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Assessment of an abandoned grassland community and the soil seed bank of a hilly relief

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Abstract

The importance of grasslands is closely linked to biodiversity and soil health. Changes in plant diversity reflect the environmental conditions and practices of grasslands management. The aim of this study was to investigate the impact of abandonment on the grassland community and soil seed bank under the conditions of a hilly relief. The experiment was carried out at the Vėžaičiai Branch of the Lithuanian Research Centre for Agriculture and Forestry on the hilly topography of Žemaičiai Highland. The study analyses long-term monitoring data of a soil erosion experiment set up on the slopes of 9–11° steepness. The soil of the southern exposition slope was a slightly eroded *Eutric Retisol.* In 1993, to protect the hill from erosion, a mixture of five grasses consisting of 20% timothy grass (*Phleum pratense* L.), 20% red fescue (*Festuca rubra* L.), 20% meadow grass (*Poa pratensis* L.), 20% white clover (*Trifolium repens* L.), and 20% common bird's-foot trefoil (*Lotus corniculatus* L.) was sown in different parts of the hill: the summit, the midslope, and the footslope. The grassland had not been fertilised and used. After 27 years, 56 vascular plant species were identified. In the summit, midslope, and footslope parts of the hill, the relative abundance (P%) of the sown species was 17.2%, 23.9%, and 27.2%, respectively. A good growth of *Festuca rubra* did not depend on abandonment. In all parts of the hill, P% of other sown species significantly decreased. The low-value plants (*Elytrigia repens* L., *Cirsium arvense* L., and *Equisetum arvense* L.) spread in grasslands. The soil seed bank of abandoned grasslands was composed of the arable weeds: *Chenopodium album* L. was the dominant species in the soil seed bank of the summit of the hill (0–15 cm depth), while *Stellaria media* (L.) Vill in the soil seed bank of the midslope, 31.3% and 18.4%, respectively, of the total seed number.

Keywords: abandoned meadow, floristic similarity, hillside ecotopes, plant species, relative abundance, soil seed bank.

Introduction

Grasslands occupy a large area of the land surface in a temperate climate zone. They are not only the core of forage production worldwide but also provide multiple additional ecosystem services such as carbon sequestration and erosion control (Tribot et al., 2018; Bengtsson et al., 2019; Hamanaka et al., 2019). Depending on local natural conditions, grasslands can be used in a variety of ways. Changes in plant diversity reflect the environmental (pedo-climate) conditions and management (mowing, fertilisation, grazing, etc.) practices (da Silveira Pontes et al., 2015). As soon as human impact on the natural environment declines, the process of re-naturalisation becomes more intensive. After 10–30 years, sown meadows have a similar structure and floristic composition as natural meadows (Sendžikaitė et al., 2013). The number of low-value species increases in unattended meadows (López-i-Gelats, Bartolomé, 2007), and trees and scrubs start to grow (Kulik, 2014). Neglect and abandonment of used grasslands can lead to the expansion of several dominant species and further to the expansion of invasive species (Pruchniewicz, Zołnierz, 2016).

Long-term (several decades) naturalisation process influences the structure of sown permanent grasslands phytocenoses: the floristic composition of vascular plants varies, their diversity increases, and phytocenotic role changes (Sendžikaitė et al., 2013). Functional plant traits are similar in mowed and abandoned communities, while functional diversity is lower in unmanaged communities (Uogintas, Rašomavičius, 2020). Despite the relatively low productivity of permanent grasslands, they remain a key source of forage in High Nature Value farming systems in Europe (Herzon et al., 2021).

The soil seed bank is a fundamental aspect of most plant communities and plays a vital role in the response of these communities to environmental perturbations such as changing climate and land use (Baskin, Baskin, 2014; Basto et al., 2015). The loss of species from the aboveground vegetation is caused by environmental change; however, seeds of these species may be buried and remain dormant in the seed bank through the storage effect (Basto et al., 2015). Grassland species are often

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found in the seed bank, where they disappear from the aboveground vegetation (Wagner et al., 2003). Seeds enter the soil through many sources, but the major source is plants that escape control and produce seeds within the field (Pupalienė et al., 2012; Auškalnienė et al., 2018). In some studies, the emergence of the plant population after cultivation was related to the size and composition of the soil seed bank (Hossain, Begum, 2015); nonetheless, in other studies (Gomaa, 2012), the relationship between soil seed bank and aboveground communities was found for only a small number of plant species.

The majority of seeds entering the seed bank come from annual weeds growing in the fields. The size of the seed bank reflects past and present field management (Auffret, Cousins, 2011). Auestad et al. (2013) indicated that the seeds accumulated in meadow soils often did not correspond to the species composition of meadow community. Janicka (2016) found that the species composition of the soil seed bank in studied sites corresponded to approximately 30–40% of the botanical composition of mowed and fertilised meadow swards. Wagner et al. (2003) state that the similarity between the seed bank and vegetation decreases with increasing time since abandonment and increasing soil depth. The importance of plant biodiversity is emphasised, because it is closely linked to soil health and functioning due to its benefits for soil microorganisms and other fauna (Lange et al., 2015).

