly orchid-rich patches with electric fences. Obviously, this has to be done in a slightly different place each year, depending on the occurrence of the populations;

4) graze rather in the second half of the summer, when the orchids have already borne fruit.

Be sure to avoid overgrazing. These opportunities for the promotion of orchids are more applicable in the orchid-rich areas of Avenetum and Molinietum types. If orchids are found on Festucetum-type limestone pavements, particularly low-load sheep grazing (1 sheep per 68 hectares, Rosén, 1982) should be used, or grazing should be totally given up in the first half of the summer.

Indicator species indicating appropriate or inappropriate grazing load

Prolonged grazing with a suitable load is indicated by the widespread distribution of low and light-loving species on alvars with thicker soils and the dense meadow turf that has not been disturbed by trampling. Indicator species for good lighting conditions are, for example, *Antennaria dioica, Helianthemum nummularium, Thymus serpyllum, Polygala sp., Cerastium semidecandrum, Anthyllis vulneraria, Potentilla tabernaemontanii, Asperula tinctoria, Carex caryophyllea*. Some of the orchids spreading in the areas can go through their entire life cycle. If the grazing load is too low or if grazing ceases, the plant litter layer will accumulate, and the species composition of the community and the species abundance relationships will change. In particular, later-developed vascular plant species and taller grasses, such as *Helictotrichon pratense, Arrhenatherum elatius, Brachypodium pinnatum, Phleum phleoides, Poa sp., Agrostis sp., Calamagrostis sp*. are beginning to proliferate. Similar to the calcareous grasslands of the Netherlands, Brachypodium pinnatum is also in Estonia, a really good indicator species of the poor status of the community even before the increase of bush cover. Many alvar species are also very resistant to the change of light conditions-

Grazing loads

The choice of grazing load must be based primarily on the conditions of each pasture and also on the summer weather, which is why one must be very flexible when choosing a grazing load, and no unambiguous instructions can be given. Kadriann Saar in Vilsandi (Saar, 1996) has carried out the largest study to find suitable grazing loads for alvars. She found that in July, the biomass of alvar grasslands with a thicker soil layer (Avenetum-type) is 1334 kg/ha and energy content of 1.6 Mcal/kg. The energy consumption of one sheep for the grazing period (180 days) is 700 Mcal, and the energy consumption of one horse for 180 days is 2300 Mcal. According to these data, one sheep in Vilsandi needs 0.6 hectares and one horse 2 hectares of alvar for one grazing period. In Swedish studies, 0.2-1 livestock units per hectare are recommended for the maintenance of alvars (cattle over 24 months old = 1 LU, young cattle = 0.6 LU, sheep, goat = 0.15 LU, lamb up to 6 months old = 0.05, horse = 1 LU, foal = 0.35 LU). It must be borne in mind that the environmental conditions vary greatly from year to year - the annual load of a dry year could be close to zero, whereas, with a rainy summer, it could be more. There are also two peaks in annual productivity of alvars: the first in June, the second during the autumn rains from late August to early September, and in the periods in between, in dry summers, there may be no biomass production whatsoever.

therefore, even in overgrown alvars or alvar forests, we can find *Galium boreale, Leucanthemum vulgare, Festuca rubra, Pimpinella saxifraga, Fragaria vesca, Helictotrichon pratense, Prunella vulgaris, Cirsium acaule, Hypericum perforatum, Filipendula vulgaris* et al.

Overgrazing, i.e., excessive grazing load over a long period or for several consecutive years, does not have a good effect on alvar biota. Nitrophilous annuals and perennial species that can withstand trampling and stress (e.g., *Trifolium repens, Plantago major, Taraxacum sp.*) will start spreading in case of long-term heavy grazing.

Brachypodium pinnatum growing during restoration works in Sutu Bay limited conservation area in Vanamõisa. It is also a good indicator species, and its appearance in open areas shows that conditions are becoming too nutritious.

Helictotrichon pratense, Dactylis glomerata, Elymus repens and species with specific anti-herbivore features (*Cirsium acaule*, which, although in smaller populations, are also present in many good alvars, *Cirsium arvense, Carduus crispus, Urtica dioica, Verbascum thapsus*, et al.) will start proliferating. In addition to vascular plants, overgrazing also negatively affects several other groups of organisms, such as butterflies or spiders. If overgrazing has taken place, the area should be allowed to rest for a year and then be grazed with a more suitable load. Many plant species (including orchids) need to be able to stay in the community longer and grow in larger populations, so the species richness of vascular plants diminishes rapidly during overgrazing. However, short-term overgrazing is less of a problem than the long-term cessation of grazing.

However, overgrazing should not be confused with batch grazing, where grazing with a high load takes place during one or more (preferably a maximum of two) short periods, using the rest of the time for allowing the community to recover and also bloom, for example.

Mowing – rather emergency maintenance

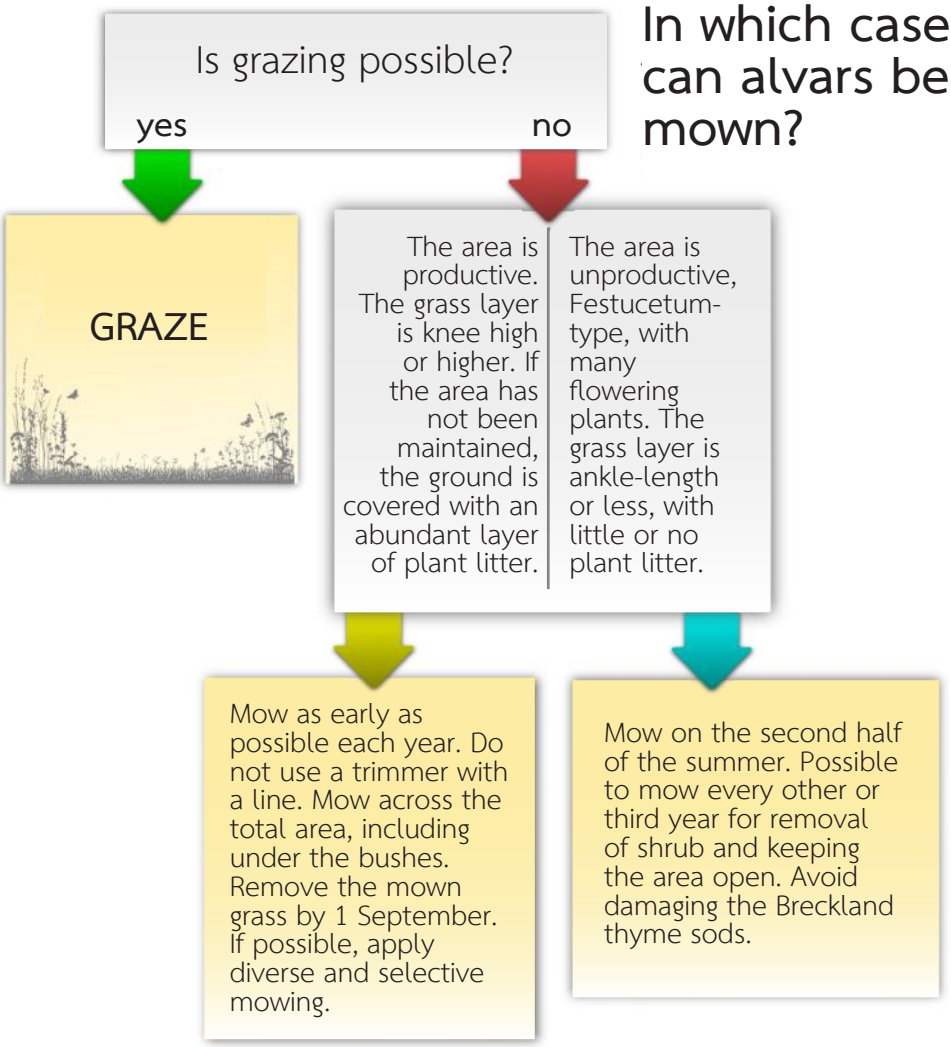
The best maintenance for alvars is grazing, and mowing should only be considered in the absence of the possibility of grazing. Under the current regulation on the maintenance of semi-natural communities, for being granted maintenance support, only grazing as a maintenance technique is allowed on eligible coastal meadows and alvars. Maintenance by only mowing is permitted if it is necessary to achieve species conservation objectives or if making hay and collecting and removing the hay is possible in the area. This is a sensible regulation that takes into account the historical use and the needs of the species. Many species are more connected to livestock and grazing. Mowing is also a suitable measure in combination with grazing with a suitable load in order to reduce the number of undesirable plants if necessary (e.g., removal of inedible plant species, weeds, etc.).

