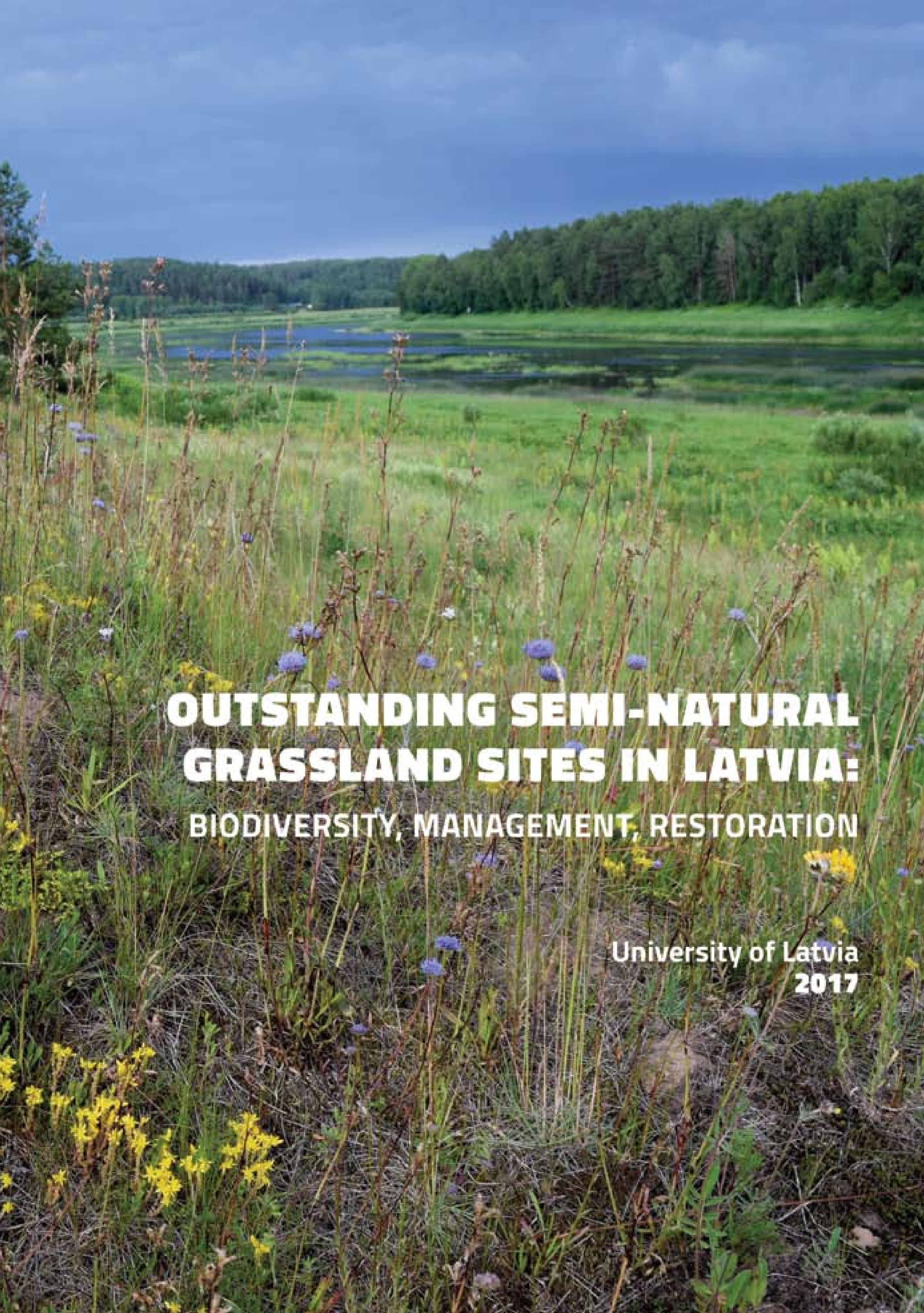

OUTSTANDING SEMI-NATURAL GRASSLAND SITES IN LATVIA:

BIODIVERSITY, MANAGEMENT, RESTORATION

University of Latvia
2017

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Edited by Solvita Rūsiņa

University of Latvia
Riga, 2017

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PREFACE

This collection of scientific articles was prepared for the 14th Eurasian Grassland Conference (EGC), held in Latvia in 2017. The EGC is the main annual event of the European Dry Grassland Group (EDGG, www.edgg.org). EDGG is a Working Group of International Association for Vegetation Science (IAVS, www.iavs.org), established in August 2008. Its basic aims are to compile and to distribute information on research and conservation of natural and semi-natural grasslands beyond national borders, thus encouraging active cooperation among scientists and practitioners. The EGCs are traditionally associated with field excursions giving the community of grassland researchers and managers the opportunity to learn more about the grassland diversity of the host country.

This volume includes scientific articles devoted to semi-natural grasslands in Latvia and provides a deeper insight into some of the most diverse Natura 2000 sites in terms of semi-natural grassland flora, fauna and vegetation. The aim of this book is to introduce the readers to biodiversity, management and restoration of semi-natural grasslands in the Nature 2000 sites included in the conference field excursions. All these sites are peculiar with their geographical location, species composition, semi-natural grassland diversity, landscape history, cultural heritage, and contemporary grassland management solutions. Our intention was to present not only the basic information and lists of selected plant species, but also to show the results of vegetation monitoring and to evaluate the restoration efficiency. We highlight both the best practice and problems related to semi-natural grassland management and restoration.

Solvita Rūsiņa

Semi-natural grasslands in Latvia

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ABSTRACT

Despite the small area of the country, the semi-natural grasslands of Latvia host a large diversity of plant and animal communities and habitat types, which is largely governed by diverse geological and phytogeographical settings. The permanent grassland area in Latvia is greater than 640 000 hectares out of which at least 10% are high nature value semi-natural grasslands. The most valuable semi-natural grassland areas are designated as Natura 2000 sites. However, more than 50% of the total semi-natural grassland area is not included in the Natura 2000 network. The area of semi-natural grassland has declined in recent decades, and the overall future trends for semi-natural grasslands are not promising in Latvia. Still, there are large areas covered with partly degraded grasslands (ex-arable land, improved grasslands, abandoned grasslands). With appropriate restoration and conservation measures, these have the potential to become diverse semi-natural grasslands.

KEY WORDS: extensive management, phytogeography, biodiversity, protected habitat.

INTRODUCTION

In Latvia, there are no natural grasslands which origin would not be affected by humans. The present-day grasslands belong either to semi-natural or human-crated grasslands. The difference between them is the extent of human influence on the species composition and environmental conditions. According to the wild herbivore hypothesis (Vera 2000), in the European forest zone before human influence several thousand years ago the grasslands were created and maintained by large herbivores (aurochs, tarpans, European bisons). Since the large herbivores are extinct in the contemporary territory of Latvia, and the natural flood rhythm in floodplains is limited by human-caused modifications, nowadays the existence of grasslands fully depends on human agricultural activity. Without mowing and grazing, they overgrow with shrubs and forest.

The grassland management characteristic for the extensive management period in most of Latvia lasted until the early 20th century. Substantial changes in the total semi-natural grassland area and their conservation status have occured during the last two decades.

The aim of this article is to give an overview of the distribution, diversity and conservation of semi-natural grasslands in Latvia. The only monograph devoted to semi-natural grasslands of Latvia was published in 1957 (Сабардина 1957). Two more recent publications provide an overview of the current situation: Rūsiņa (ed.) (2017) and Kļaviņš et al. (eds.) (2017).

BIOGEOGRAPHICAL SETTING

Latvia is a lowland country (the highest elevation is 312 m above the sea level), located on the eastern coast of the Baltic Sea. Forests cover about 50% of the country, mires – about 5%, and intensive agricultural land 38%, while semi-natural grasslands occupy only about 0.7% of the territory. The mean annual air temperature is 6.2 °C (February −4.6 °C, August +17.1 °C), and mean annual precipitation is 650 mm. The vegetation growth season (days with temperature above +5 °C) lasts for 180–200 days.

The territory of Latvia belongs to the Circumboreal (Eurosiberian) floristic region of the Holarctic biogeographical realm. The border of two floristic provinces – Eastern European and Central European, runs through the territory of Latvia (Finnie et al. 2007) (Fig. 1.). The division of the Baltic countries into two provinces is reflected in several phytogeographical divisions. For instance, according to Walter and Breckle (1996) the Eastern Baltic countries are divided into two sectors of the boreonemoral zonoecotone – the western part possesses more affinities to the nemoral zonobiome (VI temperate zonobiome, with short periods of frost), and the eastern part – to the boreal zonobiome (VIII cold temperate zonobiome, with cool summers and long winters). According to Ahti et al. (1968), the region belongs to the hemiboreal zone. The western part of it is included in the weakly oceanic Baltic sector, the eastern part into the weakly continental sector.

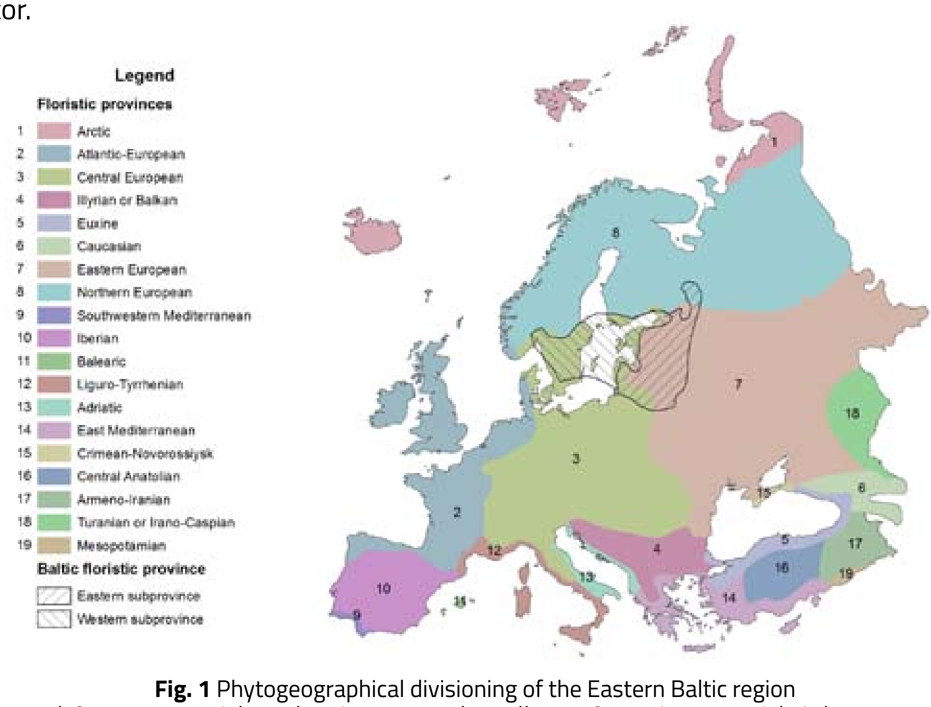

Fig. 1 Phytogeographical divisioning of the Eastern Baltic region
(after Finnie et al. (2007) and Лаасимер (1959)). Map from Kļaviņs et al. (eds.) 2017.

Phytogeographers of the Eastern Baltic countries (L. Laasimer, J. Eilart, M. Natkevičaitė-Ivanauskienė, A. Rasiņš) argue for the delimitation of an independent Baltic phytogeographical province (Лаасимер 1959; Eilart 1975) (Fig. 1). The southwestern boundary of the Baltic province coincides with the boundary of the hemiboreal zone. The northern boundary of the continuous *Carpinus betulus* distribution range is the outline of the transition of the Baltic province into the Central European province. The distributional boundary of several continental species, such as *Koeleria glauca, Astragalus arenarius, Pulsatilla pratensis, P. patens* and *Silene chlorantha*, marks the southeastern boundary with the Eastern European (Sarmatian) phytogeographical province (Eilart 1975).

The Baltic province is divided into the western and eastern subprovinces along the boundary of the highest shoreline of the Baltic Ice Lake. To the east from this boundary, the formation of the flora started several thousand years earlier than in the western part. The Western subprovince is marked very clearly by the boundary of the distribution range of more oceanic species, such as *Taxus baccata, Erica tetralix, Hedera helix* and *Myrica gale*.

Latvia is divided into eight geobotanical regions (Fig. 2). They differ considerably according to their vegetation composition and mosaics determined by climatic, geological, soil and landscape settings. The Coastal geobotanical region is characteristic with the highest forest cover among the geobotanical regions in Latvia (60–70% of the area), though three of the six largest cities of Latvia are located in this region (Riga, Liepāja and Ventspils). Typical habitat types in this region include coastal sandy beaches, stony banks, sand dunes, coastal brackish grasslands, and coastal lagoon lakes. In Western Latvia (Kurzeme) geobotanical region, forests cover less than 40% of the total area. It is the only region where *Carpinus betulus* woodlands are found in Latvia. The region possesses the most diverse dry calcareous semi-natural grassland sites of Latvia,

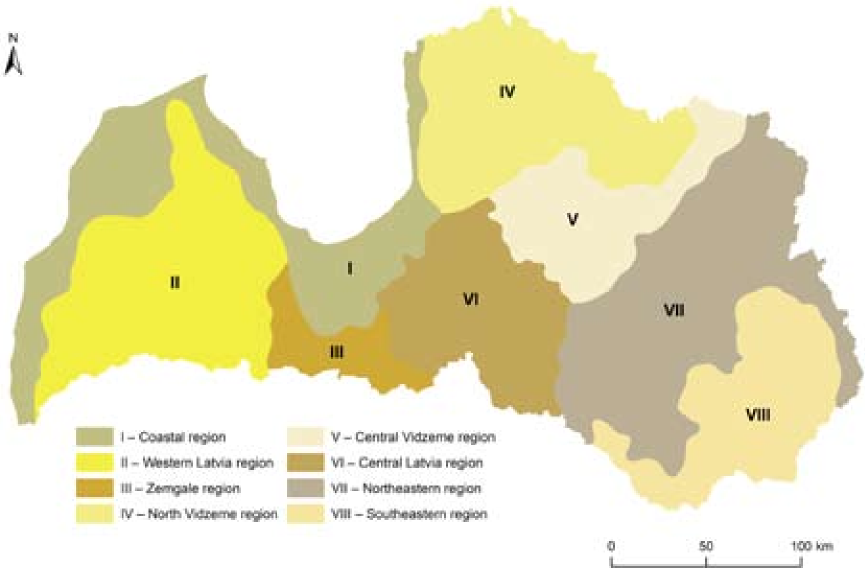

Fig. 2 Geobotanical regions of Latvia (after Галениеце 1959).

namely the Abava and the Venta River valleys. The Zemgale geobotanical region is the most human-modified, extensively cultivated geobotanical region. Agricultural lands cover 76% of the area (67% of them are arable lands). Semi-natural grasslands have remained only in very small patches in the river floodplains and on river valley terrace slopes. Broad-leaved deciduous forests (mainly dominated by *Fraxinus excelsior*) are common, though they are highly fragmented and cover small areas.

The Central Latvia geobotanical region is rich in forests, which cover about 55–62% of the territory of the country. Dry to mesic boreal and boreonemoral forest vegetation with *Pinus sylvestris* and *Picea abies* is widespread. The Daugava River, the largest river in Latvia, flows through the region. In this river stretch, dolomite outcrop habitats, which are very rare in Latvia, occur on the banks of Daugava.

The North Vidzeme geobotanical region and the Northeastern geobotanical region include plains and undulating areas. Common feature for both regions are vast raised bogs. Also dry pine forests on very nutrient-poor sandy soils of inland dunes are characteristic. The Northeastern geobotanical region hosts the largest areas of semi-natural floodplain grasslands, which lie mainly in the floodplains of the Aiviekste River and Lake Lubāns. The North Vidzeme region is famous for the Gauja River valley, which hosts large diversity of broad-leaved deciduous forests on slopes, screes and ravines, sandstone outcrops, and dry calcareous grasslands. The Central Vidzeme geobotanical region and the Southeastern geobotanical region are uplands. The landscape is a diverse mosaic, structured with an interplay of mixed boreonemoral herb-rich spruce forests and agricultural lands (mainly permanent improved and semi-improved grasslands). The Southeastern geobotanical region hosts dry calcareous grasslands with completely different plant communities than those of the calcareous grasslands in Western Latvia.

THE CURRENT EXTENT OF SEMI-NATURAL GRASSLANDS

In the contemporary Latvia, nearly 90% of all grasslands are improved permanent grasslands, while semi-natural grasslands account for 10% of the total grassland area, or 0.7% of the territory of Latvia (Fig. 3). After both world wars, the area of semi-natural grasslands began to shrink both due to the abandonment of agricultural land and the

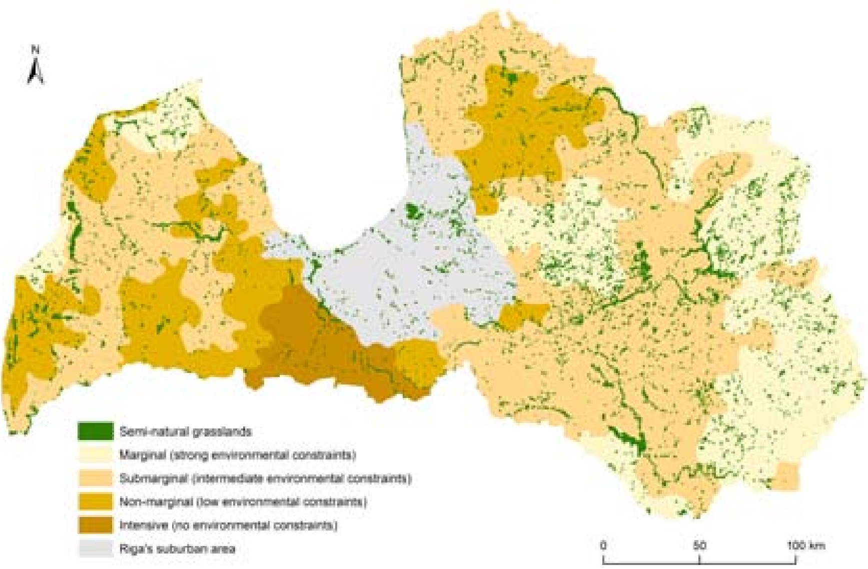

Fig. 3 Distribution of semi-natural grasslands in Latvia. Colours represent regions with different agri-environmental constraints corresponding to intensity of agriculture marginalization (regions after: Boruks 2004, grassland data after DAP 2016).

first trials to improve the grasslands. In 1930, the area of semi-natural grasslands was 1.7 million ha (Maldups 1938), whereas in the mid-20th century they only occupied 1.3 million ha (Tērauds 1955). In 2014, the area of semi-natural grasslands was just 47 600 hectares. This means that currently only 4% of the semi-natural grassland area of the mid-20th century has been preserved. The estimates of the protected habitats of European Union (EU) importance **6530*** ***Fennoscandian wooded meadows*** and **9070** ***Fennoscandian wooded pastures*** also show that only 0.7–1.6% of their original area (recorded in the early 20th century) have been preserved until nowadays (Bāra et al. 2014).

GRASSLAND BIODIVERSITY

FLORA, VEGETATION AND PLANT COMMUNITIES

The meadows and pastures in Latvia host more than 520 vascular plant species, i. e. one-third of the Latvian flora which comprises 1937 native species. In grasslands, often species of other habitats are also present. Grasslands are the most important living environment for many plant species. The grassland flora is dominated by grass species (the family *Poaceae*). About 66% of all orchid species in Latvia occur mostly in semi-natural grasslands (the genera *Dactylorhiza, Orchis, Gymnadenia*) (Rūsiņa (ed.) 2017). The majority of rare species in Latvia are unevenly distributed, and some of them reach the border of their natural range in Latvia (Fatare 1992). At least 100 of these species can be found in semi-natural meadows and pastures (from about 400 such species). Moreover, semi-natural grasslands are important not only for the conservation of rare species, but also for the preservation of the distribution ranges of these species. Semi-natural grasslands are natural habitats for 33% plant species listed in the Red Data Book of Latvia (Andrušaitis (ed.) 2003).

Meadows and pastures in Latvia belong to seven grassland and related vegetation classes (Table 1), and contain more than 60 different plant communities. 25% of all protected habitat types of EU importance are found in Latvia (Kabucis (ed.) 2001; Rūsiņa 2007; Auniņš (ed.) 2013).

GRASSLAND BIRDS

In Latvia, nearly a quarter of ca. 200 nesting bird species are regular grassland breeders. For 15 bird species grasslands are almost the only nesting habitat in Latvia (for instance, *Gallinago media, Crex crex, Acrocephalus paludicola, Philomacus pugnax, Numenius arquata, Vanellus vanellus, Motacilla flava*), and for another 30 bird species grasslands provide the most important feeding areas (for instance, *Coracias garrulus, Ciconia ciconia, Aquila pomarina, Circus aeruginosus, Emberiza citronella, Buteo buteo*). During the spring migration period, grasslands provide resting and feeding places also by bird species that do not nest in Latvia (geese, ducks), and during the spring floods they are important gathering places for waterfowl (Auniņš 2017).

Grasslands are directly related to the critically endangered *Calidris alpina schinzii*, as well as three of six globally endangered bird species nesting in Latvia – *Acrocephalus paludicola* (status "vulnerable" (VU) according to IUCN (International Union for the Conservation of Nature) criteria), *Gallinago media* and *Limosa limosa* (status "near threatened" (NT) for both). Another two globally endangered bird species are *Numenius* arquata and *Coracias garrulus* (status "near threatened" (NT) status for both). Although today they are mainly associated with other habitats (raised bogs and sparse pine woodlands with sandy or grassy open spaces), historically they have also been related to grasslands. Corncrake *Crex crex* also had this status until recently, but thanks to the species protection and grassland habitat restoration measures during the recent decades, especially in Western Europe, its population has increased, and its protection status has changed. Thus the corncrake is no longer considered a globally endangered species (Auniņš 2017).

GRASSLAND INVERTEBRATES

A third of the approximately 13 500 known invertebrate species in Latvia directly depend on grasslands. Meadows are much richer in invertebrate species than pastures. In various types of meadows the number of invertebrate species is measured in thousands, while in pastures it can be up to two times lower (Spuņģis 2008; Melecis et al. 1998; Rūsiņa (ed.) 2017).

Table 1 Phytosociological classes and alliances of semi-natural grassland vegetation of Latvia (after Rūsiņa et al. (2017); nomenclature for plant species after Gavrilova, Šulcs (1999); syntaxonomical nomenclature after Mucina et al. (2016)).

**** The protection of the habitat types marked by an asterisk is of priority importance in the EU.***

HABITAT TYPE	CLASS	*ALLIANCES*
Dry calcareous grasslands	*Festuco-Brometea*	*Filipendulo vulgaris-Helictotrichion pratensis*
Grasslands on calcareous bedrock in river valleys and on moraine hill slopes. Typical dominant species in Western Latvia are *Helictotrichon pratense, Filipendula vulgaris, Fragaria viridis, Trifolium montanum, Cirsium acaule*, in Eastern Latvia – *Poa angustifolia, Pimpinella saxifraga, Agrimonia eupatoria, Fragaria vesca, Anthemis tinctoria, Centaurea scabiosa*. Habitats listed in the EU Habitats Directive's Annex I: 6210.		
Dry sandy grasslands	*Koelerio-Corynephoretea canescentis*	*Corynephorion canescentis* *Koelerion glaucae* *Armerion elongatae*
Grasslands mainly on sandy plains, coastal and inland dunes, river floodplains on sandy nutrient-poor soils. Typical dominant species are *Poa angustifolia, Festuca trachyphylla, F. ovina, Phleum phleoides, Koeleria glauca, Carex praecox, Thymus serpyllum, Veronica spicata, Helichrysum arenarium, Viola rupestris, Cladina spp.*, mosses. Habitats listed in the EU Habitats Directive's Annex I: 6120*.		
Dry rocky grasslands	*Sedo-Scleranthetea*	*Alysso alyssoidis-Sedion*
Grasslands on dolomite outcrops and shallow calcareous substrates. Typical dominant species are *Sedum acre, Jovibarba globifera, Potentilla arenaria, Saxifraga tridactylites, Cerastium semidecandrum, Poa compressa*. The habitats listed in the EU Habitats Directive's Annex I: 6110*.		
Mesic *Nardus* grasslands	*Nardetea strictae*	*Violion caninae*
Grasslands on very nutrient-poor, acidic soils. Typical dominant species are *Nardus stricta, Sieglingia decumbens, Festuca ovina, Potentilla erecta, Viola canina, Veronica officinalis, Carex pilulifera*. The habitats listed in the EU Habitats Directive's Annex I: 6230*.		

Mesic and moist grasslands	*Molinio-Arrhenatheretea*	*Arrhenatherion elatioris* *Cynosurion cristati* *Calthion palustris* *Molinion caeruleae* *Deschampsion cespitosae* *Veronico longifoliae-Lysimachion vulgaris* *Filipendulion ulmariae* *Potentillion anserinae*
The most widespread semi-natural grassland vegetation types in Latvia. Mesic grasslands include meadows with dominant species *Festuca pratensis, Arrhenatherum elatius, Poa pratensis, Helictotrichon pubescens, Festuca rubra, Centaurea jacea, Tragopogon pratensis, Galium album, Lathyrus pratensis*; pastures with *Cynosurus cristatus, Agrostis tenuis, Anthoxanthum odoratum, Festuca rubra, Briza media, Prunella vulgaris, Plantago lanceolata*. Moist grassland plant communities with dominant *Molinia caerulea, Sesleria caerulea* (syn. *Sesleria uliginosa*), *Carex flacca, C. hartmanii, Briza media, Helictotrichon pubescens* occur on alternately dry sites, plant communities with *Alopecurus pratensis, Poa palustris, Deschampsia cespitosa, Holcus lanatus, Carex disticha, Geum rivale, Filipendula ulmaria* occur in permanently moist soils. The habitats listed in the EU Habitats Directive's Annex I: 6270* (*Cynosurion cristati, Calthion palustris, Deschampsion caespitosae*), 6510 (*Arrhenatherion elatioris, Deschampsion caespitosae*), 6410 (*Molinion caeruleae*), 6450 (*Calthion palustris, Deschampsion caespitosae* in floodplains).		
Wet paludified small sedge grasslands	*Scheuchzerio palustris-Caricetea fuscae*	*Caricion davallianae* *Caricion fuscae*
Grasslands on very nutrient-poor acidic wet peat soils (transition to poor, acidic fens) or in calcareous wet soils (transition to rich, calcareous fens). Typical dominant species in acidic small sedge grasslands are *Carex nigra, C. flava, Festuca ovina, Potentilla erecta, Viola palustris, Comarum palustre, Agrostis canina, Eriophorum spp.* Calcareous small sedge communities include *Carex davalliana, Sesleria caerulea* (syn. *S. uliginosa*), *Scorzonera humilis, Primula farinosa, Molinia caerulea*. The habitats listed in the Habitats Directive's Annex I: 6230* (*Caricion fuscae*), 7230, 6410 (*Caricion davallianae*).		
Wet paludified tall sedge and *Phalaroides arundinacea* grasslands	*Phragmito-Magnocaricetea*	*Magnocaricion gracilis* *Magnocaricion elatae*
Grasslands on peat soils in river floodplains and wet depressions. Dominant species include *Phalaroides arundinacea, Carex acuta, C. elata,* *C. acutiformis, C. vulpina, C. cespitosa, Lathyrus palustris, Galium palustre, Veronica longifolia*. The habitats listed in the EU Habitats Directive's Annex I: 6450 (only in river floodplains).		

Hay meadows have a great diversity of day moths Lepidoptera, bees and bumblebees *Apoidea, Orthoptera*, true bugs *Heteroptera*, leafhoppers *Cicadellidae*, leaf beetles *Chrysomelidae*, weevils *Curculionidae* and many other insect taxa. Seasonal sampling collected using an entomological net in the spring, mid- and late summer can include more than 100 different arthropod species (insects, spiders, mites) and hundreds of individuals. Ground beetles are mainly represented by species of the genera *Amara, Harpalus, Calathus* and *Poecilus*, which are typical of open habitats.

Pastures host a large number of species associated with the animal dung. The main decomposers of dung are, for example, members of *Calliphoridae* and *Sarcophagidae* families and *Scatophaga stercoraria. Copris lunaris* (mainly in Eastern Latvia), *Asilus crabroniformis* and *Emus hirtus* live on dry dung in dry pastures.

Dry sandy grasslands are important habitats for *Oedipoda caerulescens, Psophus stridulus, Bembix rostrata* and *Bombus schrencki*. A characteristic feature of sandy grasslands are predators that serve as grassland habitat quality indicators, for example, spider wasps *Pompyliidae, Sphecidae* (including the protected *Bembix rostrata*), mining bees of the genus *Andrenidae*, the spider *Agelena labyrinthica* and tiger beetles *Cicindela* spp. The parasitic violet oil beetle *Meloe violaceus* are often observed in these habitats, as well as colonies of ground-nesting bees.

Dry calcareous grasslands are excellent feeding habitats for protected butterflies included in the European Union (EU) Habitats Directive, especially the marsh fritillary *Euphydryas aurinia* and large copper *Lycaena dispar*. In relatively moister habitats, the moss chrysalis snail *Pupilla muscorum* and the narrow-mouthed whorl snail *Vertigo angustior* also occur.

Moist *Nardus* grasslands, where *Gentiana pneumonanthe* (the protected plant species in Latvia) occurs, are suitable habitat for the Alcon blue butterfly *Maculinea alcon*, whose larvae have specialised on this plant species and feed solely on this plant.

Molinion grasslands provide important habitats for many protected species and species included in the EU Habitats Directive's Annex II, for example, butterflies *Euphydryas aurinia, Lycaena dispar* and *Maculinea teleius*, whorl snails *Vertigo angustior, V. geyeri* and the very rare *V. genesii*. The habitat is inhabited by the ant species *Formica pressilabris*, a rare species in Latvia, which is the only species making their nest from dry grass.

Arrhenatherion hay meadows and *Cynosurion* pastures, if they are located near forest habitat, are suitable for *Parnassius mnemosyne*, the larvae of which feed on *Corydalis solida*. *Lycaena dispar*, which can fly for large distances, also occurs in these habitats and *Hypodryas maturna* can be found near forests with *Fraxinus excelsior*.