About 14% of Lithuania's agricultural land is eroded, but this number is higher in a hilly relief where it comes up to 25–53% (Lietuvos dirvožemiai, 2001). Therefore, grasslands are the most important means for soil erosion prevention (Jarašiūnas, Kinderienė, 2016). Plants cover the soil surface and protect it from rain drops and subversion by wind (Wainwright et al., 2002); the root system, especially when the turf is already formed, is a good physical barrier for the water flows along the slopes (Skuodienė et al., 2020).

There is no research on the soil seed bank of abandoned grasslands in Lithuania yet. The hypothesis underlying the present study was that the rapidity of abandoned grasslands change is determined by the present characteristics of plants and environmental conditions. The disappeared species will be replaced by the remaining resistant and new species. Before the grassland establishment, the aboveground plant species will be found in the soil seed bank. It is important to know, which plant species spread in abandoned grasslands and what their perspectives of use are.

The aim of this study was to investigate the impact of abandonment on the grassland community and soil seed bank under the conditions of a hilly relief.

Materials and methods

Experimental site. The experiment was carried out at the Vėžaičiai Branch of the Lithuanian Research Centre for Agriculture and Forestry, on the midslope soil of Žemaičiai Highland covered by different anti-erosion agrophytocenoses (Jankauskas, Jankauskienė, 2003) in Kaltinėnai (lat. 55°577′ N, long. 22°482′ E, 185.0 m a. s. l.). The steepness of the slope was 9–11°. The soil of the southern exposition slope was slightly eroded *Eutric Retisol* (loamic) according to WRB (2015) with a texture of sandy loam. Agrochemical and physical properties of the soil are presented in Table 1.

Table 1. Agrochemical and physical properties of the arable (0–15 cm) soil layer (2020)

Soil properties	Part of the hill					
	summit		midslope		footslope	
	0–5 cm	5–15 cm	0–5 cm	5–15 cm	0–5 cm	5–15 cm
Soil acidity (pH_{KCl})	5.5	5.8	6.4	6.0	5.1	4.9
Mobile P_2O_5 mg kg^{-1}	53	40	96	46	38	14
Mobile K_2O mg kg^{-1}	254	138	251	132	330	154
N_{total} %	0.132	0.096	0.150	0.124	0.162	0.101
C_{org} %	1.1	1.0	1.5	1.2	1.6	1.1
Soil texture	sandy loam	sandy loam	sandy loam	sandy loam	sandy loam	sandy loam
Sand %	71.8	70.9	69.3	72.6	58.2	59.9
Silt %	22.6	23.2	25.2	21.9	32.8	30.0
Clay %	5.6	5.9	5.5	5.5	9.0	10.1
Soil moisture[1] %	23.0–28.8	16.5–22.4	23.0–25.8	17.7–21.9	25.6–35.2	19.3–31.1

[1] – min.–max. values during the growing season

The mixture of perennial grasses for the permanent grasslands, which consisted of 20% timothy grass (*Phleum pratense* L.), 20% red fescue (*Festuca rubra* L.), 20% meadow grass (*Poa pratensis* L.), 20% white clover (*Trifolium repens* L.), and 20% common bird's-foot trefoil (*Lotus corniculatus* L.), was sown in 1993. The grasslands were not fertilized and used. In 2020 and 2021, the floristic composition of the grasslands and the soil seed bank traits was evaluated. Several plants – *Malus sylvestris* (L). Mill., *Sorbus aucuparia* L. and *Ribes nigrum* L., typical of the later successional stages – were cut down in spring 2020, before the experiment. Parts of the hill: (1) the summit, (2) the midslope, and (3) the footslope. The length of the southern slope was 65 m. For plant and soil seed bank sampling, stationary square plots of 21 m^2 (7 × 3 m) were arranged on each part of the hill. Each model plot was split into three rectangular shape replicates of 7 m^2 (7 × 1 m). Distances between model plots in different parts of the hill were 15 metres.

During the period of 1991–2021, the average annual temperature was 6.7°C, whereas during the vegetation period it was 12.2°C. Over the same period, the annual average precipitation amounted to 789 mm, while in the vegetation period it was 481 mm.

Methods of analysis. The quantitative parameters: relative abundance (P%) and frequency of occurrence of every species (F%), of species participation in grassland phytocenoses were estimated by the De Vries method (Peeters, 1989; Skuodienė, 2004). Thirty plant samples were taken from each model plot and analysed. The location of samples in a model plot was chosen randomly. The index of relative abundance of species expressed in percentage (P%) was calculated according to the formula:

$P\% = F\% / \Sigma F\% \times 100$,

where F% is the frequency of occurrence of every species:

$F\% = n/N \times 100$,

where n is the number of samples, in which species were found; N – the total number of samples in a model plot; Σ F% – the sum of frequencies of occurrence of all the plant species in a model plot.

To compare the value of the grasslands, the agronomic value (VP) was used:

$VP = (\Sigma P\% \times Ii) / 10$,

Where Σ P% is the sum of relative abundance of the species found; Ii – the forage value score of the plant species.

To assess plant species attachment to hydrological regime, soil acidity (pH) and soil nutrition, the Ellenberg's (1992) scale was used. Plant species were sorted into ecological groups according to adaptation to soil moisture (xeromesophytes, mesophytes, hygromesophytes, hygrophytes), adaptation to soil acidity (highly acid, acid, moderately acid, slightly acid, neutral), adaptation to soil nutrition (oligotrophic, oligomesotrophic, mesotrophic, eutromesotrophic, eutrophic plants) and indifferent species. Only more significant groups of plants were discussed in the results.