Some suggestions for mowing:

• Productive areas (hay height above the knee) should be mowed once a year, preferably in June or early July. Earlier mowing favors the species richness of the vegetation, which in turn has a positive effect on many other species groups. Late mowing (in August and later) promotes the dominance of grasses and the decline of plant species richness

• If possible, normal haymaking should be used, i.e., the mown hay should be dried in the same area and then removed. Drying hay in the area contributes to the ripening and spread of seeds of meadow species. However, immediate removal of freshly mown hay is recommended if there are undesirable plant species in the area (large grasses, weeds, invasive plant species).

• Very regular mowing can reduce species



In which case can alvars be mown?

richness. By applying mowing as a basic maintenance measure, different areas could be left unmowed to the extent of about 20% of the total area each year. This allows different arthropods to go through a life cycle and also favors the seed renewal of plant species. It would be good to apply diversified maintenance also to mowing: mow at different times in different years, mow at different times in the same area (mow part of the area earlier, the other part later), leave different parts unmown, and consider combining different maintenance measures if possible (grazing, mowing with different methods).

• Selective mowing is a method that favors desirable plant species; in this case, the specimens of the species whose expansion is desired are left unmowed, but the surrounding area is mowed. The method works well for orchids, for example, but also for other plant species, giving them a competitive advantage.

• When mowing, use small sized

mowing equipment (brush cutter, motoblok, small bar mower) and avoid damaging anthills covered with Breckland thyme. The use of a corded trimmer should be avoided, especially if there are young shrubs, sedge, and grass sods in the area.

• Mowing and removal of invasive shrubs for more than two-three years may be sufficient to keep low-productive Festucetum-type alvars in good status. In low-productivity areas where the height of the vegetation is less than 10 cm, the formation of the plant litter is not so great as to endanger the species richness. In this case, the purpose of maintenance is to avoid overgrowing and to prevent the expansion of existing shrubs.

• Mowing results:

Open alvar community has been preserved (shrub cover less than 40%);

Young juniper and deciduous shrubs and young pines have been removed from the area;

During mowing, the sods of larger-sized sedges and grasses have been partially broken;

Damage to anthills covered in Breckland thyme has been avoided during mowing;

At least every few years, mowing has been performed from under and around the shrubs;

Selectively, specimens of preferred plant species (e.g., protected species) have been left to grow, but mowing has been performed around them;

Diverse mowing has been applied, and if mowing is the main maintenance measure, alternating patches to the total extent of 20% are left unmowed each year.

After restoration, mowing is not a suitable method, as mowing once during the summer does not help to prevent the invasion of deciduous shrubs from the root shoots or to help the species spread seed in the restored area. If grazing (combined with root shoot shredding if necessary) is not possible after restoration, mowing combined with root shoot shredding should be carried out, or the root shoots should be removed by mowing several times during the summer; moreover, opportunities should be found to spread hay or seeds from the species-rich alvar, as there is no spread of seeds otherwise so characteristic to grazing.

Dealing with problematic species

On alvar, thistles, Brachypodium pinnatum, and in some cases, invasive species, such as Bunias orientalis, may start to proliferate in an alvar, either after restoration, during overgrazing or in case of the accumulation of nutrients in patches (for example, in the winter paddock or in the supplementary feeding area). Galega orientalis can also arrive from nearby old field edges and settle down in overly disturbed areas.

For the most part, proliferating species are predominantly a local problem that can be alleviated, for example, by trimming the area before flowering and fruiting of plants, but if there is a sufficient grazing load, the problem plants will eventually disappear on their own.

After restoration, grazing is the most suitable method for the rapid recovery of species richness and vegetation characteristics of alvars. Cattle in the Kahtla-Kübassaare limited conservation area two years after restoration work.

Chapter 5
RESTORATION

In order to ensure the preservation of this rare and rich community type in Estonia, it is necessary to increase the area of alvars in good condition to at least 11,000 hectares. Whereas in the past, alvars were restored mainly by hand and in very small volumes, then since 2014, large-scale mechanized restoration of alvars has been carried out in Estonia (see the chapter "Restoration of alvars with heavy equipment: experience of the project "LIFE to Alvars"). Practical restoration experience for large-scale works began to accumulate in Estonia within the framework of the alvar restoration project 'LIFE to Alvars' (LIFE13NAT/EE/000082). From 2014-2019, the project funded by the European Union's LIFE + program and the Environmental Investment Center restored a total of 2,500 hectares of the most valuable alvars in Saaremaa, Muhu, Hiiumaa, Lääne County, and Pärnu County. Extensive work on the restoration of alvars has also been carried out by the State Forest Management Center, which has restored large alvar areas in Vilsandi National Park, Tagamõisa Limited Conservation Area, Karala-Pilguse Limited Conservation Area (Katri cliff), Sarve Peninsula in Hiiumaa, in Oina Limited Conservation Area in Muhu and Väike Väin Strait Limited Conservation Area. Many private companies have carried out restoration work and

Changes in overgrowing of alvars and necessary activities at different stages of succession

Succession proceeds in this direction when management ceases

Habitat	Open alvar	Open alvar at risk of overgrowth	Overgrowing alvar in need of rapid restoration	Alvar juniper shrub	Alvar forest
Coverage of junipers	10-30(40)%	40-50%	50-80%	80-100%	Junipers are sparser, pines, firs, or birches are overgrown
The presence of a meadow turf	present densely located meadow species	present, meadow species dominate	turf by patches preserved, but sometimes very mossy, and vegetation is sparse	There is no turf, and the ground is covered by fallen thorns and moss, the species richness of vascular plants is low.	In a well-established alvar forest, there are several types of bushes in the undergrowth and quite a few forest species and also open alvar species in the groundcover
Necessary actions	Maintenance	Primarily maintenance; removal of junipers/trees if desired and possible	Primarily restoration (removal of junipers/trees); immediately followed by maintenance	If possible and desired, then restoration of such an area into a more open meadow is very effective, especially if open alvars have been preserved in the surroundings. If there is no desire or possibility for restoration, the area can be considered as belonging to the juniper habitat type. although preservation as a juniper shrub is not supportive of biodiversity	Human activity is not necessary to preserve the alvar

have also been gaining experience in restoration since 2015. In the course of the 'Life for Alvars' project, the Estonian Seminatural Communities Conservation Association conducted theoretical and practical training for all restorers; a total of 160 land managers, landowners, or entrepreneurs have completed the relevant training and obtained a restorer certificate in Estonia.

