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Renaturalization of *Arenosols* in the land afforested with Scots pine (*Pinus sylvestris* L.) and abandoned arable land

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Abstract

The aim of the current study was to evaluate the renaturalization of chemical parameters and the ground vegetation of *Haplic Arenosols* (*ARh*), when arable land was abandoned or afforested with Scots pine (*Pinus sylvestris* L.) plantations. It was found that over a 45-year period the former ploughing Ap horizon had been renaturalized according to the increase of Al^{3+} ions concentrations and the increase in acidity in pine plantations. Due to the accumulation and decomposition of acidic (pH_{CaCl2} 3.6) soil organic layer, the mosses of *Vaccinio-myrtillosa* forest type spread in the ground vegetation cover. The decreases in the concentrations of organic carbon, total nitrogen (N) and, especially, mineral N reflected the renaturalization of *Haplic Arenosols* in a previously intensively fertilized arable land abandoned for an 11-year-period. Vascular plants that indicate non-fertile soils with low pH values prevailed in the ground vegetation cover.

Key words: arable *Arenosols*, Scots pine plantations, abandoned land, chemical parameters, ground vegetation.

Introduction

Lithuania belongs to the transitional deciduous coniferous mixed forest hemiboreal zone of Europe (Ahti et al., 1968). In this zone, the natural afforestation of abandoned agricultural land sooner or later occurs. During the period from 2003 till 2010, the forest area in Lithuania increased by 1.8 percent points, respectively, from 31.3% to 33.1% (ME/SFS, 2010). During this period, the total area of forest stands increased by 99.9 thousand ha – up to 2050.9 thousand ha, or on average by about 14 thousand ha per year. Forests have mainly been expanding on the areas of naturally drained swamps and abandoned agricultural lands. It is considered, that countrywide it would be most appropriate to afforest in total 500–600 thousand ha of infertile agricultural land (Riepšas, 2002). The abandonment of infertile *Arenosols* in agriculture is apparent. *Arenosols* are distributed in nearly 12% of Lithuania's territory with the largest area in the southeast part of the country, and 25–30% of the Lithuanian forests are situated on *Arenosols* (Beniušis, Vaičys, 2004; Beniušis, 2008).

Abandoned arable land could be left for sustained abandonment or afforested. In both cases, in the soils, especially, in the ploughing Ap horizon, chemical properties are changing as the nutrients previously added with mineral and organic fertilizers are leached out (Aleinikovienė et al., 2007; Armolaitis et al., 2007; Marcinkonis, 2007). Therefore, mineral nitrogen (N) is leached with higher intensity. Thus, the concentrations of available K_2O, and, in particular, available P_2O_5 in the former arable soils remain increased for 10 or more years.

Compared with the soils in abandoned land, nutrient leaching in afforested arable soils is more intensive. It is especially evident, when coniferous (pine and spruce) plantations are established in abandoned soils. In these plantations the accumulation of needle litterfall is followed by the decomposition of acidic soil organic layer (Alriksson, Olsson, 1995; Grieve, 2001). This influences the increase in the concentration of Al^{3+} ions toxic for plant roots in former ploughing Ap horizon, where due to the acidification, the

leaching of available nutrients is intensified. Otherwise, in forest plantations along the decomposition of soil organic layer the organic carbon (C) is accumulated in mineral topsoil (Post, Kwon, 2000; Vesterdal et al., 2002; Armolaitis et al., 2007). Meanwhile, in the abandoned arable land as well as in arable land, where less stable soil organic matter (SOM) prevails and the abundance of SOM decomposing microbiota (mainly bacteria) is higher, the pools of organic C could decrease (Stevenson et al., 2004; Aleinikovienė, 2009; Partyka, Hamkalo, 2010).

The diversity of ground vegetation could also respond to the mentioned changes in soil chemical properties. Therefore the diversity of ground vegetation corresponds not only to the light of the habitat but also to the soil condition, especially to the soil reaction (soil pH), fertility, moisture content, pollution of mineral topsoil (Karazija, 1988; Bobbink et al., 1998; Ozolinčius, 2004; Vaičys et al., 2006). For this approach the Ellenberg phytoindication scale (Ellenberg et al., 1991) is applied nowadays, emphasizing the plants as the indicators of key environmental factors.

The aim of the current study was to compare the renaturalisation of soil chemical properties as well as of ground vegetation cover of *Arenosols*, when arable *Arenosols* had been abandoned or had been afforested with Scots pine plantations. Our research hypothesis was based on the conception, that the natural *Arenosols* could be distinguished in more than 40-year-old Scots pine stands as well as in long-term, not fertilized natural perennial grasslands.