To express floristic similarity of phytocenoses or similarity of the seed bank and actual vegetation, the coefficient of Sörensen (C_s) was used:

$C_s = 2w / (A + B)$,

where w is number of common species in both situations, A – number of species in one of two comparable situations, B – number of species in another situation.

To assess the impact of the hill slope on soil contamination by weed seeds, the seed bank was investigated at the depths of 0–5 and 5–15 cm. The seed bank was estimated from soil samples taken in spring of 2020 and 2021. In each model plot, 2 kg of soil from 20 positions were collected using an agrochemical drill. The soil was dried out. In total, five 100 g samples were taken out of 2 kg soil sample and weighed. Later, the soil samples were wet-sieved through a 0.25 mm sieve until all contents of the soil were washed out. The remaining mineral part of the soil was separated from the organic part and weed seeds using the saturated salt solution (Pupalienė et al., 2012). Weed seeds were identified using binoculars with 8.75× magnification. Weed seed species were determined by Grigas (1986). The number of weed seeds (A) was recalculated to thousands of unit per m^2:

$A = n \times h \times p \times 100$,

where A is number of seeds, seeds, m^2; n – the counted number of seeds in the soil sample; h – the depth of plough layer, cm; p – soil bulk density, g cm^3.

Chemical analyses were carried out at the Chemical Research Laboratory of the Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry. Before establishing the experiment, soil agrochemical characteristics were determined from the samples taken from the depths of 0–5 and 5–15 cm. Soil acidity (pH) was measured by the potentiometric method in the extraction of 1 M KCl (pH_{KCl}) according to standard ISO 10390:2005 (Soil quality – Determination of pH). In the soil, mobile P_2O_5 and K_2O were determined using the Egner-Riehm-Domingo (AL) method (LVP D-07:2016), total nitrogen (N_{tot}) content by the Kjeldahl method, and organic carbon (C_{org}) by the Dumas dry combustion method. Soil bulk density was determined with a 100 cm^3 cylindrical drill by the Kachinsky method. Soil moisture content was evaluated every 3–4 weeks during the plant vegetation period in 2020–2021 and expressed on a dry weight basis after oven drying to a constant weight at 105°C temperature. Soil texture was determined by the Fere triangle (FAO recommended method) according to the percentage of sand, silt, and clay fractions in the graphical diagram.

Statistical analysis. Significance of the differences between the means was determined according to the Fisher's protected least significant difference (LSD) at 0.05 probability level. The experimental data were subjected to the analysis of variance (ANOVA) (Raudonius, 2017). The average data of the experiment are presented in Tables 3 and 4. Interaction between the examined factor and years was not determined. The actual data of the seed bank were transformed (Sqr(x + 1)).

Results and discussion

Diversity and distribution of plant species. Over 27 years, species composition in sown meadow changed considerably due to spontaneous plant spread. Some of the sown plant species decreased, and the others spread, and new unsown species emerged. In total, 56 vascular plant species belonging to 17 families were identified in the abandoned grasslands during the experimental period (2020–2021) (Table 2). The dominant plant families were Asteraceae (14 species) and Poaceae (10 species). The variety of species was greater compared with the semi-natural meadow of the Minija mid-riverbanks with 23–33 species of vascular plants (Nekrošienė, Skuodienė, 2012). Similar findings were also reported by Uogintas and Rašomavičius (2020), where 46 species were identified in unmanaged plots.

Sown species in the grasslands amounted averagely to 17.2, 23.9, and 27.2 P%, respectively, in the summit, midslope, and footslope parts of the hill (Table 3). In the grasslands, *Trifolium repens*, *Lotus corniculatus*, *Poa pratensis*, and *Phleum pratense* decreased. Under the conditions of a hilly relief, plants germinate, grow, and develop unequally (Jarašiūnas, Kinderienė, 2016).

Due to the increased amount of physical clay and silt in lower parts of slope, the resources of soil moisture as well as the amounts of humus and nutrients increase but soil acidity decreases (Table 1). Due to unequal edaphic conditions in different parts of the hill and competition of various plant species, the diverse composition of phytocenoses species was determined, although the number of vascular plant species forming phytocenoses was similar: from 24 to 29 species in 2020 and from 24 to 32 in 2021 (Table 2). Unequal composition of species was confirmed by the coefficient of Sörensen (C_s): 0.56–0.61 in 2020 and 0.54–0.67 in 2021. The largest number of species was identified in the summit part of the hill. However, during the experimental period, no dominant or subdominant species common for the whole association were identified, only secondary and rare species were found. Unlike in the summit part, subdominant species (*Festuca rubra*), which forms phytocenoses, was found in the midslope and the footslope parts of the hill. Competitive species *F. rubra* that is included in most of the sown meadow seed mixtures consolidate easily in the grasslands and dominate in mesophillous phytocenoses (Sendžikaitė et al., 2013). As species forming the phytocenoses, *Dactylis glomerata*, *Elytrigia repens*, *F. rubra*, and *Vicia cracca* can be partly considered. It was observed that the distribution of these herbaceous plant species in phytocenoses was increasing in the