In order to create suitable conditions for valuable alvar species, young trees, pine crops established during afforestation campaigns, and most junipers must be removed from the overgrown areas, decreasing the coverage of woody plants to 30-40%. Then, the necessary infrastructure for the further maintenance of the areas - stock yards, roads, livestock drinking places, and, if necessary, shelters - will then be built.

Selection of suitable areas for restoration

All historic alvar pastures are suitable for restoration, even if they are relatively overgrown or forested today. Experience from restoration work so far shows that overgrown Estonian alvars have still preserved the species fund of plant species characteristic to alvars, and in most cases, also the landscape cohesion necessary for rapid recovery (the proximity of the so-called donor habitats in good status). Kalamees et al. (2012) have shown that many species characteristic of alvars have survived in the seed bank of overgrown Estonian meadows even

Restoration of an alvar on Ruhve Peninsula in the Kahtla-Kübassaare limited conservation area. Orthophoto of pre-restoration time and drone photo immediately after restoration work. Photos: Land Board, Ants Animägi, RMK.

All abandoned and overgrown alvars are subject to restoration, but due to limited resources, the following choices should be made when deciding on the order of restoration areas:

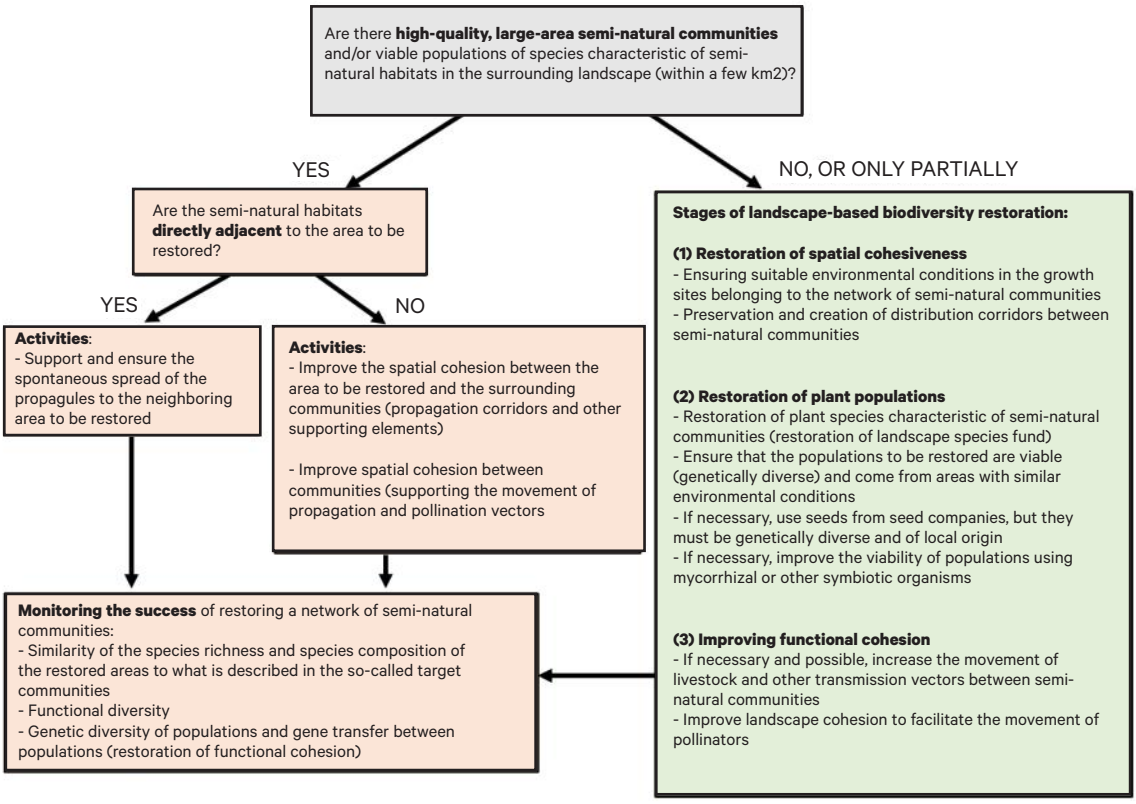
First and foremost	Secondly order
+ the nature conservation status/ representativeness of the area has received a high score in the inventories	- the nature conservation status/ representativeness of the area has received a low score
+ the interest of local residents is high, and there is a maintainer	- maintainer is more difficult to find
+historically (ca. the 1950s), the region has had a larger area of meadows	- a smaller historical area of meadows
+ the area is located in the immediate vicinity of other meadows - good connectivity with other meadows (there are similar areas at least within 600 meters)	- there are few meadows in the surrounding area - isolated
+ the area is larger	- the area is smaller
+ there are protected species related to meadows both in and around the area	- there are no protected species
+ the area is less overgrown	- the area is very heavily overgrown (including trees).
+ the populations of the species characteristic of the meadow have mostly been preserved	- very few species characteristic of meadows have been preserved
+ the area to be restored contributes to the increase of landscape diversity of the region	

50 years after being overgrown, creating opportunities for effective recovery. In Estonia, the Environmental Board has commissioned a methodology for the ecological prioritization of the restoration of semi-natural communities and a map layer that provides an overview of which areas that are still out of maintenance should be primarily focused on (Helm & Toussaint 2020). The ecological need for restoration is great: it is estimated that there must be 11,000 hectares of alvars in Estonia for the safe preservation of alvar species.

Principles of land–scape restoration

Location of restoration areas

At present, alvars are still in need of improvement in Estonia, and in order to obtain the most optimal result, it is necessary to assess whether the landscape context allows for a good recovery of the areas or whether we should contribute to improving



Decision tree for shaping the principles of restoration and planning activities depending on the status of the restored communities and landscape cohesiveness (Aavik & Helm 2017).

cohesion. Aavik & Helm (2017) has compiled a decision tree to assist in the planning of restoration work to ensure the cohesiveness required for biota (see above). From the point of view of butterflies, Tiitsaar & Talgre (2015) have estimated that in order to maintain cohesiveness, groups of adjacent areas where the habitat patches are not more than 600 m apart should be preferred for the restoration of alvars. In this case, they act as a single habitat system for butterflies, and the constant movement and exchange of specimens ensures that butterfly populations are maintained even when each particular patch is not suitable at all times (for example, there is temporary overgrazing). On the other hand, although areas should be restored in groups, the groups may be relatively far apart from each other. Butterflies are more likely to arrive successfully if they are not there before (Tiitsaar & Talgre, 2015).

