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# CHANGES IN BOTANICAL DIVERSITY OF SOWN GRASSLANDS DUE TO NATURALIZATION AND EXTENSIVE MANAGEMENT

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**Abstract**

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The paper deals with sown grassland naturalization models related to changes in botanical diversity of extensively managed meadows under temperate climate conditions. The vegetation surveys were carried out in Sėliškės and Polyma Experimental Field Stations (Lithuania). Based on our research data and literature sources (on the investigation of Lithuanian natural meadows), we developed the following hypothetical models of sown grassland naturalization: vascular plant species constancy alteration chronocline, vascular plant species constancy and productivity alteration topocline and a scheme of sown grassland naturalization on hilly landscape. Here we consider extensive management and naturalization as one of most natural and requiring minor investments method for grassland restoration.

**Keywords:** sown grassland, succession, richness, naturalization, scheme, seed mixture.

## INTRODUCTION

Grassland succession and restoration problems have been the concern of scientists from different countries of the world (Muller et al., 1998; Jones & Hayes, 1999; Pywell et al., 2002; Bakker et al., 2003; Hellström, 2004; Wilson & Pärtel, 2003; Lindborg & Eriksson, 2004; Wilson et al., 2004; Walker et al., 2004; Hedberg & Kotowski, 2010; Lencová & Prach, 2011; Török et al., 2010, 2011; Jírová, 2012, etc.). Because of the abandonment of traditional small-scale farming at the end of the 20th century, the number of semi-natural grasslands has declined in many European countries (Cramer et al., 2008). Restoration of degraded grasslands (simplified communities structure, loss of keystone and establishment of atypical plant species, damaged vegetation cover, etc.) has been carried out to rehabilitate species-rich grasslands. Different levels of degradation in grassland and meadow influence the choice of interventions required (Bradshaw, 1992; Aronson et al., 1993). Aronson et al. (1993) proposed a general model of possible responses (passive restoration, rehabilitation, reallocation) to different levels of ecosystem degradation. According to this approach, Muller et al. (1998) presented possible pathways of recreation of species-rich grasslands (rejuvenation, restoration, rehabilitation). Török et al. (2011) reviewed the most frequently used restoration techniques (spontaneous succession, sowing seed mixtures, transfer of plant material, topsoil removal and transfer) and techniques used to improve species richness (planting, grazing and mowing) to recover natural-like grasslands.

Economic activity retards succession in the grassland by impeding the prevalence of species of the following stages: forbs, shrubs and forests. Thus, the cessation of mowing or grazing provokes a rapid extension of robust, productive, and highly competitive species, first herbaceous and then woody. Concurrently, their colonization entails the retreat of species that are weaker under direct competition (Muller, 1992; Prach, 1993). In Lithuania, this phenomenon is evident in the farming areas, where economic activity has decreased or even stopped because of economic and social reasons. Therefore, it is important to reconcile agricultural and environmental objectives in grassland management, especially if we expect to retrieve the traditions of environment-friendly farming (extensive management) in abandoned or even degraded agricultural areas. Hence, investigations on changes in perennial grassland structure and productivity at different succession stages are important both from the scientific and economic point of view. Succession might be held under control by means of selecting an optimal grassland management (sowing seed mixtures, mowing, grazing, etc.).

Another important aspect of studies on sown grassland naturalization includes the processes of restoration of botanical diversity in formerly cultivated areas. It is important to know the scale, on which sown grasslands, undergoing naturalization, can reflect biological diversity of natural grasslands of synanthropic origin, characteristic to a particular area.

The aim of this paper was to summarise the results of ours previous studies on sown grassland naturalization and identify the ways of grassland succession on time and space.

## MATERIALS AND METHODS

### Study area

Lithuania lies on the western fringe of the East European Plain. The relief is a meridian-oriented alteration of lowland plains and hilly uplands. The climate falls into the zone of temperate climate, lying in the transition region between West European maritime and East European continental (Basalykas, 1958). Global radiation in Eastern Lithuania is 83–88 kcal/cm$^2$. From the hydrothermal viewpoint, the region is warmish (5.8–6.3ºC) and on the average wet (590–670 mm; hydrothermal coefficient – 1.4–1.8). Annual amount of precipitation (64–72%) falls out in the warm period (Kulienė & Tomkus, 1990; Bukantis, 2001, 2013).

The research was conducted in the perennial grasslands of Polyma and Sėliškės Experimental Field Stations (EFS) located in Utena district, Eastern Lithuania (Fig. 1).