Table 2. Species diversity and their distribution (P%) in the grasslands

Plant species	Botanic family	Part of the hill					
		summit		midslope		footslope	
		2020	2021	2020	2021	2020	2021
Anthriscus sylvestris L.	Apiaceae	2.9	3.9	5.7	3.5		
Carum carvi L.		0.7		0.8			
Achillea millefolium L.	Asteraceae	6.5	7.8	4.1	3.5	0.7	
Artemisia vulgaris L.		0.7	0.6			0.7	1.3
Cirsium arvense L.		4.3	5.0	9.8	2.5	1.4	6.7
Conyza canadensis L.		0.7				0.7	
Gnafalium sylvaticum L.			1.1		1.0	0.7	
Hieracium umbellatum L.			0.6	0.8			
Hypochaeris radicata L.					0.5		
Leontodon autumnalis L.					0.5		
Leucanthemum vulgare Lam.					0.5		
Pilosella caespitosa (Dumort.) P.D. Sell et C.West		0.7	2.8				
Pilosella officinarum F.V. Schultz et Sch.Bip.		0.7					
Sonhus spp.					3.0	0.7	1.3
Taraxacum officinale F.H. Wigg.		0.7		4.1	6.0	12.7	
Tragopogon pratensis L.							1.3
Campanula patula L.	Campanulaceae		0.6	0.8			
Campanula rotundifolia L.				0.8	1.5	0.7	
Silene vulgaris (Moench) Garcke	Caryophyllaceae	0.7	0.6	1.6		0.7	
Stellaria graminea L.			1.7		2.0	0.7	
Convolvulus arvensis L.	Convolvulaceae				0.5		
Equisetum arvense L.	Equisetaceae	12.3	12.8	4.1	9.5	5.6	
Equisetum sylvaticum L.			2.2				
Lathyrus pratensis L.	Fabaceae		0.6		0.5		2.7
Lotus corniculatus L.		0.7		0.8	1.5	4.9	6.0
Medicago lupulina L.					0.5		
Trifolium repens L.		0.7					
Vicia cracca L.		14.5	5.6	4.5	9.5	16.9	9.4
Vicia sepium L.				4.1		5.6	
Hypericum perforatum L.	Hypericaceae					0.7	
Mentha arvensis L.	Lamiaceae	0.7		0.8	1.0		
Prunella vulgaris L.			0.6	0.8			
Stachys palustris L.			5.0			0.7	4.0
Epilobium montanum L.	Onagraceae	0.7	1.1				
Plantago lanceolata L.	Plantaginaceae	0.7			0.5	0.7	
Agrostis stolonifera L.	Poaceae	2.9	1.1	0.8	0.5	2.1	0.7
Alopecurus pratensis L.				0.8			0.7
Anthoxanthum odoratum L.			0.6				
Dactylis glomerata L.		9.4	10.1	6.5	9.0	12.7	10.1
Elytrigia repens L.		9.4	3.4	17.1	8.0	4.9	6.0
Festuca ovina L.		0.7					
Festuca pratensis Huds.		8.0	1.7	0.8	2.0		3.4
Festuca rubra L.		15.1	16.2	23.0	14.5	20.6	18.1
Phleum pratense L.			0.6	3.3	3.0	1.4	1.3
Poa pratensis L.			0.6	0.8	0.5	1.4	0.7
Rumex acetosella L.	Polygonaceae		0.6		0.5		
Rumex crispus L.		0.7	0.6			0.7	
Fragaria vesca L.	Rosaceae	0.7				1.4	
Geum rivale L.		1.4	1.7		2.0		
Geum urbanum L.			2.2				
Galium aparine L.	Rubiaceae	0.7					
Galium mollugo L.			2.2	3.3	10.0		
Galium spurium L.			5.0		2.0		
Veronica arvensis L.	Scrophulariaceae		1.1				
Veronica chamaedrys L.		1.4					
Veronica longifolia L.		0.7					

P% – index of relative abundance of species

Table 3. Quantitative characteristics of grasslands, 2020–2021

Part of the hill	Number of species in grasslands	Agronomic value of grasslands	Sown species P%	Total Poaceae P%	Total Fabaceae P%	Total other species P%	Meso-phytes %
Summit	30.0 a	49.5 b	17.2 b	39.9 a	11.0 b	49.0 a	55.5 b
Midslope	27.0 ab	55.0 a	23.9 ab	45.5 a	10.7 b	43.8 b	57.4 b
Footslope	24.5 b	58.9 a	27.2 a	42.0 a	22.7 a	36.3 c	66.9 a

Note. Different letters indicate significant ($p < 0.05$) differences between the means.

downslope direction (41.8, 46.2 and 49.4 P%) during the experimental period.

The diversity of plant species has been increasing together with the grassland naturalisation process. However, the number of low-value species (*E. repens*, *Cirsium arvense* and *Equisetum arvense*) increased in the abandoned grasslands as well. The average data of 2020–2021 show that the relative abundance of these species reached 23.6 and 25.5 P% in the summit and the midslope of the hill (Table 2).

Edaphic factors such as soil moisture, acidity and nutrition are probably very important to grasslands phytocenoses succession. It was found that 55.5%, 57.4%, and 66.9% in the summit, the midslope, and the footslope of the hill, respectively of all vascular plants of the meadow were mesophyte species. In the hilly meadow, soil acidity was not determining factor for the greater part (61.8–68.0%) of plants. The greater part of mesotrophic plants was found in the summit and footslope parts and eutromesotriphic plants – in the midslope part of the hill (35.6%, 25.4%, and 32.9 %, respectively). Depending on the partition of the relief, various soil moisture and plant nutrition conditions determine different phytocenoses species composition (Nekrošienė, Skuodienė 2012; Sendžikaitė et al., 2013).