Practical activities in the restoration of alvars

Several factors need to be considered at the same time when restoring. As the aim is to create an area as rich in species and in as good a condition as possible, the work must be approached carefully.

Small and isolated areas are also important!

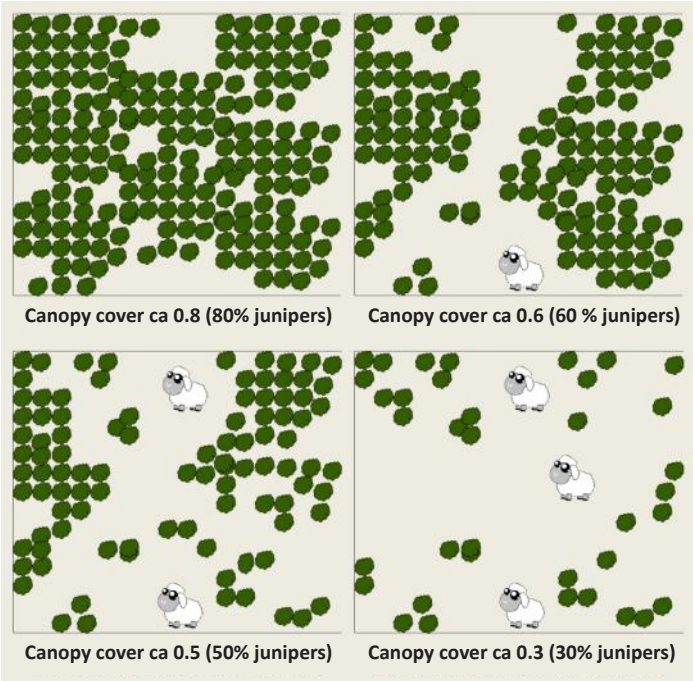
The safe survival of species connected to habitat is mainly ensured by the existence of large core areas with good cohesiveness between habitats, diverse environmental conditions, and a surrounding landscape supporting the species. However, it must be borne in mind that in depleted landscapes - cities, agricultural landscapes, areas with young forests - the still preserved meadow patches are particularly important in supporting the area's biodiversity. While such habitat patches cannot guarantee the survival of species associated with semi-natural communities, they are disproportionately important in supporting the area's biodiversity and providing important ecosystem services. All surviving historical semi-natural communities must be preserved, protected, and restored today.

Arranging maintenance

Before starting restoration work, the arrangement of further maintenance must be clear. As a result of the restoration, the area must be suitable for entering the maintenance scheme. As a result of the restoration, a safe environment for livestock and conditions suitable for alvar species is ensured. It is a good practice that the future maintainer of the area is also involved in the restoration work, thus ensuring that the restoration will result in an area suitable for maintenance.

Reducing the coverage of junipers and other woody plants

As a result of the restoration, up to 30 (40)% coverage of woody plants should be achieved; moreover, it would be preferable if the restoration results in the emergence of different-looking areas with the coverage of different woody plants in the same region. The more open areas are for many bird species, and areas with juniper groves are for butterflies and bush-nesting birds. Visually judging, 30% coverage is where from between the shrubs and trees generally a view opens on the paddock and all the way to the horizon or until the boundary of the area. In the case of juniper coverage of 30-50%, the alvar is still relatively



The aim of restoring overgrown areas is to increase the coverage of junipers and other woody plants by 30-40%.

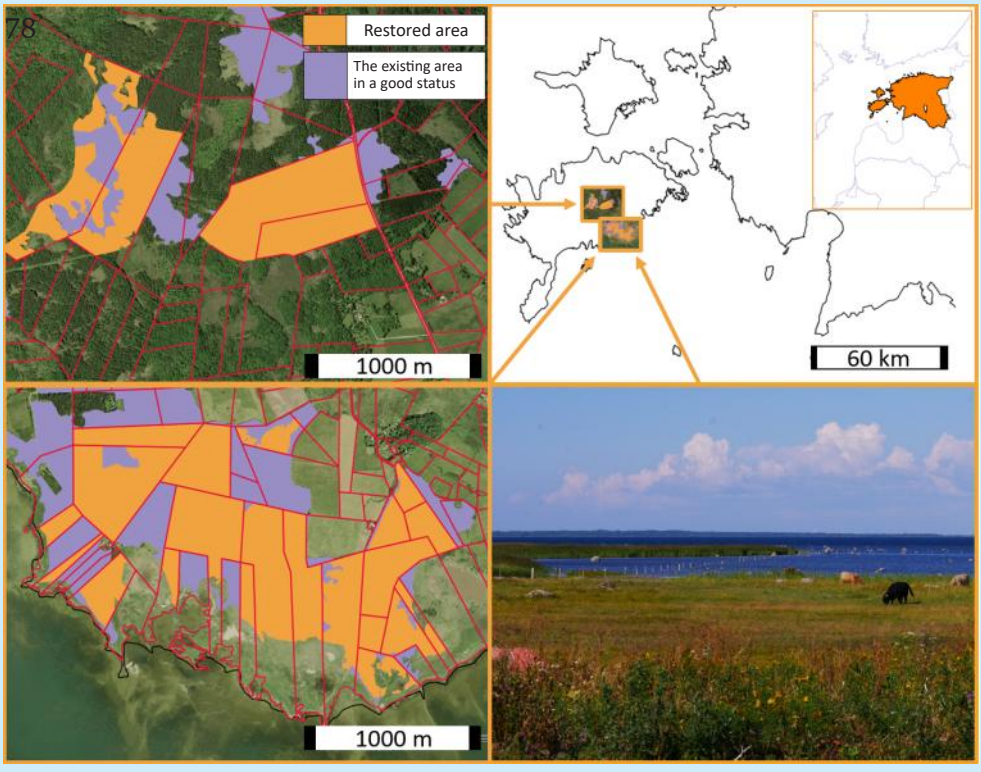
open, and all the features characteristic of alvars are represented there. In this case, the primary task should not be to thin the junipers (which, of course, can be done) but to maintain and monitor the area so that the area does not overgrow further.

Creating a diverse landscape

It is a good practice to create a mosaic landscape, where the open areas and the patches of scattered junipers alternate with denser groups of bushes. Larger trees and shrubs are good for windbreaks and shelters from the sun. It is worth avoiding the design of the area, where junipers are placed one by one at regular intervals. In the forested areas, junipers are often long and sparse, which, when left in an open area, break with wind and snow and also suffer from sun damage. In this case, it is better to create more open places in these areas.