Fig. 1. Location of study sites

Polyma EFS (55° 21’ N, 25° 46’ E; 20 ha area) was established in the area of drained fen and its surroundings. The seed mixture of mesohygrophilous species *Dactylis glomerata*, *Festuca pratensis*, *Festuca rubra*, *Poa pratensis*, *Poa palustris*, *Phleum pratense*, *Lolium perenne*, *Bromopsis inermis*, *Glyceria fluitans*, *Trifolium hybridum* and *Trifolium repens* was sown to the arable field in 1971.). Sowing rate was 28 kg/ha (Lapinskienė, 1986; Ėringis & Sendžikaitė, 2002; Sendžikaitė, 2002b; Pancekauskiene et al., 2005). The drained peat soils prevail in the area of EFS, only on higher elevations occur sod-gley podzolic soils. The grassland was irregularly mowed once a year (since the end of June), occasionally grazed (0.2 cattle/ha) and not fertilized for the last 15 years.

Sėliškės EFS (55° 20’ N, 25° 51’ E; 4 ha area) was established on the southern slope (4–6° inclination) of the hill (relative height is 11 m). The seed mixture of mesophilous species *Alopecurus pratensis*, *Dactylis glomerata*, *Festuca pratensis*, *Poa pratensis*, *Phleum pratense*, *Trifolium pratense*, *Trifolium repens* was sown to the arable field in 1987 (Sendžikaitė, 2000, 2002a). Sowing rate was 25 kg/ ha. The grassland occurs on slightly podzolized sod-podzolic, sod-gley podzolic and deluvial soils. It was mowed once a year (since the end of June), occasionally grazed (0.4 cattle/ha) and not fertilized for the last 8 years.

**Methods**

This paper summarizes the authors' previously published research data (1998–2000) on naturalization of sown grasslands at Polyma and Sėliškės Experimental Field Stations (SENDŽIKAITĖ, 2000, 2002a, b). The research material was supplemented by the data of other investigators (LAPINSKIENĖ, 1986, unpublished data; PANCEKAUSKIENĖ, 1987, unpublished data), who carried out botanical studies on grasslands (1st–2nd and 4th–6th years of running) at Polyma EFS (1972–1973 and 1975–1977; 50 relevés, i.e. 10 each year). After more than 25 years, a phytocoenotic research on naturalized grasslands was repeated at Polyma EFS by the authors of the paper. The data on 164 relevés (trial plots 100 $m^2$) were collected in 1998–2000 (SENDŽIKAITĖ, 2002a, b). Phytocoenotic relevés of sown grasslands were performed applying the principles of French-Swiss (Zürich-Montpelier) vegetation research approach (BRAUN-BLANQUET, 1964). Based on the percentage of relevés, in which a species was presented, the constancy of each species was put into five constancy classes (BRAUN-BLANQUET, 1964). Nomenclature of vascular plant species followed GUDŽINSKAS (1999). Ecological groups of vascular plants were presented according to ELLENBERG (1992). Classification of plant communities followed DIERSSEN (1996) and RAŠOMAVIČIUS (1998).

Aboveground phytomass (dry weight, g/$m^2$) of grassland communities was ascertained at Sėliškės EFS in 1998–2000. The investigations were carried out according to the programme and methods for geobotanical investigations described by LAPINSKIENĖ (1986). Aboveground phytomass was investigated annually in four parts (top, upper, middle and lower) of the hill slope in June (1st harvest) and August (2nd harvest). In each permanent study plot, the aboveground phytomass was measured in three trial plots of 1 $m^2$ in size (total – 72 samples). The aboveground part, mown down to the soil level, was divided into vascular plants (arranged into species), bryophytes and dead parts of plants. The sorted samples were dried and weighed, and the weight of each species of herb was determined (SENDŽIKAITĖ, 2000, 2002a, b). The data were processed applying *Microsoft Excel* and *STATISTICA for Windows*.

To summarize our research data obtained at Polyma EFS and Sėliškės EFS and literature sources on the investigations of Lithuanian natural meadows (BALEVIČIENĖ, 1991; RAŠOMAVIČIUS, 1998), we ascertained correlation between the number of vascular plant species and grassland age (the year of seed mixture sowing was set to 0, the age of natural communities hypothetically was set to 50 years). We also worked out a hypothetical model of species constancy alteration chronocline in grassland communities. For his purpose we used some often and abundantly growing vascular plant species characteristic to the Lithuanian natural grasslands, belonging to the Ass. *Festucetum pratensis* (RAŠOMAVIČIUS, 1998).

To develop a model (topocline) related to changes in species composition and productivity (aboveground phytomass) of the grassland along hill slopes, we used the data on constancy and productivity of sown species and other plant species growing on different parts of the hill slope at Sėliškės EFS (SENDŽIKAITĖ, 2000, 2002a).