CONSERVATION OF SEMI-NATURAL GRASSLANDS

PARADIGMS OF SEMI-NATURAL GRASSLAND CONSERVATION

In Latvia, conservation of semi-natural meadows and pastures did not receive sufficient attention until the late 20th century, and the active protection of these habitats only started in the late 20th century while preparing for the EU accession.

Latvian scientific literature published in the 1970s and 1980s contained indications that semi-natural habitats should be protected. However, in reality the emphasis was put on the species conservation. Habitat ecology and the provision of the abiotic conditions required for the species were sometimes ignored or misunderstood. Decision No. 421 by the Latvian SSR Council of Ministers of 1977 prehibited the hay harvesting in nature reserves and in ornithological reserves with substantial grassland areas (for example, on all islets and on the eastern shore of Lake Engure, one of the species-richest bird areas in Latvia). The hay making and pasturing bans in the ornithological reserves resulted in reduction of bird species for which protection these bans were established (for example, waders in Vecdaugava and Daugavgrīva, Jelgava Pilssala and Lake Engure, where the primary target was to increase the duck population). Absence of grassland management resulted in a short-term success, whereas in long term the bird populations declined, as the grasslands overgrew with shrubs.

These practices contributed to a significant reduction in the semi-natural grassland areas in protected nature areas. There is still a common misconception that mowing and grazing is not allowed in protected nature areas. The history of negative experience still often hinders cooperation with landowners regarding the management and restoration of semi-natural grasslands in Natura 2000 areas. Active protection of semi-natural grasslands only began in the late 20th century, when the approach changed from non-intervention to active management.

PROTECTED GRASSLAND HABITAT TYPES

In Latvia, all semi-natural grasslands are regarded as EU-importance protected habitats. For conservation purposes, a method has been developed to distinguish semi-natural grasslands from (semi)improved grasslands or fallow land (Fig. 4). The method involves the use of semi-natural grassland indicator species – plant species that indicate the naturalness of the grasslands and long-term extensive management. Such species have become adapted to nutrient-poor soils and disappear from the grassland as soon as the environmental conditions change, for instance, when the grassland is fertilised or abandoned. The higher the number and abundance of such species in the grassland, the better its conservation status. In Latvia, 54 plant species are used as indicator species of semi-natural grasslands, including *Briza media, Plantago media, Polygala* spp., *Carex panicea, C. flacca, Primula veris, Trollius europaeus, Stachys officinalis, Pimpinella saxifraga*, etc. The list was created in the late 1990s on the basis of the Swedish list of semi-natural grassland indicator species (Ekstam, Forshed 1997). It was adapted to the conditions in Latvia on the basis of expert experience.

Thirteen types of EU protected habitats occur in Latvia, including juniper stands as a significant component of such habitat is grassland vegetation. Five of these are of priority importance (marked with an asterisk in the Habitats Directive's Annex I). The priority habitats are under the threat of extinction at the EU scale, thus the Member States are especially responsible for their conservation:

1630* Boreal Baltic coastal meadows;
5130 *Juniperus communis* formations on heaths and calcareous grasslands;
6110* Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*;
6120* Xeric sand calcareous grasslands;
6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites);
6230* Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submontain areas in continental Europe);
6270* Fennoscandian lowland species-rich dry to mesic grasslands;
6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*);
6430 Hydrophilous tall herb fringe communities of plain and of the montane to alpine levels;
6450 Northern boreal alluvial meadows;
6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*);
6530* Fennoscandian wooded meadows;
9070 Fennoscandian wooded pastures.

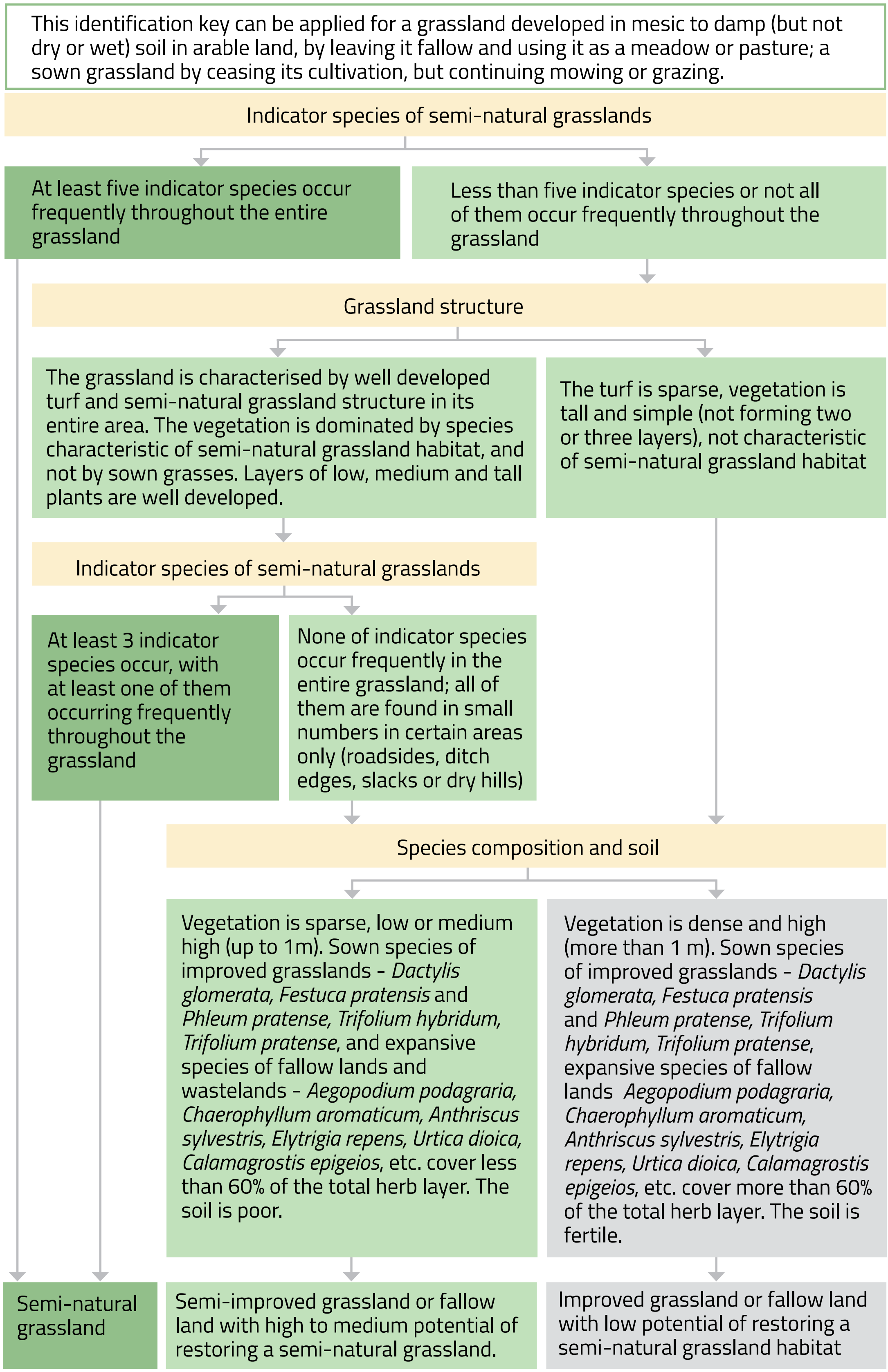

Fig. 4 Semi-natural grassland identification key using semi-natural grassland indicator species. The identification key cannot be used for wet floodplain grasslands (after Rūsiņa (ed.) 2017).

PROTECTED GRASSLANDS IN NATURA 2000 SITES

In Latvia, 333 protected nature territories are designated as Natura 2000 sites. Protected grassland habitats occur at 153 Natura 2000 sites, but their total area exceeds 20 ha at only half of these sites (Fig. 5). Only 40–45% (approximately 20 000–23 000 ha) of protected grassland habitat areas are included in the Natura 2000 network, the remaining ca. 60% occur in the mosaic of agricultural land and forests and are heavily fragmented, as a result of which it is administratively complicated to establish protected areas to preserve them. It should be also noted the fact that the establishment of the Natura 2000 network was largely based on the protected nature territories that existed before the accession of Latvia to the EU. Until the late 20th century, due to the prevailing nature conservation approach, there were very few grasslands within protected nature areas, many of which had been formed in the Soviet era (only half of the 153 Natura 2000 areas containing protected grassland habitats had been established before 1990).

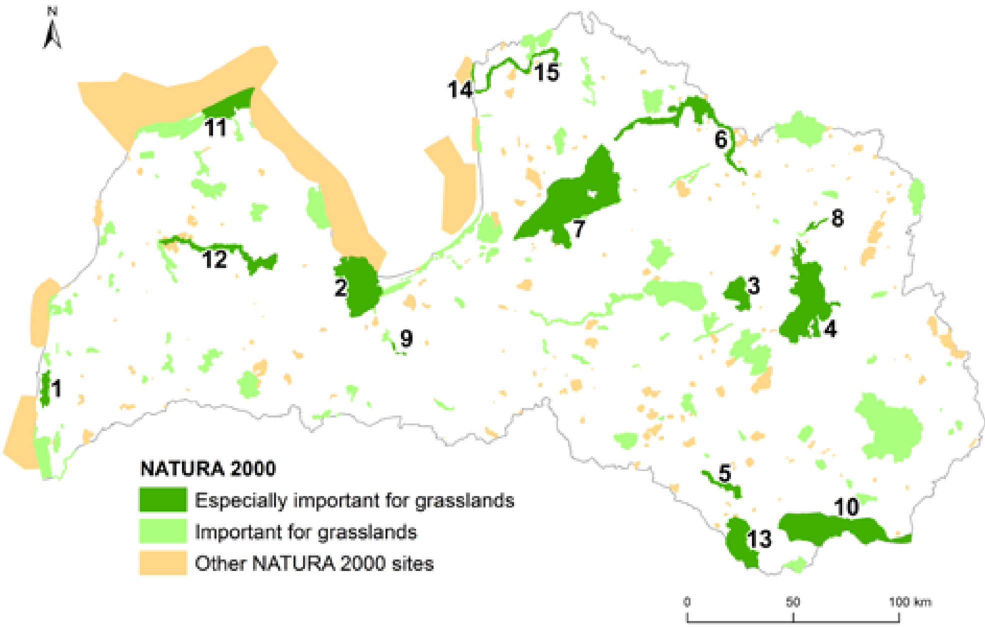

Fig. 5 Natura 2000 sites of importance for the conservation of semi-natural grasslands in Latvia. The numbers indicate the most important 15 Natura 2000 sites in terms of grassland protection, which contain the largest areas of semi-natural grasslands. 1 – Liepāja Lake (habitat types 6410, 6210); 2 – Ķemeri National Park (5130, 6410, 6510); 3 – Kuja (6270*, 6510, 6450); 4 – Lubāns Wetland (6120*, 6230*, 6270*, 6450, 6510, 6530*); 5 – Dviete Floodplain (6270*, 6450); 6 – Northern Gauja (5130, 6120*, 6210, 6450, 6530*); 7 – Gauja National Park (6110*, 6120*, 6210, 6230*, 6510); 8 – Sita and Pededze Floodplain (6450, 6510); 9 – Lielupe Floodplain Meadows (6450, 6510); 10 – Augšdaugava (6120*, 6210, 6270*); 11 – Slītere National Park (6230); 12 – Abava Valley (6120*, 6210); 13 – Augšzeme (6210); 14 – Randu Meadows (1630*); 15 – Salaca Valley (6230*).

PRESSURES AND THREATS

In Latvia, the conservation status of all EU protected grassland habitat types that are completely dependent on agricultural activity (extensive mowing and grazing) is unfavourable with an ongoing negative trend. Over the last years, even in mown and grazed semi-natural grasslands the species diversity and vegetation structure have impoverished. The main pressures and threats are listed in Table 2.

In total, more than 7200 ha of semi-natural grasslands in Latvia have been restored since 2000. Since 2000, 41 projects funded by the LIFE programme are implemented in Latvia, 15 of them deal with restoration of grassland habitats. Grasslands have also been restored within several projects financed from other funds, such as the Latvian Environmental Protection Fund, the European Neighbourhood and Partnership Instrument and others. Experience of grassland habitat restoration has been published in four volumes of articles dedicated to habitat restoration (Opermanis (ed.) 2002; Auniņš (red.) 2008; Reihmanis (ed.) 2011; Priedniece, Račinskis (eds.) 2015).

Table 3 Conditions of the agri-environmental measure "Maintenance of Biological Diversity in Grasslands" under the Latvian RDP (after LVAEI 2013, updated after Anon. 2016).

<table>
<tr><th>Conditions</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th></tr>
<tr><td>Grazing
Livestock stocking rate
(livestock units ha -1)</td><td colspan="4">0.65-0.74</td><td colspan="7">0.4-0.9</td><td colspan="3">0.3-0.9</td></tr>
<tr><td>Mowing
(single mowing allowed)</td><td colspan="14"></td></tr>
<tr><td>10 July – 10 September</td><td colspan="4"></td><td colspan="10"></td></tr>
<tr><td>1 August – 15 September</td><td colspan="4"></td><td colspan="2"></td><td></td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>15 August – 15 September</td><td colspan="6"></td><td></td><td colspan="7"></td></tr>
<tr><td>No starting date – 15 September</td><td colspan="11"></td><td colspan="3"></td></tr>
<tr><td>Grass removal compulsory</td><td colspan="4"></td><td colspan="7"></td><td colspan="3"></td></tr>
<tr><td>Mulching and leaving of grass allowed</td><td colspan="4"></td><td colspan="7"></td><td colspan="3"></td></tr>
<tr><td>Support in EUR ha^{-1}</td><td colspan="4">138</td><td colspan="7">123</td><td colspan="3">differenti-
ated</td></tr>
</table>

The following grassland habitat restoration activities have been of primary importance in Latvia: arrangement of land ownership rights (purchasing of land), restoration of the hydrological regime (infilling of ditches, re-meandering the streams and restoring the flood rhythm), removal of trees and shrubs, mulching and grinding of shrub roots, mowing, establishment of pastures, and purchasing of grazing animals.

The only permanent EU financial instrument available for grassland management is the agro-environmental measures under the Rural Development Programme (RDP). By 2016, only one agro-environmental measure of the RDP was directly aimed at maintaining the biodiversity in Latvia: "Maintenance of Biological Diversity in Grasslands" (MBG).

The MBG measure has been implemented since 2004. Currently, about 60% of semi-natural grasslands are being managed within the MBG framework, which is a significant improvement compared to the period, when support for the management of grasslands was not available to the land owners. The MBG measure has significantly facilitated the maintenance of semi-natural grasslands in Latvia, protecting them from complete abandonment and overgrowth with shrubs.

The MBG measure experienced substantial changes during the implementation period from 2004 to 2017. The most important changes were triple change of allowed starting date for mowing and permission to mulch the grass and leave it on the field (Table 3).

Two reports on the effectiveness of the RDP measures in preserving semi-natural grassland biodiversity have been prepared within the scope of the Ongoing Evaluation System of the RDP 2007–2013 (LVAEI 2013, 2014). The outcome of the grassland survey conducted in 2013 shows that the objective set for the MBG measure has not been reached during the period of the RDP 2007–2013, as 24% of the surveyed MBG areas had ceased to conform to MBG criteria (plant species richness has declined, expansive nitrophilous species, for instance, *Aegopodium podagraria* and *Anthriscus sylvestris* have colonised the areas, etc.), while high biodiversity was preserved only in ca.15% of the total area managed in the MBG measure.

The most important factor resulting in failure to reach the objective was inadequate implementation of the MBG measure – late mowing and mulching. The inappropriate management has negatively affected plant diversity. The non-differentiated single support payment created an unbalanced representation of the habitat types of the EU importance in the areas in question. This has resulted in smaller number of biologically most valuable and diverse grasslands being the subjects of applications under the MBG mechanism, because they mostly are more difficult to manage and have lower economic value.

Since 2014, the conditions of the MBG measure were changed in order to eliminate the previous inconsistencies with the management requirements of semi-natural grasslands. The current conditions of the MBG measure include compulsory hay (or fresh biomass) removal, and the time of mowing is not restricted to a particular starting date (Table 3).

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Semi-natural grasslands of the "Daugavas loki" Nature Park

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ABSTRACT

The "Daugavas loki" Nature Park includes the Daugava River stretch with eight spectacular river meanders. This stretch of the Daugava River and its valley is the least influenced by human activities. The Daugava River valley is one of the major species dispersal corridors in the Baltic phytogeographical province. In total, eleven protected habitat types of European Union importance and more than 134 rare and protected species (birds, invertebrates, plants) are recorded in the Nature Park.

The Nature Park is rich in dry xerothermic semi-natural grasslands belonging to the classes *Festuco-Brometea* and *Koelerio-Corynephoretea* which occur mostly on the terrace slopes and the gullies of the Daugava River valley. During the last decades, the grasslands are shrinking due to cessation of management. Results of dry grassland vegetation monitoring from 2003 to 2016 in the Slutišķi village indicated gradual degradation of vegetation due to abandonment. Restoration commenced in 2014 induced the increase in species richness in dry sandy grasslands (*Koeleria glauca* community) and on dry ex-arable land, while the restoration was less successful in calcareous grassland (*Centaurea scabiosa-Agrimonia eupatoria* community).

KEY WORDS: plant community, xerothermic grassland, restoration, abandonment, vegetation monitoring.

INTRODUCTION

The "Daugavas loki" (Daugava Meanders) Nature Park was established in 1990 to protect the unique landscape of the Daugava River (Western Dvina) midstream valley, habitat and species diversity, as well as natural heritage in the valley. The Daugava River is the largest river of Latvia rising in the Valdai Upland, Russia, and flowing through Russia, Belarus, and Latvia into the Gulf of Riga. The river stretch in Latvia is 352 km long. The total length of the river was 1020 km before the construction of three hydroelectric power plants. Several important cities, such as Daugavpils, Krustpils and

Riga, are located on its banks. Picturesque landscapes and cultural heritage sites, e. g. numerous castle mounds, create favourable prerequisites for advancement of tourism industry (Nikodemusa 1994; Pastors 1994).

The Nature Park is located in the southeastern part of Latvia, in the administrative territories of Daugavpils county and Krāslava county. The total area of the Nature Park is 12 372 hectares. In 2004, the Nature Park was included into the Natura 2000 site "Augšdaugava" (site code LV0300200), a protected landscape area with the total area 52 098 ha (Anon. 2010) (Fig. 1).

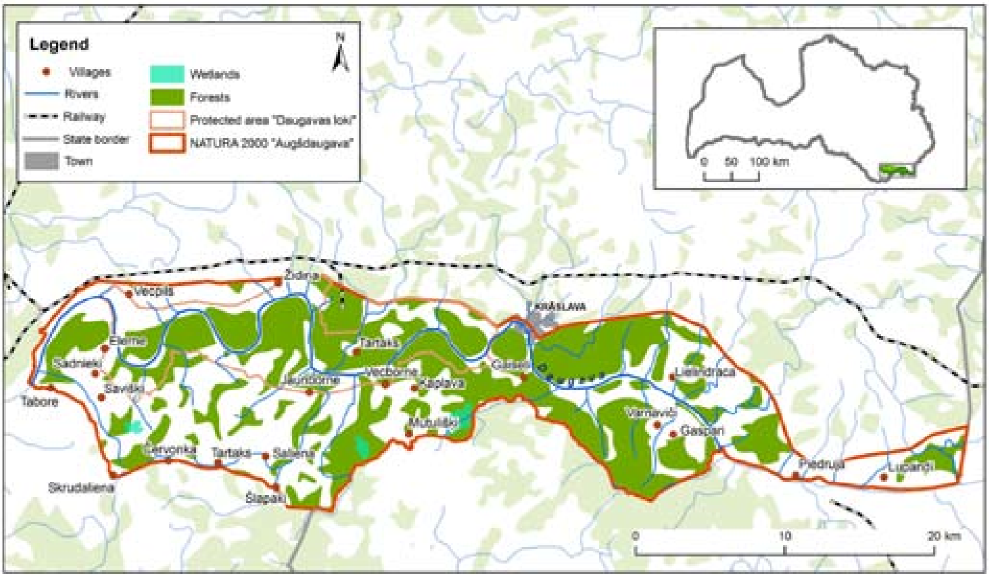


Fig. 1 Location of the "Daugavas loki" Nature Park and the "Augšdaugava" Protected Landscape Area in Latvia.

The Nature Park includes the Daugava River stretch with eight spectacular river meanders, each of them stretching for 4–6 kilometres. It is the most picturesque river valley segment in Southern Latvia in terms of landscape and terrain (Fig. 2). The Daugava River stretch which is included into the Nature Park is the least influenced by human activities. During the 20th century, three hydroelectric power plants were constructed downstream of the town of Daugavpils – Pļaviņas, Ķegums, and Riga hydroelectric power plants. They have changed the river flow substantially. Three river sections with the total length of 113 km were flooded, thus creating large water reservoirs (Melluma 1983; Pastors 1994).

a | b

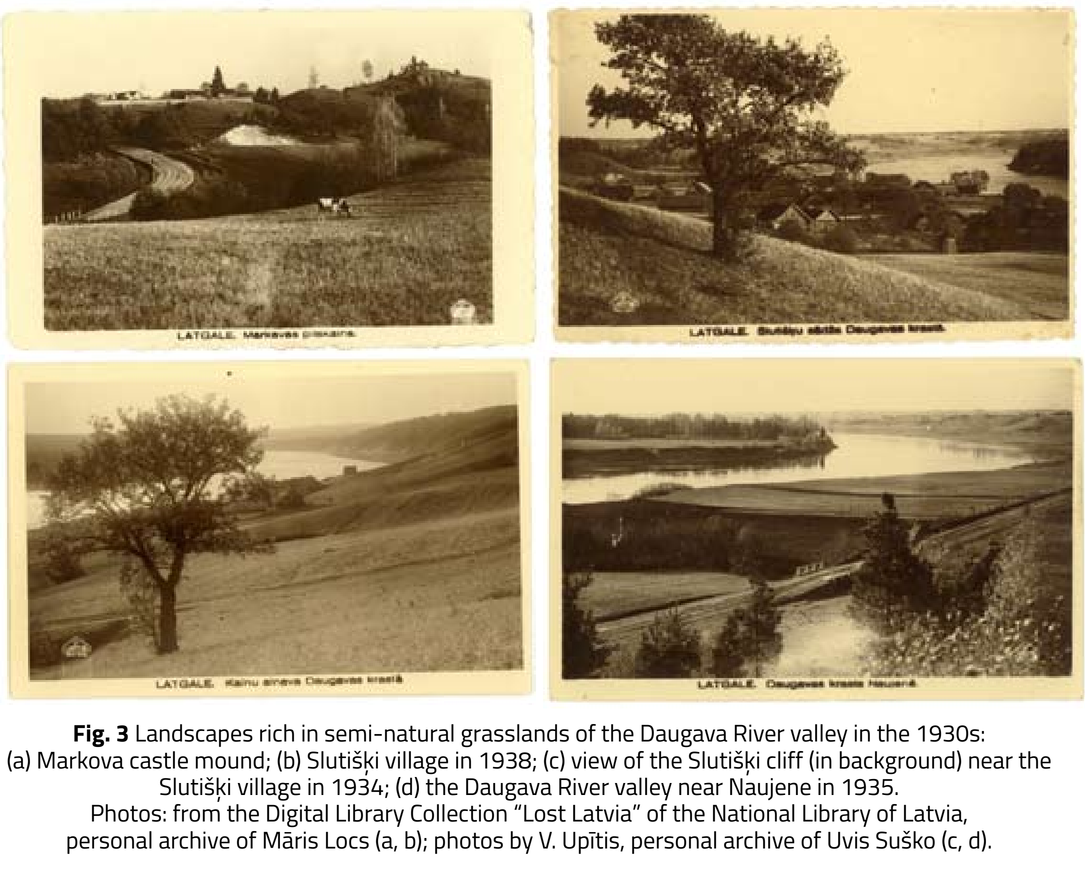
Fig. 2 The Daugava River meanders (a) near the Slutišķi village in 2017 and (b) near the Vasargelišķi village in 2007. Photos: S. Rūsiņa

LANDSCAPE HISTORY

Since ancient times, the Daugava River has played an important role in economic development of the surrounding region. Once the water level in the river was much higher than nowadays, and Daugava served as a trading route, ancient settlements and burial grounds have been discovered on its banks, and it has always been the "backbone" in economic development of the adjacent areas. Humans arrived approximately 11 000 years ago. The earliest evidence of household items is from the Stone Age. Ancient burial grounds, castle mounds and settlements found in the territory of the Nature Park show the significance of the cultural activity, ethnicity, traditions, and history in this region (Graudonis 1972; Jansons 1999).

The Daugava River is mentioned in the Scandinavian sagas from the 5th century BC. In the 10th century AC, it was an important route part in voyage from Varangian to Greek areas. During the 18th century, some stretches of the Daugava riverbed were deepened to adjust the depth of the stream (Graudonis 1972).

Numerous abandoned homestead sites, often indicated by a great abundance of introduced ornamental species, such as *Sorbaria sorbifolia* and *Robinia* spp., suggest that at the end of the 19th century all of the territory of the Nature Park was densely populated. The landscape was more open, with large areas of semi-natural grasslands, mostly used as pastures (Fig. 3). Nowadays the use of land has dramatically changed – large areas of old fields, pastures and grasslands have overgrown with shrubs and gradually turn into forests (Fig. 4).



a | b
c | d

Fig. 3 Landscapes rich in semi-natural grasslands of the Daugava River valley in the 1930s:
(a) Markova castle mound; (b) Slutišķi village in 1938; (c) view of the Slutišķi cliff (in background) near the Slutišķi village in 1934; (d) the Daugava River valley near Naujene in 1935.
Photos: from the Digital Library Collection "Lost Latvia" of the National Library of Latvia, personal archive of Māris Locs (a, b); photos by V. Upītis, personal archive of Uvis Suško (c, d).

a
b
c

Fig. 4 Overgrowing of semi-natural grasslands in the Slutišķi village.
(a) Overgrowing with pines have started recently and is continuing on both sides of the gully, 2006;
(b) young pines have closed the view to the other side of the gully (2012);
(c) after removal of pines, the view was opened to the other side of the gully with continuous overgrowing (2016). Photos: S. Rūsiņa.

CLIMATE, TERRAIN, AND SOILS

The "Daugavas loki" Nature Park is located in the warmest region of Latvia. The mean temperature in the Nature Park is -6.6 ˚C in January and +17.6 ˚C in July. The amplitude of mean minimal and maximal air temperature in January varies from -10.3 ˚C to -3.9 ˚C and from +11.9 ˚C to 23.2 ˚C in July. The mean annual air temperature is +5.4 ˚C, but amplitude of the mean temperatures is 24.2. The frost-free period (mean air temperature of the day is above 0 ˚C) lasts for 236 days. The vegetation growth period (average daily air temperature is above +5˚C) lasts 187 days and is approximately 7–11 days longer than outside of the Daugava River valley. Vegetation growth period, when the average daily air temperature is above +10 ˚C, lasts for 140 days. There is relatively high precipitation reaching 730–760 mm per year. Snow cover is inconstant, usually stable snow cover forms at the end of December or early January and lasts until the end of March or early April (Āboltiņš 1995; Kalniņa 1995).

The terrain of the Nature Park has formed by glacial processes during the Pleistocene glaciations. The valley of the Daugava River is a proglacial spillway which was formed by glacial meltwater streams during the Late Pleistocene and influenced by the fluvial processes in the Holocene. The valley is up to 45 m deep and 500 to 1200 m wide, gentle slopes alternate with very steep slopes along the concave banks of the meander bands. The bedrock surface is represented mainly by poorly cemented sandstone of Upper Devonian origin. The bedrock is covered by ca. 40–50 m thick Quaternary sedimets along the flanks of the spillway valley, whereas at the bottom of the spillway valley the Upper Devonian bedrock is exposed or covered by thin drift in many places. Fluvial forms created by gully erosion are characteristic features of the valley. There are more than 350 permanent gullies differing in size and morphology dissecting the main valley sides along the 50 km long stretch from Krāslava down to Krauja (Soms, Zelčs 2014; Эберхард 1972).

Geological peculiarities, diverse terrain, different humidity conditions and bedrocks have created a large variety of soils. Alluvial soils have formed in floodplains of the River Daugava and its tributaries, in some depressions with groundwater supply half-hydromorphic turf-gleyic and gleyic soils have formed. On terrace surfaces typical podsol soil is widespread, and the bedrock has high water permeability – in such areas coniferous forests are common. Considering the fact that part of the Nature Park adjacent to the valley has been cultivated and used in farming for a long time, the widespread podsol soil area on hill slopes is lightly to moderately eroded. The dominating soil bedrocks in this territory are moderate and heavy rocky moraine loam, as well as the gravel-sand silt formed by glacier meltwaters (Anon. 2010).

FLORA, VEGETATION, AND PROTECTED HABITAT TYPES

The Nature Park is located in the South Eastern geobotanical region of Latvia. The species composition has been influenced by many factors – specific microclimate and soils, and phytogeographical location of the territory that serves as a major species dispersal pathway. Distribution of several species (Fig. 5) clearly shows the importance of the Daugava River valley as one of the major species dispersal corridors in the Baltic phytogeographical province linking it with regions of Eastern European phytogeograhical province and ensuring species dispersal between hemiboreal and forest steppe zones (Фатаре 1989).

Fig. 5 Distribution of (a) *Koeleria glauca* and (b) *Silene tatarica* in Latvia (after Fatare 1992, maps from Kļaviņš et al. (eds.) 2017).

The area is considered as one of the most peculiar territories in Latvia in terms of endangered species richness. In total, 11 protected habitat types and many rare and protected species – 34 bird species, 50 invertebrate species, 50 vascular plant species are registered there (in total 826 vascular plant species have been listed). The highest number of rare species can be found in forest and grassland habitats. In total, 100 rare or nationally protected species of vascular plants in Latvia and 46 rare or nationally protected species of mosses are found in the Nature Park. Five species are listed in the EU Habitats Directive's Annex II: *Agrimonia pilosa, Cypripedium calceolus, Liparis loeselii, Pulsatilla patens*, and *Buxbaumia viridis* (Anon. 2010).