Materials and methods

Study site. The study was carried out at the Perloja Experimental Station of Lithuanian Institute of Agriculture in the forest-arable land productivity comparison experiment established on arable *Arenosols* in 1960 (hereafter – Perloja experiment) following professor P. Vasinauskas' idea and professor A. Tindžiulis' methodology (Gudaitienė et al., 1984; Kupčinskas, 1999; Aleinikovienė et al., 2007; detailed description in Armolaitis et al., 2007). For our study, three contrasting treatments of the Perloja experiment were selected in 2005–2007. Soil chemical parameters and ground vegetation were investigated: 1) in non-fertilized 45-year-old Scots pine (*Pinus sylvestris* L.) plantations established on an arable land; 2) in an abandoned for the last 11–13 years former arable land, which previously had been intensively fertilized (90 kg N, 90 kg of available P_2O_5, and 60 kg of available K_2O per ha applied annually and 60 Mg ha^{-1} of cattle manure every six years); 3) abandoned for the last 11–13 years former arable land, where before the abandonment agricultural plants had been managed without fertilization. The soil was a well-drained *Haplic Arenosol* (*ARh*) (Buivydaitė et al., 2001; FAO/UN, 2006) developed on glaciofluvial sandy deposits from Riss-Wurm (Weichselian) glaciation. The *ARh* consisted of coarse sand with a high proportion (10–20%) of coarse particles (>2 mm) and a low clay + fine silt content (less than 5%). The depth of the former ploughing Ap horizon was about 20 cm.

Pure Scots pine plantations had an initial planting density of 10 000 trees per ha. The stand density in the pine plantation sample plots in 2005 was about 3000 trees ha^{-1}, mean tree height was 16.9 m, mean diameter at breast height (1.3 m) was 12.8 cm, stem volume was 340 m^3 ha^{-1}, and mean fallen dead stem wood volume (mean diameter 10 cm and more) was 31 m^3 per ha. Before the abandonment, the total nutrient additions to the formerly fertilized arable land were about 1.4 Mg of nitrogen (N), 2.0 Mg of P_2O_5, and 2.9 Mg of K_2O per ha using mineral fertilizers, and 28.8 Mg of organic carbon (C), 1.6 Mg N, 0.7 Mg P, and 1.8 Mg K per ha using farmyard manure (calculated according to Tripolskaja, 2005).

The mean annual precipitation in the study area is about 680 mm. The mean annual temperature is 6.2ºC, with a mean January temperature of −5.4ºC and a mean July temperature of 18.6ºC.

Soil sampling and chemical analyses. In 2005, the sampling was carried out in September. In Scots pine plantations and in abandoned arable land, composite soil samples (from 0–10 and 10–20 cm deep mineral layers) were collected in *Haplic Arenosols* from former ploughing Ap horizon in each plot at 10 systematically distributed points along the 20-m transects in three replicates.

For chemical analyses, mineral soil samples were dried at 40ºC and sieved through a 2 x 2 mm sieve. Soil chemical analyses were performed at the Agrochemical Research Centre of Lithuanian Institute of Agriculture. Organic carbon (C) concentration was determined with a Heraeus apparatus (ISO 10694, dry combustion at 900ºC), and total nitrogen (N) was analyzed using the Kjeldahl method (ISO 11261). Concentrations of mineral N were determined by the spectrometric method (ISO 14256-2) in 1 M KCl extraction: NH_4-N using sodium phenolate and sodium hypochlorite, and NO_3-N using sulfanilamide. Available K_2O and available P_2O_5 were determined by the Egner-Riehm-Domingo (A-L) method (Egnér et al., 1960). Also, pH was potentiometrically measured in a 0.01 M $CaCl_2$ suspension (ISO 10390). The results were calculated into the mass of dry soil.

For the estimation of the renaturalisation, the mean chemical parameters of former Ap horizon in *Arenosols* in Scots pine plantations and abandoned arable land of Perloja experiment were compared with the Lithuanian forest soil monitoring data (1992, in total 20 plots) and Beniušis data (2008) on mean chemical parameters of *Arenosols* in Scots pine stands in Lithuanian background contamination areas.

The data on soil chemical parameters were statistically evaluated in the order of reliability of $P < 0.05$, while significance of data differences – using *Student t-test*.

Study of ground vegetation. The diversity and projection coverage (in %) of vascular plants, epi-

geous lichens and mosses were estimated during the period of June–July 2005–2007 in 1 m^2 plots systematically distributed in each biotope in sixteen (n = 16) replicates. Further, the transect method was used in order to more precisely estimate the diversity of vascular plants in abandoned arable land.