## RESULTS AND DISCUSSION

Based on statistical analysis of our survey (SENDŽIKAITĖ, 2000, 2002a, b) as well as the data of other researchers (LAPINSKIENĖ, 1986, unpublished data; PANCEKAUSKIENĖ, 1987, unpublished data; BALEVIČIENĖ, 1991; RAŠOMAVIČIUS, 1998), we found a significant positive relationship ($r_{50} = 0.84$) between the number of vascular plant species and grassland age (Fig. 2). This indicates that under temperate climate conditions, the richness of plant species in extensively used sown grasslands increases with the age. The number of vascular plant species in sown grasslands of 30–35 years after sowing is similar

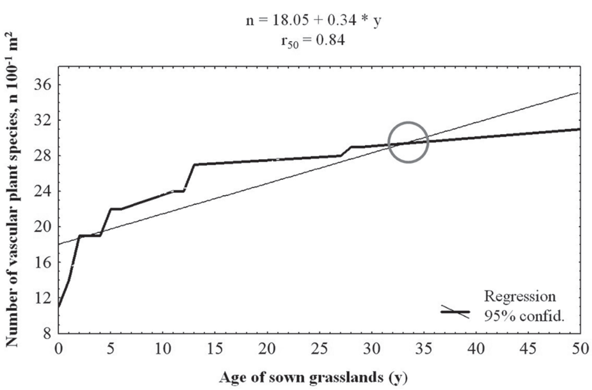


Fig. 2. Hypothetical correlation (r) between the number (n) of vascular plant species and the age (y) of sown grassland

to that of natural *Festucetum pratensis* communities. Although it is a time-consuming technique, we should note that this is a relatively cheap and effective method for the restoration of species richness in formerly intensively used agricultural areas.

SMITH et al. (2003) suggested that the restoration of hay-meadows might take over 20 years when using extensive management only (assuming a linear increase in species richness). It was noted that an increasing richness of plant species within time, as the species in the region had the opportunity to colonize, although rare species, dependent on disturbance, might require additional years for the recovery of their population (TIKKA et al., 2001). Increase in species richness during restoration is possible only if a large pool of suitable species has been preserved near the site, and if the species are able to spread to the site within a moderate time. The species richness of a community depends both on the pool of available species and on biotic mechanisms that lead to the exclusion of some of the species from a community (ZOBEL, 1997). In our case, the richness of vascular plant species increased within time, because non-sown species (e.g. *Vicia cracca*, *Trifolium pratense*, *Medicago lupulina*, *Centaurea jacea*, etc.) constantly colonized the sown grassland (Fig. 3).

According to our research data, the competitive species *Festuca pratensis*, *F. rubra*, *Phleum pratense*, *Poa pratensis* as well as *Trifolium repens* (species included in most seed mixtures) easily consolidate in the grassland and for many years remain constant and often dominate in mesophilous communities. Similar features are also characteristic to *Dactylis glomerata*, however, the constancy of this species in natural communities is not very high. *Lolium perenne* and *Trifolium hybridum* are not typi-