Forests cover 58% (6653 hectares) of the Nature Park. Dry pine forests prevail, but majority of the forests stands are relatively young. They mostly correspond to the class *Vaccinio-Piceetea*. The most significant protected forest habitats are ravines with deciduous trees belonging to ***Tilio-Acerion* forests of slopes, screes and ravines (9010*)**, and fragments of older pine forests belonging to **Western taiga (9010*)**.

Xerothermic habitats are common in the valley, especially in sections with steep terrace slopes and ravines. Such habitats support subcontinental vegetation types, such as xerotermic grasslands of *Festuco-Brometea* and fringe communities of *Trifolio-Geranietea* classes, as well as dry pine (*Pulsatillo-Pinetea*) and oak (*Querco pubescenti-Petraea*) forests with some elements of steppe vegetation, e. g. *Phleum phleoides, Medicago falcata, Trifolium montanum, Carex praecox, Koeleria glauca, Filipendula vulgaris, Brachypodium pinnatum, Veronica spicata*.

The Nature Park is one of the most important protected nature areas in Latvia for conservation of the habitat types **6120* Xeric sand calcareous grasslands** (23% of the total area of the habitat type occurring in the Natura 2000 network in Latvia). The Nature Park is among the first fifteen Natura 2000 areas which are important for the conservation of the habitat types **6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometea*), 6270* Fennoscandian lowland species-rich dry to mesic grasslands, 6450 Northern Boreal alluvial meadows, 6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)**. These grasslands provide important habitats for numerous protected plant species, such as *Gentiana cruciata, Gladiolus imbricatus, Iris sibirica, Cnidium dubium*, and *Orobanche caerulescens* (DAP 2016).

CHARACTERISTICS OF DRY GRASSLAND PLANT COMMUNITIES

According to Jermacāne and Laiviņš (2002), the dry grassland vegetation in the Nature Park can be assigned to three plant communities at the association level.

***Centaurea scabiosa-Agrimonia eupatoria* community** is the most widespread in the area (Fig. 6). The mosses cover on average 20%, herbs – 90%. Character species of three vegetation classes occur together in this community (Rūsiņa 2005): *Festuco-Brometea* (xerothermic grasslands), *Molinio-Arrhenatheretea* (mesic grasslands), and *Trifolio-Geranietea* (forest fringe vegetation). These species are among the common dominants, for instance, *Briza media, Poa angustifolia, Festuca rubra, Carex caryophyllea, Agrimonia eupatoria, Fragaria vesca, Centaurea scabiosa, Leontodon hispidus*. The relevés of this plant community were assigned to the association *Centaureo scabiosae-Fragarietum vescae* Rūsiņa 2007 in the regional syntaxonomical analysis of dry grassland vegetation of Latvia (Rūsiņa 2007). According to Dengler et al. (2009), most probably the association belongs to the North European alliance *Filipendulo vulgaris-Helictotrichion pratensis* Dengler & Löbel in Dengler et al. 2003 of the class *Festuco-Brometea*.

***Poa compressa-Thymus ovatus* community** occurs on the steepest parts of the south and west facing slopes in gravely substrate. Vegetation is relatively sparse (average cover

a
b | c

Fig. 6 *Centaurea scabiosa-Agrimonia eupatoria* community with (a) large cover of *Trifolium montanum* and *Anthyllis vulneraria*, (b) *Lychnis viscaria, Silene nutans, Anthyllis vulneraria*, (c) *Agrimonia eupatoria* and *Centaurea scabiosa* dominating in the herb layer. Photos: S. Rūsiņa of mosses is 23%, herbs – 74%), and the sward is lower than that of *Centaurea scabiosa-Agrimonia eupatoria* community (Fig. 7). The community belongs to the class *Koelerio-Corynephoretea*, although some character species of the class *Festuco-Brometea* are also present (*Carex caryophyllea, Poa angustifolia, Pimpinella saxifraga, Trifolium montanum*). *Thymus ovatus, Poa angustifolia, Artemisia campestris* and *Abietinella abietina* prevail in the moss layer. Species of dry sandy habitats are typical for the community, e. g. *Poa compressa, Helichrysum arenarium*, as well as annuals and biennials *Acinos arvensis, Consolida regalis, Echium vulgare, Berteroa incana, Trifolium arvense*. In the regional syntaxonomical analysis of dry grassland vegetation in Latvia (Rūsiņa 2007), the relevés of this plant community were assigned to the association *Poetum compressae* Kizienė 1998 of the alliance *Koelerion glaucae* (the class *Koelerio-Corynephoretea*).

***Koeleria glauca* community** develops exclusively on sandy deposits, found in small patches sporadically throughout the Nature Park. Vegetation is very sparse (mean cover of herb layer is 55%), whereas the moss layer is more pronounced than in other grassland communities (mean cover – 50%). The herb layer is dominated by *Koeleria glauca* (Fig. 8). In some cases also *Carex caryophyllea, Artemisia campestris* and *Sedum acre* may have large cover. In the moss layer, *Brachythecium albicans, Ceratodon purpureus and Abietinella abietina dominate, Polytrichum piliferum* and *Tortula ruralis* are

a
b | c

Fig. 7 *Poa compressa-Thymus ovatus* community: (a) sparse vegetation dominated by *Pilosella officinarum, Echium vulgare, Melilotus officinalis*, and *Anthyllis vulneraria*; (b) *Consolida regalis* and *Anthemis tinctoria*; (c) *Anthemis tinctoria* and *Polygala comosa*. Photos: S. Rūsiņa.

a
b | c

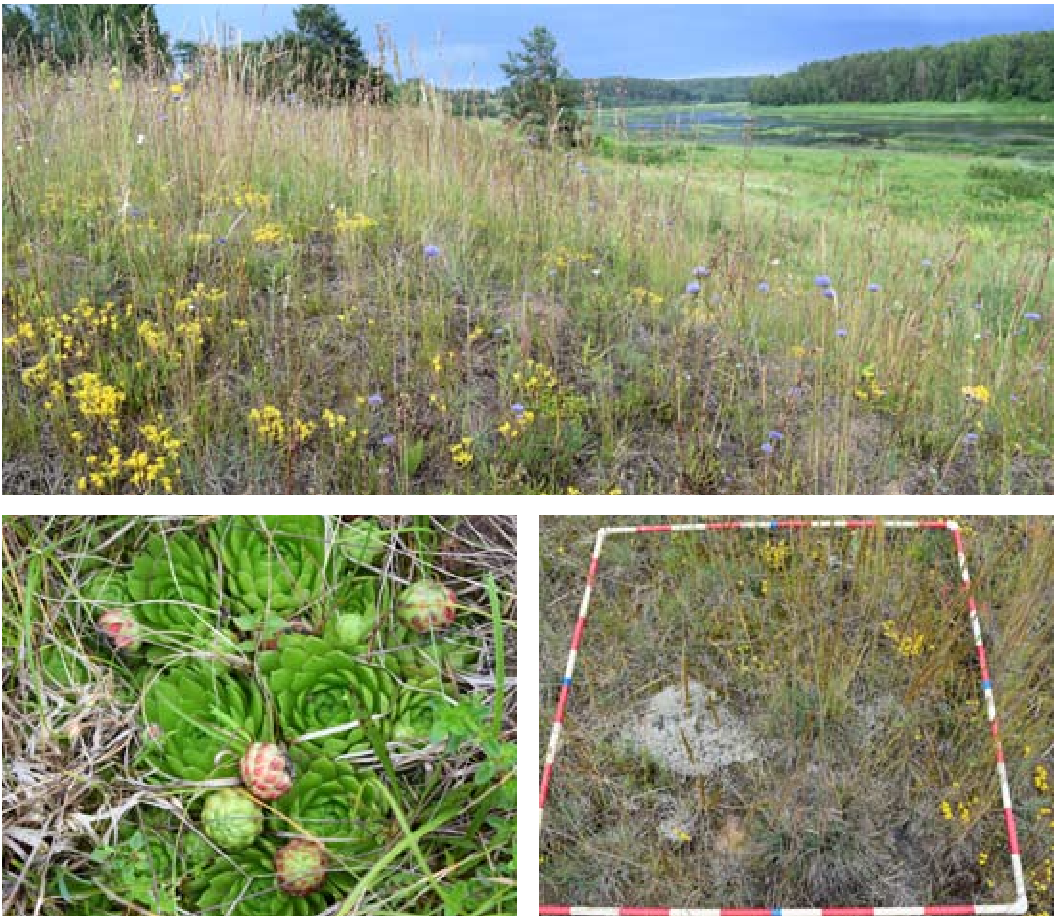


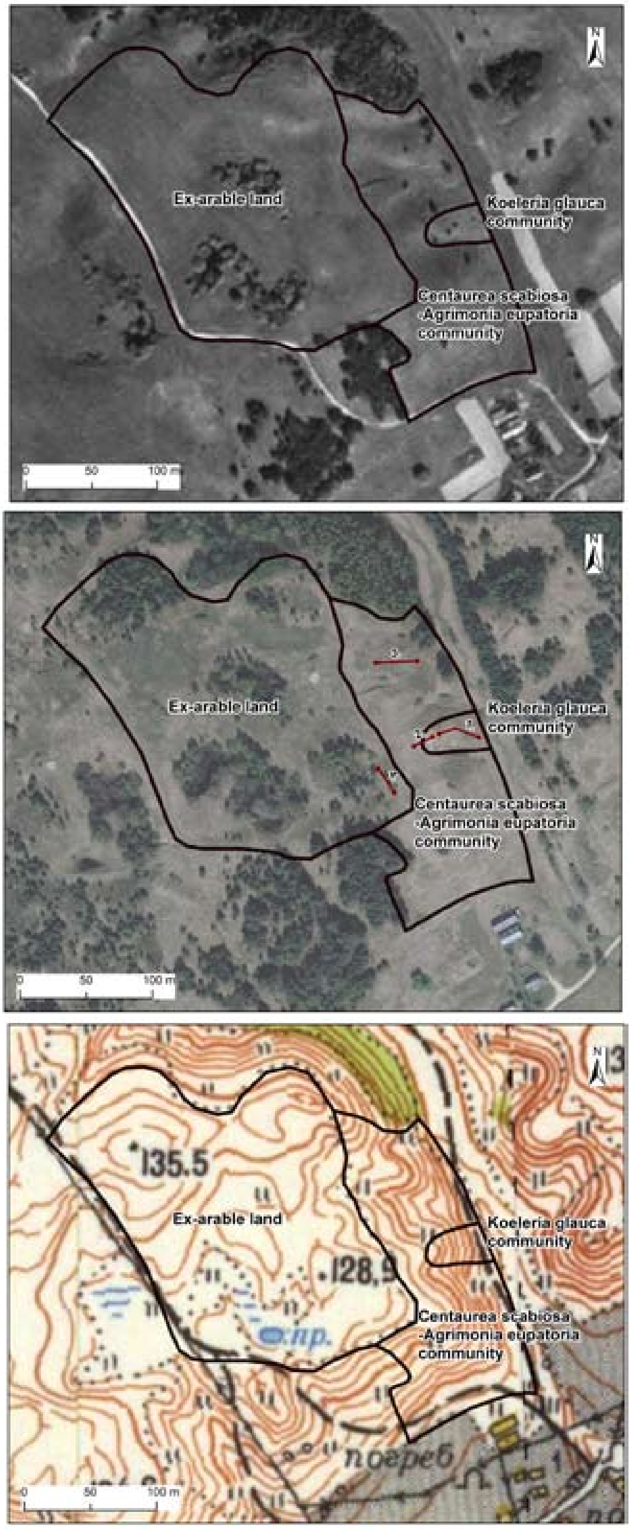
Fig. 8 *Koeleria glauca* community: (a) *Koeleria glauca, Jasione montana, Sedum acre* in bloom; (b) *Jovibarba globifera*; (c) *Cladina* spp. and *Cladonia* spp. are important species in the moss layer. Photos: S. Rūsiņa.

frequent. Several lichen species, such as *Peltigera rufescens, Cladonia fimbriata* and *C. gracilis*, have a high constancy. Some protected rare vascular plant species are present in the community: *Jovibarba globifera, Dianthus arenarius* subsp. *borussicus, Helichrysum arenarium*, and *Centaurea rhenana*. In the regional syntaxonomical analysis of dry grassland vegetation of Latvia (Rūsiņa 2007), the relevés of this plant community were assigned to the association *Festucetum polesicae* Regel 1928 of the alliance *Koelerion glaucae* (the class *Koelerio-Corynephoretea*).

DRY GRASSLAND VEGETATION DYNAMICS: AN EXAMPLE FROM THE SLUTIŠĶI VILLAGE

DESIGN OF VEGETATION MONITORING AND DATA ANALYSIS

In 2003, the vegetation monitoring was commenced in the dry grasslands of the Slutišķi village in a 15 ha large area. Three permanent transects in two different plant communities were established (Fig. 9). The first transect was placed in *Koeleria glauca* community (in total, eight 1 m^2 plots). The second and the third transect were located in *Centaurea scabiosa-Agrimonia eupatoria* community (in total, fifteen 1 m^2 plots). In 2012, the fourth transect was established on ex-arable land with ten 1 m^2 plots. In the transects, the distance between the plots was two metres. In each plot, the total



a
b
c

Fig. 9 The study site in the Slutišķi village. (a) Monitoring transects in the dry grasslands on the orthophoto map of 2014: 1, 2 – *Koeleria glauca* community, 3 – *Centaurea scabiosa-Agrimonia eupatoria* community, 4 – transect in ex-arable land; (b) orthophoto map showing situation in 1995; (c) topographic map showing situation in 1972. Maps: orthophoto map at a scale of 1: 10 000, © Latvian Geospatial Information Agency (ORTHOPHOTO 1, 5); topographic map at a scale of 1: 10 000 (TOPO 10K PSRS), LU ĢZZF WMS http://www.geo.lu.lv/kartes.

cover of litter, herb and moss layer, as well as the cover of each species in percent was determined visually. The vegetation was monitored every year in the period from 2003 to 2006, and from 2012 to 2016 in June or August.

The vegetation data were stored in a database using the software program TURBOVEG (Hennekens, Schaminée 2001). Significance of differences between the first and the last year observations with respect to species richness were evaluated by the non-parametric Wilcoxon test using the software package SPSS for Windows, version 17.0 (SPSS 2008). Non-metric multidimensional scaling (NMS) (McCune, Grace 2002) was applied to analyse the variation in species composition among different years. The software PcORD 5 was used (McCune, Mefford 1999). The square-root transformation of species cover percentages was applied. Sørensen distance measure was used. Monte Carlo test with 250 randomized runs was used to evaluate the extracted axes (McCune, Grace 2002). Ellenberg indicator values for nutrients, moisture and soil reaction (Ellenberg et al. 1992) were calculated as weighted means using the program JUICE (Tichý 2002). Species nomenclature followed Gavrilova and Šulcs (1999), for bryophytes and lichens – Āboliņa et al. (2015), syntaxonomical nomenclature followed Mucina et al. (2016).

PREVIOUS MANAGEMENT AND RESTORATION ACTIVITIES

In the past, the steep slopes of the valley were used for sheep grazing. The slopes have never been ploughed or improved. They were used for mowing and grazing until 2001, when the management was ceased. During the 12-year abandonment period, overgrowing with pines, accumulation of excessive litter layer, development of high anthills, and establishment of expansive grass species *Calamagrostis epigeios* took place (Fig. 10). Expansive moss species, characteristic for dry coniferous forests, for instance, *Pleurozium schreberii, Dicranum polysetum* and *Hylocomium splendens* developed a thick layer in some parts of the *Koeleria glauca* community. The ex-arable land was used irregularly (not every year) for crop growing until the 1990s, when it was abandoned.

In 2014, the restoration of dry grasslands was commenced as an action within the LIFE+ project "National Conservation and Management Programme for Natura 2000 Sites in Latvia" LIFE11 NAT/LV/000371 (2012–2017). The pines were felled and

Fig. 10 Dry grassland in the Slutišķi village before restoration on 14 February 2014.

removed from the entire area, and the mosses were raked in some patches (including the monitoring plots) of the *Koeleria glauca* community in January-February 2014. Mowing with hay removal was carried out on the ex-arable land in July 2014, and 2015 (in 2015, also *Centaurea scabiosa-Agrimonia eupatoria* community was mown). In 2015, anthills were smoothed by rakes in patches with the monitoring plots (Fig. 11).

VEGETATION RESPONSE TO RESTORATION MEASURES

Until 2013, as suggested by the NMS diagramm (Fig. 12), the vegetation changes in the *Koeleria glauca* community can be interpreted as a succession leading to more acidophytic and more closed vegetation with more pronounced moss layer. After 2013, when the pines were removed, species composition became again more similar to the

a	b
c	d
e	f
g	h

Fig. 11 Restoration management in the dry grasslands of the Slutišķi village: (a, b) raking of excessive moss layer in *Koeleria glauca* community, February 2014; (c) pines were felled so that the stumps remain as low as possible to ease the futher management (2014); (d) grasslands after the smoothing of anthills; (e, f) mowing and raking of excessive litter layer in spring, 2015; (g) mown slope with *Centaurea scabiosa-Agrimonia eupatoria* community, (h) burning of the branches of the felled trees in spring 2015. Photos: S. Rūsiņa (a, b, g, h), J. Jātnieks (c - f).

vegetation recorded in 2003, and the species richness increased. From 2003 to 2005, the species richness increased from 14.4 ± 4.5 species per 1 m^2 in 2003 to 19.5 ± 6.9 in 2005 (Fig. 13). After 2005, there was a well-pronounced decrease of the species richness, which reached the lowest point in 2013 (decrease from 19.5 ± 6.9 in 2005 to 10.4 ± 3.8 in 2013. The non-parametric Wilcoxon test showed significant differences in the distribution of species richness from 2005 to 2013. From 2013 to 2016, an increase in the number of species was observed. The mean number of species per 1m^2 increased to 15 ± 4.3 in 2016. So it can be concluded that the restoration induced recovery of the species richness in the *Koeleria glauca* community.

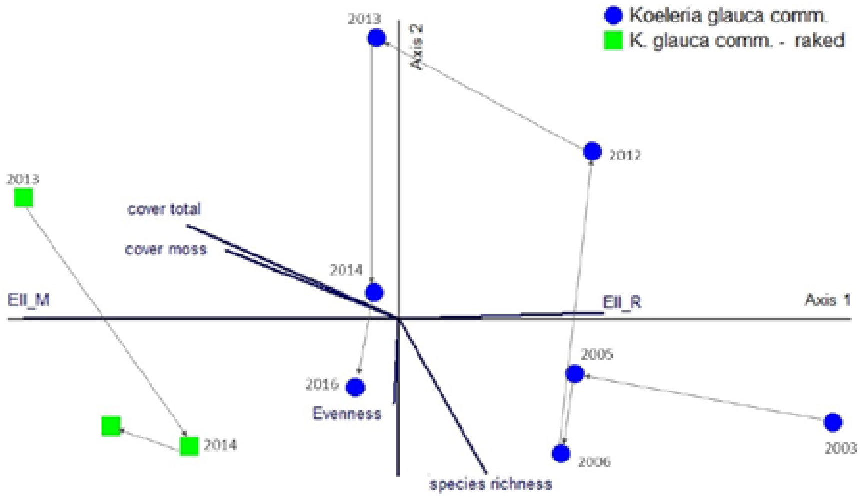


Fig. 12 NMS ordination of vegetation plots of the *Koeleria glauca* community. The number of runs with real data was 59, final stress was 3.75, final instability – 0.00, two-dimension solution was reached. The after-the-fact evaluation of ordination axes showed that 72% of the variance in the data set can be explained by the first axis and 17% by the second axis.
Ell_M – Ellenberg values for moisture, Ell_R – reaction.

Raking of the moss layer did not affect the vegetation substantially, i. e. relevés moved along the second axis, but almost did not change the position along the first axis. The moss layer promoted establishment of mesic species, as the mean Ellenberg indicator values for moisture were slightly higher for relevés with dense moss layer, and they increased constantly in relevés of the *Koeleria glauca* community during the research period (Fig. 14).

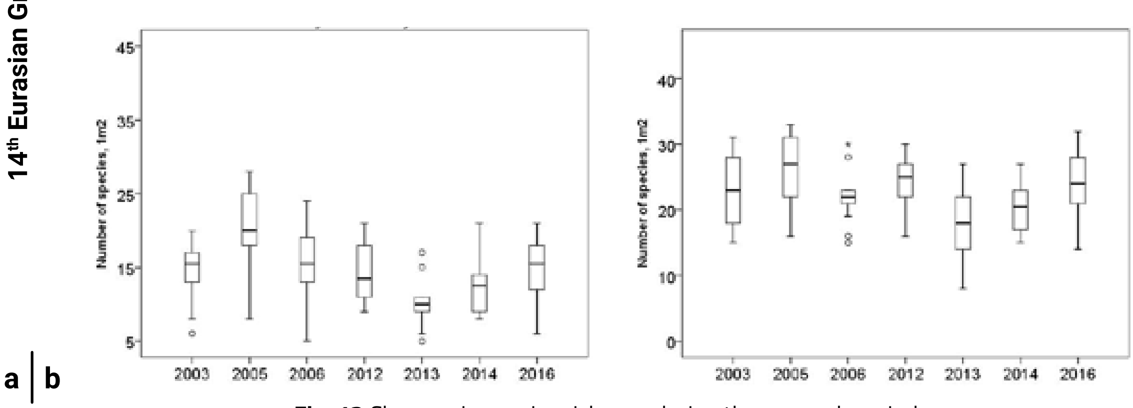


Fig. 13 Changes in species richness during the research period:
(a) *Koeleria glauca* community; (b) *Centaurea scabiosa-Agrimonia eupatoria* community.

a | b

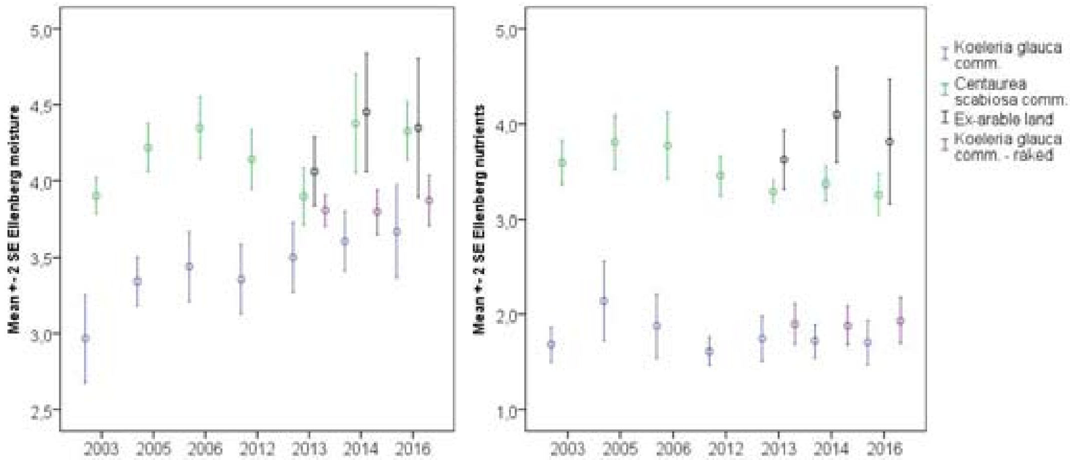


Fig. 14 Mean Ellenberg indicator values for moisture (a) and nutrients (b).

The core of the *Koeleria glauca* community remained the same during the study period. The dominant and constant species were *Koeleria glauca, Festuca rubra, Poa angustifolia, Pimpinella saxifraga, Trifolium arvense, Veronica spicata*, and *Artemisia campestris* (Fig. 15). Over the years, several annual species decreased in their abundance, for instance, *Viola arvensis, Myosotis micrantha, Senecio vernalis, Erophila verna, Jasione montana*. Species which decreased in abundance during the abandonment period and increased again after the restoration in 2013 were *Sedum acre, Rumex acetosa, Achillea millefolium*, and several annuals – *Scleranthus perennis, Veronica verna, Arenaria serpyllifolia*, indicating positive effect of restoration on substrate availability for propagation. Substantial changes were observed in the bryophyte and lichen layer under the influence of abandonment (Table 1). The cover of lichen species (*Cladina* spp., *Cladonia* spp.) and light-demanding moss species (*Ceratodon purpureus*) mostly decreased, whereas the cover of other two moss species (*Abietinella abietina* and *Climacium dendroides*) increased.

a | b | c

Fig. 15 Vegetation changes in *Koeleria glauca* community:
(a) 10 June 2006 with three 2–3 years old pines;
(b) the same plot on 16 August 2012 – pines shade the entire plot;
(c) after the removal of pines on 21 June 2015. Photos: S. Rūsiņa.

Species composition of the *Centaurea scabiosa-Agrimonia eupatoria* community changed slightly during the research period (Fig. 16, 17). The first axis of the NMS ordination diagram can be interpreted as species composition gradient between the *Centaurea scabiosa-Agrimonia eupatori*a community and the ex-arable land. Correlation of axes with Ellenberg indicator values suggests that the main ecological gradients underlaying these differences were soil reaction and nutrient content (Fig. 14, 16). In contrary to the *Koeleria glauca* community, there was not an overall trend in species richness until the restoration in 2013. From 2003 to 2013, there were peaks and troughs. The mean number of species per 1 m2 increased from 23.1 ± 5 in 2003 to the highest number of

Table 1 Changes in species composition of bryophytes and lichens between 2003 and 2012 (percentage frequency with cover range) in *Koeleria glauca* community.

Year	2003	2012
No. of relevés	10	10
Oxyrrhynchium hians	10 ^{r}	.
Cladonia verticillata	10 ^{2}	.
Bryum argenteum	10 ^{r}	.
Placynthiella uliginosa	10 ^{r}	.
Amblystegium serpens	10 ^{r}	.
Cladonia gracilis	.	40 $^{r-2}$
Peltigera canina	.	20 $^{r-+}$
Cladonia macrophylla	.	10 ^{r}
Cladonia crispata	.	10 ^{r}
Bryum capillare	.	10 ^{r}
Cladina rangiferina	.	10 ^{r}
Ceratodon purpureus	100 $^{r-3}$	30 $^{r-3}$
Brachythecium albicans	80 $^{r-2}$	80 $^{r-2}$
Cladonia subulata	70 $^{r-2}$	30 $^{r-2}$
Peltigera rufescens	60 $^{r-2}$	10 ^{2}
Cladonia chlorophaea	40 $^{r-2}$	10 ^{r}
Cladonia ramulosa	40 $^{r-2}$	10 ^{2}
Cladina mitis	30 $^{r-3}$	10 $^{+}$
Syntrichia ruralis	60 $^{r-2}$	50 $^{+-3}$
Abietinella abietina	60 $^{2-3}$	90 $^{r-3}$
Cladonia pyxidata	50 $^{r-2}$	70 $^{r-2}$
Cladonia furcata	20 ^{r}	50 $^{r-2}$
Polytrichum piliferum	30 $^{r-+}$	40 $^{r-1}$
Climacium dendroides	10 ^{r}	40 $^{2-3}$
Cladonia glauca	10 ^{r}	20 $^{r-2}$
Polytrichum juniperinum	10 ^{r}	20 $^{+-1}$

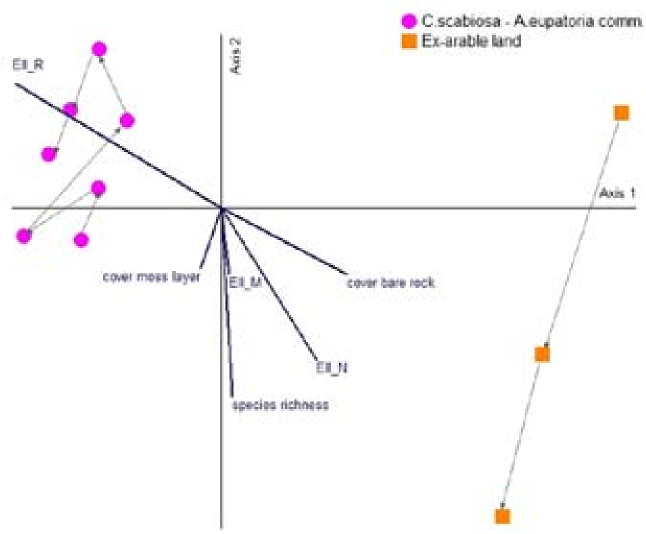


Fig. 16 NMS ordination of vegetation plots of *Centaurea scabiosa-Agrimonia eupatoria* community and ex-arable land. The number of runs with real data was 146, final stress was 4.80, final instability – 0.00, two-dimension solution was reached. The after-the-fact evaluation of ordination axes showed that 54% of the variance in the data set can be explained by the first axis and 35% by the second axis.

species 26.29 ± 5.7 in 2005 (Fig. 13). After that, the species richness decreased slowly. In 2013, there was the lowest mean number of species with 17.9 ± 5.4 species per 1 m^2. After restoration, there was an upward trend until 2016. The mean number of species per 1 m^2 increased to 24.1 ± 5.2 in 2016. The non-parametric Wilcoxon test showed a significant difference in distribution of species richness from 2013 to 2016.

The dominant species of the *Centaurea scabiosa-Agrimonia eupatoria* community with almost no changes in abundance during the monitoring period were *Centaurea scabiosa, Agrimonia eupatoria, Poa angustifolia, Festuca rubra*, and *Achillea millefolium*. Over the years, several forb species decreased in their abundance, for instance, *Viola rupestris, Plantago media, Pimpinella saxifraga, Galium album, Plantago lanceolata*. They were mostly low-growing species influenced negatively by the accumulation of litter. Species which decreased during the abandonment period but increased after the restoration in 2013 were *Centaurea jacea, Polygala comosa, Ranunculus polyanthemos, and Fragaria vesca*.

a

b

Fig. 17 Vegetation changes in *Centaurea scabiosa-Agrimonia eupatoria* community: (a) the situation on 16 August 2012 with young pines creating shade; (b) the same area on 21 June 2015 after removal of pines. Photos: S. Rūsiņa.