Distribution of plant species in ground vegetation cover was determined according to the ecological indicator values elaborated by Ellenberg (Ellenberg et al., 1991). The four indicator values used are defined in Table 1.

Table 1. The explanation of Ellenberg's ecological indicators employed (from Ellenberg et al., 1991; McCollin et al., 2000)

Ellenberg's indicator	Description	Indicator values
E_L	Light	Scale from 1 (plant species of deep shade) to 9 (plants of full sun)
E_F	Soil moisture	From 1 (plant species of extreme dry land) to 9 (wet-site indicators)
E_R	Soil reaction (soil pH)	A gradient from 1 with calcifuge plant species to 9 with calcicole plants of calcareous soils
E_N	Soil nitrogen	From 1 (plant species with little requirement for soil nitrogen on extremely infertile soils) to 9 (indicator of extremely rich soils with surplus of nitrogen)

Results and discussion

Soil chemical parameters. Perloja experiment data showed (Table 2) that in both treatments of the abandoned arable land, e.g., formerly fertilized as well as in non-fertilized, the chemical parameters in *Haplic Arenosols* (hereafter – *Arenosols*) did not differ significantly ($P > 0.05$). The obtained results allowed us to state that in *Arenosols* the nutrients introduced along with the fertilization (especially NH_4-N and NO_3-N, as well as K_2O and P_2O_5) over the 11 years leached from the former ploughing Ap horizon.

Table 2. The mean chemical parameters of humic mineral A and AE in *Haplic Arenosols* of Perloja experiment and Lithuanian background contamination areas

Soil parameters	Perloja experiment (2005)			Scots pine stands in Lithuanian background contamination areas (data of Lithuanian forest soil monitoring, 1992)[x]
	in 45-year-old non-fertilized Scots pine plantations	in former fertilized arable land abandoned for the last 11 years	in former non-fertilized arable land abandoned for the last 11 years	
		0–10 cm		
pH_{CaCl2}	**4.7 ± 0.4** a	**6.9 ± 0.1** b	6.5 ± 0.4 b	4.3 ± 0.2 a
Organic C (g kg^{-1})	10.9 ± 0,6	**5.7 ± 0.2** b	5.4 ± 0.2 b	7.2 ± 0.4 a
Total N (g kg^{-1})	**0.9 ± 0.1** ab	**0.8 ± 0.1** ab	0.7 ± 0.0 b	0.6 ± 0.1 a
Al^{3+} (cmol(+) kg^{-1})	**5.9 ± 0.2** a	**0.0 ± 0.0** b	0.3 ± 0.3 b	4.9 ± 0.6 a
NH_4-N (mg kg^{-1})	6.9 ± 0.6	**4.1 ± 0.4** b	3.8 ± 0.3 b	–
NO_3-N (mg kg^{-1})	**1.8 ± 0.1** b	**2.1 ± 0.1** b	2.2 ± 0.2 b	–
P_2O_5 (mg kg^{-1})	47 ± 8	**198 ± 23** b	168 ± 19 b	–
K_2O (mg kg^{-1})	49 ± 2	**136 ± 10** b	110 ± 5 b	–
		10–20 cm		
pH_{CaCl2}	**5.5 ± 0.5** a	**6.9 ± 0.2** b	6.3 ± 0.5 b	4.7 ± 0.4 a
Organic C (g kg^{-1})	**4.6 ± 0.4** ab	**4.6 ± 0.7** ab	4.7 ± 0.3 b	3.5 ± 0.2 a
Total N (g kg^{-1})	**0.4 ± 0.0** ab	**0.6 ± 0.1** ab	0.6 ± 0.1 ab	0.6 ± 0.1 a
Al^{3+} (cmol(+) kg^{-1})	**3.3 ± 0.4** a	**0.0 ± 0.0** b	0.1 ± 0.1 b	3.2 ± 0.2 a
NH_4-N (mg kg^{-1})	**3.5 ± 0.2** b	**2.9 ± 0.5** b	3.3 ± 0.5 b	–
NO_3-N (mg kg^{-1})	**1.8 ± 0.1** b	**1.8 ± 0.1** b	2.1 ± 0.1 b	–
P_2O_5 (mg kg^{-1})	46 ± 4	**153 ± 12** b	186 ± 16 b	–
K_2O (mg kg^{-1})	48 ± 2	**111 ± 6** b	112 ± 9 b	–

Note. Means ±SE are given in the table. Different letters show significant ($P < 0.05$) renaturalization of soil parameters (these parameters are in bold): a – comparing with *Arenosols* in Scots pine stands in Lithuanian background contamination areas; b – comparing with former non-fertilized abandoned arable land in Perloja experiment. [x]Mean ± SE values in humic mineral A horizon of *Haplic Arenosols* in Lithuanian Scots pine stands: pH_{CaCl2} 4.2 ± 0.1; organic C – 8.0 ± 1.0 g kg^{-1}; total N – 0.7 ± 0.1 g kg^{-1} (Beniušis, 2008).