Selection of restoration sites in the LIFE to Alvars project

The areas restored during the "Life for Alvars" project were selected so that they were located in the immediate vicinity of better-preserved alvars. This will ensure the rapid spread of the species to the restored area. The drawings show the preserved areas and the areas that have been restored in the Ilpla alvar (Tahula-Reo limited conservation area, above) and in the Vanamõisa - Suure-Rootsi alvar (Sutu Bay limited conservation area).



Freshly restored area on Ruhve Peninsula in Kahtla-Kübassaare limited conservation area. As the area was pretty overgrown, the restorer decided to design the area so that the larger juniper groves alternate with an open area. Photo: Ants Animägi, RMK.

Creating and maintaining biodiversity-preserving elements and preserving cultural heritage sites

It is important to preserve the landscape elements that have emerged during the restoration works: stone fences, foundations, single stones, stone ridges, quarry sites, remarkable trees, thicker snags, or other landscape-enriching phenomena. They provide habitat for different groups of biota and enrich the landscape. For example, single stones and stone fences provide a nesting site for the Oenanthe oenanthe.

Timing of restoration work

It is important to carry out restoration work (deforestation and removal of material) outside the breeding season of birds, i.e., from August to April. The earliest arrivals of alvar nesting species in March -April are the species nesting in the ground: Vanellus vanellus, Alauda arvensis, and Emberiza citrinella. The species of protection category III returning to the breeding areas later, in mid-May, are the Lanius collurio and the Sylvia nisoria, which nest in the bushes (incl. junipers). NB! As several species (e.g., Lanius collurio, Motacilla alba, Erithacus rubecula, Muscicapa striata) also sometimes choose to breed in

Restoration work often reveals old cultural heritage sites, settlements, stone fences, veteran trees, and other exciting things. An old settlement in Igaküla, Muhu, was revealed during the alvar restoration carried out in 2016. Ants Animägi, RMK

wood piles are cut and left to dry during the restoration, and it is important that the material is also transported outside the breeding season.

Damage to the grass turf, storage of timber

• Damage to the grass turf, either due to wheels/tracks or in the course of crushing operations, is somewhat unavoidable during restoration work, and one doesn't necessarily have to be afraid of it. Experience so far has shown that, for example, the disturbance caused by the operation of a chain shredder in the thorn and plant litter covering an overgrown area is necessary for the seeds of meadow species slumbering in the seed bank to receive a signal of changed conditions. However, no one likes big track trails, so it is worth choosing the right weather conditions and season for the restoration work according to the technology used. Special care should be taken in wetter areas.

• The resulting trails must definitely be leveled in the year following the formation (i.e., before new vegetation has formed on the trails) to make further maintenance easier and more visually pleasing.

• It is important to avoid the establishment of transportation routes and storage sites for felled trees and shrubs on the still open alvar areas and potential habitats for protected species (e.g., orchids). Where possible, a site without grass turf or with scarce grass turf (e.g., the base of a former dense juniper group) should be chosen for burning or storage.

• Damage to landscape elements of archaeological or cultural significance, as well as damage to known habitats of protected plants (e.g., Cypripedium, Asplenium, etc.), must be avoided.

• The material to be felled (both trees and shrubs) must be collected during the same restoration season and burned in a suitable place or stored for removal/chipping. The stored material must be removed from the area as soon as possible. Longer-term storage promotes the proliferation of weeds and accumulation of nutrients

Figure. Junipers and pines collected from the restored area are waiting to be removed. Timber should not be stored for more than one season.

under the storage site.

• Stored material must not be removed during bird peace.

Shrub layer formation

• Experience to date has shown that in an area covered with trees and shrubs, it is useful to first thin the shrub cover to a suitable coverage and only then start removing the trees.

• All progeny of conifers (pine, spruce) must be removed from the shrub layer.

• Selective removal of loose or dead junipers, except in the case of coarse junipers (junipers with a trunk diameter of more than 10 cm, in which case they are also an important habitat when dried).

• Preserve coarse-stemmed veteran junipers (so-called tree-shaped junipers).

• Deciduous shrub stump shoots must be additionally removed (mowed, crushed) in the subsequent years, if necessary

• When restoring, junipers should be left standing in groups of different sizes, i.e., instead of individual junipers, smaller juniper groves should be left, at least some of which could be at least 10 x 10 m wide and at least 1.5 m high. The presence of such groves favors the nesting of Sylvia, Lanius collurio, and other passerines nesting in the juniper shrubs. It is important that the preserved juniper grove is dense and at least 1.5 m high. Birds generally do not nest in low and sparse groves.

• The stumps formed when removing woody plants must not be higher than 10 cm.

• There must be no tree trimmings left in the restoration area

Lõetsa alvar in Muhu before (in 2015) and immediately after restoration (in 2017).

with more than 5 cm in diameter and more than 0.5 m long.

• Do not use the shredder to restore an area with large (over 1.2 m) junipers. The resulting tree trimmings hinder the regeneration of the area's vegetation and the risk of proliferation of weeds increases.

• Think of a wind shelter; if it is not a transition to a coastal meadow (in this case, open the community to the sea), then leave a shrub grove or bush strip in the seaward areas to create slightly more windless conditions in some areas.

Restoration work and trees

• The restored alvar area may be free of trees, with few trees (NB not conifers but rather the Swedish whitebeam, rowans, oak, birch, and other deciduous trees) or with small wood groves if there is a need to provide shade for livestock and create more diverse conditions in the area.

• Young and middle-aged pines and spruces must be removed from the alvar.

• Preserve veteran trees (both coniferous and deciduous); if they are present in the area, including laying trunks with a larger diameter (over 30 cm) if they are available.

• Hardwoods (oak, rowan, Swedish whitebeam, birch, etc.) and shrubs should be preserved, for example, near stone fences, limestone quarries, and other landscape elements.

• Preservation of small groups of conifers in the restored alvar is conceivable if there is no other suitable shade for the livestock in the paddock. Preference should be given to the deciduous tree group.

• In otherwise open coastal areas, it is not good to leave taller individual trees or groups of trees in the restored area, as such trees are used by crows (hooded crow, raven) to observe the surroundings and find food in the nests of other birds. Leaving single tall trees in an open area can reduce the nesting success of ground-nesting waders (Vanellus vanellus, Numenius arquata, Gallinago gallinago,Tringa totanus). If for some reason (e.g., to provide shade for grazed animals), trees are necessary for the management of the area, they could be left at the edge of the restored area and not in the middle of it.

• The size of groups of trees or shrub groves left in the area should not exceed 0.05 hectares.

Construction of stock yards and infrastructure for grazing

When setting up the stock yard, it should be borne in mind that the areas to be maintained are often large, but the stock yards to be built must not restrict the access of wild animals to the rest of the landscape and should not force wild animals to cross highways or otherwise restrict their movement. For example, when grazing parts of a peninsula, care must be taken not to close the entire peninsula to wild animals.

For winter or some other periods, when there is no livestock in the area, the stock yards need not be open at least partially to ensure that wild animals have access to the grazed area.

It has been a good practice to make stock yard posts from split oak posts that are long-lasting and weather-resistant. Stock yards built of juniper trunks are also durable.