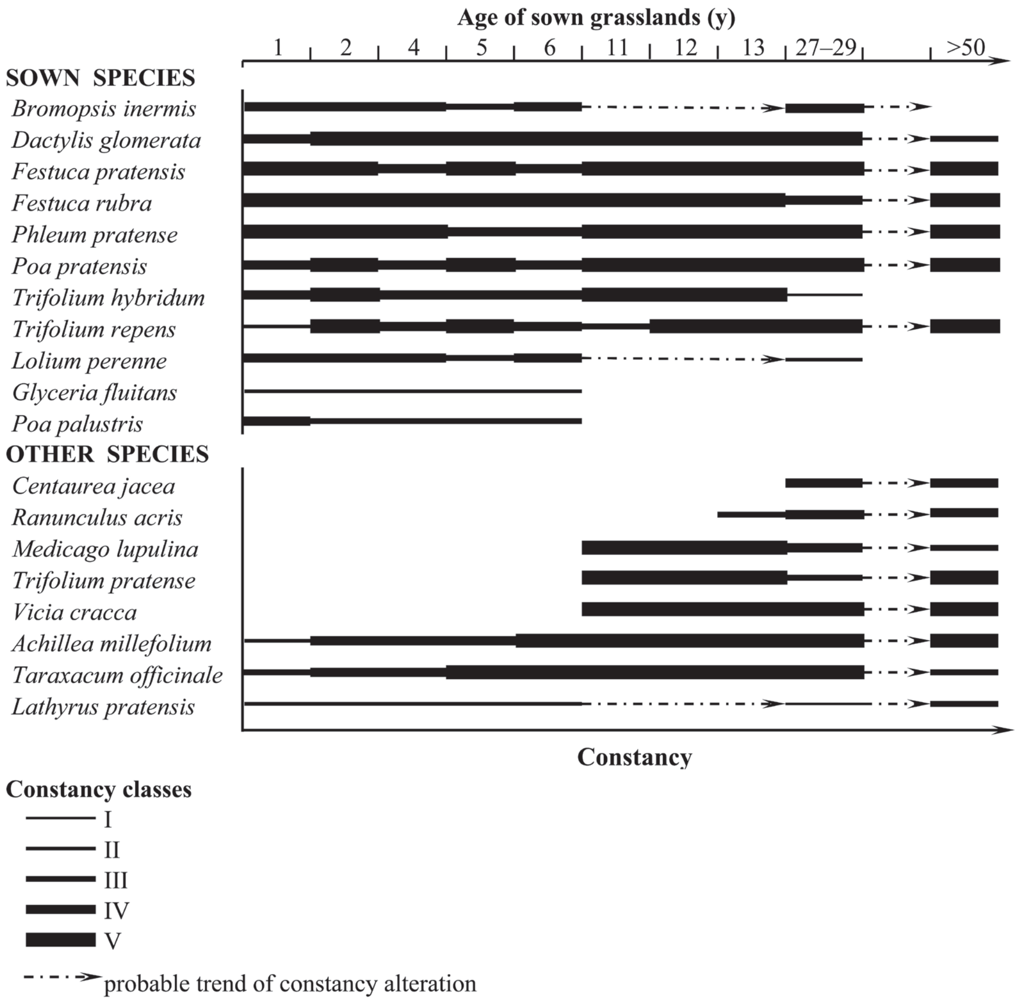


Fig. 3. Constancy alteration chronocline of vascular plant species of sown grasslands

cal in natural grasslands of *Festucetum pratensis* in Lithuania. Although they are not very stable, they can remain for many years in properly maintained mesophilous grasslands. Non-adaptable to ecological conditions species are usually eliminated from the grassland and more adaptable ones occupy their place. In mesophilous communities, the sown-in hygrophytes (*Glyceria fluitans* and *Poa palustris*) appeared to be the weakest competitive species unable to adapt under unfavourable insufficient humidity conditions. During the first years of running, the grassland is formed not only of sown-in species, but also of other species grown up from vegetative parts of plants and seeds occurring in the soil. Török et al. (2010) indicate that using low-diversity seed mixtures can lead to the restoration of basic grassland vegetation dominated by perennial grasses as fast as in 3–4 years and the immigration of rare herbaceous species can be very slow. According to our data within several years, *Achillea millefolium*, *Taraxacum officinale* (in drier habitats) as well as *Lathyrus pratensis* (mesic habitats) and other species become more and more constant in the communities. High constancy of *Vicia cracca*, *Trifolium pratense*, *Medicago lupulina*, *Ranunculus acris*, *Centaurea jacea* and other species was observed in the grasslands that were run for over 10 years. However, no redlisted species were found.

To explain how individual vascular plant species impact the aboveground phytomass of grasslands (10–12th year of running) depending on habitat topographical situation (hill slope), we developed a constancy and productivity alteration topocline of vascular plant species of sown grassland communities (Fig. 4).

We grouped the vascular plant species according to their constancy and productivity on individual parts of the hill slope into four groups:

Group 1 – constant species found on all parts of the slope (mesophytes – *Dactylis glomerata*, *Festuca pratensis*, *F. rubra*, *Phleum pratense*, *Poa pratensis*, *Alopecurus pratensis* and *Achillea millefolium*). The aboveground phytomass of individual species depends on soil moisture. On the top and upper part of the slope, the highest phytomass is produced by *Dactylis glomerata* (up to 41% and 48% of phytomass); on the middle part of the slope – *Alopecurus pratensis* (up to 28%) and *Dactylis glomerata* (up to 25%); on the lower part of the slope – *Phleum pratense* (up to 22%) and *Alopecurus pratensis* (up to 17%).

Group 2 – constant species producing low aboveground phytomass on the top of the hill and upper part of the slope – mostly xeromesophytes (*Anthemis tinctoria*, *Leucanthemum vulgare*, *Medicago lupulina*) and xerophytes (*Potentilla argentea*).

Group 3 – high constancy vascular plant species producing varying aboveground phytomass on the middle and lower parts of the slope. Mesophytes (*Carex hirta*, *Elytrigia repens*, *Tussilago farfara*) and hygromesophyte *Phalaroides arundinacea* dominate. The highest aboveground phytomass on the middle part of the slope is produced by *Phalaroides arundinacea* (up to 41 %) and *Carex hirta* (up to 18 %).

Group 4 – high constancy vascular plant species producing low aboveground phytomass on the lower part of the slope (mesophytes *Anthriscus sylvestris*, *Lathyrus pratensis*, *Lysimachia nummularia*, hygromesophytes *Deschampsia cespitosa*, *Filipendula ulmaria*, *Juncus compressus* and hygrophyte *Stellaria palustris*). The most significant species of the group is *Lathyrus pratensis*, a valuable fodder plant producing up to 14% of the aboveground phytomass.