The agronomic value of the grasslands depended on the amount of Fabaceae species and the relief as well. The largest part (22.8 P%) of Fabaceae species was determined averagely in the footslope part of the hill. Due to the greater amount of Fabaceae species, the agronomic value of the grasslands was greater in the footslope and medium in the summit and midslope parts of the hill (Table 3).

Seed distribution in the soil. The seed bank is the resting place of seeds and an important component of the life cycle of plants (Hossain, Begum, 2015). The average data for 2020–2021 show that at the soil depth of 0–15 cm of the abandoned grasslands, the number of seeds reached 4192, 4708, and 4142, respectively, in the summit, the midslope, and the footslope parts of the hill (Table 4).

Table 4. Quantitative characteristics of the soil seed bank, 2020–2021

Part of the hill	Number of species in soil seed bank	Seed number m^{-2}			Coefficient of Sörensen[1]
		0–5 cm depth	5–15 cm depth	0–15 cm depth	
Summit	17.0 a	1976.5 a	2215.0 a	4191.5 a	0.09 / 0.23
Midslope	13.5 a	2445.5 a	2263.5 a	4708.5 a	0.11 / 0.19
Footslope	14.5 a	2060.5 a	2081.5 a	4142.0 a	0.19 / 0.17

Note. Different letters indicate significant ($p < 0.05$) differences between the means; [1] – comparison of vegetation and seed bank in 2020 / 2021.

In the soil seed bank of the midslope of the hill, the number of seeds was by 12.3% and 13.7% higher compared to the summit and footslope parts. A small number of seeds identified in the soil of long-abandoned meadows conform to the data of the research done by Wagner et al. (2003). The species composition of the flora may be more important than the total number of seeds (Jastrzębska et al., 2013). In our experiment, the seeds represented 32 species including 11 meadow species, 20 segetal, and one tree (Table 5).

Table 5. Seed species composition of grassland soil (%) at the depth of 0–15 cm

Plant species	Botanic family	Part of the hill					
		summit		midslope		footslope	
		2020	2021	2020	2021	2020	2021
Chenopodium album L.	Amaranthaceae	33.8	28.7	14.1	12.6	8.0	21.4
Centaurea cyanus L.	Asteraceae		6.9				
Cirsium arvense (L.) Scop.		7.7	4.0	9.1	9.2	2.7	14.3
Lapsana communis L.			1.0				
Sonchus oleraceus L.		3.1	1.0	1.0	1.7	3.5	4.5
Betula pendula Roth.	Betulaceae	3.1	1.0				
Myosotis arvensis L.	Boraginaceae		1.0				
Capsella bursa-pastoris (L.) Medik.	Brassicaceae	1.5					
Erysimum cheiranthoides L.			7.9		0.6		2.7
Stellaria media (L.) Vill.	Caryophyllaceae	12.3	9.9	24.2	12.6	2.7	3.6
Silene vulgaris L.		12.3		20.2	33.3	8.0	2.7
Spergula arvensis L.		3.1	1.0		1.7	0.9	
Lotus corniculatus L.	Fabaceae	1.5	15.8	6.1	19.0	2.7	25.0
Trifolium arvense L.			1.0	3.0		1.8	
Trifolium repens L.			3.0	1.0	2.9		1.8
Vicia cracca L.						1.8	
Vicia irsute L.							15.2
Vicia villosa Roth.				1.0			
Juncus bufonius L.	Juncaceae		2.0		1.1		0.9
Galeopsis ladanum L.	Lamiaceae		5.0				
Galeopsis tetrahit L.						0.9	
Lamium purpureum L.						1.8	
Stachys palustris L.		1.5	1.0				
Epilobium montanum L.	Onagraceae		4.0				
Fumaria officinalis L.	Papaveraceae	10.8		4.0		24.8	
Papaver rhoeas L.						29.2	0.9
Poa annua L.	Poaceae		1.0				
Fallopia convolvulus (L.) A. Löve.	Polygonaceae	4.6	1.0	2.0		2.7	
Rumex acetosella L.			2.0		0.6		
Rumex crispus L.						0.9	
Veronica arvensis L.	Scrophulariaceae	1.5	2.0	2.0	3.5	1.8	
Viola arvensis Murr.	Violaceae	3.1		12.1	1.1	6.2	7.1

In the soil seed bank, the most numerous were dicotyledonous species of the arable land use. Similar findings were also reported by Kurdyukova (2018). Lopez-Marino et al. (2000) indicate that after changing the land use form from arable to grassland, over half of the seed bank in the soil is often composed of the arable weeds creating long-term persistent seed banks that are non-significant for the structure of grassland community. One of the reasons for this phenomenon is the low dispersal and accumulation ability of the diaspores (Janicka, 2016). Moreover, the seeds of most target species from the mesic grassland, especially grass seeds, tend to remain in the soil for a short time (they form only a transient seed bank). This is mainly due to their limited viability, usually from three to five years (Smith et al., 2002). Other authors point out that soil seed banks are typically characterised by their longevity and are determined by how long an individual seed may reside within it in a viable state. This longevity depends primarily on plant species (Hossain, Begum, 2015). Moreover, Lewis et al. (2013) found that arable weed seed banks are essential for the sustainability of cropping systems, because they provide the basis for the aboveground flora that contributes to biodiversity and supports ecosystem services within otherwise simplified agroecosystems.