What to do with felled junipers and trees?

Junipers can be used in different ways: you can build fences, make chips, use them for heating, mulch, and coarser ones for products made of juniper wood. On-site burning may be considered for smaller jobs.

Sowing seeds to speed restoration

In isolated and degraded areas, the use of locally sourced (i.e., from well-preserved alvar in the same area) seed mixtures may be considered to accelerate vegetation recovery. In Estonia, the sowing of seeds by various methods on alvars has been tried with good results within the framework of the "Life for Alvars" project (MTÜ Elurikas Eesti, 2018). In order for seed mixtures to be used efficiently and sustainably, the following advice should be adhered to: seed mixtures must be of local origin, i.e., come from meadows of the same type in the same area (within a radius of 50 km). Specialists should definitely be consulted here for planning and carrying out the work.

Figure. Split oak poles as holders of electric fence in Võiküla alvar in Muhu.

Movable watering barrels for livestock purchased under the 'Life for Alvar' project.

In Estonia, the sowing of seeds from nearby areas has been used for the restoration of alvars. The picture shows the equipment used to collect the seeds.

Restoration of alvars with heavy machinery: the experience of the 'LIFE to alvars' project

Annely Holm

Until 2014, the restoration of alvars overgrown with woody vegetation took place mainly by hand, where a chainsaw and trimmers were used to remove bushes and trees.

Attempts were made to gradually restore overgrown alvars by gradually reducing coverage using slow manual restoration techniques. This often led to a situation where the newly restored area was covered with bush again before maintenance could even begin. The light conditions created during the gradual and slow restoration were not sufficient for the regeneration of the grassland vegetation. From 2007-2014, the area of Estonian alvars increased by only 500 hectares during manual restoration. In 2013, during the preparation of the project "LIFE to alvars," tests were carried out on the restoration of an alvar with machines in Kassari, Hiiumaa. As part of a project launched in 2014, the reclamation of alvars was started using machines. Based on the tests, a completely new integrated approach to the restoration of alvars was developed, which is currently used also in the restoration of other semi-natural communities.

A chain shredder attached to the excavator helps to crush low junipers.

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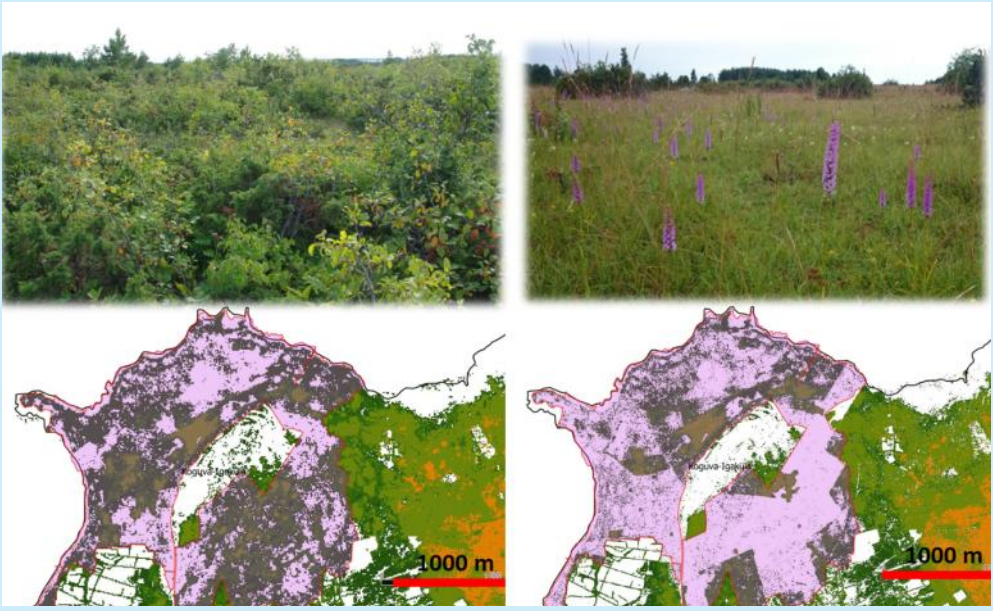

Left column: Koguva alvar in 2014 before restoration, the image above shows a view of the area, the image below shows the vegetation height of the entire restoration area based on the vegetation height model based on aerial laser scanning (LiDAR). Right column: Koguva alvar in 2017 after restoration.

As an innovative solution, an excavator-mounted chain shredder and guillotine, as well as conventional forestry machines such as a harvester and forwarder, were introduced to restore alvars. A chain shredder has typically been used to clean the area under power lines and to trim bushes at the roadsides. The excavator-mounted chain shredder and guillotine were found to be an effective combination for cleaning overgrown alvars. The forwarder is efficient for collecting and exporting cut biomass, and a harvester is efficient for felling larger trees and upcycling material.

Prior to the start of the restoration work, the biggest fear was that large machines such as the harvester, forwarder, and excavator would leave deep trails during the work and damage the areas to be restored. Experience has shown that, given the weather conditions, the use of heavy machinery during restoration work does not pose a threat to the habitat. If the ground is excessively

Restoration costs: example 1

Restoration with machines in Koguva

During the 24-week period in the winter of 2018-2019, a 60 ha alvar was restored in Koguva alvar with one set of machines, which included a guillotine, a chain shredder, a harvester, and a forwarder. In total, two people worked, each estimated for 190 days or about 1,500 hours. It took an average of 50 hours to restore one hectare of alvar. The cost of restoration of one hectare of alvars, including all expenses, was 1,500 euros.

Manual restoration on Pädaste alvar. Photo: Annely Holm

Restoration costs: example 2

Manual restoration in Pädaste

In the winter period of 2018-2019, a 0.6-hectare alvar was manually restored during a three-week period. In total, two people worked, each estimated for 100 days. Recalculating the cost of working time to restoration of one hectare of alvar, manually, it would take an estimated 330 hours. The cost of restoration of 0.6 hectares of alvars, including all expenses, was 1800 euros. The cost of restoring one hectare of alvar, recalculated, would be 3000 euros.

wet during heavy rains or after melting snow, work must be stopped for a while, and crossing areas with a marshy ground must be avoided. By following these simple rules, existing machines can be used effectively to restore alvars. They allow fast restoration work over a large area. The average time spent on mechanized restoration per hectare is about one week, but in the case of manual restoration, this work takes about two months to complete. In addition, mechanized restoration is more cost-effective than manual restoration. Thus, when the goal is to restore hundreds or thousands of hectares, mechanized restoration is clearly preferred in terms of time and budget.

The restoration process implemented under the project was divided into two phases: the first involved the cutting and removal of large amounts of shrub and tree layer from the overgrown alvar. The second phase was usually carried out about one year after the end of the first phase when the height of the stumps was adjusted with the chain crusher. The second phase was necessary because a thick layer of thorn litter had accumulated on the ground in the project areas, where pines and junipers had been growing for decades. When trees and shrubs are cut down, and the layer of thorn litter is trampled during grazing, the stumps become taller again as the thorn layer and moss sink lower and begin to recede. Stumps crushed by a chain shredder also decompose much faster than those with a straight cutting surface, as it is difficult for rainwater, fungi, and other decomposing organisms to penetrate into it the latter.