To retrieve a traditional small-scale and environment-friendly farming in abandoned agricultural areas, we should not only select an optimal grassland management way, but also, if it is necessary, choose proper seed mixtures or other restoration techniques for renovation of degraded grasslands. Our research data indicated that seed mixtures for grassland renovation on a hilly relief should contain the competitive species with biological and ecological characteristics corresponding particular ecological conditions of habitats. General analysis of the data presented in this paper, both obtained by the author and found in literature references (Lapinskienė 1986, 1999; Rašomavičius 1998; Pancekauskienė & Ėringis 1999; etc.), enable to recommend plant species used in mesoxerophilous, mesophilous and mesohygrophilous seed mixtures corresponding to ecological diversity of hilly relief habitats under the Lithuanian natural conditions (Table 1).

Mesoxerophilous mixtures used for sown grasslands on the upper part of a hill slope should contain the *Fabaceae* family plants (*Medicago falcata*, *Onobrychis viciifolia*, *Trifolium hybridum*, *Vicia*

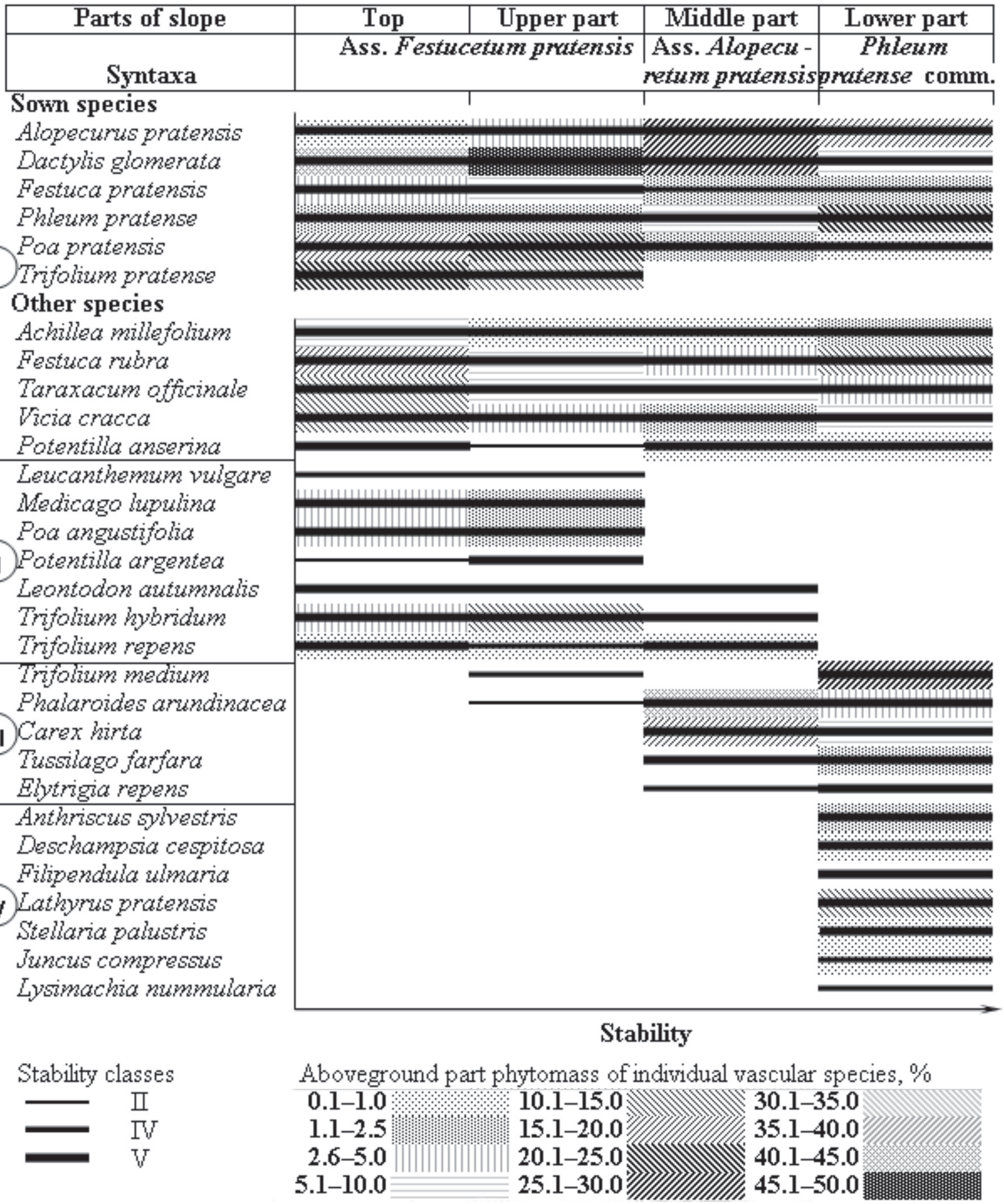


Fig. 4. Constancy ant productivity alteration topocline of vascular plant species of sown grasslands