The species composition of the soil seed bank in nearby parts of the hill varied slightly (Cs = 0.63–0.76). The most similar species composition of the soil seed bank was in the summit and midslope parts of the hill (Cs = 0.76), while it was the greatest in the summit and footslope parts of the hill (Cs = 0.63). On the other hand, the size of the reserve of seeds in the soil was diverse. *Chenopodium album* was the dominant species in the soil seed bank of the summit of the hill (0–15 cm depth), while *Stellaria media* in the soil seed bank of the midslope – 31.3% and 18.4% of the total seed number, respectively. In the soil seed bank of the footslope of the hill, these species formed only 17.2%, while the seeds of other species (*Papaver rhoeas*) formed the main part (15.1%) of the soil seed bank. *Ch. album* form a persistent seed bank with the ability to remain viable in the soil for many decades (Hossain, Begum, 2015). It is possible that in previous years, the number of weeds in crops was greater than in the summit part of the hill due to lower weed competition with crops. The seeds of *Ch. album* are still found in the soil seed bank because of their characteristic feature of longevity.

The number of seeds at the soil depth of 0–5 and 5–15 cm changed depending on the relief. It was observed that at the depth of 0–5 cm, the number of seeds increased in the downslope direction. In the soil seed bank of the summit of the hill, the number of seeds was 47.7%. In the soil seed bank of the midslope of the hill, the number of seeds was similar both in the upper and lower soil layers (averagely 50% in each). In the soil seed bank of the footslope of the hill, the number of seeds reached 53.0% of the total number (Table 4).

Comparison between the seed bank and vegetation. Many species present in the vegetation of the investigated sites may not have been detected in the soil samples. The species of the abandoned grassland did not corelate well with the seed bank data. The coefficient of Sörensen (C_s) was 0.09–0.19 in 2020 and 0.17–0.23 in 202 (Table 4). The literature indicates that they maintain only a transient seed bank and, therefore, were absent from the seed bank at the time of sampling. On the other hand, it cannot be excluded that other species were not detected due to a lack of appropriate conditions for germination (Wagner et al., 2003). Janicka (2006) states that the species structure of the soil seed bank did not reflect the floristic composition of the grassland, because (1) the sward was dominated by the species, whose survival strategy was related to vegetative reproduction, and (2) along with the change of management, the seeds of species characteristic of the previous type of management remained in the soil creating a persistent seed bank.

Conclusions

1. During 27 years of the experiment, the floristic composition of the abandoned grassland (56 vascular plant species were identified) became similar to that of natural meadows. Competitive species *Festuca rubra*, which was included in the grass mixture, prevailed in all meadows, especially in the midslope and the footslope of the hill. The species of Poaceae and Fabaceae families dominated (51.0–64.8 P%) in all parts of the hill, but the larger number of these species was identified in the footslope. However, the low-value plants with great adaptability to different habitations (*Elytrigia repens*, *Cirsium arvense*, and *Equisetum arvense*) spread in the grassland. The largest amounts of these species were found in the summit and midslope parts of the hill (23.6 and 25.6 P%).

2. The seeds accumulated in soil did not correspond to the species composition of grassland community. The similarity (C_s) between the seed bank and the overlying plant community at a given site was low (0.09–0.23). In the seed bank, the seeds of dicotyledonous arable weeds were identified; they created stable long-term seed banks and were not typical in grassland community.

3. The number of seeds at the soil depth of 0–5 and 5–15 cm soil changed depending on the relief. At the depth of 0–5 cm, the number of seeds increased in the downslope direction, 47.7%, 50.4%, and 53.0%, respectively, in the summit, midslope, and footslope parts of the hill. At the soil depth of 5–15 cm, the number of seeds decreased: 52.3%, 49.6%, and 47.0%, respectively, in the summit, midslope, and footslope parts of the hill.

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References

Auestad I., Rydgren K., Spindelböck J. P. 2013. Management history affects grassland seed bank build-up. Plant Ecology, 214 (12): 1-14. https://doi.org/10.1007/s11258-013-0267-x

Auffret A. G., Cousins S. A. O. 2011. Past and present management influences the seed bank and seed rain in a rural landscape mosaic. Journal of Applied Ecology, 48 (5): 1278–1285. https://doi.org/10.1111/j.1365-2664.2011.02019.x

Auškalnienė O., Kadžienė G., Janušauskaitė D., Supronienė S. 2018. Changes in weed seed bank and flora as affected by soil tillage systems. Zemdirbyste-Agriculture, 105 (3): 221–226. https://doi.org/10.13080/z-a.2018.105.028

Baskin C. C., Baskin J. M. 2014. Seeds: ecology, biogeography, and evolution of dormancy and germination. Academic Press, p. 187–225. https://doi.org/10.1016/C2013-0-00597-X

Basto S., Thompson K., Phoenix G., Sloan V., Leake J., Rees M. 2015. Long-term nitrogen deposition depletes grassland seed banks. Nature Communications, 6: 6185. https://doi.org/10.1038/ncomms7185

Bengtsson J., Bullock J. M., Egoh B., Everson C., O'Connor T., O'Farrerll P. J., Smith H. G., Lindborg R. 2019. Grasslands – more important for ecosystem services than you might think. Ecosphere, 10 (2): e02582. https://doi.org/10.1002/ecs2.2582

da Silveira Pontes L., Maire V., Schellberg J., Louault F. 2015. Grass strategies and grassland community responses to environmental drivers: a review. Agronomy for Sustainable Development, 35: 1297–1318. https://doi.org/ 10.1007/s13593-015-0314-1

Grigas A. 1986. Lietuvos augalų vaisiai ir sėklos [Fruits and seeds of Lithuanian plants]. Vilnius, Lithuania, 604 p. (in Lithuanian).