Restoration of an alvar on Sarve Peninsula. View of the area before restoration in January 2016 and after restoration in April 2016. Ants Animägi, RMK

Post–restoration grazing and shrub care

Freshly restored areas must be immediately engaged in grazing. It is most practical for livestock to be able to move between areas that are in good status and newly restored areas so that the species can spread quickly. After restoration, it is not reasonable to limit the grazing load and take rest years. In order to take the growth of shrubs and trees under control and for the recovery of the grass turf, a grazing load close to the maximum (even periodically) must be applied, and transition must be made on grazing with varying loads later when the area has fully recovered.

In order to remove the deciduous shrub that emerged from the stump shoots, it may be necessary to crush the area with a chain shredder in the second and/or the third year after restoration and later if necessary.

Upgraded machines

In the case of restoration felling, a condition is that no logging waste more than 5 cm in diameter and longer than 0.5 m long may remain in the felling area. The stumps must also be as low as possible and cut parallel to the ground so that they do not endanger the feet of the cattle. This is a challenge for the restorer, but only temporarily. Thus, the restorers themselves have built chain shredders at the end of the excavator boom, which break the last branches still lying in the area and soften the ends of the stumps. The picture shows a chain shredder built by the restorer of Atla alvar. Photo by Kaupo Kohv, RMK.

Practical challenges in restoration

In coastal areas, nets left by fishermen and waste from different times, including scrap metal, barbed wire, etc., often lie in dense juniper shrubs or under forests. The nets have become fragile over time, but they still get caught between the tools. Scrap metal can damage the machines and can also be dangerous to the operator. Caution is appropriate.

When grazed with a suitable load, the overgrown area recovers quickly, especially if the area still has some grassland characteristics of the open alvar before the restoration.

The young deciduous shrub that emerges in the restored area needs to be crushed again in the second or third year. In the photo, alder, buckthorn, and honeysuckle emerging on the restored alvar of Kassari.

Chapter 6

JUNIPER SHRUBS IN ESTONIA

Juniper shrubs belong to habitat type 5130 of Annex I of the European Union's Habitats Directive (juniperus-communis-formations-on-heaths-or-calcareous-grasslands). The juniper shrubs widespread in Estonia can be broadly divided into juniper shrubs in the former alvars (alvar juniper shrubs, which emerged upon overgrowing of open alvars) and juniper shrubs that have arisen during the overgrowing of different meadows (Boreal heaths and dry and fresh grasslands) as well as felling areas or fallow fields with junipers (Paal, 2000). Juniper shrubs of primary origin are found to a small extent only in coastal pebble ridges (Paal, 1997). As with many other meadow communities, juniper in Estonia is not a climax community (i.e., a long-term independently permanent community) but a successional (non-permanent) community before the formation of a forest community. Mapping the distribution of juniper shrubs has not been specially addressed. At present, 4800 ha of junipers have been mapped in Estonia on the basis of the combined data layer of the map layer of semi-natural communities, the map layer of Natura habitats, and the ESCCA map layer, of which ~ 3600 ha are protected areas.

In this guide, the distinction between 'alvar juniper shrubs' and 'juniper shrubs' is used, as their origin and possible maintenance are different.

Alvar juniper shrubs

An overgrown alvar that either has no restoration potential into an open alvar or there is no wish to restore the area can be considered alvar juniper shrubs. In most cases, it is a successional state between an open alvar and an alvar forest (mostly pine forest, in some rare cases also deciduous or spruce forest). Alvar juniper shrubs are distinguished from juniper shrubs that emerged from other types of meadows by 30 centimeters thinner carbonate soil.

According to the Habitats Directive's habitat manual (Paal 2000) in Estonia, overgrown alvars were considered to be juniper shrubs in Estonia, but it was already clear at that time that in the case of an alvar as a degraded (overgrown) key habitat, it was important to improve their status, rather than assign them to a new habitat type. Dense juniper shrub grows fairly quickly in alvars - no later than 30–40 years after the completion of the maintenance of the area, the coverage of junipers in areas with thicker soils can be close to 100%. Juniper grows the fastest at the age of 5-20 years. Today's dense juniper shrubs common in Saaremaa and Western Estonia are 40–50 years old (Kalamees, 2004). In the case of very dense and youngish (less than 100 years old) alvar juniper shrubs in Estonia, it is mostly an extremely species-poor community.

Although habitat type 5130 is also considered to be worthy of protection on a European scale, we here in Estonia are primarily responsible for the preservation and well-being of high this priority and unique alvar habitat type. Thus, in order not to risk the destruction of alvars in Estonia and the extinction of the species growing there, we must first of all restore and manage as many alvars as possible (even if this has to be done at the expense of habitat type 5130). The overgrown habitats should be predominantly restored as open alvars, and it is, therefore, important to consider the historic alvar habitat type, which is 50% denser juniper coverage as a habitat type * 6280, which preserves the possibility of their restoration and further maintenance.

As the share of light-demanding meadow species in the community begins to decrease rapidly at about 80% of juniper cover (or pine canopy cover) (Pärtel et al. 1999), the designation of the area as alvar before justifying reaching this coverage and the restoration of the area to a more open community is also effective and highly recommended whenever possible. Experience from Estonian alvar restoration works (e.g., the "LIFE to Alvars" project) has shown that even in areas that are completely overgrown with junipers, restoration is very effective, and biodiversity is restored quickly if it is a historical meadow and if in the immediate surroundings the species characteristics of open alvars are still preserved.

However, if the area does not have restoration potential, there are no interested maintainers, or if it is preferred to maintain a denser juniper shrub than is recommended for open alvar (less than 50%), designation of the habitat under habitat type 5130 may be considered. However, in a well-maintained juniper shrub habitat type, the coverage of junipers and other woody plants should not exceed 75-80%. Therefore,

the recommended range of juniper coverage in alvar juniper shrubs (i.e., in areas that could also be potentially alvars) could be about 50-80%. An area with less than 50% coverage should definitely be designated as open alvar with habitat type code *6280. In addition to vascular plants, which prefer more open conditions, many birds associated with junipers (barred warbler, Red-backed shrike) prefer mosaic meadows with juniper groves rather than an area covered with junipers. The richness of the species gradually increases as the juniper shrubs age, as the lighting conditions improve slightly, and the undergrowth and trees and shrubs characteristic of the alvar forest are added. At the latest, when the first-generation junipers die (and in some areas much earlier), the conditions are usually created also for the formation of pine, birch, maple bush, and subsequently alvar forest.

In the Estonian practice in the period 2007-2020, overgrown alvars have mainly been treated as alvars, rather than juniper shrubs. However, it should be emphasized that, if the following conditions are met, an overgrown area or an area at risk of overgrowing with junipers site should be continued to be considered an alvar (Habitats Directive habitat type * 6280) and not juniper shrubs (5130):

(1) the previous condition of the area was alvar grassland;

(2) soil thickness (without thorn litter) less than 30 cm;

(3) adjacent to the area or in the immediate vicinity (up to 200 meters away) of the area are preserved open alvars (even if they are small areas of a few hundred square meters).