Removal of pines and commencement of mowing induced substantial increase in species richness on the ex-arable land (Fig. 13). The species richness had an upward trend from 2013 to 2016. The non-parametric Wilcoxon test showed a significant difference from 2013 to 2016 and from 2014 to 2016. The mean number of species per 1 m^2 increased from 19.4 ± 4.7 in 2013 to 30.7 ± 4.5 in 2016.

The dominant species on the ex-arable land with only minor change in abundance were *Galium album, Poa angustifolia, Pimpinella saxifraga*, and *Achillea millefolium*. Several species typical for dry grasslands increased in abundance, for instance, *Plantago media, Polygala comosa, Ranunculus polyanthemos*, and *Briza media*. Species which decreased in abundance were *Vicia cracca* and *Veronica chamaedrys*.

The difference in the species composition between the ex-arable land and the *Centaurea scabiosa-Agrimonia eupatoria* community was not very well-pronounced (Fig. 18). Common species in both plant communities were *Festuca rubra, Carex caryophyllea, Poa angustifolia, Ranunculus polyanthemos, Festuca pratensis, Veronica chamaedrys, Galium album, Achillea millefolium*, and *Pimpinella saxifraga*. However, there was a group of species distinguishing both communities – the ex-arable land hosted larger number of annual species, such as *Senecio jacobaea, Cerastium semidecandrum, Vicia hirsuta, Arenaria serpyllifolia, Trifolium arvense* (probably because the turf was less developed, and the litter layer was not so thick). Several species with weak competitive ability were also more abundant on the ex-arable land, for instance, *Silene nutans, Sedum acre, Anthyllis vulneraria, Medicago lupulina, Pilosella officinarum, Polygala comosa*. On the other hand, some species, e. g. *Centaurea scabiosa, Vicia cracca, Festuca rubra, Agrimonia eupatoria, Carex caryophyllea, Thymus ovatus, Fragaria vesca, Primula veris, Agrostis tenuis*, were more abundant in the *Centaurea scabiosa-Agrimonia eupatoria* community. Overall, the ex-arable land was richer in species than the *Centaurea scabiosa-Agrimonia eupatoria* community (on average 30.7 ± 4.5 versus 24.1 ± 5.2 species per 1 m^2 in 2016).

a
b

Fig. 18 Ex-arable land (a) before the restoration on 16 August 2012 and (b) after it on 21 June 2015. Photos: S. Rūsiņa.

To conclude, the best results were achieved in the *Koeleria glauc*a community where the pine removal and moss raking resulted in increased species richness. Without restoration the community would disappear and turn into a pine stand within few years.

Restoration of grassland community on the ex-arable land facilitated development of vegetation which is typical for dry grassland plant communities. There were still signs of fallow vegetation – some ruderal species and expansive nitrogen-demanding species, weakly developed turf, absence of several dry grassland diagnostic species. Nevertheless, the area can already be recognised as a protected habitat type of EU importance **6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometea*)**, although in unfavourable insufficient condition.

Restoration activities did not induce substantial changes in the *Centaurea scabiosa-Agrimonia eupatoria* community. It can be explained by insufficient restoration measures – mowing was performed only once and not in the most appropriate time. It was done in spring 2015 by removing only the litter layer.

The future prospects of dry grassland management in the Slutišķi village are challenging. The experience of the LIFE project "National Conservation and Management Programme for Natura 2000 Sites in Latvia" showed that the main problem was not the availability of funding for the restoration, but people who could do the restoration works. Although the project offered higher payment for carrying out the restoration works than on average, it did not succeed in contracting anybody for mowing and hay removal in 2014 and 2016. Mowing was performed only partly in 2015. The contractor refused to complete the works due to complicated terrain conditions with many hardly noticeable stones which broke the equipment several times. Thus, the future of these highly valuable grasslands depend on the motivation of local authorities, awareness of local farmers and land owners to maintain the biodiversity and landscape values related to the grasslands, and efforts of nature conservation authorities to encourage the land managers to be active in conservation of semi-natural grasslands.

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Vegetation dynamics of floodplain grasslands restored by grazing and mowing in the "Dvietes paliene" Nature Park (Dviete Floodplain)

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ABSTRACT

The "Dvietes paliene" Nature Park includes the ancient valley of the Dviete River, a tributary of the Daugava River. The Dviete Floodplain encompases great diversity of wetland habitats including a variety of floodplain grasslands which host several protected plant species. During the last decades of the Soviet period the management of floodplain grasslands declined, and due to abandonment large areas overgrew by shrubs. At the beginning of the 21st century, two large grassland restoration projects were implemented in this area. Four-year vegetation monitoring results suggest that grazing of semi-feral herbivores was more effective in grassland restoration than mowing in a short-term perspective. Species diversity and typical floodplain grassland species established in grazed areas in higher numbers and abundance than in mown grasslands.

KEY WORDS: plant community, semi-feral herbivores, stump grinding, vegetation monitoring.

INTRODUCTION

The area of the "Dvietes paliene" Nature Park (Dviete Floodplain) covers 4959 hectares. It is located in the southeastern Latvia (Fig. 1). The Nature Park has been established and included in the Natura 2000 network in 2004. It encompases the ancient valley of the Dviete River, which is a tributary of the Daugava River (with total length 1005 km) – one of the largest rivers in Eastern Europe (Anon. 2005). The Dviete River flows across the East Latvian Lowland. The Dviete floodplain is located within the Daugava valley on the left side of the Daugava floodplain, and its hydrological regime is governed by the Daugava River. The Dviete floodplain accumulates a large proportion of the Daugava River maximum runoff (Gruberts 2015).

Since 2000, Dviete Floodplain has been recognized as an Important Bird Area of EU importance. Fourty protected bird species are found there. The most prominent meadow bird species are *Crex crex* and *Gallinago media*. Grasslands are important as feeding grounds for *Aquila pomarina*. During the spring migration, more than 20 000 geese are resting here at a time (Račinskis 2004). In the period from 2006 to 2015, 25 farmland bird species have been recorded in the Dviete Floodplain, for instance, T*etrao tetrix, Porzana porzana, Vanellus vanellus, Gallinago gallinago* and *Asio flammeus* (Ķerus et al. 2015).

The Dviete Floodplain encompases great diversity of wetland habitats including a variety of floodplain grasslands which host several protected plant species, for instance, *Gladiolus imbricatus, Iris sibirica* and *Cnidium dubium*. It encompases 16% of the total area of the EU protected habitat type 6450 *Northern boreal alluvial meadows* within the Natura 2000 network in Latvia (the second largest area for floodplain grasslands after the "Lubāna mitrājs" Nature Park (Lake Lubāns Wetland). The total area of the EU protected grassland habitats in the Dviete Floodplain is ca. 2080 ha (Anon. 2005; DAP 2016).

The nature values of the Dviete Floodplain have experienced substantial changes during the last decades. Two main conservation-related problems are land abandonment and altered hydrological regime. Massive abandonment of agricultural lands in the Dviete Floodplain affected the area since 1990. After the collapse of socialist economics, most of the state-owned lands were privatized in post-socialist countries of Eastern Europe. Due to lack of resources many of these agricultural lands were abandoned (Vanwambeke et al. 2012; Jepsen et al. 2015). Along with the access to the support within EU agri-environmental schemes and LIFE programme, in large proportion of formerly abandoned agricultural lands active management was re-initiated in Latvia.

The aim of the present article was to review the conservation efforts affecting the grassland habitats and species in the Nature Park "Dvietes paliene" and to present the data of grassland vegetation after commencement of mowing and grazing.

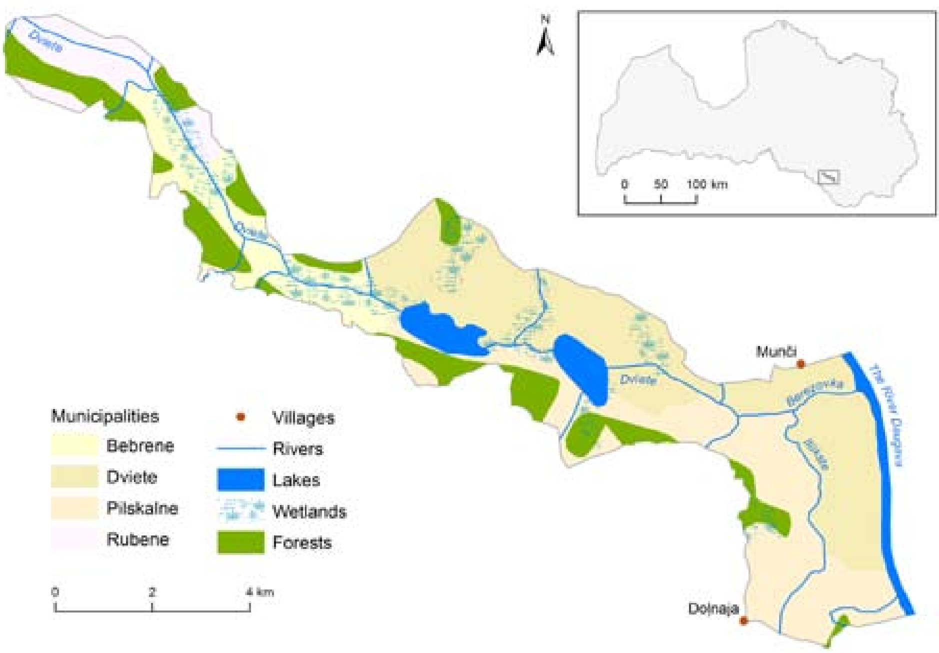

Fig. 1 Location of the "Dvietes paliene" Nature Park.

CLIMATE, GEOLOGY, HYDROLOGY, AND SOILS

In this region, climate is relatively mild, temperate, semi-humid, influenced by westerly transfer of oceanic air masses. The mean annual temperature is +5.7 °C. The coldest month is January with mean temperature –6.5 °C, while the warmest is July with mean temperature +17.0 °C. The mean annual precipitation is 620–650 mm (Anon. 2005; Gruberts 2015).

The Dviete ancient valley is part of the ancient valley network of the southeastern Latvia buried with glacial deposits. The area is located in the territory where glaciolacustrine clay and silt deposits of the last glaciation origin are covered by Holocene sandy loam and sand alluvial deposits. Terrain is slightly undulated, the altitude ranges between 90 and 103 m a. s. l (Škute et al. 2008). Two floodplain lakes of glacial origin are situated in the ancient valley – Lake Skuķu and Lake Dviete. They are the largest floodplain lakes in Latvia.

Dviete floodplain is a part of the Middle Daugava valley stretch, which is up to 4 km wide. Seasonal fluctuation of water level in this stretch is determined mainly by natural factors, such as the amount of snow accumulated in the catchment area during winter, rate of the air temperature increase and snow melt in spring or formation of ice jams during the spring floods (Škute et al. 2008).

Spring floods usually start in late March or April with the duration of several weeks depending on a year. The highest water level during the year is usually observed on 12–14 April, and it can rise for up to 6 metres. Flood waters of the Daugava River enter the floodplain, and then the water flow is reverse to the normal flow of the Dviete River. The maximum discharge can reach 399 m3 per second during the maximum rise of water level. Maximum rise of water level, which has been observed, was 2.89 m in 24 hours. A 1.5 m deep and 55 km long waterbody with the total area of 200 km^2 can develop during the spring floods (Škute et al. 2008; Gruberts 2015).

The Middle Daugava floodplain, which includes the Dviete River floodplain, reduces the annual amplitude of water level fluctuation by 3–4 metres. It intercepts ca. 20% of the Daugava daily runoff amounts at the beginning of the floods. In the light of climate change it is assessed that the Dviete River floodplain preservation will maintain not only wetland and grassland ecosystems, but also mitigate the risk of flooding (Gruberts 2015).

The water flow in the Dviete River is slow – about 0.05 m km^{-1} which causes grassland management problems due to flood duration. Even relatively small rise of water level can inundate large areas for a long time. Area of inundated areas in different municipalities at mean flood level ranges from 13 to 15%. At maximum flood level the Dviete municipality experiences the largest inundated area – 46% (5381 ha) of the total municipality area at maximum flood level (1% probability floods with re-occurrence interval of 100 years) (Škute et al. 2008).

The Dviete River was straightened and its floodplain was drained in the 1930s (Fig. 2). As a result, the water level of both largest floodplain lakes dropped by 1.5 m. The area of mesic and moist grasslands increased at the expense of wet grasslands (Anon. 2005).

Groundwater table in the floodplain depends on the level of surface waters and local conditions. Groundvater table changes are closely related to the amount of precipitation. It rises by 10 cm if the precipitation is more than 15 mm a week. During the periods of precipitation less than 10–15 mm a week the groundwater table drops. The deepest groundwater table has been observed in low water periods in May-June (Gruberts 2015).

a | b

Fig. 2 The example of the stretch of the Dviete River before and after straightening.
(a) A topographical map with the scale 1:75 000 of the Latvian army general staff prepared in 1921–1940; (b) A sattelite map of the Republic of Latvia with the scale 1:50 000 of the State Land Service (both maps available at http://www.geo.lu.lv/kartes).

Soils of the floodplain are formed on alluvial bedrock of sandy and clay material interspersed by organic matter. Soils are waterlogged for the most time of the vegetation period, thus peat formation is common. Glaciofluvial deposits (sand, sandy loam, loam, gravel) dominate on hills of ancient valley banks (Anon. 2005).

The landscape of the Dviete floodplain is mainly characterised by agricultural lands – grasslands and arable lands. Semi-natural grasslands have been extensively managed for decades until the mid-20th century. During the Soviet period the management of floodplain grasslands declined which was associated with land nationalization, abandonment of individual farmsteads and decrease of lands managed by private owners. Soviet agriculture aimed at creating sown cultivated grasslands and use heavy, large machines in agriculture which were not suitable for wet floodplain areas. After the collapse of socialist economics, most of the state-own land became private. Presently, the majority of floodplain grasslands are privately owned with 1472 cadaster units (Anon. 2005; Priedniece, Račinskis (eds.) 2015).

FLOODPLAIN VEGETATION BEFORE GRASSLAND RESTORATION IN 2013

Before restoration, large areas of floodplain were dominated by *Salix* spp. and *Alnus glutinosa* scrub (Fig. 3). Frequent shrub species in the lower shrub layer were *Frangula alnus, Salix pentandra, S. cinerea*. Under shrubs, the herb layer was sparse, more developed only in openings. Nitrophilous species, such as *Symphytum officinale, Urtica dioica, Phalaroides arundinacea* and hygrophilous species *Scutellaria galericulata, Stachys palustris, Carex cespitosa, Solanum dulcamara* and *Filipendula ulmaria* were abundant.

Floodplain areas, where the grasslands were restored in 2004–2006, in 2013 were dominated by herbaceous vegetation composed mainly of tall herbs, such as *Lysimachia vulgaris, Phalaroides arundinacea, Lythrum salicaria, Filipendula ulmaria, Thalictrum flavum,* *Scutellaria galericulata, Polygonum hydropiper*. Shrub species were abundant in herb layer, for instance, *Salix cinerea, S. pentandra, S. myrsinifolia* (Fig. 4, 5).

Pastures and meadows continuously managed even before 2004 until present were characteristic with polydominant herb layer without tree and shrub species (Fig. 6). The dominant species were *Filipendula ulmaria, Carex acuta* and *Phalaroides arundinacea*. The most frequent species were *Cnidium dubium, Galium palustre, Bidens tripartita, Agrostis stolonifera, Lysimachia vulgaris, Polygonum hydropiper, Ranunculus repens*.

Fig. 3 Shrub vegetation. Before restoration most of grassland areas were covered by shrubs. Photo: S. Rūsiņa.

a
b

Fig. 4 Grasslands restored in 2006 by mowing (a), and grazing (b). Situation in 2014. Mowing management for several years without shrub stump and root grinding was not very successful in controlling shrub regrowth. Still, it had better results than grazing. Shrub regrowth was higher and denser in grazed areas. Photo: S. Rūsiņa.

The herb layer in continuously managed meadows was dominated by *Alopecurus pratensis, Phalaroides arundinacea* and *Poa palustris*. Species with high frequency were *Bromopsis inermis, Ranunculus repens, Lychnis flos-cuculi, Galium rivale, Vicia cracca, Veronica longifolia, Galium palustre, Filipendula ulmaria*.

Fig. 5 Differences in vegetation structure in pastures and meadows. On the left side of the fence high tussocks of *Carex cespitosa* are visible in grazed part, on the right side of the fence – vegetation has very even structure without high tussocks in mown part. Photo: S. Rūsiņa.

a

b

Fig. 6 The herb layer in continuously managed pastures (a) was heterogeneous, with typical structure of pastures formed by vegetation of different height dominated by *Carex acuta, Filipendula ulmaria* and *Phalaroides arundinacea*. Continuously managed meadow (b) was very uniform with even distribution of grass and forb species and polydominant vegetation structure. Photo: S. Rūsiņa.

RESTORATION ACTIVITIES IN DVIETE FLOODPLAIN

LIFE project LIFE04 NAT/LV/000198 "Meadows – Restoration of Latvian Floodplains for EU Priority Species and Habitats" (2004–2008) aimed at initiation a coordinated nation-wide programme for the restoration and long-term management of floodplains. Dviete Floodplain was one of 15 Natura 2000 sites where grassland restoration was commenced. About 160 ha of abandoned and overgrown floodplain grasslands were restored by shrub removal, restorative mowing and grazing. Pastures for semi-feral herbivores (18 'Highlander' cattle and 22 'Konik' horses) were created in a 98 ha area near the information center "Gulbji" (Priedniece, Račinskis (eds.) 2015).

In 2013, another LIFE project LIFE09 NAT/LV/000237 "DVIETE – Restoration of Corncrake Habitats in Dviete Floodplain Natura 2000 site" (2013–2016) was carried out to improve the extent, connectivity and quality of open grassland habitats for breeding corncrakes Crex crex. In total, 113 ha of grasslands were restored by shrub removal, stump grinding, and establishment of pastures of semi-feral herbivores (Fig. 7, 8). To improve the hydrological regime the natural riverbed of the Dviete River was restored in a 1.8 km long section (Priedniece, Račinskis (eds.) 2015).

Fig. 7 Stump and shrub root grinding in winter 2014-2015. Photo: S. Rūsiņa.

Fig. 8 Grassland after grinding. Photo: S. Rūsiņa.

A small area of an overgrown meadow (1 ha) was restored by stump grinding and mowing within the frame of the LIFE project LIFE11 NAT/LV/000371 "National Conservation and Management Programme for Natura 2000 sites in Latvia" (2012–2017).

DESIGN OF VEGETATION MONITORING AND DATA ANALYSIS

Vegetation monitoring was started in 2013. The monitoring aim was to evaluate the influence of different restoration activities on grassland vegetation. In total, 53 semi-permanent vegetation plots of 25 m^2 (squares of 5 × 5 m) were established is seven areas with different grassland restoration history (Table 1, Fig. 9).

Table 1 Description of monitoring sites.

MONITORING SITE	NUMBER OF VEGETATION PLOTS	YEARS OF MONITORING	MANAGEMENT HISTORY
Control shrubland	5	2013	For 20 years abandoned grassland, overgrown with *Salix* spp. and *Alnus incana*.
2013 pasture	15	2013–2015	For 20 years abandoned grassland (before restoration vegetation was the same as in control plots). Grassland restored in 2012–2013 by shrub removal and commencement of grazing by semi-feral herbivores (year-round grazing with supplementary feeding in winter by baled hay from adjacent meadows). Grinding of shrub stumps performed in winter 2015.
2006 pasture	12	2013–2016	Abandoned grassland restored in 2004–2006 by shrub removal and commencement of grazing by semi-feral herbivores (year-round grazing with supplementary feeding in winter by baled hay from adjacent meadows). Grinding of shrub stumps performed in winter 2015.
Continuously managed pasture	3	2013–2016	Continuously grazed grassland with short period of abandonment (overgrowing with shrubs have not been present). Year-round grazing with supplementary feeding in winter by baled hay from adjacent meadows.
2013 meadow	10	2013–2016	Abandoned meadow partly overgrown with shrubs. Shrubs removed in winter of 2013, mowing commenced in 2014 and continued in next years (hay not removed because of too wet conditions), stump and tussock grinding in winter 2015.
2006 meadow	3	2013–2016	Abandoned meadow partly overgrown with shrubs. Restoration of meadow performed in 2004–2006 by shrub removal and commencement of mowing with hay removal.
Continuously managed meadow	5	2014	Continuously mown meadow (mowing one or twice per year depending on moisture regime and weather conditions) with hay removal without abandonment period.

The number of plots was not the same in all monitoring sites due to time and financial limitations. The minimum plot number per monitorings site was 3 plots (Table 1). Vegetation plots were established in transects with the distance of 15 m between plots at mown sites. In other monitoring areas, the locations of the plots were chosen in stratified random design, where the most typical and homogeneous parts in terms of vegetation of the restoration area were subjectively selected. Location of vegetation plots were placed in a transect across this area with at least 15 m between the plots. The plots were georeferenced using GPS receiver with precision of 5 m. In each plot, total cover of litter, herb and moss layer as well as percentage cover of each species was determined visually. Bryophytes and lichens were excluded from the analysis as they were not recorded each year. Vegetation was recorded in July–August.

Vegetation data were stored in a database using the software program TURBOVEG (Hennekens, Schaminée 2001). Significance of differences between the first and the last year of observation with respect to species richness was evaluated by the non-parametric Wilcoxon test using the software package SPSS for Windows, version 17.0 (SPSS 2008). Non-metric multidimensional scaling (NMS) (McCune, Grace 2002) was applied to analyse the variation in species composition among years. The software PcORD 5 was used (McCune, Mefford 1999). The square-root transformation of species cover percentages and downweighting of rare species was applied. Sørensen distance measure was used. Monte Carlo test with 250 randomized runs was used to evaluate the extracted axes (McCune, Grace 2002). Species nomenclature followed Gavrilova and Šulcs (1999).

Fig. 9 The monitored grassland restoration sites in the Dviete Floodplain.
Vegetation plots marked with violet dots. Map: Orthophoto map at a scale of 1: 10,000
© Latvian Geospatial Information Agency (ORTHOPHOTO 5).

NMS diagramm shows substantial changes in vegetation during the monitoring period in grasslands restored both by mowing and by grazing. Vegetation composition changed in all monitoring sites – vegetation plots of subsequent years changed their position along Axis 1 and Axis 2. Plots of shrub vegetation were located in the right end of the first axis, but plots of continuously managed pastures and meadows were located on the left end of the axis (Fig. 10).

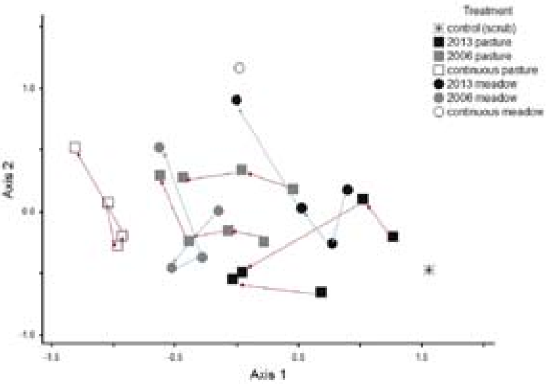

Fig. 10 NMS ordination of vegetation plots. Number of runs with real data was 89, final stress was 8.74, final instability – 0.00, three-dimension solution was reached. The after-the-fact evaluation of ordiantion axes showed that 84% of the variance in the data set can be explained by the first three axis.

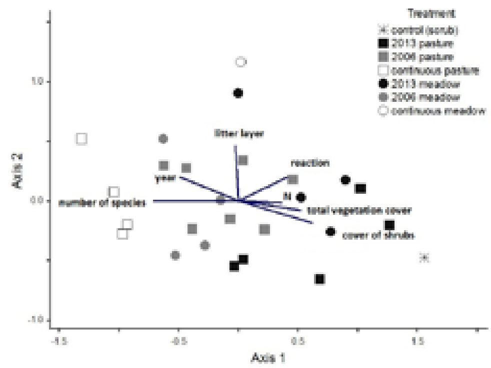

Fig. 11 Overlay of NMS axis with weighted means of Ellenberg indicator values and vegetation parameters. N – Ellenberg nitrogen value, reaction – Ellenberg reaction value.

Correlations of NMS axes scores with weighted means of Ellenberg indicator values, vegetation structure, and species richness parametres (Fig. 11) indicated that the main gradient in species composition was related to vegetation succession from shrub vegetation to open grassland vegetation. The Ellenberg indicator value for nutrients increased along Axis 1, while the number of species decreased. A positive correlation of Axis 1 with the observation year can be interpreted as successional gradient.

Axis 2 showed correlation with the cover of litter layer. Litter layer is commonly well developed in grasslands with well-pronounced dominance of tall grasses. Scrub vegetation did not possess litter layer because the tree shrub leaves decompose rapidly and the ground vegetation did not contain grasses in significant abundance.

Initial species composition was similar in treatments 2013 pasture and 2013 meadow before commencement of restoration (Fig. 12, 13). Grasslands restored by grazing experienced substantial changes in vegetation composition after the grinding of shrub stumps and roots and establishment of grazing (Table 2). Although the dominant species (*Phalaroides arundinacea, Filipendula ulmaria*) were the same after three years of grazing, the frequency and abundance of grazing-tolerant species increased, for instance, *Rumex crispus, Ranunculus repens, Agrostis canina, Juncus bufonius, Bidens tripartita, Agrostis stolonifera*.

Vegetation remained more similar to initial composition in grasslands restored by mowing than in grasslands restored by grazing. Abundance and frequency of dominant species did not change substantially. Dominant species were *Filipendula ulmaria, Phalaroides arundinacea, Carex acuta*. Number and frequency of forb species increased –

July 2013, before the restoration.

July 2014, after the removal of shrubs which was done in winter 2013–2014.

July 2015, the first vegetation season after the grinding of shrub roots and stumps. Shrub shoots regrew vigorously, probably due to too shallow grinding which did not completely destroy the roots.

July 2016, abundance of shrub shoots have decreased, they are not taller than the vegetation in the herb layer.

Fig. 12 Vegetation changes of the treatment *2013 meadow* during the monitoring period. Photo: S. Rūsiņa.

Lycopus europaeus, Veronica longifolia, Scutellaria galericulata, Ranunculus repens, Galium palustre. Mowing was successful in controlling the invasive species *Echinocystis lobata*. Frequency of this species decreased from 50 to 10%.

However, neither the grasslands restored in 2006, nor those restored in 2013 supported rare and endangered plant species. Two protected plant species typical for floodplain grasslands in the Dviete floodplain – *Cnidium dubium* and *Viola persicifolia* (Fig. 14), were encountered only in continuously grazed and mown grasslands.

Table 2 Shortened synoptic table of grasslands restored in 2013 by mowing and grazing

Treatment		2013 pasture			2013 meadow	
Year	2013	2014	2015	2013	2014	2015
Filipendula ulmaria	100^{2-5}	100^{r-3}	100^{2-2}	80^{r-3}	100^{2-5}	100^{2-3}
Lycopus europaeus	50^{r-4}	60^{r-2}	78^{r-2}	.	50^{r-1}	50^{r-1}
Stachys palustris	80^{r-3}	70^{r-3}	56^{r-2}	100^{r-2}	70^{r-2}	100^{r-2}
Urtica dioica	80^{2-2}	100^{r-3}	67^{r-r}	40^{-2}	90^{r-2}	100^{r-2}
Veronica longifolia	20^{r-r}	50^{r}	11^{r}	.	30^{r}	50^{r}
Calamagrostis canescens	30^{r-2}	70^{r-2}	22^{2-2}	10^{r}	40^{r-+}	60^{r-2}
Scutellaria galericulata	60^{r-3}	70^{r-2}	78^{r-2}	20^{r}	90^{r-3}	100^{r-2}
Phalaroides arundinacea	80^{r-4}	90^{r-r}	100^{r-3}	80^{2-5}	90^{r-2}	100^{-2}
Thalictrum flavum	50^{r}	80^{r}	67^{r-2}	60^{r-2}	80^{r-2}	60^{r-2}
Lysimachia vulgaris	30^{r-2}	90^{r-2}	89^{2-2}	100^{1-3}	100^{-3}	90^{2-3}
Galium boreale	50^{r-2}	40^{r-2}	11^{r}	.	.	10^{r}
Carex cespitosa	70^{r-2}	50^{r-2}	56^{r-2}	20^{+}	20^{r-+}	.
Alopecurus pratensis	30^{r-2}	40^{r-2}	.	.	.	.
Symphytum officinale	40^{r-2}	50^{r-r}	78^{r-+}	.	.	.
Bidens tripartita	60^{r-2}	90^{r-2}	100^{2-3}	10^{r}	10^{r}	10^{r}
Rumex crispus	10^{r}	30^{r-r}	67^{r}	.	.	10^{r}
Ranunculus repens	30^{r}	30^{r-2}	100^{2-3}	.	40^{r-2}	60^{r-2}
Galium palustre	40^{r-2}	60^{r-+}	89^{r-2}	.	60^{r-3}	80^{r-2}
Humulus lupulus	10^{r}	20^{r}	33^{r-1}	40^{r-2}	50^{r-4}	20^{r-2}
Lathyrus palustris	.	40^{r-r}	33^{r-r}	20^{r}	60^{r-2}	80^{r-2}
Lychnis flos-cuculi	.	.	56^{r-1}	.	40^{r}	80^{r-2}
Carex acuta	.	20^{r-+}	56^{r-3}	90^{r-2}	80^{r-2}	80^{r-3}
Echinocystis lobata	.	.	.	50^{r-2}	10^{r}	10^{r}
Agrostis canina	.	.	33^{r-r}	.	.	.
Stellaria palustris	.	.	33^{r}	.	10^{r}	.
Juncus bufonius	.	.	44^{r-2}	.	.	.
Rorippa palustris	.	.	44^{r}	.	.	.
Plantago major	.	10^{r}	44^{r}	.	.	.
Carex leporina	.	.	56^{r-2}	.	.	.
Phalacroloma annuum	.	.	56^{r}	.	.	.
Rumex obtusifolius	.	.	56^{r-+}	.	.	.
Agrostis stolonifera	.	20^{r-r}	44^{r-2}	.	.	.
Juncus articulatus	.	.	67^{r-1}	.	.	.
Ranunculus flammula	.	20^{r}	67^{r-+}	.	.	.
Poa trivialis	.	10^{r}	89^{r-2}	10^{r}	.	.
Polygonum hydropiper	.	20^{r}	89^{r-2}	.	.	.
Poa palustris	.	20^{r-2}	89^{r-+}	.	.	.
Barbarea stricta	.	10^{r}	78^{r-1}	.	.	40^{r-r}
Carex flava	.	40^{r}	89^{r}	.	.	10^{r}

July 2013, after clearing of shrubs. Due to the high winter flood water level with development of permanent ice cover during the winter of 2013–2014, shrubs were cut at 1 to 1.5 m height from the earth surface. It was the reason why the grinding of stumps and roots was planned for the winter 2013–2014.