Ellenberg H. 1992. Zeigerwerte der Gefäßpflanzen (ohne *Rubus*). Scripta Geobotanica, 18: 9–166 (in German).

Gomaa N. H. 2012. Soil seed bank in different habitats of the Eastern Desert of Egypt. Saudi Journal of Biological Sciences, 19 (2): 211–220. https://doi.org/10.1016/j.sjbs.2012.01.002

Hamanaka A., Sasaoka T., Shimada H., Matsumoto S. 2019. Experimental study on soil erosion under different soil composition using rainfall simulator. Plant, Soil and Environment, 65 (4): 181–188. https://doi.org/10.17221/68/2019-PSE

Herzon I., Raatikainen K. J., When S., Rūsiņa S., Helm A., Cousins S. A. O., Rašomavičius V. 2021. Semi-natural grasslands in boreal Europe: the rise of a socioecological research agenda. Ecology and Society, 26 (2): 13. https://doi.org/10.5751/ES-12313-260213

Hossain M. M., Begum M. 2015. Soil weed seed bank: importance and management for sustainable crop production – a review. Journal of the Bangladesh Agricultural University, 13 (2): 221–228. https://doi.org/10.3329/jbau.v13i2.28783

Janicka M. 2006. Species composition of the soil seed bank in comparison with the floristic composition of meadow sward. Grassland Science in Europe, 11: 200–203.

Janicka M. 2016. The evaluation of soil seed bank in two arrhenatherion meadow habitats in Central Poland. Acta Scientiarum Polonorum Agricultura, 15 (4): 25–38.

Jankauskas B., Jankauskienė G. 2003. Long-term soil erosion studies on the Žemaičiai Upland: 2. Intensity of water erosion. Zemdirbyste-Agriculture, 82 (2): 20–34 (in Lithuanian).

Jarašiūnas G., Kinderienė I. 2016. Impact of agro-environmental systems on soil erosion processes and soil properties on hilly landscape in Western Lithuania. Journal of Environmental Engineering and Landscape Management, 24 (1): 60–69. https://doi.org/10.3846/16486897.2015.1054289

Jastrzębska M., Jastrzębski W. P., Hołdyński C., Kostrzewska M. K. 2013. Weed species diversity in organic and integrated farming systems. Acta Agrobotanica, 66 (3): 113–124. https://doi.org/10.5586/aa.2013.045

Kulik M. 2014. Changes of biodiversity and species composition of Molinia meadow depending on use method. Polish Journal of Environmental Studies, 23 (3): 11–20.

Kurdyukova O. M. 2018. Seed production capability of monocotyledonous and dicotyledonous weeds in segetal and ruderal habitats. Ukrainian Journal of Ecology, 8 (1): 153–157. https://doi.org/10.15421/2018_200

Lange M., Eisenhauer N., Sierra C. A., Bessler H., Engels C., Griffiths R. I., Mellado-Vázquez P. G., Malik A. A., Roy J., Scheu S., Steinbeiss S., Thomson B. C., Trumbore S. E., Gleixner G. 2015. Plant diversity increases soil microbial activity and soil carbon storage. Nature Communications, 6: 1–8. https://doi.org/10.1038/ncomms7707

Lewis T. D., Rowan J. S., Hawes C., McKenzie B. M. 2013. Assessing the significance of soil erosion for arable weed seedbank diversity in agro-ecosystems. Progress in Physical Geography, 37 (5): 622–641. https://doi.org/10.1177/0309133313491131

Lietuvos dirvožemiai [Lithuanian soils]. 2001. Lietuvos mokslas. Kn. 32, p. 745–747 (in Lithuanian).

López-i-Gelats F., Bartolomé J. 2007. The effects of agricultural abandonment on botanical diversity in mountain hay meadows. Grassland Science in Europe, 12: 404–409.

Lopez-Marino A., Luis-Calabuig E., Fillat F., Bermudez F. F. 2000. Floristic composition of established vegetation and the soil seed bank in pasture communities under different traditional management regimes. Agriculture, Ecosystems and Environment, 78: 273–282. https://doi.org/10.1016/S0167-8809(99)

Nekrošienė R., Skuodienė R. 2012. Changes in floristic composition of meadow phytocenoses, as landscape stability indicators, in protected areas in Western Lithuania. Polish Journal of Environmental Studies, 21 (3): 703–711.

Peeters A. 1989. Management, vegetation and feeding quality of grasslands: study of their triangular relationships in forage systems: doctoral dissertation. University of Louvain, Belgium, 287 p. (in French).