Other types of juniper shrubs

Juniper shrubs are not always associated with limestone areas, and in addition to alvars, several other semi-natural meadows can overgrow with junipers: drier boreo-nemoral meadows and dry heath meadows, and boreal meadows with sandy soils (Jürgens & Sammul, 2004). In most cases, the proliferation of junipers is a sign of

Juniper shrub partly maintained by chopping, in Kalvi limited conservation area in West-Viru County. It is probably a juniper shrub formed on calcareous grassland, which would need mowing (at the end of June - in July with the removal of hay) or, preferably, grazing in order to maintain its biodiversity. Dense vegetation has prevented the wider spread of junipers.

inadequate meadow maintenance. However, in some cases, such communities may also have a high nature conservation value even when overgrown with junipers (for example, Koiva-Mustjõgi); therefore, other types of junipers can be defined as Natura 2000 habitat type 5130 with a lower juniper coverage than the 80% that is the limit in case of alvar juniper shrubs. For more information, see the chapter "Maintenance of other types of juniper shrubs."

Juniper shrubs can also form in areas where the previous condition has not been a semi-natural grassland. Examples of such areas are abandoned farmland, clearings, and others. Juniper shrubs formed in place of felled alvar forests in Western Estonia are common (Jürgens & Sammul, 2004).

It is most likely that when aging and with an invasion of deciduous or coniferous trees, all of these juniper shrubs will turn into a forest that one day will correspond to the soil type.

With their completely natural origin, juniper shrubs have emerged as primary communities on the pebble ridges that emerged from the sea (e.g., Hiiumaa, Suur-Pakri Island).

Restoration of juniper shrubs into meadows

Restoration of an area with more than 80% juniper cover to the previous community type (both alvar and other types of meadows) is also possible. This is especially worthwhile if the meadow turf is still preserved, the junipers have not quite 100% coverage, and the meadow species are still preserved in the surrounding landscape. When restoring such areas, follow the restoration recommendations provided in Chapter 5. After restoration, depending on the area, biomass production may be higher than that normally found in meadows. In this case, grazing must be started with a slightly heavier load and reduced to moderate from year to year.

Maintenance of juniper shrubs

There are no guidelines for the management of juniper shrubs (5130) in the general management guidelines for Natura 2000 habitats (Management of Natura 2000 Habitats. Http://ec.europa.eu).

The habitat type of juniper shrubs may be of semi-natural origin in most cases, but in the case of more than 80% of juniper (in some cases in addition to junipers also deciduous bushes) coverage, it is not expedient to maintain the community without intervention, it is necessary to decide whether to leave the area in natural development or in case of a desire to restore, to thin the coverage of woody vegetation. The juniper shrub is not a long-term, self-sustaining community, as when the junipers of the first generations die, the progeny of junipers is unlikely to be able to compete with the faster-growing deciduous trees or pines. Succession leads to the creation of an alvar forest.

However, even without any maintenance, the juniper shrub can last for quite a long time (up to several hundred years). The dynamics of juniper shrubs that have formed on heaths or boreal meadows may differ from alvar juniper shrubs (for example,

it may take longer for them to reach maximum juniper coverage), but there are no studies on this. In the case of juniper shrubs formed on grasslands with dense grass cover, the overgrowth with junipers and other woody plants is not very fast, and such areas often remain open for quite a long time.

Grassland with junipers belonging to the juniper shrub (5130) habitat type in Akn□ste area of Latvia.

It is not justified to provide land management support for the maintenance of juniper shrubs (juniper coverage over 80%). At the same time, grazing does not hurt them, so they do not have to be left out of the pastures.

Maintenance of alvar juniper shrubs

The alvar juniper shrubs are former alvar areas with a total juniper coverage (soil layer less than 30 cm thick), and in case of less than 80% juniper coverage, they should be defined as alvar areas in need of restoration. It should be considered that the maintenance of alvar juniper shrubs (removal of trees, grazing) is no longer practical if the community type is correctly defined in such areas (i.e., juniper cover over 80% in case of juniper shrubs emerged from alvars, meadow turf destroyed and lighting conditions under junipers very poor). If there is a desire to maintain (graze) such an area, the area must first be restored as open alvar, and the success of the recovery must be assessed in advance (whether the species have somewhere to come from, i.e., whether there are open alvars in the vicinity, post-restoration grazing opportunity, etc.). See Chapter 5 for restoration.

Maintenance of other types of juniper shrubs

The definition of the other type of juniper shrubs and the instructions for their maintenance are different from those given for the alvar juniper shrubs. Juniper communities formed from grassland, heath meadows, and boreanemoral meadows can also be defined as juniper shrubs at 30-80% coverage and maintained as juniper shrubs subject to maintenance (5130). However, for the start of maintenance, the coverage of junipers should not exceed 60%, which ensures their suitability for species that prefer both shady places and more open spots. Openness is ensured only by grazing in the long run or cutting out junipers and other woody plants

from time to time.

If a massive juniper shrub has already formed (the coverage of junipers and other woody plants is over 80%, the species characteristic of the meadow are lost), the area must either be restored to be eligible for maintenance (i.e., the coverage of woody plants must be brought to less than 60%) or it must be left for natural development. Otherwise, maintenance (similar to alvar juniper shrubs) is not justified.

In short, in the case of other types of juniper shrubs, it is necessary to consult the landowner and decide together whether

to maintain the area as an unmanaged massive juniper shrub (code 5130, juniper coverage> 80%, without maintenance support);

to maintain the area as a maintained juniper shrub, to remove junipers from time to time to maintain suitable coverage (5130, total coverage of junipers and other woody plants 30-60%, restoration support, maintenance support). Suitable care is mowing or grazing; chopping is not suitable;

to restore the area to the previous condition either as a maintained grassland, heath meadow, or boreo-nemoral meadow (coverage <30%, restoration support, maintenance support), to maintain it in accordance with the maintenance recommendations of the habitat type. Juniper shrubs of primary origin on pebble ridges generally do not require maintenance, but grazing does not harm them either.

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ALVARS and JUNIPER SHRUBS

Semi-natural communities are valuable and species-rich natural ecosystems that have been passed down to us through millennia as a result of the sustainable use of land by our ancestors. In order for Estonia's semi-natural communities to survive in the future, we must continue grazing, mowing, and other necessary activities to support biodiversity. So here you are holding a guide that gives you an overview of how to best operate in Estonia's **alvar pastures**. The guide provides an overview of alvar and juniper shrub habitat types, describes the bases for the development and conservation of their species richness, summarizes general guidelines for the most appropriate management of communities, and provides a theoretical basis for the creation of further area-based management plans. The guide is intended for all people and institutions interested in Estonian semi-natural communities and, above all, could be of help to the caretakers of Estonian semi-natural communities and various institutions dealing with nature conservation, agriculture, and sustainable landscape use.