July 2014, the first vegetation season after the grinding of shrub roots and stumps. Grinding was successful and no shrub regrowth was observed during the following vegetation growth season after grinding.

July 2015, the herb layer vegetation has recovered.

Fig. 13 Vegetation changes of the treatment *2013 pasture* during the research period. Photo: S. Rūsiņa.

Fig. 14 Protected plant species *Cnidium dubium* (a1, a2) and *Viola persicifolia* (b). Photo: S. Rūsiņa.

Not only the composition of species, but also species richness changed substantially in both mown and grazed grasslands restored in 2013 (Fig. 15). The most pronounced increase in species richness was observed in grasslands restored in 2013 by grazing (treatment 2013 pasture). The mean number of species per 1 m2 was 8.7±1.8 in 2013. It increased to 18.7±3.1 species per 1 m2 in 2015 (there were no data for 2016). Non-parametric Wilcoxon test showed significant differences in distribution of species richness in all years. Similar increase was observed also in treatment 2013 meadow where number of species per 1 m2 increased from 3.8±7.9 in 2013 to 12.0±3.1 in 2016. Non-parametric Wilcoxon test showed significant differences in distribution of species richness in all years for treatments 2013 meadow and 2013 pasture.

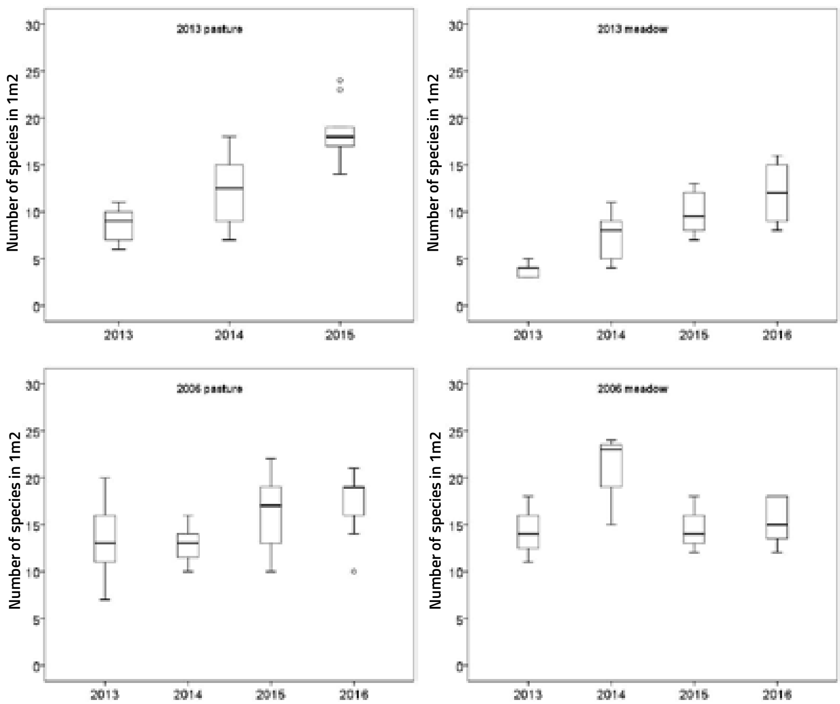

Fig. 15 Changes in species richness in 1 m^2 (axis y) in restored grasslands in the course of time .

In treatment 2016 pasture, the distribution of species richness in 2013 and 2014 significantly differed from the years 2015 and 2016. It can be explained by the influence of shrub stump grinding in these areas in winter 2014–2015. No significant changes were observed in treatment 2006 meadow (no stump and root rinding was performed there).

To conclude, the monitoring results in the Dviete Floodplain grasslands confirmed the findings of other grassland restoration studies which have found that grazing is more effective and gives faster results in grassland restoration than mowing (Moog et al. 2002). Restoration was very successful in terms of typical floodplain grassland vegetation recovery. Restoration was more successful than in several other studies. For instance, Bischoff (2002) studied vegetation recovery in a restored previously intensively managed grassland in the Saale River floodplain (Germany). Grassland vegetation did not contain typical floodplain grassland species even after 10 years of restorative management, although the species pool was available in surroundings. Similar results were obtained in the study of Bissels et al. (2004) in the Upper Rhine (Germany). In both studies, low species arrival was attributed by poor dispersal abilities of floodplain grassland plants. In our study, the lack of rare grassland species in grasslands restored in 2013 and 2006 suggests that also in the Dviete area the main limiting factor could be the low dispersal ability of floodplain grassland plants.

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Semi-natural grasslands in the "Abavas senleja" Nature Park (Abava River Valley)

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ABSTRACT

The "Abavas senleja" Nature Park is one of the most valuable and diverse nature areas in Latvia. Many protected habitat types and protected species are recorded there. It is among the most important protected nature areas in Latvia for conservation of habitat types of European Union importance **6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometea*), 6120* Xeric sand calcareous grasslands** and **5130 *Juniperus communis* formations on heaths or calcareous grasslands**.

Drubazas farm is one of the most spectacular dry grassland areas in the Abava River Valley. This paper provides an insight in the grassland vegetation peculiarities of this area. In Drubazas, the vegetation monitoring was commenced in 2000 in three permanent transects with different vegetation types: semi-natural grassland with *Filipendula vulgaris-Helictotrichon pratense* community, ruderalised grassland with *Calamagrostis epigeios* community, and ex-arable land with *Poa angustifolia-Filipendula vulgaris* community. Long-term monitoring showed successful recovery of dry grassland in the former arable land under the influence of mowing with grass removal.

KEY WORDS: plant communities, Drubazas, ex-arable land, vegetation monitoring, grassland restoration.

INTRODUCTION

The "Abavas senleja" Nature Park (Abava River Valley) is located in Western Latvia and is split among four counties – Kandava, Kuldīga, Talsu and Ventspils counties (Fig. 1). The Nature Park was established in 1957 as a complex botanical reserve, but in 2005 it was designated as a Natura 2000 site (site code LV0302100). In Latvia, nature parks are territories that represent the natural, cultural and historical values of the particular area and that are suitable for recreation and education. Organization of recreation and economic activities in the nature parks shall be carried out by ensuring the preservation of the natural, cultural and historical values. Among 42 nature parks of Latvia, the "Abavas senleja" Nature Park is the largest one and covers approximately 14 933 ha (Abava River Valley 2016).

The Abava River Valley forms the most expressive river valley in Western Latvia in terms of landscape and terrain. The valley is 30 to 40 m deep and up to 300 m wide. The Abava River (totally 129 km long) flows through the territory. Two small historical towns are located in the valley: Sabile and Kandava.

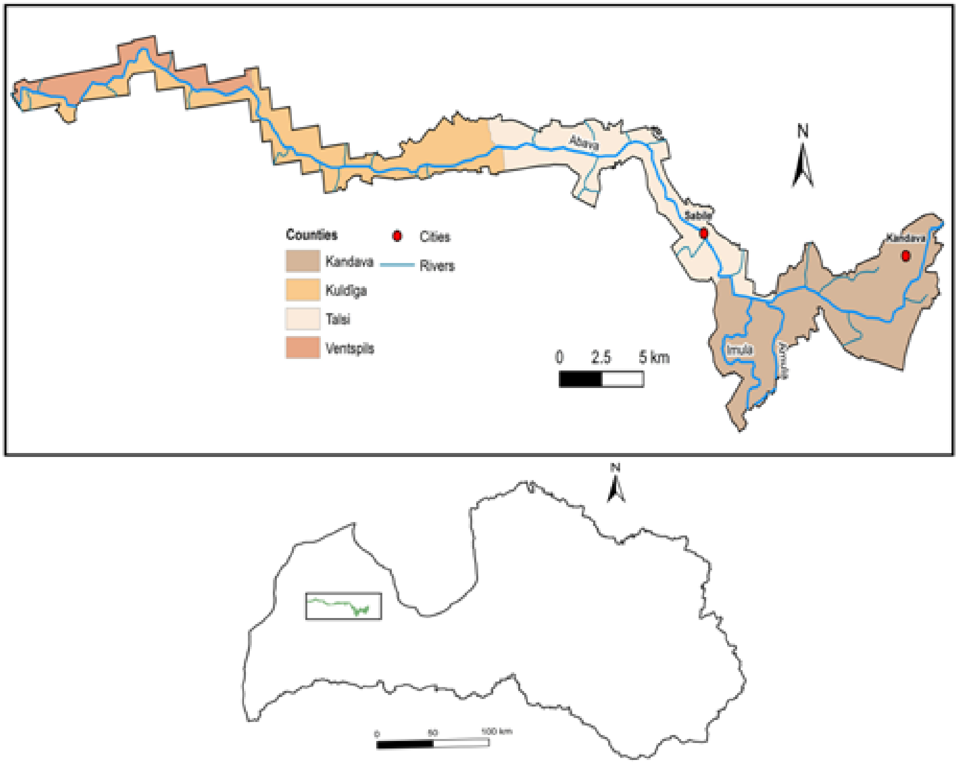


Fig. 1 Location of the "Abavas senleja" Nature Park in Latvia.

Abava River nature valley is one of the best dry calcareous grassland areas in Latvia, representing the remnants of species-rich semi-natural grasslands. All grassland habitat types listed in the Habitats Directive's Annex I occurring in Latvia are present here.

CLIMATE, GEOLOGY, AND SOILS

In this region, the climate is relatively mild and moist. It is slightly more continental in the valley than outside it. The differences in microclimate depend on the valley slope exposure and height above the level of the Abava River. Temperature inversions and enhanced haziness are often observed in here (Strautnieks 1994). The mean annual temperature is 5.7 °C. The coldest month is February with the mean temperature –9.7 °C, whereas the warmest month is August with +22.0 °C (Abava River Valley 2016). The mean annual precipitation is 650–750 mm. Precipitation is higher in the warm period. Frost-free period lasts from 130 to 140 days per year. Snow cover remains averagely from 80 to 110 days. The vegetation period lasts about 180–200 days (Strautnieks 1994; Kalniņa 1995).

Abava River Valley is formed by melting glacier water. The bedrock surface is mainly composed of sandstone, aleirite, dolomite, domerite, clay, limestone and gypsum. Sandstone outcrops can be found on the banks of the Abava River and on the side ravines. Alternating dolomite and gypsum or deposits of clay and domerites are exposing on the banks of the Abava River and its tributaries. The sulphur springs which form in the subsurface layers in the contact zone with the gypsum bedrock can be found near Kandava. Placoderm fossils are found in blue-gray and light gray sandstones on the banks of Imula and Amula Rivers. On the valley slopes in the Abava River Valley and its tributaries, there are places with tufa deposits which have developed by precipitation of calcium carbonate from carbonatic subsurface waters. Large tufa deposits are found in the Čužu Mire near Kandava, which is also largest deposit in Latvia covering about 70 hectares.

In the Nature Park, sod-podzolic soils prevail. The prevailing soil bedrocks are sand and loam. Cultivated alluvial sod calcareous soils are common in the Abava River floodplain where dolomites are close to soil surface, whereas on the valley slopes rendzinas support development of species-rich calcareous grasslands. Brown soils can be found on the upper part of steep slopes which are usually overgrown with deciduous broadleaved forests. Peat soils with medium decomposition levels have developed in moist depressions and in the floodplain.

LANDSCAPE HISTORY

The Nature Park is valuable with its unique landscape, protected species and habitats, as well as the diversity of geological monuments: caves, outcrops and waterfalls. Long-time interaction between nature and humans has evolved the unique landscape of the Nature Park. The Abava River Valley uniqueness is determined also by the shape of the valley characterised by relatively steep slopes, where rocky outcrops and ravines can be found. Agricultural lands, forest clusters, individual trees, rows of trees and shrubs along the ditches and roads, human settlements (towns, villages, homesteads) and roads altogether form a mosaic – a spatially fragmented landscape. A substantial part of the Nature Park is comprised by increasing forest area which is rising due to overgrowing of abandoned fields. Mixed broadleaved and pine forests and spruce forests prevail, as well as secondary forests among which the main role is played by white alder forests (Табака, Клявиня 1981).

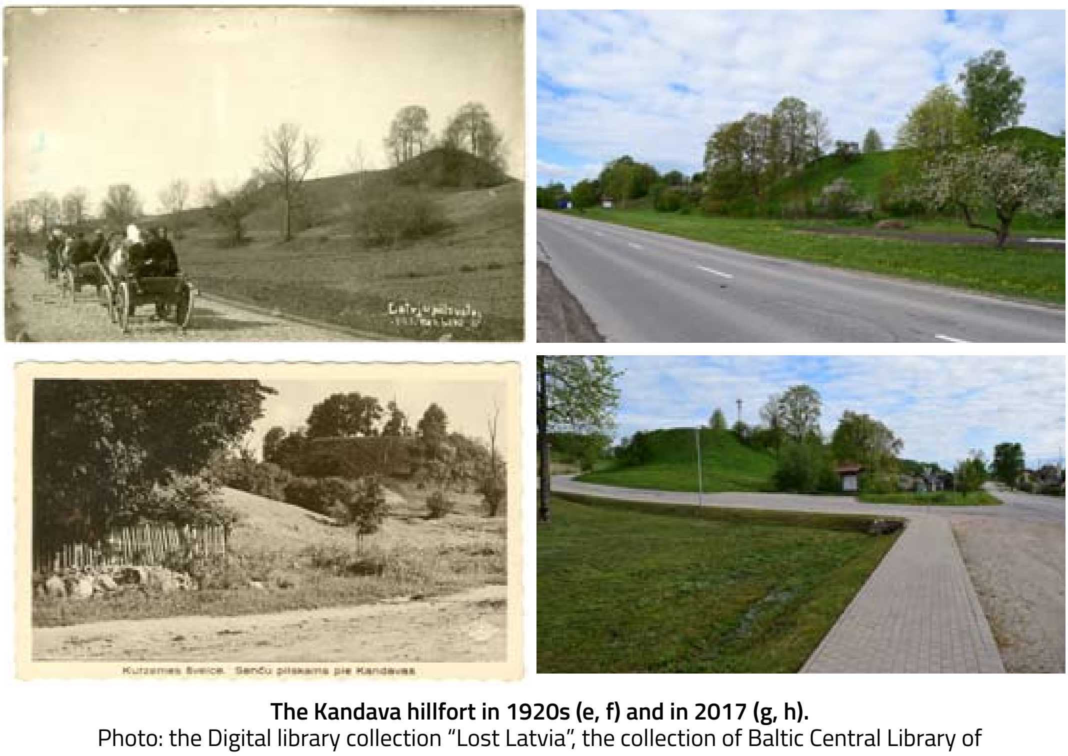
The area is rich in historical monuments. Thirty-eight archaeological monuments can be found in the valley, for example, twenty burial grounds one fossil field and eight ancient cult places. Three historical settlements can be found near Tojāti, Tapilnieki and Renda. Tojāti settlement (located near Sabile) is the oldest known evidence of human activities in the Abava River Valley. The settlement has been built in the 2nd millennium B.C. Primitive hunters and fishermen tools made of bones and horn and ceramic objects been found in Tojāti settlement (Klabere 2007). Several hill-forts are located on the valley slopes in Renda, Valgale, Rumba, Matkule, Čāpuļi, Kandava and Sabile. Kandava hill-fort is most significant hill-fort in valley, and it was inhabited since the late Iron Age (Brastiņš 1923). Several settlements along the Abava River were established already in the 13th century: Pūre, Kandava, Sabile, Pidole (later – Pedvāle), Valgale, and Renda, and they exist until nowadays. The Kandava and Sabile town centres are historical monuments of town construction of national importance. Later, during the 20th century, the towns and largest villages (Kandava, Sabile, Renda) have expanded along with development of industries and residential areas.

In the Abava River Valley, there are several old manors. They were surrounded by

a | c
b | d

View from the Greiļa hill in 1930s (a, b) and in 2007 (c, d).
Photo: the Digital library collection "Lost Latvia", the collection of Baltic Central Library of Lettonica and Baltic Centre of the National Library of Latvia (a, b), A. Kuzemko (c), S. Rūsiņa (d).

e | g
f | h



The Kandava hillfort in 1920s (e, f) and in 2017 (g, h).
Photo: the Digital library collection "Lost Latvia", the collection of Baltic Central Library of Lettonica and Baltic Centre of the National Library of Latvia (e, f), S. Rūsiņa (g, h).

Fig. 2 Landscapes in the"Abavas senleja" Nature Park in the 1930s and 2000s.

different household buildings, parks, alleys and farm territories. Some old manors with the complex of buildings and parks are part of the contemporary villages or industrial centres.

Since the 1920s, the Nature Park is one of the most popular tourist destinations in Latvia. Popular destinations are Vīnakalns (*Grape Hill*) in Sabile, where the grapes for wine making are being cultivated, as well as the open-air art museum at Pedvāle near Sabile. There are nature trails for tourists, and Abava is the most popular river for boating in Kurzeme. Popular destinations are also Abavas rumba (*Abava Waterfall*), Īvande and Veģupīte falls. There are several nature objects – large boulders, sandstone outcrops and caves, such as Velnakmens (*Devil's Stone*) and Velnala (*Devil's Cave*), Laupītāju ala (*Robbers' Cave*) and Māras kambari (*Māra's Chambers*) which are frequently visited by tourists. In the wintertime, visitors can go skiing, and in the summer ride summer toboggans at Zviedru cepure (*Swedish Hat*).

FLORA, VEGETATION AND EU-IMPORTANCE PROTECTED HABITAT TYPES

The Nature Park is one of the most biologically valuable and diverse nature area in Latvia. Twenty eight protected habitat types of EU (European Union) importance and 252 protected species are registered there. Habitat types listed in the EU Habitats Directive's Annex I cover 1758 ha (12% of the total area of the Nature Park) (Table 1).

The Nature Park is located in the Western Latvia geobotanical region, and hosts 826 plant species which largely represent flora of the entire region. Majority of rare species are found in forests and grasslands. In total, 100 rare, protected vascular plant species of vascular plants and 46 rare, protected moss species are found in the Nature Park. Three species are listed in the Habitats Directive's Annex II – *Agrimonia pilosa, Pulsatilla patens, Buxbaumia viridis*.

Forests cover about 50% (7452 ha) of the Nature Park. Almost all the native tree species occurring Latvia can be found in the Abava River Valley (except *Taxus baccata* and *Carpinus betulus*). The protected forest habitats of EU importance occupy about 1006 hectares (7% of the total area of the Nature Park or 14% of the forest area in the Nature Park).

In the valley, forests dominated by *Pinus sylvestris* are found mainly on poor sandy soils. Dry pine forests in Latvia mostly correspond to the class *Vaccinio-Picetea*. In the Abava River Valley, there are also rich pine forests corresponding to the class *Pyrolo-Pinetea sylvestris* with such species as *Lathyrus niger, Carex ornithopoda, Geranium sanguineum, Brachypodium pinnatum, Pulsatilla pratensis*.

Mixed broadleaved-spruce forest groundlayer is rich in the species of the vegetation class *Carpino-Fagetea sylvaticae*, for instance, *Pulmonaria obscura, Asarum europaeum, Asperula odorata, Sanicula europaea, Pimpinella major, Laserpitium latifolium*. Rare species include *Allium ursinum, Lunaria rediviva, Polygonatum verticillatum*, etc. (Табака, Клявиня 1981). Remnants of oak *Quercus robur* forests preserved in some parts of the Nature Park allow assuming that once the areas of mixed broadleaved and oak forests were larger.

In total, nine EU protected forest habitat types are found in the Nature Park. The largest area of EU importance protected forest habitats is covered by **9180*** ***Tilio-Acerion***

Table 1 Protected habitats of EU importance in the Abava River Valley.

HABITAT CODE	HABITAT TYPE	AREA, ha
3150	Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation	12
3260	Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation	212.1
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation	0.03
4030	European dry heaths	0.7
5130	*Juniperus communis* formations on heaths or calcareous grasslands	3.2
6120*	Xeric sand calcareous grasslands	32.7
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)	235.9
6270*	Fennoscandian lowland species-rich dry to mesic grasslands	39.9
6410	*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	29.8
6430	Hydrophilous tall herb fringe communities of plains and the montane to alpine levels	6.4
6450	Northern Boreal alluvial meadows	103.2
6510	Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	43.2
6530*	Fennoscandian wooded meadows	7.7
7110*	Active raised bogs	3.8
7160	Fennoscandian mineral-rich springs and springfens	5.8
7220*	Petrifying springs with tufa formation (*Cratoneurion*)	5.1
7230	Alkaline fens	10
8210	Calcareous rocky slopes with chasmophytic vegetation	0.3
8220	Siliceous rocky slopes with chasmophytic vegetation	0.2
9010*	Western taiga	324.8
9080*	Fennoscandian deciduous swamp forests	7.4
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*	13.1
9180*	*Tilio-Acerion* forests of slopes, screes and ravines	388.3
91D0*	Bog woodland	232.7
91E0*	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-padion, Alnion incanae, Salicion albae*)	30.3
2180	Wooded dunes of the Atlantic, Continental and Boreal region	1.4
9020*	Fennoscandian hemiboreal natural old broad-leaved deciduous forests (*Quercus, Tilia, Acer, Fraxinus* or *Ulmus*) rich in epiphytes	0.7
9050	Fennoscandian herb-rich forests with *Picea abies*	7.1

forests of slopes, screes and ravines (22% of the forest area in the Nature Park), **9010* Western taiga** (18%) and **91D0* Bog woodland** (13%) (Table 1).

Mire habitats occupy about 24 hectares. In total, four EU-importance protected mire habitat types are found in the Nature Park: **7110* Active raised bogs, 7160 Fennoscandian mineral-rich springs and springfens, 7220* Petrifying springs with tufa formation (*Cratoneurion*)** and **7230 Alkaline fens** (Table 1). The species-richest mire habitats are alkaline fens belonging to the alliance *Caricion davallianae* (the class *Scheuchzerio palustris-Caricetea fuscae*). A significant proportion of the total population of *Carex davalliana* in Latvia occurs in the Abava River Valley, which can be found, though rarely, in the slopes of the valley with calcareous spring discharges. In the past, these places were used for grazing. Typical species in these spring-fed alkaline fens are *Schoenus ferrugineus, Carex davalliana, C. hostiana, Molinia caerulea, Succisa pratensis, Primula farinosa, Pinguicula vulgaris*. Čužu Mire near Kandava is the only locality of *Pentaphylloides fruticosa* in Latvia.

Freshwater habitats are associated with the Abava River and its tributaries. Three protected freshwater habitat types of EU importance occur there: **3260 Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation, 3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation** and **3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation** (Table 1). These freshwater habitats host eight species listed in the Habitats Directive's Annex II and 45 nationally protected species, e. g. *Alisma lanceolatum* and *Platyhypnidium riparioides*. Abavas rumba, a spectacular rapid, has formed where the river flows over dolomite bedrock. The water flows through the dolomite cliffs creating about 1 m high waterfall (the second widest waterfall in Latvia after Ventas rumba in Kuldīga). Swift steps provide the necessary suitable conditions for *Fontinalis antipyretica, Platihypnidium riparioides, Chara* spp., *Hildebrandia rivularis* and certain vascular plant species, such as *Berula erecta, Hydrocharis morsus-ranae, Veronica beccabunga*.

Grassland habitats. In the Abava River Valley, most of the semi-natural grasslands are located in the floodplain, on the valley terraces and on the terrace slopes. In total, ten EU protected grassland habitat types covering 503 ha are found in the Nature Park (Table 1). Dry to moist calcareous grasslands are the most characteristic for the valley. The Nature Park is among the most important nature protected areas in Latvia for conservation of the habitat types **6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometea*)** (13% of the total area of the habitat type in Natura 2000 network in Latvia), **6120* Xeric sand calcareous grasslands** (9%) and **5130 *Juniperus communis* formations on heaths or calcareous grasslands** (6%) (Abava River Valley 2016).

CHARACTERISTICS OF SEMI-NATURAL GRASSLAND PLANT COMMUNITIES

In order to characterise the grassland plant communities, vegetation classification was carried out using Cluster Analysis (Sørensen distance measure, beta-flexible clustering (flexible beta set to -0.25). 191 vegetation relevés stored in the Semi-natural grassland vegetation database of Latvia (Rūsiņa 2012) were classified. They were collected using Braun-Blanquet approach in the period from 1998 to 2010. The relevé area varied from 4 to 25 m^2. Only relevés of dry and mesic grasslands were available.

In total, 397 vascular plant species were recorded; the bryophytes were excluded from the analysis. Nomenclature for vascular plants followed Gavrilova, Šulcs (1999), for higher syntaxa: Mucina et al. (2016). Diagnostic species for vegetation units were used from Rusina (2005), Salmiņa (2009) and Priede (2011).

Five clusters were distinguished in the dataset. According to the diagnostic species composition (species with the highest fidelity using phi coefficient with the threshold value of 40) they were assigned to plant communities previously described in Latvia (Rūsiņa 2007; Priede 2011).

Cluster 1: *Sesleria caerulea-Inula salicina* community. Previously the community was described in the Ķemeri National Park (Priede 2011). The plant community belongs to the alliance *Molinion* of the class *Molinio-Arrhenatheretea*. The sward is low, and it is dominated by *Sesleria caerulea* and *Carex flacca*. Typical forbs are *Inula salicina, Centaurea jacea, Linum catharticum, Scorzonera humilis*. Rare species include *Pentaphylloides fruticosa, Orchis militaris, Viola collina, Pimpinella major*.

Cluster 2: *Brachypodium pinnatum* community. The plant community develops in forest-dry grassland ecotones on calcareous soils. It belongs to the *Geranion sanguinei* alliance of the class *Trifolio-Geranietea*. Most often it occurs in mosaic with *Filipendula vulgaris-Helictotrichon pratensis* community. Commonly *Brachypodium pinnatum* is found also as a satellite species in calcareous grasslands and starts to dominate after the abandonment of grassland or after frequent burning. The vegetation is species poor. The typical species are *Trifolium montanum, Ononis arvensis, Agrimonia eupatoria, Campanula rapunculoides*.

Cluster 3: *Phleum phleoides* community. The plant community represents a transitional succession stage between two dry grassland classes: *Koelerio-Corynephoretea* and *Festuco-Brometea*. It develops in calcareous sandy soils. Sward is dominated by *Phleum phleoides* and *Festuca trachyphylla*. Species of both vegetation classes are present. Constant species are *Arenaria serpyllifolia, Trifolium arvense, Sedum acre, Artemisia campestris, Poa angustifolia, Veronica spicata*. In Latvia, previously it has been assigned to the association *Pulsatillo-Phleetum phleoidis* Passarge 1959 of the alliance *Koelerio-Phleion* Korneck 1974 (Rūsiņa 2007). The syntaxonomical revision is necessary to clarify the position of this vegetation type in the classification framework.

Cluster 4: *Filipendula vulgaris-Helictotrichon pratense* community. The community belongs to the association *Filipendulo-Helictorichetum* Rūsiņa 2007, alliance *Filipendulo-Helictotrichion* of the class *Festuco-Brometea* (Rūsiņa 2007). This is the central association of dry calcareous grasslands in Western Latvia. Typical species composition includes the dominant grass species *Helictotrichon pratense, Poa angustifolia, Phleum phleoides, Festuca rubra* and forbs *Filipendula vulgaris, Fragaria viridis, Galium verum, Trifolium montanum, Cirsium acaule*. Rare plant species typical for this plant community include *Carex ornithopoda, Astragalus danicus, Gymnadenia conopsea, Viola collina*.

Cluster 5: *Arrhenatherion* grasslands. The cluster combined vegetation relevés of mesic grasslands. The most abundant species were diagnostic species of the order *Arrhenatheretalia* of the class *Molinio-Arrhenatheretea*. The cluster was rather heterogeneous, but due to small number of relevés no further division was performed. Mesic grasslands occur mostly on north and east sloping terraces of the valley and

Table 2 Synoptic table of dry and mesic semi-natural grassland plant communities in the "Abavas senleja" Nature Park.
* Categorical frequency with fidelity measure phi coefficient in superscript.
Clusters: 1 – *Sesleria caerulea-Inula salicina* community; 2 – *Brachypodium pinnatum* community; 3 – *Phleum phleoides* community; 4 – *Filipendula vulgaris-Helictotrichon pratense* community; 5 – *Arrhenatherion* communities.