*cracca*). On eroded infertile soils with insufficient humidity in growth season, the *Poaceae* family plants can suffer from drought and produce a poor harvest. Meanwhile, the *Fabaceae* family plants with long taproots are able to provide themselves with moisture from deeper layers of soil. Besides, even growing in nitrogen-poor habitats they improve soil fertility due to *Rhizobium* bacteria by enriching it with nitrogen and organic matter. The data obtained by Maikštienė & Arlauskienė (2001) state that the *Medicago* and *Trifolium* genera plants accumulate up to 100–235 kg ha$^{-1}$ of biological nitrogen in dead parts and roots, which is very important to sustain potential productivity of soil and grasslands.

On the middle part of a slope, it is suggested to use *Festuca pratensis*, *F. rubra*, *Poa pratensis*, *Phleum pratense*, *Lathyrus pratensis*, *Trifolium pratense*, *T. repens* in mesophilous seed mixtures. On the low-

Table 1. Plant species recommended to use in seed mixtures for grassland formation on a hilly landscape

| Parts of slope | Top of a hill, upper part | Middle part | Lower part |
|---|---|---|---|
| Type of seed mixture | Mesoxerophilous | Mesophilous | Mesohygrophilous |
| Species | | | |
| *Medicago falcata* | + | | |
| *Onobrychis viciifolia* | + | | |
| *Trifolium hybridum* | + | | |
| *Poa pratensis* | + | + | |
| *Trifolium repens* | + | + | |
| *Dactylis glomerata* | + | + | + |
| *Festuca pratensis* | + | + | + |
| *Festuca rubra* | + | + | + |
| *Vicia cracca* | + | + | + |
| *Phleum pratense* | | + | + |
| *Lathyrus pratensis* | | + | + |
| *Trifolium pratense* | | + | + |
| *Alopecurus pratensis* | | | + |
| *Beckmannia eruciformis* | | | + |
| *Phalaroides arundinacea* | | | + |
| *Poa palustris* | | | + |

er part of a hill slope, in addition to *Poaceae* family plants (*Alopecurus pratensis*, *Poa palustris*) rather effective *Phalaroides arundinacea* could be used as a valuable fodder rhizoid plant producing a considerable aboveground phytomass as well as luxuriant aftermath. An appropriate selection of species for grassland formation as well as proper management influence grassland's longevity, quality and crop capacity.

Based on the above-mentioned data as well as the results obtained by other investigators (Balevičienė, 1991; Rašomavičius, 1998), we worked out a scheme of sown grassland naturalization on a transformed hilly landscape (Fig. 5).

The initial starting point was considered to be grassland seed mixtures selected taking into account ecological and hydrological conditions of habitats. A mesophilous seed mixture (e.g. *Festuca pratensis*, *F. rubra*, *Poa pratensis*, *Dactylis glomerata*, *Trifolium pratense*, etc.) is commonly used for the establishment of grasslands on average humidity habitats. On the 2nd–4th years of running – *the stage of prevalence of cultural components* (Mirkin et al., 2001) – the sown species stabilize in the grassland, among which *Dactylis glomerata* is the most stable and abundant (*Dactylis glomerata* stage). Subsequent course of the succession depends upon habitat edaphic and hydrological conditions as well as the character of grassland management. In the habitats with a sufficient amount of available nutrients, properly maintained grassland transforms into the Ass. *Festucetum pratensis* communities. Under extensive management, grassland succession becomes more intensive; therefore, on a little drier eroded sod-podzolic soils the communities of the *Trifolio-Geranietea sanguinei* class (e.g. *Trifolion medii*) can form. Within many years the latter can transform into mixed forests (a zonal type of Lithuanian vegetation). Eventually, in the habitats with lower amount of available nutrients and insufficient soil humidity, the All. *Cynosurion cristati* communities can form of the mesophilous mixture.

After some years of abandonment, the grasslands that were formed from mesophilous or mesohygrophilous mixtures begin to degrade, especially in the habitats with sufficient amount of available nutrients (the soil is rich in humus and nitrogen compounds). Due to favourable conditions for the growth of nitrophilous plants (*Urtica dioica*, *Anthriscus sylvestris*, *Artemisia vulgaris*, etc.), the *Artemisietea vulgaris* communities occur. The discussed-above phenomena were observed in the grasslands established on drained peat bogs.