Pruchniewicz D., Zołnierz L. 2016. The influence of *Calamagrostis epigejos* expansion on the species composition and soil properties of mountain mesic meadows. Acta Societatis Botanicorum Poloniae, 86 (1): 3516. https://doi.org/10.5586/asbp.3516

Pupalienė R., Jodaugienė D., Sinkevičienė A., Bajorienė K. 2012. Effect of different organic mulches on weed seed bank. Žemės ūkio mokslai, 19 (1): 20–26 (in Lithuanian). https://doi.org/10.6001/zemesukiomokslai.v19i1.2233

Raudonius S. 2017. Application of statistics in plant and crop research: important issues. Zemdirbyste-Agriculture, 104 (4): 377–382. https://doi.org/10.13080/z-a.2017.104.048

Sendžikaitė J., Pakalnis R., Gudžinskas Z. 2013. Changes in botanical diversity of sown grasslands due to naturalization and extensive management. Botanica Lituanica, 19 (2): 99–110. https://doi.org/10.2478/botlit-2013-0013

Skuodienė R. 2004. Comparison of grasslands botanical composition determination by weight and handful (De Vries) methods. Zemdirbyste-Agriculture, 87 (3): 145–156 (in Lithuanian).

Skuodienė R., Kinderienė I., Tomchuk D., Šlepetys J., Karčauskienė D. 2020. Root development of temporary and permanent grasslands and their anti-erosion significance on a hilly terrain. Zemdirbyste-Agriculture, 107 (3): 209–216. https://doi.org/10.13080/z-a.2020.107.027

Smith R. S., Shiel R. S., Millward D., Corkhil P. I., Sanderson R. A. 2002. Soil seed banks and the effects of meadow management on vegetation change in a 10-year meadow field trial. Journal of Applied Ecology, 39: 279–293. https://doi.org/10.1046/j.1365-2664.2002.00715.x

Tribot A.-S., Deter J., Mouquet N. 2018. Integrating the aesthetic value of landscapes and biological diversity. Proceedings of the Royal Society B: Biological Sciences, 285 (1886): 20180971. https://doi.org/10.1098/rspb.2018.0971

Uogintas D., Rašomavičius V. 2020. Impact of short-term abandonment on the structure and functions of semi-natural dry grasslands. Botanica, 26 (1): 40–48. https://doi.org/10.2478/botlit-2020-0004

Wagner M., Poschlod P., Setchfield R. P. 2003. Soil seed bank in managed and abandoned semi-natural meadows in Soomaa National Park, Estonia. Annales Botanici Fennici, 40: 87–100.

Wainwright J., Parsons A. J., Schlesinger W. H. 2002. Hydrology–vegetation interactions in areas of discontinuous flow on a semi-arid bajada, Southern New Mexico. Journal of Arid Environments, 51 (3): 319–338. https://doi.org/10.1006/jare.2002.0970

WRB. 2015. World reference base for soil resources. World Soil Resources Reports No. 106.

Apleisto žolyno bendrijos ir dirvožemio sėklų bankas kalvotame reljefe

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Santrauka

Žolynų svarba yra glaudžiai susijusi su biologine įvairove ir dirvožemio sveikata. Augalų įvairovės pokyčiai priklauso nuo aplinkos sąlygų ir žolynų priežiūros. Tyrimo tikslas – nustatyti apleistumo įtaką žolynų bendrijai ir dirvožemio sėklų bankui kalvoto reljefo sąlygomis. Eksperimentas buvo įrengtas LAMMC Vėžaičių filiale, kalvotame Žemaičių Aukštumos reljefe. Analizuoti 9–11° statumo šlaituose įrengto dirvožemio erozijos eksperimento ilgalaikio monitoringo duomenys. Pietinės ekspozicijos šlaito dirvožemis – menkai eroduotas nepasotintasis balkšvažemis. Siekiant kalvą apsaugoti nuo erozijos, 1993 m. skirtingose kalvos dalyse (viršūnėje, šlaite ir pašlaitėje) buvo pasėtas penkių žolių mišinys: pašarinis motiejukas (*Phleum pratense* L.) 20 %, raudonasis eraičinas (*Festuca rubra* L.) 20 %, pievinė miglė (*Poa pratensis* L.) 20 %, baltasis dobilas (*Trifolium repens* L.) 20 % ir paprastasis garždenis (*Lotus corniculatus* L.) 20 %. Po 27 metų buvo nustatytos 56 induočių augalų rūšys. Sėtų rūšių santykinis gausumas (P %) buvo 17,2, 23,9 ir 27,2 % atitinkamai kalvos viršūnėje, šlaite ir pašlaitėje. Geras *F. rubra* augimas nepriklausė nuo to, kad žolynas buvo visiškai nenaudojamas. Kitų sėtų augalų rūšių santykinis gausumas žymiai sumažėjo visose kalvos dalyse. Žolynuose išplito menkaverčiai augalai (*Elytrigia repens* L., *Cirsium arvense* L. ir *Equisetum arvense* L.). Apleistų žolynų dirvožemio sėklų banką sudarė ariamų laukų piktžolės: kalvos viršūnės dirvožemio sėklų banke (0–15 cm gylyje) vyraujanti rūšis buvo *Chenopodium album*, o kalvos šlaito dirvožemio sėklų banke vyravo *Stellaria media*, atitinkamai 31,3 ir 18,4 % bendro sėklų skaičiaus.

Reikšminiai žodžiai: apleista pieva, augalų rūšys, dirvožemio sėklų bankas, floristinis panašumas, santykinis gausumas, šlaitų ekotopai.