No. of cluster	1	2	3	4	5
No. of relevés	12	16	17	101	45
Diagnostic species of plant communities					
Sesleria caerulea	V ^{57*}	I $^{---}$	. $^{---}$	II $^{---}$	I $^{---}$
Inula salicina	III ^{33}	I $^{4.2}$	. $^{---}$	I $^{---}$	I $^{---}$
Brachypodium pinnatum	. $^{---}$	V ^{96}	. $^{---}$	I $^{---}$	. $^{---}$
Phleum phleoides	I $^{---}$	. $^{---}$	V ^{75}	III ^{15}	I $^{---}$
Helictotrichon pratense	I $^{---}$	I $^{---}$	I $^{---}$	IV ^{52}	II $^{---}$
Filipendula vulgaris	II $^{---}$	V ^{51}	. $^{---}$	III ^{31}	I $^{---}$
Festuca rubra	II $^{---}$	. $^{---}$	II $^{1.2}$	III ^{15}	IV ^{43}
Taraxacum officinale	II $^{1.7}$	I $^{---}$	I $^{---}$	II $^{5.6}$	IV ^{48}
Elytrigia repens	. $^{---}$	I $^{---}$	II ^{18}	I $^{---}$	III ^{47}
Artemisia vulgaris	. $^{---}$	I $^{---}$	I ^{2}	I $^{---}$	III ^{47}
Medicago sativa	. $^{---}$	. $^{---}$	I $^{---}$	I $^{---}$	III ^{56}
***D. Molinion caeruleae* (*Molinio-Arrhenatheretea*)**					
Carex flacca	V ^{42}	III ^{10}	. $^{---}$	II $^{---}$	. $^{---}$
Carex panicea	II ^{16}	I $^{---}$	. $^{---}$	I $^{---}$	. $^{---}$
Dactylorhiza baltica	I $^{---}$	I $^{---}$	. $^{---}$	I $^{---}$	. $^{---}$
Epipactis palustris	I $^{---}$	. $^{---}$	. $^{---}$	I $^{---}$	. $^{---}$
Festuca arundinacea	II $^{2.6}$	III ^{36}	I $^{---}$	II $^{1.3}$	II ^{2}
Gymnadenia conopsea	. $^{---}$	I ^{12}	. $^{---}$	I $^{---}$	. $^{---}$
Molinia caerulea	III ^{34}	. $^{---}$	. $^{---}$	I $^{---}$	. $^{---}$
Orchis militaris	II ^{43}	I $^{8.2}$	. $^{---}$	. $^{---}$	. $^{---}$
Pentaphylloides fruticosa	II ^{54}	. $^{---}$	. $^{---}$	. $^{---}$	. $^{---}$
Polygala amarella	II ^{31}	. $^{---}$	. $^{---}$	I $^{---}$	. $^{---}$
Potentilla erecta	I $^{---}$	II $^{5.5}$	. $^{---}$	I $^{---}$	I $^{---}$
D. Geranion sanguinei* *(Trifolio-Geranietea)					
Agrimonia eupatoria	. $^{---}$	III ^{34}	I $^{---}$	III ^{24}	II $^{---}$
Geranium sanguineum	. $^{---}$	. $^{---}$	I ^{19}	I ^{12}	I $^{---}$
Origanum vulgare	. $^{---}$	I ^{26}	. $^{---}$	I ^{17}	. $^{---}$
Seseli libanotis	. $^{---}$	II ^{33}	I ^{12}	I $^{---}$	I $^{---}$
Trifolium medium	. $^{---}$	I ^{13}	. $^{---}$	I ^{22}	I ---

D. Armerion elongatae
(Koelerio-Corynephoretea)

Acinos arvensis	. ---	. ---	II 49	I ---	I ---
Arenaria serpyllifolia	. ---	. ---	V 79	I ---	I ---
Artemisia campestris	I ---	I ---	V 70	I ---	I ---
Berteroa incana	. ---	. ---	II 54	I ---	. ---
Bromus mollis	. ---	. ---	II 40	I ---	I ---
Cerastium semidecandrum	. ---	. ---	II 48	I ---	. ---
Erigeron acris	. ---	. ---	III 51	I ---	I ---
Festuca trachyphylla	. ---	. ---	II 51	. ---	. ---
Jasione montana	. ---	. ---	III 61	. ---	. ---
Pilosella officinarum	I ---	. ---	III 44	II 12	I ---
Potentilla argentea	. ---	. ---	IV 63	I ---	I ---
Sedum acre	. ---	. ---	V 81	I ---	I ---
Trifolium arvense	. ---	. ---	V 76	I ---	I ---
Veronica spicata	. ---	. ---	I 32	I 4.6	. ---

D. Filipendulo-Helictotrichion
(Festuco-Brometea)

Briza media	II 7.3	II 12	I ---	III 31	I ---
Campanula rapunculoides	I ---	II 29	I ---	II 10	I ---
Carex caryophyllea	II 23	I ---	I ---	I 14	I ---
Carlina vulgaris	III 45	II 7.1	I ---	II 5.6	. ---
Centaurea scabiosa	I ---	IV 37	II ---	III 28	I ---
Cirsium acaule	II 12	III 35	. ---	I 4.3	I ---
Fragaria viridis	. ---	II ---	III 19	IV 38	II 1.2
Galium verum	I ---	III 6.4	V 42	IV 24	II ---
Knautia arvensis	II ---	IV 29	III ---	IV 24	I ---
Medicago lupulina	I ---	I ---	I ---	III 24	III 22
Pimpinella saxifraga	I ---	III 26	II ---	III 21	I ---
Plantago media	I ---	II 16	I ---	II 23	I ---
Poa angustifolia	I ---	II ---	IV 38	III 22	II ---
Polygala comosa	. ---	I 6	I ---	II 22	I 3.8
Primula veris	I 3.5	I 6.2	. ---	III 36	I ---
Trifolium montanum	I ---	III 46	. ---	II 21	I ---

D. Arrhenatheretalia (Molinio-Arrhenatheretea)

Achillea millefolium	II ---	III 5.8	III 8.1	IV 22	V 31
Agrostis tenuis	. ---	. ---	II 7	I 2.6	IV 52
Anthriscus sylvestris	I 9.1	I 3	. ---	I ---	II 24
Carum carvi	I 11	. ---	. ---	I 11	II 22
Centaurea jacea	V 28	IV 21	I ---	III ---	II ---
Cerastium holosteoides	I 8.5	. ---	. ---	I 8.7	II 29
Dactylis glomerata	I ---	IV 11	II ---	IV 12	IV 22
Filipendula ulmaria	I 8	II 20	. ---	I ---	I 9.6
Galium album	II ---	IV 24	II ---	IV 28	IV 21
Helictotrichon pubescens	I 1.7	I ---	I ---	II 8.1	II 17
Heracleum sibiricum	I 4.9	II 16	. ---	I 1.2	II 12
Lathyrus pratensis	I ---	I 7.6	. ---	I 6.4	II 27
Ononis arvensis	. ---	III 44	. ---	II 23	I ---
Phleum pratense	. ---	. ---	II ---	II 11	V 64
Plantago lanceolata	I ---	I ---	II ---	III 23	IV 35
Poa pratensis	I ---	I ---	. ---	I ---	III 46
Prunella vulgaris	II 23	I 4	. ---	I 7.5	I ---
Ranunculus acris	II 9	. ---	. ---	II 7.5	III 45
Rumex acetosa	I ---	. ---	II 13	II 15	III 29
Stellaria graminea	I ---	I ---	. ---	II 20	II 17
Trifolium pratense	. ---	I ---	I ---	II 9.6	III 46
Veronica chamaedrys	I ---	I ---	. ---	II 9.6	IV 55
Vicia cracca	II ---	IV 27	II ---	III 19	III 13
Leontodon hispidus	III 26	I ---	. ---	II 13	II 4
Festuca pratensis	. ---	. ---	. ---	I ---	III 61
Trifolium repens	. ---	. ---	I ---	I 1.6	III 49

in the floodplains. Mostly they have been improved or were ploughed in the second half of the 20th century. Dominant species are *Poa pratensis, Festuca rubra, Dactylis glomerata*. Species indicating vegetation development from ex-arable land are *Elytrigia repens, Artemisia campestris, Medicago sativa, Taraxacum officinale*.

VEGETATION DYNAMICS OF DRY GRASSLANDS: EXAMPLE OF THE DRUBAZAS FARM

One of the most spectacular dry grassland areas throughout the Abava River Valley is Drubazas farm (Fig. 3). The farm has specialized in projects aimed at solving environmental issues and provision of tourism services (production of wine using local fruits and berries, boating in Abava River, crossing Abava River by a cableway, camping places). A special offer is a guided walk along the two-kilometre Drubazas botany trail. The total grassland area in the farm is 14.5 hectares, and they are located on the terraces and terraces slopes. The slopes are relatively steep (25°) with south aspect. Semi-natural grasslands are surrounded by forests and agricultural lands – ex-arable land (fallows) and improved grasslands (Jermacāne u. c. 2001).

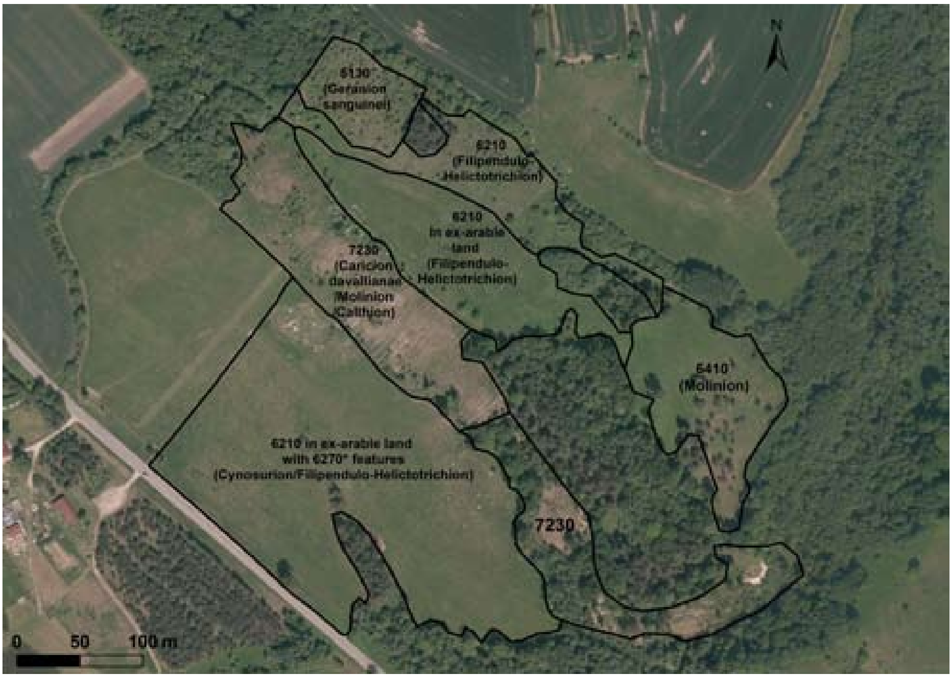


Fig. 3 Protected grassland habitats of EU importance in Drubazas farm. Map: Orthophoto map at a scale of 1: 10,000 © Latvian Geospatial Information Agency (ORTHOPHOTO 5).

Historically area has been used for mowing and livestock grazing. Drubazas slope has never been ploughed or improved and has been used as mowing and grazing area until today, except for a short period of abandonment in the 1990s. During the abandonment period, pine stands and the expansive grass species *v*established in some patches. The flat terraces were used as arable land until 1990 and then abandoned. In the late 1990s, the abandoned grasslands were restored (the shrubs were cleared, mowing and cattle grazing established). The ex-arable land was used as a meadow for haymaking.

Vegetation monitoring was commenced in 2000 (Jermacāne u. c. 2001; Rusina, Kiehl 2010; Kupča, Rūsiņa 2016). Three permanent transects, each in different plant community, were established (Fig. 4). The first transect was located on southern slope with dry *Filipendula vulgaris-Helictotrichon pratense* grassland on calcareous soil (Fig. 5a). The second transect was placed on southern slope with dry grassland on calcareous soil which was overgrowing with *Calamagrostis epigeios* (Fig. 5b). The third transect was located on a terrace on ex-arable land which was abandoned in 1990 and mowing was commenced in the late 1990s (Fig. 5c). In total, twenty-eight 1 m² plots were monitored in Drubazas. In the transect, the distance between the plots was 2 metres. In each plot, the total cover of litter, herb and moss layer, as well as cover of each species in percent was determined visually. The vegetation was monitored every year in July or August until 2007, and then every two years. Chemical properties of soil were determined in 2007 (Table 3).

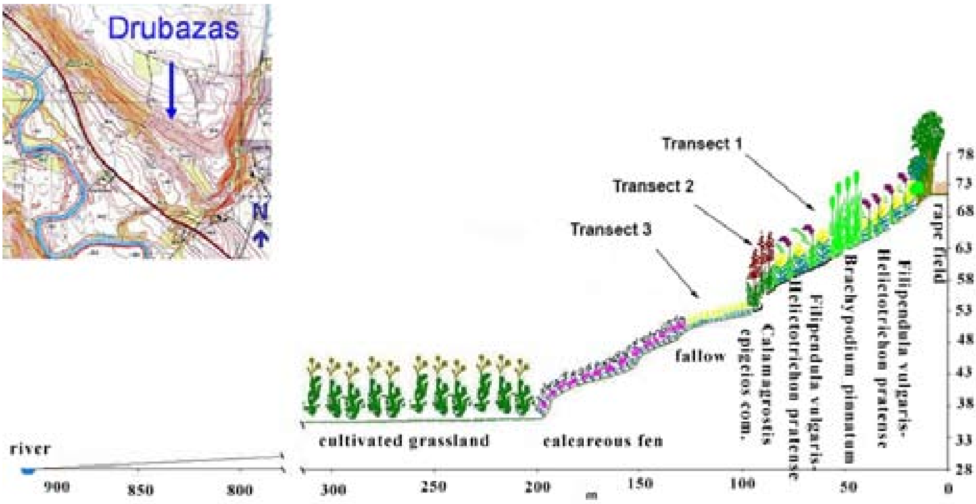


Fig. 4 Location of the monitoring transects in the vegetation profile (Rusina, Kiehl 2010).

Ancient grassland – *Filipendula vulgaris-Helictotrichon pratense* community. Over the 16 years period, the average species richness has been rather stable, though it experienced slight fluctuations. The average number of species per 1 m² was 26 (± 4 species). No statistically significant changes in species richness were observed among years. The most abundant species with almost no changes in cover were *Filipendula vulgaris, Helictotrichon pratense* and *Ononis arvensis*. Occurrence of several species has changed substantially – *Taraxacum officinale, Carex flava* and *Galium borale*. Some species experienced decrease in abundance – *Carex flacca, Ranunculus polyanthemos, Carlina vulgaris, Festuca pratensis* and *Dactylis glomerata*, while some other species (*Hypericum perforatum, Trifolium repens, Polygala comosa, Carex ornithopoda, Linum catharticum, Veronica chamaedrys, Phleum pretense, Brachypodium pinnatum* and *Festuca ovina*) increased in abundance.

Ruderalised grassland – *Calamagrostis epigeios* community. Ruderalised grassland experienced a strong tendency in increase of the species number (Fig. 6b). In the first monitoring years, the average number of species was 16 per 1 m², whereas in the last two years there were 22 species in average. The most abundant species with almost no changes in cover were *Calamagrostis epigeios, Vicia cracca, Helictotrichon pratense* and *Filipendula vulgaris*. Abundance of several species, such as *Aegopodium podagria, Veronica chamaedrys* and *Carlina vulgaris*, has changed substantially. *Plantago*

Table 3 Physical and chemical properties of the upper soil layer, and soil horizons (according to the FAO soil classification).
FvHp – *Filipendula vulgaris-Helictotrichon pratense* community;
Calepi – *Calamagrostis epigeios* community;
PaFv – *Poa angustifolia-Filipendula vulgaris* community.

	FvHp	Calepi	PaFv
Physical and chemical parameters of the upper soil layer (0–10 cm)			
Clay [%]	6	10.3	No data
Silt [%]	74.5	76.6	No data
Sand [%]	19.5	13	No data
pHKCl (0–10 cm)	6.9	7.1	7.0
pHKCl (50 cm)	7.5	6.9	7.2
Exch. bases [meq/100 g]	43.3	49.7	49.6
Organic C [%]	4.5	4.1	3.4
N [g/kg]	2.1	2.2	1.9
P_2O_5 [mg/100 g]	1.9	2.5	3.1
K_2O [mg/100 g]	5.6	8.4	32.9
CaO [mg/100 g]	145.5	128.7	119.3
MgO [mg/100 g]	107.5	71.9	49.7
Description of exemplary soil profiles (horizon, depth, texture)			
	ApB 9–26	Ap 13–49	Apk 5–23
	silty clay	sandy loam	fine sand
	Bg 26–40	ApB 49–80	Bk 23–38
	clay	fine sand	clay loam
	Bk 40–65	BC >80	BCk >38
	clay	fine sand	clay loam
	Bt >65		
	very fine sand		

media and *Potentilla reptans* experienced decrease in abundance, while some other species (*Aegopodium podagria, Veronica chamaedrys, Carlina vulgaris, Carex caryophyllea, Briza media, Fragaria viridis, Centaurea scabioasa, Viola collina* and *Gymnadenia conopsea*) increased in abundance.

Fig. 5a

Fig. 5b

Fig. 5c

Fig. 5a Ancient grassland – *Filipendula vulgaris-Helictotrichon pratense* community in 2006 and 2013.

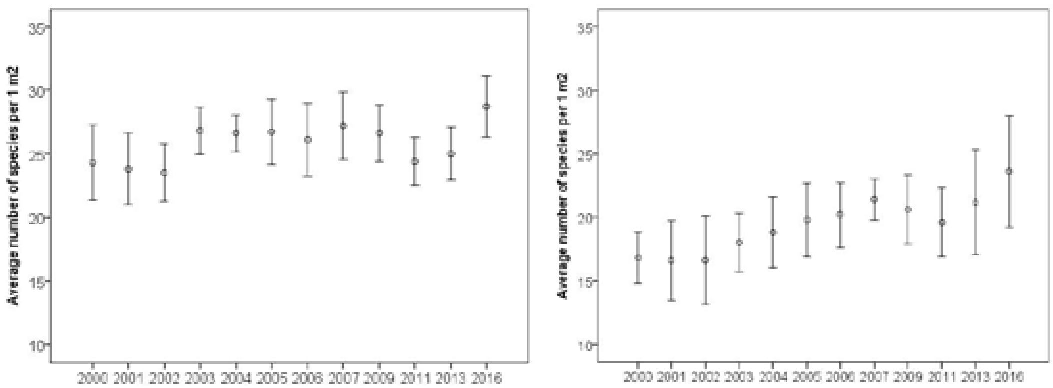
Fig. 5b Ruderalised grassland – *Calamagrostis epigeios* community in 2006 and 2013.

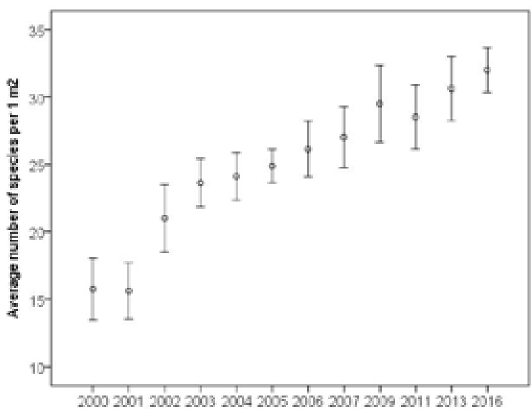
Fig. 5c Ex-arable land – *Poa angustifolia-Filipendula vulgaris* community in 2007 and 2013.

Ex-arable land – *Poa angustifolia-Filipendula vulgaris* community. The vegetation of ex-arable land experienced the most evident increase in the number of species (Fig. 6c). Statistically significant increase in the number of species began in 2002. The number of species has increased from averagely 16 to 30 species over the last six years. The smallest number of species was 11, whereas the largest number was 36 species, 25 species on average (± 6 species).

The most abundant species with almost no changes in abundance were *Poa angustifolia, Galium album* and *Filipendula vulgaris*. Abundance of several species changed substantially among years – *Elytrigia repens, Calamagrostis epigeios, Linum catharticum, Cirsum arvensis* and *Primula veris*. Some species experienced decrease in abundance – *Silene vulgaris, Convolvulus arvensis, Artemisia vulgaris, Agrostis gigantea* and *Cirsium arvense*. Abundance of *Leontodon hispidus, Trifolium repens, Ranunculus polyanthemos, Lathyrus pratensis, Trifolium pratensis, Veronica chamaedrys, Festuca arundinacea, Dactylis glomerata* and *Plantago lancelota* increased.

It can be concluded that the ex-arable land turned into dry semi-natural grassland during a 15-year period. The restoration success can be explained by the proximity of species-rich grasslands with rich species pool and by the appropriate soil conditions – soil phosphorus content was 3.1 mg per 100 g soil (using Egner-Rhiem method).





a | b
c

Fig. 6 Changes in species richness in the Drubazas monitoring area: (a) ancient calcareous grassland (*Filipendula vulgaris-Helictotrichon pratense* community), (b) ruderalised calcareous grassland (*Calamagrostis epigeios* community), (c) ex-arable land (*Poa angustifolia-Filipendula vulgaris* community).

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APPENDIX 1 Synoptic table with percentage frequency and cover range in *Filipendula vulgaris-Helictotrichon pratense* community.

Group No.	1	2	3
Year	2000-2004	2005-2009	2011-2016
Carex flacca	100^{+-3}	95^{+-2}	83^{2-3}
Filipendula vulgaris	96^{r-2}	100^{r-2}	100^{r-2}
Hypericum perforatum	4^{r}	15^{r}	23^{r}
Carex flava	.	2^{2}	17^{2-2}
Sesleria caerulea	46^{r-3}	38^{r-2}	20^{r-3}
Trifolium repens	6^{r-r}	2^{r}	17^{r}
Ranunculus polyanthemos	20^{r-r}	10^{r}	7^{r}
Polygala comosa	14^{r-r}	12^{r-r}	23^{r}
Carex ornithopoda	46^{r-2}	65^{r-2}	67^{r-2}
Linum catharticum	36^{r-r}	40^{r}	53^{r}
Carlina vulgaris	46^{r-+}	38^{r-r}	27^{r}
Festuca pratensis	50^{r-2}	32^{r}	23^{r}
Veronica chamaedrys	12^{r-1}	18^{r-r}	20^{r-2}
Phleum pratense	2^{r}	5^{r}	10^{r-r}
Galium boreale	18^{r-1}	48^{r-1}	50^{r-2}
Plantago media	86^{r-2}	72^{r-2}	67^{r-+}
Dactylis glomerata	24^{r-2}	28^{r-+}	7^{r-r}
Briza media	98^{r-2}	100^{r-2}	97^{r-2}
Centaurea jacea	80^{r-1}	78^{r-+}	60^{r-r}
Taraxacum officinale	16^{r-r}	35^{r}	53^{r}
Ononis arvensis	100^{+-3}	100^{r-3}	97^{r-2}
Festuca rubra	74^{r-2}	72^{r-1}	63^{r-2}
Pimpinella saxifraga	98^{r-+}	95^{r-+}	97^{r-r}
Agrimonia eupatoria	96^{r-2}	100^{r-2}	97^{r-2}
Helictotrichon pratense	100^{1-4}	100^{r-2}	93^{r-2}
Achillea millefolium	64^{r-r}	30^{r}	47^{r-r}
Poa angustifolia	88^{r-2}	85^{r-2}	80^{r-2}
Centaurea scabiosa	58^{r-2}	58^{r-2}	43^{r-2}
Gymnadenia conopsea	50^{r-2}	35^{r-2}	33^{r-2}
Festuca ovina	14^{r-2}	55^{r-2}	47^{r-1}
Scorzonera humilis	26^{r-3}	32^{r-3}	37^{r-3}
Prunella vulgaris	30^{r-r}	28^{r}	23^{r}
Medicago sativa	26^{r-2}	28^{r-2}	30^{r-2}
Helictotrichon pubescens	6^{r-2}	8^{r}	3^{r}
Brachypodium pinnatum	2^{r}	8^{r-1}	27^{r-2}
Leontodon danubialis	32^{r-+}	22^{r}	13^{r}
Quercus robur	6^{r}	15^{r}	7^{r}
Lotus corniculatus	6^{r-r}	12^{r-r}	13^{r}
Inula salicina	.	5^{r-r}	17^{r-2}
Viola rupestris	22^{r-r}	18^{r}	13^{r}
Leucanthemum vulgare	32^{r-r}	22^{r}	13^{r}

APPENDIX 2 Synoptic table with percentage frequency and cover range in *Calamagrostis epigeios* community.

Group No.	1	2	3
Year	2000-2004	2005-2009	2011-2016
Veronica chamaedrys	4^{r}	15^{r}	33^{r-r}
Sesleria caerulea	12^{r-r}	15^{r-1}	.
Ranunculus polyanthemos	4^{r}	15^{r-r}	20^{r-r}
Leontodon danubialis	12^{r-2}	15^{r}	7^{r}
Dactylis glomerata	12^{r-r}	25^{r-+}	13^{r-r}
Ranunculus acris	12^{r-r}	20^{r-r}	20^{r}
Carlina vulgaris	.	30^{r}	40^{r-r}
Carex panicea	12^{r-r}	20^{r-+}	20^{r}
Aegopodium podagraria	8^{r}	40^{r-2}	53^{r-4}
Plantago media	36^{r-2}	20^{r-r}	13^{r}
Carex caryophyllea	12^{r-r}	35^{r-+}	40^{r-+}
Briza media	24^{r-2}	20^{r-r}	40^{r-1}
Campanula rapunculoides	24^{r-r}	70^{r-1}	53^{r-1}
Potentilla reptans	72^{r-r}	60^{r-+}	27^{r}
Taraxacum officinale	32^{r-r}	65^{r-r}	47^{r-r}
Galium boreale	40^{r-2}	40^{r-2}	53^{r-2}
Fragaria viridis	24^{r-r}	40^{r-r}	47^{r-+}
Rubus caesius	40^{r-1}	55^{r-2}	27^{r-+}
Festuca rubra	60^{r-2}	100^{r-2}	93^{r-2}
Plantago lanceolata	32^{r-r}	30^{r}	13^{r}
Festuca arundinacea	24^{r-2}	20^{r-1}	33^{r-r}
Agrimonia eupatoria	96^{r-2}	85^{r-2}	87^{r-2}
Carex flacca	100^{r-2}	95^{+-2}	80^{2-2}
Pimpinella saxifraga	88^{r-r}	90^{r-r}	73^{r-+}
Vicia cracca	84^{r-r}	100^{r-2}	100^{r-r}
Calamagrostis epigeios	100^{1-3}	95^{2-3}	100^{r-2}
Achillea millefolium	80^{r-+}	90^{r-r}	100^{r-r}
Galium album	80^{r-1}	75^{r-1}	93^{r-1}
Knautia arvensis	64^{r-+}	70^{r-1}	40^{r-+}
Helictotrichon pratense	80^{r-2}	100^{r-2}	87^{r-2}
Filipendula vulgaris	88^{r-2}	85^{r-2}	100^{r-2}
Centaurea scabiosa	68^{r-2}	85^{r-2}	93^{r-2}
Poa angustifolia	84^{r-2}	90^{r-2}	87^{r-2}
Cirsium acaule	40^{r-2}	40^{1-2}	33^{+-2}
Ononis arvensis	40^{r-2}	60^{r-2}	60^{r-2}
Centaurea jacea	36^{r-r}	30^{r-+}	40^{r-r}
Viola collina	24^{r-1}	35^{r-2}	47^{r-r}

APPENDIX 3 Synoptic table with percentage frequency and cover range in *Poa angustifolia-Filipendula vulgaris* community.

Group No.	1	2	3
Year	2000-2004	2005-2009	2011-2016
Leontodon hispidus	.	3^{r}	18^{r-+}
Calamagrostis epigeios	8^{r-2}	14^{r-2}	41^{r-2}
Filipendula vulgaris	72^{r-2}	89^{r-2}	95^{r-2}
Silene vulgaris	75^{r-2}	40^{r-+}	18^{r-r}
Trifolium repens	8^{r-r}	11^{r-2}	54^{r-2}
Ranunculus polyanthemos	28^{r-1}	17^{r-r}	51^{r-r}
Polygala comosa	.	11^{r-r}	23^{r-r}
Primula veris	8^{r-r}	43^{r-1}	69^{r-2}
Lathyrus pratensis	18^{r-2}	43^{r-2}	44^{r-2}
Equisetum arvense	58^{r-2}	51^{r-1}	72^{r-2}
Linum catharticum	.	9^{r-r}	54^{r-2}
Carlina vulgaris	2^{r}	6^{r-r}	10^{r}
Trifolium pratense	5^{r-+}	40^{r-2}	64^{r-2}
Elytrigia repens	100^{r-5}	31^{r-+}	10^{r}
Ranunculus acris	18^{r-2}	71^{r-1}	54^{r-1}
Viola collina	.	6^{r}	21^{r-r}
Convolvulus arvensis	95^{r-2}	89^{r-2}	77^{r-2}
Fragaria viridis	.	9^{r-r}	13^{r-2}
Festuca pratensis	20^{r-r}	37^{r-2}	67^{r-2}
Veronica chamaedrys	20^{r-2}	83^{r-r}	79^{r-2}
Phleum pratense	82^{r-3}	100^{r-2}	82^{r-2}
Rubus caesius	15^{r-2}	14^{r-2}	8^{r-2}
Festuca arundinacea	8^{r}	54^{r-2}	74^{r-2}
Carex caryophyllea	.	3^{r}	15^{r}
Plantago media	.	3^{r}	8^{r-+}
Dactylis glomerata	45^{r-2}	91^{r-3}	85^{r-3}
Plantago lanceolata	35^{r-1}	91^{r-2}	82^{r-2}
Briza media	.	3^{r}	21^{r-+}
Centaurea jacea	70^{r-4}	89^{r-2}	97^{r-2}
Taraxacum officinale	98^{r-3}	100^{r-3}	87^{r-3}
Ononis arvensis	52^{r-2}	51^{r-2}	31^{r-2}
Potentilla reptans	98^{r-3}	100^{r-3}	82^{r-2}
Festuca rubra	58^{r-3}	71^{r-2}	90^{r-2}
Helictotrichon pratense	30^{r-r}	37^{r-r}	51^{r-2}
Achillea millefolium	88^{r-2}	91^{r-2}	87^{r-2}
Galium album	90^{r-2}	100^{r-2}	95^{r-2}
Poa angustifolia	85^{r-2}	100^{r-2}	95^{r-2}
Galium verum	30^{r-2}	34^{r-r}	38^{r-2}
Gymnadenia conopsea	.	3^{r}	13^{r-r}
Carum carvi	5^{r}	14^{r}	21^{r-2}
Helictotrichon pubescens	10^{r}	11^{r-1}	28^{r-2}
Heracleum sibiricum	.	14^{r-r}	21^{r-1}
Leontodon danubialis	.	6^{r-r}	13^{r}
Trifolium medium	5^{r}	17^{r-2}	13^{r-2}
Chaerophyllum aromaticum	5^{r-r}	6^{r-r}	13^{r-+}
Stellaria graminea	2^{r}	11^{r-r}	13^{r-r}
Potentilla anserina	18^{r-r}	14^{r-r}	3^{r}
Artemisia vulgaris	30^{r-2}	34^{r-2}	8^{r}
Agrostis gigantea	38^{r-3}	20^{r-2}	10^{r-r}
Cirsium arvense	68^{r-1}	60^{r-+}	13^{r-+}

Grasshopper and ground beetle fauna of calcareous grasslands in Abava River valley

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ABSTRACT

Dry calcareous grasslands have a great value in terms of plant diversity and serve as habitats for numerous specialized invertebrate species. Grasshoppers and ground beetles each represent different insect functional groups are both commonly used as indicators for habitat quality and ecosystem functionality. A multitaxon approach is crucial when assessing the effects of processes in habitats. Even though the dispersal ability and level of specialization widely varies within the orders, the species diversity is endangered as the area of semi-natural grasslands declines. In this article, responses of grasshopper and ground beetle diversity on habitat quality and management are analyzed. The results show that the vegetation structure has major influence on insect diversity, but the main factors that influence grasshoppers and beetles can slightly differ, highlighting the necessity of multitaxon studies. Habitat management had mixed effects on the mentioned organisms, but both grasshopper and ground beetle diversity benefited from extensive grazing. Grasshopper and ground beetle species composition has to be considered when assessing the importance of dry, calcareous grasslands for insect conservation, focusing on the preservation of characteristic, habitat specialist species.