In the habitats with a well aerated, sufficiently humid and rich in available nutrients soil, the communities of *Alopecurion pratensis* alliance can form from

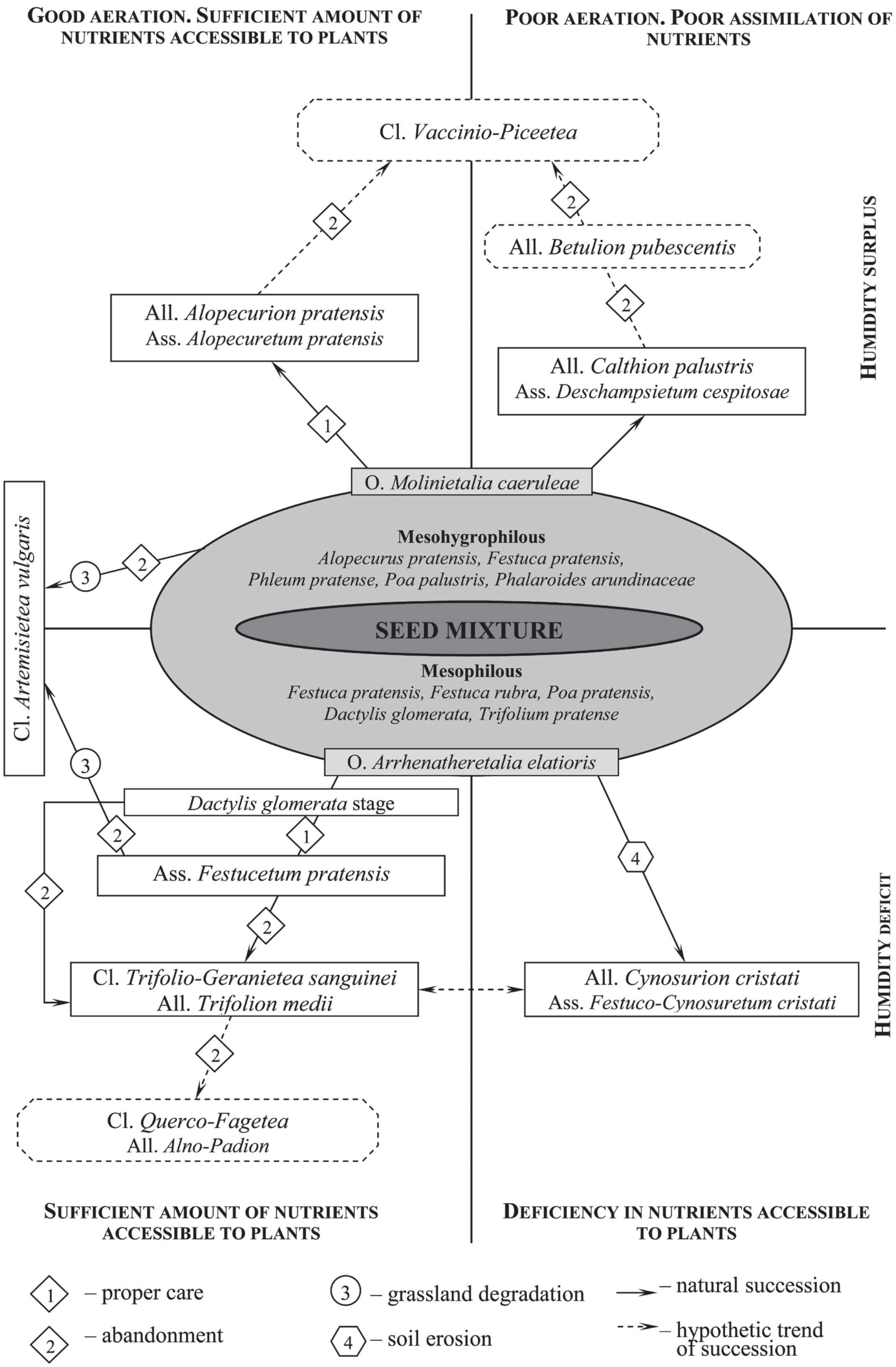


Fig. 5. Scheme of sown grassland naturalization on a hilly landscape transformed by land reclamation

mesohygrophilous mixtures (*Alopecurus pratensis*, *Festuca pratensis*, *Phleum pratense*, *Poa palustris*, *Phalaroides arundinacea*). The *Calthion palustris* alliance communities (*Deschampsietum cespitosae*) establish in improperly managed areas, where soil is badly aerated and plants poorly assimilate nutrients. A.-P. Huhta (1996) affirms that *Deschampsia cespitosa* tends to increase in the cover after the cutting or grazing ceases. This species is most abundant in fields abandoned for 15–24 years.