Thus comparing with the former fertilized as well as non-fertilized abandoned arable lands, many chemical parameters in *Arenosols* differed significantly ($P < 0.05$) in Scots pine plantations (Table 2). Though, it was estimated that in pine plantations in the uppermost 0–20 cm mineral layer the mean concentration of Al^{3+} ions was 3.3–5.9 cmol(+) kg^{-1}, thus, mineral topsoil was acid with pH_{CaCl2} 4.7–5.5. Meanwhile, in the abandoned arable land the Al^{3+} ions toxic for the plant roots were practically not found, and the mean acidity (pH_{CaCl2} 6.3–6.9) of mineral topsoil was by 0.8–2.2 pH_{CaCl2} units lower. Even though the abandoned arable land had been formerly intensively fertilized, the concentrations of total N there were not higher, moreover, the mean concentration of organic C was even by 1.9 times lower in the 0–10 cm mineral topsoil than in pine plantations. Thus, in *Arenosols* the concentrations of mineral N also differed significantly only in the uppermost 10 cm thick mineral layer where the NH_4-N concentrations were on average by 1.7 times higher in pine plantations. Although in the abandoned *Arenosols* the mineral N introduced with fertilizers was leached out, the mean concentrations of P_2O_5 and K_2O in the former Ap horizon were still higher than those in pine plantations, by 3–4 and 2–3 times, respectively.

It is maintained, that forest plantations during over a 40-year-long period tend to be more like natural forest (Mohr et al., 2005; Marcos et al., 2007). The present study also confirmed that the afforestation of nutrient-poor sandy soils could result in an increase of soil C stores within a short period (Post, Kwon, 2000; Vesterdal et al., 2002). In our case, the changes in chemical properties of *Arenosols* in 45-year-old Scots pine plantations could be explained by the accumulation and decomposition of acid soil organic layer (mean mass – 5.5 kg m^{-2}, pH_{CaCl2} 3.6). Therefore, as it was estimated in Norway spruce plantations (Grieve, 2001; Andersson et al., 2002) Al^{3+} ions toxic for the plant roots in former Ap horizon appear and, because of soil acidification, the leaching of mobile K_2O is intensified. Thus, the presumption of the decrease in concentrations of organic C, total and mineral N in abandoned arable land was also confirmed (Stevenson et al., 2004; Sabienė et al., 2010).

It is worth comparing the chemical parameters of investigated *Haplic Arenosols* with mean parameters of *Haplic Arenosols* in Scots pine stands of Lithuanian background contamination areas (unpublished data of Lithuanian forest soil monitoring, 1992; Beniušis, 2008). The data presented in Table 2 show that the renaturalisation of the former Ap horizon in 45-year-old pine plantations of Perloja experiment occurred by the changes in pH value and in the concentrations of Al^{3+} ions and organic C. However, by the concentrations of total and mineral N (compared with the data obtained in Scots pine plantations) and in some extent by the concentrations of organic C the renaturalisation of *Arenosols* also occurred in abandoned land over the 11 years. Meanwhile abandoned *Arenosols* in the former arable land still could be distinct with the lower pH value and the higher concentrations of P_2O_5 and K_2O. Otherwise, the renaturalisation of *Arenosols* in abandoned arable land could be indicated also as the deterioration of chemical parameters in comparable values in the former intensively fertilized as well as in non-fertilized abandoned arable land.

Ground vegetation. The coverage of ground vegetation in Scots pine plantations and in abandoned arable *Arenosols* was similar and comprised 74–87% (Table 3). However, in the dense (with on average 3000 trees per ha) 45-year-old pine plantations in general 7 species of the mosses comprised ground vegetation (the coverage – 80–92%) with narrow extent (1–2%) of epigeous lichens. The moss cover was dominated mainly by *Pleurozium schreberi* (Brid.) Mitt., with an admixture of *Dicranum polysetum* Sw. and *Hylocomium splendens* (Hedw.) Schimp. Thus, the cover by vascular plants was tenuous (coverage comprised only 1%) with detection of 15 species of vascular plants, where *Thymus serpyllum* L., *Rubus idaeus* L., *Fragaria vesca* L., *Pyrola rotundifolia* L. and *Hieracium pilosella* L. were the predominant species.