KEY WORDS: grassland management, grassland quality, Orthoptera, Carabidae.

INTRODUCTION

Grassland habitats host large number of plant and insect species, including many specialized and rare ones (Weiss et al. 2012). In Europe, the area of grasslands has declined because of land use change, lack of management, habitat degradation and fragmentation (Wissman et al. 2008; Weiss et al. 2012). In North European semi-natural grasslands, extensive grazing is generally considered to be the optimal management practice to maintain and improve the diversity of flora and fauna (Wissman et al. 2008). In Latvia, the conservation status for dry, calcareous grasslands is unfavourable (Anon. 2013), and their area is decreasing mainly due to abandonment (Rūsiņa, Kiehl 2010) and cultivation (Rūsiņa 2008).

Grasshoppers and ground beetles represent different insect functional groups – hortobionts and ground dwellers. The wide range of species can be grouped by their level of specialization, feeding type, dispersal ability and other ecology aspects. Usually the insect diversity and biomass mainly consists of generalist species, and specialist species are rare, although they are particularly sensitive to changes in elements concerning their niche (Duelli, Obrist 2003; Rainio, Niemelä 2003; Hodkinson, Jackson 2005). The most important local factors for insects are weather, light regime, microclimate, terrain and exposition, soil characteristics, vegetation structure and diversity, natural succession and habitat management. At a broader scale, landscape factors, such as fragmentation, isolation, edge effect, habitat change and others, are also significant, but will not be reviewed in this paper. It is not uncommon in studies of insect ecology that it is rather difficult to identify the factors affecting the species, and to determine the scale at which these factors work (Zulka et al. 2014). For example, for grasshoppers, the responses can be very complex and the identification and measurement of significant factors – challenging (Bazelet, Samways 2011). It is worth pointing out that the ecology of each species will determine its responses to changes in the environment. Feeding type, reproduction strategy, survival rates in different life stages, dispersal ability, population dynamics and other mechanisms can sometimes vary even between different species of the same genus.

Climate is a well known major factor that determines the distribution of habitats. Local climate has direct impact on grasshopper physiological processes, flight activity and reproduction (Ingrisch 1986; Kohler et al. 1999). At a finer scale, microclimate is the main factor directly linked to microhabitat (Kirby 2001; New 2009). It influences the species composition and population density of grasshoppers (Kati et al. 2003; Gardiner, Dover 2008; Gardiner, Hassall 2009; Benton 2012; Fartmann et al. 2012; Kenyeres, Cservenka 2014). The diversity and abundance of grasshoppers is high on south-facing slopes, where the microclimate is warm and dry (Holst 1986; Kirby 2001; Benton 2012; Weiss et al. 2012).

A particularly significant structure is bare ground. For grasshoppers it serves as breeding, basking and ovipositioning habitat (Holst 1986; Weiss et al. 2012), and for ground beetles as hunting, basking, nesting and dispersal sites. Soil acidity, salinity, alkalinity, humidity, granularity and organic matter all influence ground beetles (Paje, Mossakowski 1984; Nietupski et al. 2010). Soil that is loose and dries quickly is more suitable for grasshoppers and ground beetles than soil that is dense and moist (Kirby 2001). Ground beetles are ground-dwellers, though some species can climb vegetation to feed on seeds or search for mates (Sasakawa 2010), therefore also vertical vegetation structures matter.

Vegetation structure and heterogeneity is a very important local factor that mostly depends on grassland quality and management practice (Holst 1986; Kirby 2001; Buse, Griebeler 2011; Benton 2012; Spalinger et al. 2012; Kenyeres, Cservenka 2014; Rada et al. 2014). Different vegetation structures can serve as microhabitats, therefore maintaining high diversity of invertebrates (Kirby 2001). For example, the more natural succession stages present in a habitat, the higher the grasshopper diversity (Wunsch et al. 2011).

Plant diversity mostly influences ground beetles indirectly through prey ecology. Ground beetles are mostly entomophagous (Lövei, Sunderland 1996), but many species are granivorous (Honek et al. 2003), and some even prefer certain plant species (Martinkova et al. 2006). Although most of the grasshopper species in Latvia are phytophagous, their feeding is non-specific (Holst 1986; Senn et al. 2011), and so they are not directly dependent on one or other plant species, but rather are influenced by the vegetation structure formed by dominating plant communities (Labadessa et al. 2015). Even so, a positive correlation with grass *Poaceae* cover has been reported and most probably linked to feeding (Fartmann et al. 2012; Rozenfelde 2014).

Habitat degradation has a high cost for insect conservation. Overgrowing of open habitats has a negative effect on grasshopper abundance and diversity, as shading from trees changes microclimate conditions (Guido, Gianelle 2001; Kati et al. 2003). Accumulation of dead grass (i. e. litter) negatively influences xerophilous species that prefer sparse vegetation and bare ground (Fonderflick et al. 2014). If lack of grassland management has resulted in a decline of local diversity of grasshoppers, then even after restoring the habitat in its original quality, the grasshopper fauna will no longer be the same (Knop et al. 2008).

Appropriate habitat management is crucial to maintain and improve the habitat quality and therefore also insect diversity. Policies against the transformation and abandonment of natural and semi-natural grasslands should be applied and extensive habitat management should be ensured at the landscape level (Marini et al. 2008; Weking et al. 2016). The choice of management practice is complex, and usually the management type that favors most taxa is chosen. For both grasshoppers and ground beetles, the abundance and number of species varies along a gradient of disturbance (Marini et al. 2008; Nietupski et al. 2015; Hanson et al. 2016). Overall, the best management practices are the extensive ones, such as low intensity grazing or mowing once per vegetation season without fertilization (Marini et al. 2008; Fonderflick et al. 2014). Mowing is advisable once per year in July, with leaving patches of unmown vegetation that insects can use as a refuge (Humbert et al. 2012). If sufficient number of refuges are available, the number of species can become re-established rather quickly (Humbert et al. 2012). The mown grass should be removed in a manner that is most beneficial for plant seed dispersal, as for insects the manner does not greatly matter (Rūsiņa 2008). Ground beetles can even benefit from the mass of other insects that die during mowing and serve as easy prey (Humbert et al. 2012). Even so, extensive grazing is the management type that benefits most insect ecological groups. Only soil invertebrates are known to have a disadvantage from grazing, since trampling causes the soil to become dense and uninhabitable for many (Boschi, Bour 2007). Therefore, when choosing grazing as management, it is important to carefully calculate the optimal density of animals. Overgrazing can seriously degrade the invertebrate fauna, and therefore grazing intensity should be held at 0.1 to 0.3 animal units per hectare, and the cover of flovering plants should be monitored and maintained at 20% of the grazing area (Rūsiņa 2008). If grazing in calcareous grassland is too intensive, the abundance of insects can become lower than in grassland that has no management (Ledergerber et al. 1997). Grazing should also be recurrent to ensure that the vegetation structure does not become homogenous (Fonderflick et al. 2014). In places where wild animals graze, the vegetation structure is mosaic-like and provides habitat for more grasshopper species than in homogenous grasslands (Spalinger et al. 2012). In pastures, the grasshopper diversity is also higher than in meadows (Senn et al. 2011) and it is especially distinct for dry, calcareous grasslands (Weiss et al. 2012). Doing nothing can also be applied as a habitat management option for the conservation of some species (New 2009), but grassland habitats in temperate zone cannot exist in long term without some sort of interference.

The aim of this study was to analyze the ways how the grassland quality, management and abandonment affect insect diversity in dry calcareous grasslands of the Abava River valley. To achieve the aim, datasets of grasshopper *Orthoptera* and ground beetle *Carabidae* occurrence data were used. We hypothesize that grassland quality and management can cause diverse effects on insect species, depending on their ecology.

MATERIAL AND METHODS

TERRITORY AND SAMPLE SITES

All field surveys were conducted in the Abava River valley, in the Kandava and Talsi districts, in the area between the towns of Kandava and Sabile (Fig. 1). Study sites (n = 17) of three grassland types were chosen: (1) abandoned, low quality calcareous grasslands (n = 7); (2) average to high quality calcareous grasslands (n = 6); (3) cultivated grasslands (n = 4) (Fig. 2).

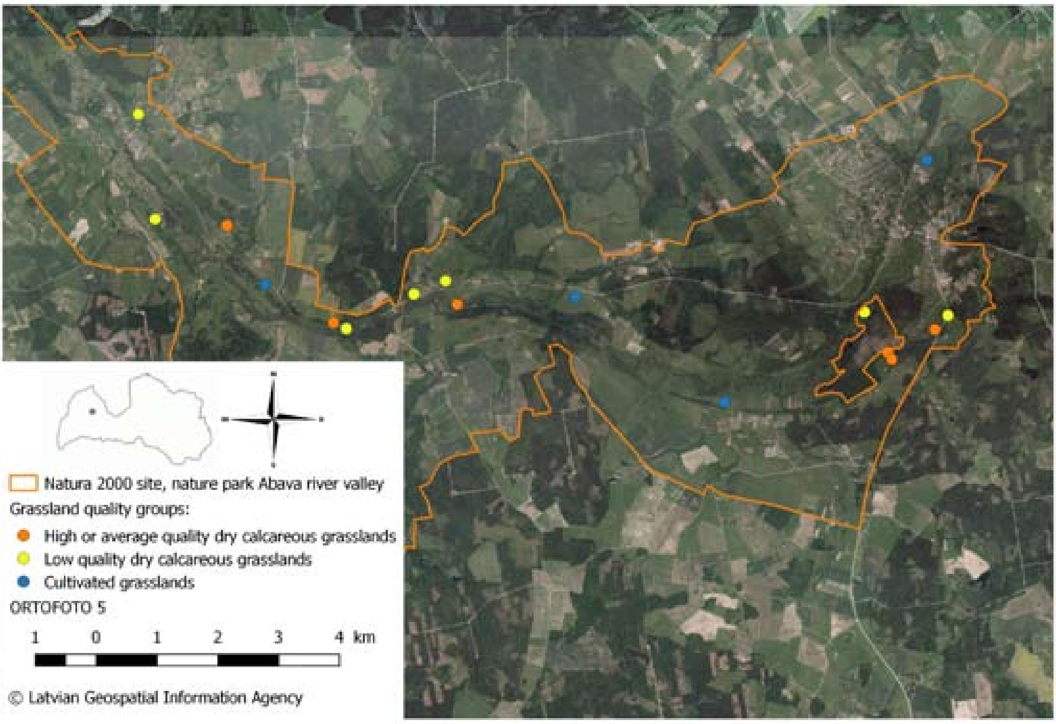

Fig. 1 Study area and locations of study sites.

Cultivated grasslands were mown in June to July, and in most of them signs of cultivating of highly productive or nutritionally valuable plants (*Trifolium* spp., *Medicago sativa, Dactylis glomerata*) were observed. Management of calcareous grasslands was mostly extensive grazing by horses, but in one territory – mowing in September. Some high quality calcareous grasslands were not managed during the season of insect collection. Most of the calcareous grasslands were situated on slopes, which might explain the lack of management in most of them. As the information about management type was obtained on site, the number of abandoned and managed grasslands is not equal.

a
b
c

Fig. 2 Examples of grassland quality and management types: (a) high quality dry, calcareous grassland without management; (b) low quality abandoned dry calcareous grassland; (c) cultivated grassland, mown in July. All photos were taken in August 2015. Photo: R. Rozenfelde.

INSECT COLLECTION AND VEGETATION DESCRIPTION

Ground beetles were collected in 17 sites and grasshoppers – in 15. Two territories were not used for grasshopper data analysis, as in one of them mowing in August interfered with sample collection, and in another one the level of overgrowth with expansive plant species was so high, that no grasshopper individuals were collected. Avoiding edge effect, a transect of 10 pitfall traps was placed in each grassland area with a two metre gap between the traps. Traps with 7 cm mouth diameter were used for trapping. The pitfall traps (n = 170) were exposed from 15th to 29th June 2015 for ground beetle collection. For grasshoppers the same transects were used, excluding the two mentioned sites. Grasshoppers were collected in two periods, from 21st July to 4th August (n = 150) and from 25th August to 8th September (n = 150).

Pitfall trapping is a commonly used method for ground-dwelling invertebrate collection (Lövei, Sunderland 1996; Niedobová, Faltýnek 2014), and can also be used in grasshopper research as opposed to sweep-netting, the results are cumulative, not influenced by weather and more accurate for diversity comparison (Duelli, Obrist 1998; Maes, VanDyck 2005; Schirmel et al. 2010; Zulka et al. 2014). In the traps, 4% formaldehyde solution was used as a preservative, and in the laboratory, the material was transferred to 70% ethanol for species determination.

Information about plant species composition and vegetation structure was obtained using two kinds of sample plots. First, a 25 m^2 vegetation plot was placed in the most representative place of each site. In addition, one 1 m^2 sample plot around the 5th pitfall trap was sampled, representing a random sample and smaller local scale. In both plots, occurrence of all plant species was recorded using the Braun-Blanquet method (Braun-Blanquet 1964). The plant taxa were mostly determined to species, sometimes to genus level. In 1 m^2 around each pitfall trap, vegetation height was measured, the cover of woody plants, herbaceous plants, bare ground, moss, lichens and litter were estimated as percentage cover, the number of ant nests, molehills and plant indicator species and expansive plant species were counted. The average depth of litter was also measured. The plant indicator species and expansive species were categorized as in semi-natural grassland monitoring methodology in Latvia (Lārmanis (red.) 2014).

Results of vegetation height cannot be extrapolated outside this study, as some sample plots were mown prior to the measurement. Soil sample near 5th pitfall trap was collected in each territory and placed in a hermetic container. Later in laboratory soil relative humidity (%) and pH level was measured.

DATA ANALYSIS

All data were analyzed using the R software (version 3.1., R Core Team 2014) extension R Studio 1.0.136 (R studio Team 2016) and PC–ORD 5.0 (McCune, Mefford 1999). The territory map was created in QGIS 2.14.3 (QGIS Development Team 2016) using ORTOFOTO 5 data (LGIA 2017), provided by the Latvian Geospatial Information Agency, available from the map server of the University of Latvia, Faculty of Geography and Earth Sciences.

Data compliance to normal distribution was tested in R 3.1.1 using the graphical method *qqPlot*. For further data analysis non-parametric methods were used. Shannon-Wiener diversity index H’ (Shannon index) was calculated in R 3.1.1 using the package *vegan*

(Oksanen et al. 2013) function *diversity*, and number of species was calculated using the function *specnumber*. Evenness *E* was calculated in PC-ORD 5.0, using the function *row and column summary*. Species dominance structure was calculated manually according to the Engelmann's scale (Engelmann 1978).

To compare values of diversity and species abundance between grassland and management types, the non-parametric *Kruskal-Wallis* rank sum test (R 3.1.1) was used. To analyze correlations between vegetation parameters and insect abundance data, Spearman's correlation analysis was used (R 3.1.1, package *ltm*, function *rcor.test*, argument *method = Spearman*). When searching for correlates between plant and insect species, data from 1 m^2 vegetation plots were used. To increase the interpretation accuracy, indicator species analysis was applied to 25 m^2 vegetation data and vegetation structure data from 1 m^2 plots (PC-ORD 5.0, randomization 999 times). Only species and structures with $p < 0.05$ and indicator value $IV > 50$ in the *Monte Carlo* test were considered as significant indicators.

RESULTS

SOIL PARAMETERS

Soil relative humidity values varied greatly, from 0.16% to 23.31%, and pH levels from 5.63 to 7.8. In high/average quality calcareous grasslands, the average soil humidity was 8.41% and the average pH level was 6.89, in low quality calcareous grasslands – 8.37% and pH 7.49, and in cultivated grasslands – 2.44% and pH 6.34, respectively. When analyzing the data according to the management groups, in mown grasslands the average relative humidity was 3.63% and the average pH level 6.20, in extensively grazed grasslands – 13.8% and pH 7.17, and in abandoned grasslands –7.31% and pH 7.38, respectively. We want to point out that in this study, the number of grasslands with similar management is uneven, therefore the data dispersion is heterogeneous. The *Kruskal-Wallis* test showed no significant differences between the soil parameters, neither between the quality, nor the management type, though there was a tendency for the soil humidity and pH levels to be relatively lower in cultivated mown grasslands.

VEGETATION STRUCTURE

In total, 97 vascular plant species were recorded, out of which 18 were semi-natural grassland indicator species, 14 expansive species (interpreted as provided by Lārmanis (red.) (2014)) and 17 species characteristic of dry, calcareous grasslands (interpreted as provided by Auniņš (ed.) (2013)). Significant differences in the number of plant species, number of semi-natural grassland indicator species and Shannon index for vegetation were observed (Fig. 3). Diversity variables were generally higher on average to high quality and extensively grazed calcareous grasslands, and lower in cultivated grasslands.

For each grassland area, relative quality and management type, significant vegetation indicators were obtained (Table 1). The results show that number of semi-natural grassland indicator species, litter cover and depth are the main diversity and structure variables that are characteristic to a certain group of grasslands. We want to point out the significance of the willowleaf yellowhead *Inula salicina* in low quality calcareous grasslands, as it was a typical expansive species in the research area.

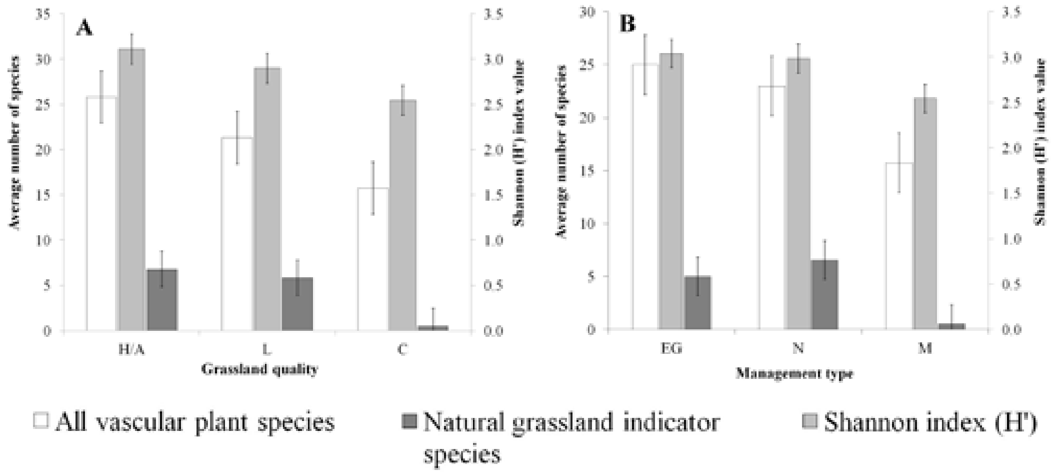

Fig. 3 Comparison of vegetation diversity indices depending on grassland quality (A) and grassland management type (B). On the primary y axis, the average number of plant species and semi-natural grassland indicator species is shown. On the secondary y axis, the average Shannon index values are shown. All averaged values are shown with standard error bars.
Abbreviations: H/A – high and average quality calcareous grasslands, L – low quality calcareous grasslands, C – cultivated grasslands; EG – extensive grazing, N – no management, M – mowing.

Table 1 Characteristic plant species, vegetation structures and diversity indices for each grassland quality and management type (results from indicator species analysis). Significance level 0.05 (*0.055). Only species and structures with indicator value (IV) greater than 50.0 are shown. Abbreviations: (a) grassland quality groups: H/A – high / average quality calcareous grasslands, L – low quality calcareous grasslands, C – cultivated grasslands; (b) management types: EG – extensive grazing, N – no management, M – mowing.

GRASSLAND GROUP		CHARACTERISTIC SPECIES	IV	CHARACTERISTIC STRUCTURES AND DIVERSITY INDICES	IV
a) Relative quality	H/A	*Agrimonia eupatoria* *Filipendula vulgaris** *Fragaria viridis* *Potentilla erecta* *Trifolium arvense*	55.1 55.0 63.6 58.4 56.5	Number of semi-natural grassland indicator species in 1 m^2 plot Number of semi-natural grassland indicator species in 25 m^2 plot	54.5 51.8
	L	*Inula salicina*	66.7	Litter cover (%) Litter thickness (cm)	51.3 54.9
	C	*Dactylis glomerata* *Taraxacum officinale* *Trifolium pratense*	58.2 95.5 56.2	Cover of expansive plant species (%)	64.3
b) Management type	EG	*Centaurea jacea* *Daucus carrota* *Fragaria viridis* *Potentilla erecta* *Primula veris* *Prunella vulgaris*	75.0 93.1 61.2 73.8 62.6 100.0	Moss cover (%)	76.7
	N	*Centaurea scabiosa*	68.4	Number of semi-natural grassland indicator species in 1 m^2 plot Number of semi-natural grassland indicator species in 25 m^2 plot Litter cover (%) Litter thickness (cm)	57.6 54.4 62.2 56.8
	M	*Dactylis glomerata* *Taraxacum officinale*	59.4 96.9	Cover of expansive plant species (%)	70.2

Overall, 506 individuals of 18 grasshopper species were collected in the two sampling periods. The most common species were *Omocestus viridulus, Chorthippus paralellus* and *Chorthippus albomarginatus*. In July, the second most common species was *Euthystira brachyptera*, which is a calcareous habitat specialist species (Kenyeres, Cservenka 2014). For ground beetles, 1094 individuals of 41 species were collected. A dry calcareous grassland specialist *Harpalus caspius* (Barševskis 2003) and 23 other species characteristic to dry grasslands (Luff et al. 1992; Barševskis 2003; Da Silva et al. 2008; Schirmel et al. 2015; Александрович 1996) were collected. The most common ground beetle species were *Poecilus versicolor, Poecilus cupreus* and *Amara aenea*. The data of both grasshopper and ground beetle abundance did not correspond to a normal distribution, and due to the large number of sporadic species, the data corresponded to Poisson distribution.

When analyzing the dominance structure of grasshoppers, the only eudominant species, *Omocestus viridulus*, was recorded in low quality and abandoned calcareous grasslands, and the largest number of recedent and subrecedent species was recorded from high/average quality calcareous grasslands and extensively grazed calcareous

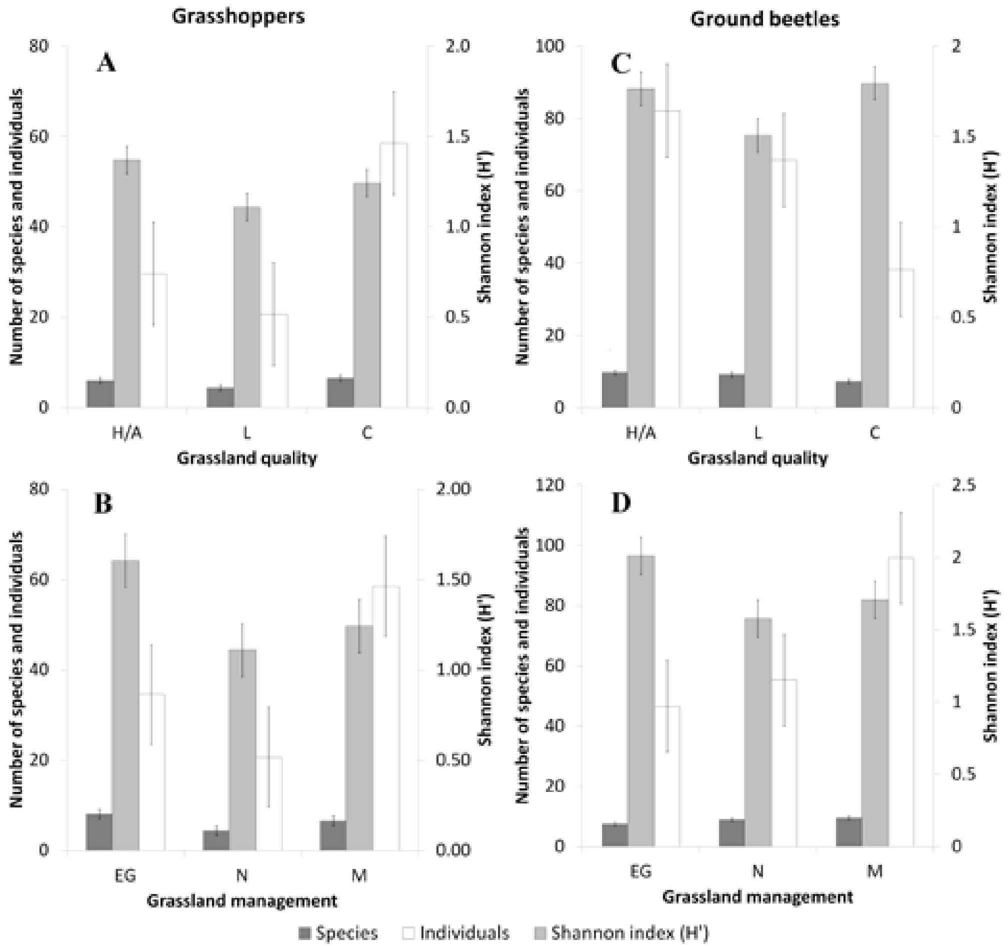

Fig. 4 Comparison of grasshopper (A, B) and ground beetle (B, C) diversity indices according to grassland quality (A, C) and management (B, D).

grasslands. The evenness index *E* did not differ significantly between the quality groups or management types, but it was higher in high/average quality (E = 0.81), low quality and abandoned (E = 0.83) and extensively grazed (E = 0.78) calcareous grasslands than in mown or cultivated grasslands (E = 0.67). For ground beetles none of the relative quality or management type groups had any eudominant species. Low quality calcareous grasslands had the tendency to host the largest number of dominant and subdominant species, but the highest number of recedent and subrecedent species was in high/average quality calcareous grasslands.

The diversity indices for grasshoppers and ground beetles did not significantly differ neither within the quality groups, nor the management types (*Kruskal-Wallis* rank sum test). Although for grasshoppers all the indices were the lowest in low quality calcareous grasslands (Fig. 4), but the highest diversity (H') was in high/average quality, as well as in extensively grazed calcareous grasslands. Regardless of inconclusive results on the comparison of insect diversity between the relative grassland quality and management type, significant ($p < 0.05$) negative correlations between the number of grasshopper species and litter cover ($r_S = -0.54$), as well as vegetation height ($r_S = -0.63$) were found. Also, the abundance of several grasshopper and ground beetle species differed significantly between the grassland quality and management types.

Multiple ground beetle and two grasshopper species were significant ($p < 0.05$) indicators of cultivated and mown grasslands (Table 2). No significant indicators for high/average or low quality grasslands were obtained. The cricket *Metrioptera brachyptera* was found to be an indicator of abandoned dry, calcareous grasslands, and the grasshopper *Chorthippus apricarius* – for extensive grazing.

Table 2 Grasshopper and ground beetle indicator species for relative grassland quality and management type. Significance level 0.05. Only species with indicator value (IV) greater than 50.0 are shown.
Abbreviations: (a) grassland quality groups: H/A – high / average quality calcareous grasslands, L – low quality calcareous grasslands, C – cultivated grasslands; (b) management types: EG – extensive grazing, N – no management, M – mowing.

GRASSLAND GROUP		FAMILY	SPECIES	INDICATOR VALUE (IV)
Relative quality	**H/A**	-	-	-
	L	-	-	-
	C	Acrididae	*Chorthippus dorsatus*	100.0
		Carabidae	*Amara communis*	88.8
		Carabidae	*Amara aenea*	73.5
		Acrididae	*Chorthippus albomarginatus*	73.1
		Carabidae	*Poecilus versicolor*	69.8
		Carabidae	*Poecilus cupreus*	66.7
		Carabidae	*Harpalus latus*	64.5
		Carabidae	*Ophonus rufipes*	63.9
Management type	**EG**	Acrididae	*Chorthippus apricarius*	87.1
	N	Tettigoniidae	*Metrioptera brachyptera*	75.7
	M	Acrididae	*Chorthippus dorsatus*	100.0
		Carabidae	*Amara aenea*	84.1

DISCUSSION

VEGETATION

The vegetation parameters (Table 1) suggest that the grassland territories were categorized successfully, as the results of this study coincide with the previous knowledge (Lārmanis (red.) 2014). Cultivated grasslands were typically dominated by *Dactylis glomerata* and *Taraxacum officinale*, which also turned out to be indicators for cultivated grasslands in this research. Here the cultivated grasslands were not fertilized during the research period, and the mown hay was later bailed and removed from the field, leaving no hay. The vegetation was low during the ground beetle sampling, while at the time of grasshopper sampling, the vegetation had grown to approximately 50 centimetres. There were still some semi–natural grassland indicator species present in the cultivated grasslands, which we would mainly explain by the diversity of different surrounding grassland types in the Abava River valley.

In this study, the differences between high/average and low quality calcareous grasslands were less distinct. For this reason the quality groups are relative. Only three grassland areas had some management applied during the research period. The other high quality calcareous grasslands were probably only recently abandoned, judging from the relatively small litter cover and depth, and in succession phase that is characterized by short-term increase in plant diversity (Rūsiņa 2013). The low quality calcareous grasslands, on the other hand, were already characterized by greater cover and depth of litter. In this successional stage, an increase in expansive plant species is common (Rūsiņa 2013). Although in the methodology of grassland habitat monitoring (Lārmanis (red.) 2014) yellowhead willowleaf *Inula salicina* is not mentioned as an expansive species, in the Abava River valley it was one of the main species with such behaviour.