Based on the developed scheme of sown grassland naturalization, the succession of abandoned grasslands towards mixed forest formation is as follows: under surplus humidity and poor aeration conditions – to *Vaccinio-Piceetea*, while under humidity deficiency conditions in more fertile soils – to *Querco-Fagetea*. Thus, forest might again eventually advance at the expense of grassland. All lies on land originally cleared from forest and, without any management, would revert to forest through a process of natural succession (Green, 1990). Pasturage and haymaking hinder overgrowth with shrubs and trees as well as condition the formation of grasslands with wide diversity of species. Development of grasslands depends upon different factors manifesting simultaneously. In case the factor provoking alterations in communities is not replaced by another one and remains steady, the communities become rather stable (for example, in the countryside the pastures survive for hundreds of years).

## CONCLUSIONS

The presented models of grassland naturalization enable to prognosticate directions of sown grassland succession depending on ecological conditions and habitat management. Positive correlation ($r_{50} = 0.84$) between the number of vascular plant species and the age of sown grassland shows that richness of plant species in extensively used sown grassland increases within the age. Under favourable conditions and proper management, grazed or mown formerly cultivated fields might develop to species-rich semi-natural vegetation types. On the other hand, the termination of cutting and grazing results in the process of succession of natural vegetation and the colonization by trees leading to forest, which is a natural climax vegetation in Lithuania. Therefore, the future grasslands depend on specific habitat conditions, farming and recreational possibilities.

Naturalization enlarges the diversity of species in sown grassland and induces restoration of biological diversity on large areas, where landscape was intensively drained on the second half of the $20^{th}$ century. Naturalization of sown grasslands is considered as a method for ecological restoration requiring minor investments. Conservation of extensively used naturalized grasslands is important to preserve biological and landscape diversities as well as to develop agricultural tourism, especially in the areas, where economic activity is currently impaired.

## IMPLICATIONS FOR PRACTICE

Restoration of semi-natural ecosystems by naturalization of sown grasslands under temperate climate conditions involves exceptional advantages compared to other restoration methods. It is comparatively cheap, undemanding for huge long-term investments and labour expenditures. The chances for the establishment of alien, poorly adapted to ecological conditions plants of genotypes unacceptable in particular areas are lower (the danger of alien plant species invasion still remains). It is necessary to consider that diasporas can spread into the sites undergoing naturalization from the neighbouring sites or regenerate from the soil seed bank. This method does not demand for complete suspension of economic activity and grassland exploitation.

It is most beneficial to apply this method in *protected areas* because of the necessity to sustain the diversity of ecosystems, to create favourable conditions for the existence and development of biological diversity. Gradual long-term process of sown grassland naturalization conditions the establishment of different rare and protected species of plants capable to adapt to grassland succession stages.

Application of this method in the *areas of economic priority* is different: 1. It is effective in the areas characterized by wide diversity of site ecological conditions as well as sown and natural grassland sites arranged in mosaic; 2. Less reasonable in the areas, where the diversity of site ecological conditions is poor, sown grasslands cover large areas and there are only few natural sites capable to serve as donors of diasporas; 3. Not always effective in the drainage areas with thick peat soil layer.

To work out projects on ecological restoration of grasslands undergoing naturalization, it is necessary to point out the primary species composition of the grassland, specific ecological conditions and reference ecosystems. Based on the above-discussed data, priority should be given to the establishment of types of the future grassland ecosystems potentially capable to sustain particular desirable species diversity and other values of biological diversity. In accordance with definite objectives, the most relevant ways and methods for the management and maintenance of the grassland undergoing restoration can be selected.

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## SĖTŲ PIEVŲ BOTANINĖS ĮVAIROVĖS KAITOS DĖL ŽOLYNŲ NATŪRALĖJIMO IR EKSTENSYVAUS NAUDOJIMO

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### Santrauka

Straipsnyje pateikti sėtų pievų natūralėjimo modeliai, susiję su ekstensyviai naudojamų žolynų botaninės įvairovės kaitomis vidutinio klimato sąlygomis. Daugiamečiai augalijos kaitų tyrimai atlikti Sėliškių ir Polymos eksperimentinių tyrimų stotyse (Utenos r., Rytų Lietuva). Remdamiesi mūsų pačių atliktais tyrimais bei literatūros šaltinių apie Lietuvos natūralių pievų augaliją analize sukūrėme induočių augalų rūšių pastovumo laike (chronoklinas) ir erdvėje (topoklinas) modelius bei pateikėme sėtų pievų natūralėjimo kalvotame kraštovaizdyje schemą. Ekstensyvus sėtų pievų naudojimas ir su tuo susijęs žolynų natūralėjimas yra efektyvi ir didelių investicijų nereikalaujanti botaninės įvairovės atkūrimo priemonė, taikytina anksčiau žemės ūkyje intensyviai naudotose, o dabar apleistose ar minimaliai tvarkomose teritorijose.