GRASSHOPPER AND BEETLE FAUNA

The diversity indices of grasshoppers and ground beetles mostly did not directly correspond to plant diversity or vegetation structure. These results coincide with the theory that diversity indices are not always sufficient in describing diversity (Duelli, Obrist 1998; Bazelet, Samways 2011). For grasshoppers, an inconsistent diversity response is in accordance with previous studies (Ledergerber et al. 1997; Fonderflick et al. 2014; Rada et al. 2014). Grasshopper abundance and diversity is not always explainable with the vegetation diversity or grassland management (Duelli, Obrist 1998; Matisons 2005; Rada et al. 2014).

Although the results were statistically insignificant, there was a tendency for the grasshopper diversity and abundance in low quality abandoned calcareous grasslands to be even lower than in cultivated grasslands (Fig. 4). This can mainly be explained with the negative influence of litter cover (Fonderflick et al. 2014), which, in this study, was a characteristic structure in abandoned and low quality calcareous grasslands (Table 1). This is due to altered microclimate caused by dense cover of litter, which is one of the main factors for grasshoppers (Kati et al. 2003; Gardiner, Dover 2008; Gardiner, Hassall 2009; Benton 2012; Fartmann et al. 2012; Kenyeres, Cservenka 2014). In cultivated grasslands, litter cover was small, and during the grasshopper sampling, the vegetation height was high enough to provide suitable microhabitat. Here it is important to point out the origin and botanical value of these cultivated, as well as abandoned calcareous grasslands, which allows assuming that they still have a high recovery potential of natural value if appropriate management would be applied. Some studies suggest that the insect diversity after habitat restoration rarely recovers to the previous level (Knop et al. 2008), so grassland abandonment should be prevented *ex-ante*. The number of ground beetle individuals was also highest in cultivated grasslands (Fig. 4), which can be explained by disturbance caused by mowing in the period of beetle sampling. An increase of activity density along disturbance gradients has been reported in previous research (Da Silva et al. 2008; Woodcock et al. 2009). This can be explained by an increase in food resources and decrease in competition in the mown grassland.

For grasshoppers, all diversity indices, except for number of individuals, had the tendency to have (non-significantly) higher values in high/average quality calcareous grasslands (Fig. 4). The reason for the weakness of this trend could be the lack of management in most of the studied high/average quality grasslands. Although these territories still had high botanical value, the litter cover might have changed the microclimatic conditions, thus interfering with the abundance of grasshoppers. The number of recorded ground beetle species in this research was slightly higher than in other similar studies (Nietupski et al. 2015; Schirmel et al. 2015). The most common ground beetle species – *Amara aenea, Poecilus cupreus* and *P. versicolor*, are ecologically plastic and commonly found in various habitats (Luff et al. 1992; Barševskis 2003). Approximately half of the recorded species were xerophilous (Luff et al. 1992; Cole et al. 2002; Barševskis 2003, Da Silva et al. 2008; Tuf et al. 2008; Schirmel et al. 2015; Александрович 1996). There were also fairly large numbers of hygrophilous species that could be explained either by their relation with humid grassland patches or the proximity of the Abava River. It is known that forest and forest edge species often use adjacent grasslands as feeding habitats (Luff et al. 2002; Kagawa, Maeto 2014).

In cultivated grasslands, three ground beetle species amounted to 76% of all individuals. A similar dominance structure of ground beetle species was observed in agrocoenoses (Александрович 1996), which suggests that in this study the ground beetle fauna of cultivated grasslands is more similar to that of agricultural lands than that of semin-natural grasslands. The Shannon index value was also higher in high/average botanical quality grasslands. Here, the vegetation species and structural diversity is most likely to positively influence the distribution of ground beetle species (Kirby 2001; Batáry et al. 2007; Schirmel 2015). For grasshoppers, the dominance structure results were less distinct, although for some species the changing position in the dominance structure between the grassland quality and management groups suggested specialization. *Metrioptera brachyptera* (Table 2) can be used as an indicator for changes in the dry grassland microclimate. The species is characteristic of a moist microclimate and typically occurs in grasslands with a dense vegetation structure and lack of management (Holst 1986; Benton 2012; Weking et al. 2016), and is sensitive to intensive disturbance and management (Maes, Van Dyck 2005).

Even though only two out of 17 grasslands were grazed during the season of sampling, the results coincide with other studies. The main concern regarding this management type is overgrazing (Ledergerber et al. 1997). However, the pastures included in this research were extensive and the vegetation structure was diverse, which is known to positively influence grasshopper diversity and abundance (Spalinger et al. 2012; Kenyeres, Cservenka 2014; Rada et al. 2014). The results also coincide with the observations by Weiss et al. (2012) and Senn et al. (2011) suggesting that in pastures the grasshopper species diversity is higher than in meadows, and with opinion of Wissman et al. (2008) that grazing is the most appropriate management type for semi-natural grassland flora and fauna conservation.

We would also like to emphasize the significant negative role of *Inula salicina* and *Rubus caesius* co-domination, caused by lack of management resulting in a homogenous vegetation structure that was unfavorable for both grasshoppers and ground beetles. In one of such grassland areas, strongly dominated by these two species, no grasshopper individuals were collected.

The inconsistent results suggest that further research on characteristic and rare species would contribute to the knowledge of insect response to changes in grassland habitats. Further research, including studies of a broader range of insect functional groups, is needed to understand how processes in grasslands, for example, management or overgrowth, change the abundance and species composition of the entomofauna. The main focus of grassland insect conservation should be not only on protecting the rare species, but also on preserving the characteristic ones.

CONCLUSIONS

The grasslands included in this study differed both in their botanical quality and management type. High/average botanical quality grasslands have the highest value for the conservation of grasshopper and ground beetle diversity. Extensive grazing also had a positive influence on both grasshopper and ground beetle species diversity. The main factors that influence grasshoppers in dry, calcareous grasslands are microclimate, vegetation structure and species composition and grassland management. The main factors influencing ground beetles were vegetation height, herbaceous plant cover and soil pH level. Grasshopper and ground beetle species composition has to be considered when assessing the importance of dry, calcareous grasslands for insect conservation.

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Species composition and diversity in dry semi-natural grasslands: a comparison of two different landscapes

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ABSTRACT

Intensive farming practices over a long period of time have caused decline of natural and semi-natural vegetation, particulary grasslands. Species-rich grasslands have been preserved in river valleys that are relatively less affected by intensive farming. The Zemgale Plain is the oldest agricultural region in Latvia. Nowadays, most of Zemgale region is used as arable lands, whereas semi-natural grasslands occupy only small patches in river valleys. On the contrary, the Abava River valley is considered as an area still rich in semi-natural grasslands.

The aim of this study was to compare species composition of dry semi-natural grasslands in these two territories. In total, 125 relevés were analysed: 74 of them represent the Abava River valley, 51 – several river valleys of the Zemgale Plain.

Larger diversity of species and communities was found in the dry semi-natural grasslands in the Abava River valley; they hosted also larger diversity of semi-natural grassland indicator species, rare and protected species than in the Zemgale Plain. In the Zemgale Plain, the vegetation was dominated by mesophilous species *Dactylis glomerata, Festuca pratensis, Poa pratensis, Calamagrostis epigeios, Rubus caesius*, whereas the grasslands of the Abava River valley were characteristic with presence of *Filipendula vulgaris, Phleum phleoides, Galium verum, Rumex thyrsiflorus, Artemisia campestris, Sesleria caerulea, Astragalus danicus, Veronica teucrium, Arenaria serpyllifolia* and *Sedum acre*.

Two main groups of factors cause differences of the plant species composition in the Abava River valley and the Zemgale Plain. The first group combines climatic factors determining the regional distribution of plant species. The second group summarizes the factors associated with human activities, agriculture in particular.

KEY WORDS: plant species composition, plant species richness, intensive agriculture, river valleys.

INTRODUCTION

River valleys are important refuges for natural and semi-natural vegetation. Many scientific papers are devoted to dry grasslands of the large river valleys of Eastern and Northern Europe: Vistula (Banaszak et al. 2006), Odra (Hensen 1997; Barańska, Żmihorski 2008), Rekijoki (Luoto et al. 2003), Bug (Glowacki et al. 2002), Desna (Shelyag-Sosonko et al. 1987), and many others. Daugava (Rūsiņa 2007; Фатаре 1989), Gauja, Venta, Lielupe (Rūsiņa 2007) and Abava (Табака, Клявиня 1981; Rūsiņa 2007) river valleys are the most important semi-natural grassland areas in Latvia. Grasslands in the Abava River valley (hereafter – Abava) represent an outstanding example of grassland habitats of Latvia (Kupča, Rūsiņa 2016).

The semi-natural grasslands in Northern Europe were associated with the slopes of river valleys also during the period of extensive farming. When the intensification of farming practices became dominant in the mid-20th century, river valleys were perceived as economically marginal by the farmers, and intensification occurred mainly in the surrounding plains (Luoto et al. 2003). Intensification of farming causes decline of the area and frequency of natural and semi-natural habitats. This can be illustrated by examples from the neighbouring countries. In Finland, the density of semi-natural and natural habitats in agricultural landscapes has decreased by 90% (Hietala-Koivu et al. 2004) during the second half of the 20th century. In Sweden, the area of semi-natural grasslands had declined from 60% in 1854 to 5% today (Cousins, Eriksson 2008), in Lithuania – from 19.6% in 1956 to 6.5% in 1980 (EPMRL 1998), and in Latvia – from 30% in the beginning of the 20th century to 0.7% today (Rūsiņa 2008; Gustiņa u. c. 2012). In agricultural regions of the United Kingdom, remnants of grasslands occupy small patches along the margins of crop fields, track and road verges, as well as on undrained areas or steep slopes (Sutton, Tittensor 1988). In the Latvian agricultural region Zemgale Plain (hereafter – Zemgale), only 0.8% of all semi-natural grasslands of Latvia occur (Gustiņa u. c. 2012). Here, semi-natural grasslands have been preserved mainly in river floodplains and areas that are not usable for intensive farming, i. e. on the steep slopes of river valleys (Ābele 1961; Tabaka 2001; Straupe, Adamovičs 2003; Rūsiņa 2007; Gustiņa 2012).

Dense (0.27 km/km^2) radial river network, consisting of the left bank tributaries of the Lielupe River, is typical for Zemgale (Rutkis 1960; Ramans 1970). Almost all rivers are straightened during the Soviet period. Nowadays only Mūsa, Mēmele, Lielupe, Svēte and Vilce have kept their natural riverbeds. Many smaller rivers do not have any natural stretches at all (Anon. 2008).

Dry grassland patches occur both in the Abava River valley and the river valleys of Zemgale. Dry grassland plant communities of calcareous soils have been observed in both areas (Rūsiņa 2007). This study aims at comparing the dry grasslands of both territories and determining whether the prevailing agricultural practices in the particular areas have affected the plant species composition in the grassland communities.

METHODS

Grassland vegetation data used in this study characterises plant species composition of 13 river valleys: Abava, Lielupe, Bērze, Auce, Skujaine, Tērvete, Svēte, Platone, Vircava, Svitene, Īslīce, Ceraukste and Iecava. Five of these rivers are more than 100 km long – Abava, Lielupe, Bērze, Svēte and Iecava. Abava is located in the western part of Latvia (Fig. 1). Annual precipitation in this region is 600–750 mm; the frost-free period lasts from 130 to 140 days per year. The average annual temperature in the region is +5.7 °C. The depth of the Abava valley varies from 10 to 40 metres. Microclimatic differences influenced by exposure and inclination angle of the valley slopes can be observed there. Abava is a protected nature area since 1927. More than 826 plant species and eight semi-natural grassland types were found there. Nowadays 50% of the valley is covered by forests and only 28% are used as agricultural lands, including semi-natural and cultivated grasslands. Only 14% of the Abava are used as arable lands (SIA METRUM 2016).

Other 12 rivers are located in Zemgale (Fig. 1). Annual precipitation in this region is 500–550 mm; the frost-free period lasts on average 150 days per year. Zemgale is considered the warmest and driest region in Latvia. The valleys of the surveyed rivers have different depth. Those in the western and eastern parts of Zemgale have deeper valleys (up to 15 m deep) with steep slopes, whereas the river valleys in the central part of Zemgale are wide and reach only 3–5 m depth; the slopes are gentle. Zemgale is one of the oldest and the most deforested territories in Latvia (Zunde 1999; Tabaka 2001), as it is an ancient farming region. Even the oldest forest patches in the Tērvete neighbourhood (western part of Zemgale) have developed on the former arable lands (Zunde 1999). The earliest cultivated grasslands and *Trifolium pratense* fields in Latvia were established in Zemgale in the early 19th century, as there was lack of grasslands (Boruks 2003). Zemgale was still the most important agricultural region in Latvia also in the first half of the 20th century (Rutkis 1960) and during the Soviet period. In the Soviet time, more than 90% of this region was used for intensive farming. The intensification of farming affected Zemgale more than the rest of Latvia (Melluma 1994; Boruks 2003). Nowadays the proportion of farmlands here comprise more than 76%. The proportion of arable land in Zemgale is the highest in Latvia – more than 67% of all agricultural land, while cultivated meadows and pastures occupy less than 4% of farmland (Boruks 2004). The occurrence of semi-natural grasslands in Zemgale is averagely 2.3 to 1000 hectares (Gustiņa et al. 2012). Semi-natural grasslands in Zemgale occur mostly as narrow strips along riverbank slopes or in floodplains (Gustiņa 2012).

Fig. 1 Study areas: 1. – Abava River valley; 2. – Zemgale Plain.

Vegetation data from two data sources were used to accomplish this paper. Data on the grasslands in the Abava and Lielupe river valleys were selected from the Semi-natural grassland vegetation database of Latvia (Rūsiņa 2012), but data about the grassland vegetation of Zemgale were taken from the study concerning the distribution of dry grassland plant species in Zemgale (Gustiņa 2012). All data were collected using Braun-Blanquet method in the period from 1998 to 2010. Only relevés with size of 4–9 m^2 were selected for analysis. The nomenclature for vascular plants follows Gavrilova and Šulcs (1999).

Initially, the number of relevés was 158. Average Ellenberg's indicator values for moisture (Ellenberg et al. 1992) per relevé were calculated using the JUICE program (Tichy 2002). The size of the data plot was reduced to 125 by removing relevés with the value higher than 4.9 according to the information about the moisture regime of the dry grasslands in Latvia (Rūsiņa 2007).

Differences in the species composition were evaluated using the following variables which characterise the species composition: total number of species, number of indicator species of semi-natural grasslands (Auniņš (ed.) 2013), number of protected species (Priedītis 2014), number of rare species (Priedītis 2014), number of species indifferent to light, temperature, continentality, moisture, soil pH or nutrients (Ellenberg et al. 1992). Ellenberg's indicator values were used to characterise the environmental conditions (Ellenberg et al. 1992).

In order to clarify the differences in species composition between both study areas, several methods were applied. The differences of plant species composition between the study areas and classification of relevés were analysed using the Detrended Correspondence Analysis (DCA) and cluster analysis (distance measure – Sørensen; group linking method – beta-flexible (flexible beta set to -0.25)), performed by PCORD 5.0 (McCune, Mefford 1999). In the DCA, the option of downweighting rare species was selected. Plant communities were defined according to the composition of diagnostic species and named after communities described earlier in Latvia (Rūsiņa 2007; Priede 2011). Diagnostic species identified using fidelity calculated in the JUICE program (Tichý 2002).

RESULTS

In the data set, 74 relevés represented the dry grassland vegetation in Abava and 51 relevés – in the river valleys of Zemgale. The total number of plant species found in the dry grassland patches of Abava was 190, but in the grassland fragments of the river valleys in Zemgale comprised only 147 species. Differences were observed not only in the total number of species, but also in the specific species groups, i. e. the number of semi-natural grassland indicator species and the number of protected and rare plant species was greater in the Abava grasslands than those in Zemgale (Table 1). Typical species of the dry grasslands of Abava were *Filipendula vulgaris, Phleum phleoides, Galium verum, Rumex thyrsiflorus, Artemisia campestris, Sesleria caerulea, Astragalus danicus, Veronica teucrium, Arenaria serpyllifolia* and *Sedum acre*. These species were rare in Zemgale, majority of their localities occured in the western part of the plain. The dry grasslands of the river valleys of Zemgale were rich in species characteristic to mesic, cultivated and improved grasslands, such as *Poa pratensis, Festuca pratensis, Dactylis glomerata, Medicago sativa* and *Arrhenatherum elatius*. Plant species indicating

Table 1 Plant species richness.

	ABAVA RIVER VALLEY	ZEMGALE PLAIN
Total number of plant species	190	147
Number of semi-natural grassland indicator species	37	24
Number of protected plant species	17	1
Number of rare plant species	24	5

ruderalization and overgrowing (*Senecio jacobaea, Calamagrostis epigeios, Rubus caesius, Artemisia vulgaris*) were more often found in the grasslands of Zemgale than in those of Abava.

The cluster analysis resulted in four clusters – four plant communities (Fig. 2):

1. *Sesleria caerulea-Inula salicina* community;
2. *Phleum phleoides* community;
3. *Filipendula vulgaris-Helictotrichon pratense* community;
4. *Festuca pratensis-Medicago falcata* community.

Sesleria caerulea-Inula salicina, Phleum phleoides and *Filipendula vulgaris-Helictotrichon pratense* communities were characteristic to Abava. Only six relevés with these communities were described in Zemgale. The species composition of these communities is analysed by L. Kupča (2017, in this book). Relevés of the *Festuca pratensis-Medicago falcata* community were described in Zemgale except one relevé in Abava. These communities were dominated by mesophilous grasses, such as *Dactylis glomerata, Festuca pratensis* and *Poa pratensis*; typical forbs were *Rubus caesius, Vicia cracca, Hypericum perforata, Plantago lanceolata, Thymus ovatus, Medicago falcata, Pastinaca sativa*. Many plant species characteristic to dry calcareous grasslands occured in the relevés of the *Festuca pratensis-Medicago falcata* community: *Helictotrichon pratense, Phleum phleoides, Trifolium montanum, Pimpinella saxifraga, Galium verum, Fragaria viridis, Cirsium acaule*. The occurrence of woody species in the grasslands of Zemgale was higher than in Abava (*Betula pendula, Rosa* spp., *Malus sylvestris, Alnus incana, Euonymus europaea, Fraxinus excelsior, Quercus robur* and *Ulmus glabra*).

The DCA ordination plot distinguishes the communities along the first two axes rather clearly (Fig. 3.). The first two axes of the DCA explain 42.2% of variance in the species data. Obviously, the grasslands of Zemgale are poorer not only in the number of species, but also plant community diversity is lower. The relevés of Abava are distributed more widely along the ordination axis showing more poronounced variation in species composition, while the relevés of Zemgale are located closer to each other.

Variables having strong correlation with Axis 1 were Ellenberg's moisture and nitrogen values. Some other variables, such as Ellenberg's light, soil reaction, and number of protected species had moderate correlation with Axis 1. Only three variables correlated with Axis 2 – Ellenberg's temperature, moisture and reaction (Table 2).

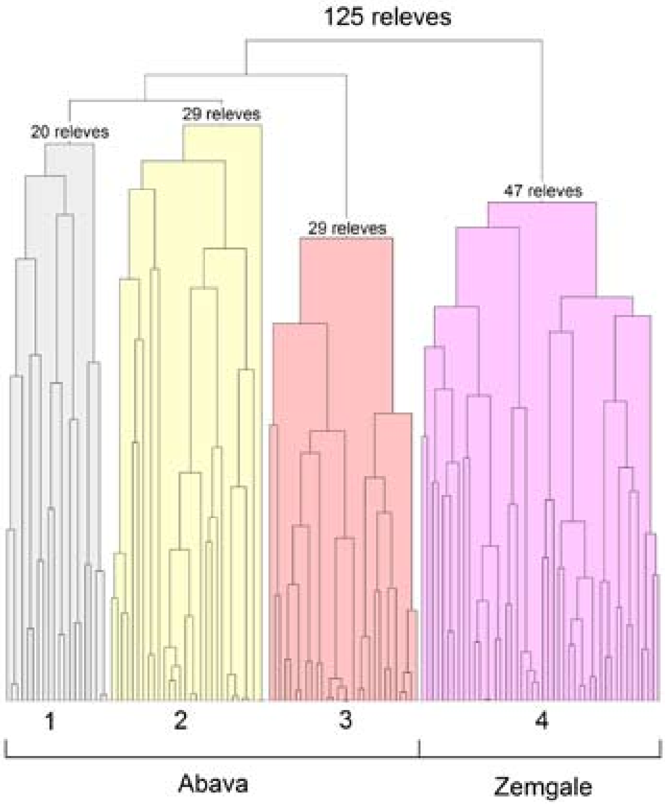

Fig. 2 Dendrogram: 1 – *Sesleria caerulea-Inula salicina*; 2 – *Phleum phleoides*; 3 – *Filipendula vulgaris-Helictotrichon pratense*; 4 – *Festuca pratensis-Medicago falcata*.

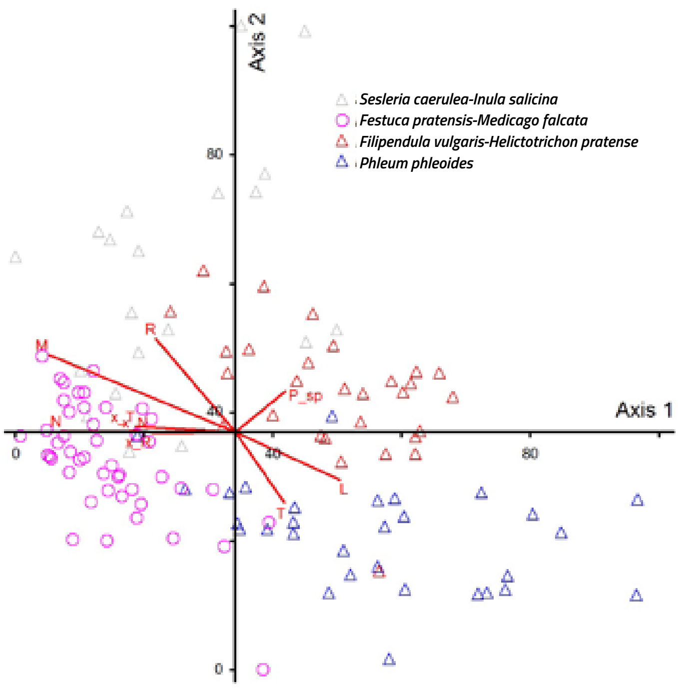

Fig. 3 DCA ordination plot of sample and variables of dry grassland vegetation relevés: M; N; R; T; L – Ellenberg's value for moisture, nitrogen, soil pH, temperature and light; x_T; x_R; x_N – number of species indifferent to the Ellenberg's value for temperature, soil pH and nitrogen; P_sp – number of protected species. Axis 1 λ = 0.40; axis 2 λ = 0,28.

Table 2 Kendall correlations with Axis and Axis 2.

VARIABLE	AXIS 1	AXIS 2
Total number of species	-0.349	0.062
Number of semi-natural grassland indicator species	-0.047	0.284
Number of rare species	0.263	0.221
Number of protected species	**0.417**	0.377
Ellenberg's light	**0.568**	-0.384
Number of species indifferent to light	-0.335	0.043
Ellenberg's temperature	0.388	**-0.472**
Number of species indifferent to temperature	**-0.587**	0.161
Ellenberg's continentality	0.386	-0.130
Number of species indifferent to continentality	-0.144	-0.098
Ellenberg's moisture	**-0.767**	**0.488**
Number of species indifferent to moisture	-0.393	0.125
Ellenberg's soil reaction	**-0.501**	**0.534**
Number of species indifferent to soil reaction	**-0.517**	-0.056
Ellenberg's nutrients	**-0.749**	0.081
Number of species indifferent to soil nutrients	**-0.530**	0.067

DISCUSSION

Dry grasslands of Abava and Zemgale differed from each other in plant species composition. Many of the species that are characteristic of Abava reach the eastern border of their distribution range in Latvia (*Helictotrichon pratense, Sesleria caerulea*); *Filipendula vulgaris* is found mostly in the western part of Latvia (Priedītis 2014). *Helictotrichon pratense* and *Sesleria caerulea* are also characterized by low Ellenberg's indicator value for continentality (Ellenberg et al. 1992). Weak climate continentality is characteristic to the western part of Latvia where Abava is located; the continentality increases eastward (Laiviņš, Melecis 2009). The spreading of *Artemisia campestris, Sedum acre* and *Phleum phleoides* in Zemgale is limited by soil conditions; these species can grow only on poor sandy soils (Ellenberg et al. 1992), but Zemgale is characterized by heavy clay soils with a high nutrient content (Boruks 2004). Semi-natural grasslands on sandy and gravely soils can be found only in the western part of Zemgale along the Tērvete River and the Skujaine River (LVGD Kvartargeologija 2004).

Despite the fact that Abava has smaller area than all the river valleys of Zemgale together, this territory comprise more semi-natural grassland patches and has higher diversity of both plant species and grassland communities. Zemgale is one of the most homogeneous regions of Latvia due to its terrain and soils (Ramans 1975) and land use (Boruks 2004). The landscape is dominated by crop fields, but natural and semi-natural habitats are small, highly fragmented and mutually isolated. Low landscape diversity explains the low richness of habitats and species (Lindenmayer, Fischer 2006) as this has been found also in Zemgale. In comparison to Zemgale, Abava is located in an undulated area, rich in small rivers and streams. It is characteristic with diversity of terrain, soils, land use and landscape features (Табака, Клявиня 1981).

Many plant species that are common in the rest of Latvia are rare in Zemgale (Gustiņa 2012). Presence of grassland plant species in some territories can be restricted by many factors. The grassland patches in Zemgale are highly fragmented and isolated from each other by unsuitable habitats, thus the ability of plants to spread into other territories is low. The long-distance dispersal capability of grassland plant species is very low (Hensen 1997; Dixon 2002; Brys, Jacquemyn 2009; Stevens et al. 2012). The isolation of natural grasslands in agricultural landscape can be so high that even those species, whose seeds spread with the wind, are unable to colonize new sites (Soons et al. 2005). Low dispersal ability affects not only the ability to move from one area to another, but also increases the risk of inbreeding and decline of genetic diversity (Cousens et al. 2008). The loss of plant genetic diversity reduces the viability of species, and the species can become extinct after some time (Verkaar 1990). This affects both rare and common species (van Rossum et al. 2004). In addition, many grassland species do not form a soil seed bank or it is transient (Grime et al. 2007). The distribution of many grassland species in Zemgale is limited by dominance of other species – *Dactylis glomerata* and *Calamagrostis epigeios*. Grassland specialists are poor competitors (Tikka et al. 2001) in contrary to the species, which dominate in the grasslands of Zemgale. For example successful survival of *Dactylis glomerata* is provided by the ability to survive drought periods during the first year of life (Volaire 2003), but grassland specialists cannot invade the surrounding area after third year under reduced competition (Tikka et al. 2001). If grassland is not managed, *D. glomerata* forms large tussoks and a thick layer of litter that inhibits germination of other species (Pavlu et al. 2016). Seed germination of some grassland specialists requires light (Milberg 1994; Stevens et al. 2012; Cojocariu et al. 2013), but the light availability is limited by dense sward of other grasses and litter.

The species composition in the grasslands of Zemgale is deterimined also by soil properties – richness of nutrients, moisture and pH. The soils of Zemgale are naturaly fertile and carbonate-rich (Seile 1981). During the Soviet period the intensively used arable lands were abundantly fertilized with chemical fertilizers (Anspoks 1989; Cimdiņš, Liepa 1989; Boruks 2003). Intensive use of fertilizers leads to the pollution of groundwater and surface water, causing eutrophication (Bowler 2002), which negatively affects the nutrient-poor and moderate-rich plant communities (Smart et al. 2003), including semi-dry grasslands. Plant species composition changes by increasing of soil nutrients – the proportion of potentially expansive species increases, and they become dominant, resulting in reduced species diversity (Davis et al. 2000), while the number of rare species decreases (Blomqvist et al. 2003). The abundance of grasses like *Dactylis glomerata, Festuca pratensis*, etc. clearly indicates the eutrophication process in Zemgale. It can be also hypothesized that the dominance and high occurrence of these species is a remnant of cultivated grasslands. Besides, the dominance of *Rubus caesius* and *Calamagrostis epigeios* as well as presence of woody species in the grasslands of Zemgale indicate that the areas are abandoned (Rebele, Lehmann 2001; Kupča, Rūsiņa 2016). The lack of management contributes the accumulation of litter that, in turn, increases the soil fertility and moisture (Straupe, Adamovičs 2003).

It is possible to conclude that the two main groups of factors cause differences of the plant species composition in Abava and Zemgale. The first group combines climatic factors determining the regional distribution of plant species. The second group summarizes the factors associated with human activities – altered soil fertility due to fertilization and increased habitat fragmentation and isolation caused by continuous monoculture fields. Fertilization and monocultures both are basic practices of intensive farming. These practices are a part of system in which each action depends on the others and reinforces the necessity of using the others – intensive tillage, drainage, chemical pest control and genetic manipulations of crop plants (Gliessman 2000).

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http://eu.wiley.com

Embassy of Finland, Riga
www.finland.lv/public/

Daugavpils District Tourism, Recreation and Culture Agency "TAKA"
Rīgas street 2, Daugavpils, LATVIA
+371 65476748, taka@dnd.lv, www.daugavpilsnovads.lv/turisms-un-daba

Daugavpils Tourist Information Centre
Rīgas street 22a, Daugavpils, LATVIA
+371 65422818, +371 26444810 turisms@daugavpils.lv, www.visitdaugavpils.lv

Welcome to Daugavpils District in Latvia – to explore our meadows, forests, lakes and rivers! You can go by bike or to rent a boat or raft to travel in Daugavas loki/Augšdaugava, and to have a rest in cosy guest house with sauna. There are numerous opportunities of leisure, sports, sightseeing, visitig culture, historical and nature objects.


Photo by Solvita Rūsiņa