Table 3. The species abundance and coverage of vascular plants, mosses and epigeous lichens in ground vegetation cover of *Haplic Arenosols* in Perloja experiment (2005–2007)

Biotop	*Vascular* plants		Mosses and lichens		Total coverage %
	species number, n	coverage %	species number, n	coverage %	
Scots pine plantations	15	1 ± 0	9	86 ± 6	87 ± 6
Abandoned arable land	116	36 ± 7	13	38 ± 6	74 ± 11

Note. Mean coverage ± SE are given in the table.

In the former intensively fertilized as well as in non-fertilized abandoned arable land, over the 11–13 years 116 species of vascular plants, 9 species of mosses and 4 species of lichens had spread (Table 3). The coverage by the above mentioned plants comprised on average 63–85%, meanwhile, the coverage by mosses and lichens was equal to that of vascular plants. Further, in abandoned arable *Arenosols* the *Hieracium pilosella*, *Oenothera biennis* L., *Achillea millefolium* L. and *Fragaria vesca* were dominant plants in the vascular plant cover. The mosses of *Brachythecium* sp. and *Polytrichum commune* Hedw. prevailed in the moss cover, while *Peltigera praetextata* ((Flörke ex Sommerf.) Zopf) and *Cladonia* sp. Hill ex P. Browne were mostly common among the lichens.

As it was estimated, during the period of 45 years the mentioned semi-shade mosses (indicator value $E_L = 6$) as well as light-loving vascular plants ($E_L = 7$ and 8) such as *Rubus idaeus*, *Thymus serpyllum* and *Fragaria vesca* became dominant in Scots pine plantations (Table 4). According to the moisture requirements, almost half of the plant species, mainly mosses, can be defined as dry-site and moderate-dry-site plants ($E_F = 4$). In the moss cover the *Pleurozium schreberi* dominated due to the increased soil acidity ($E_R = 2$). Thus, among the not-indifferent vascular plants species mainly growing in acid soils ($E_R = 3$) as well as in weakly acid ($E_R = 5$) soils were dominant. There were also many species of vascular plants that are indifferent to the soil N. Among the indicators, the plants capable of growing not only in extremely infertile soils with low N content ($E_N = 1$ and 2; *Thymus serpyllum*, *Hieracium pilosella*) but also nitrophylous plants occurred ($E_N = 6$; *Rubus idaeus*, *Fragaria vesca*, *Mycelis muralis* (L.) Dumort., etc.).

Table 4. The distribution of soil ground vegetation species (%) of *Haplic Arenosols* according to their indicator value (Ellenberg et al., 1991) in Scots pine plantations of Perloja experiment (2005–2007)

Environmental factor	Indicator value									
	1	2	3	4	5	6	7	8	9	x
E_L – light				14	14	25	22	21		4
E_F – soil moisture		7		43	11	4	4	3		28
E_R – soil reaction (pH)		7	14	11	14	4	4	3		43
E_N – soil nitrogen	14	27	9	9	5	13				23

x – indifferent species

As it is shown in Table 5, in abandoned land (former intensively fertilized as well as in non-fertilized) there were predominant light-loving plants ($E_L = 7–9$) and dry-site as well as temperate-moist-site plants ($E_F = 3–5$): mainly *Hieracium pilosella*, *Oenothera biennis*, *Achillea millefolium*, *Fragaria vesca*. Herewith, there were also vascular plants that could grow not only in very acidic soils ($E_R = 2$; *Trifolium arvense*, *Rumex acetosella* L.) but also in alkaline soils ($E_R = 7$; *Arenaria serpyllifolia* L., *Convolvulus arvensis* L., *Senecio jacobaea* L., etc.). The vascular plants of non-fertile ($E_N = 2$; *Hieracium pilosella*, *Jasione montana* L.) and temperate-fertile soils ($E_N = 4$ and 5; *Achillea millefolium*, *Senecio jacobae*, *Linaria vulgaris* Mill.) were dominant. Even though *Trifolium arvense*, *Helichrysum arenarium* and some other plants were estimated as plants growing in soils with very-low N content ($E_N = 1$), herewith *Taraxacum officinale* F. H. Wigg. ($E_N = 7$) and *Artemisia vulgaris* L. ($E_N = 8$) were defined as the plants of fertile or, even, extremely-fertile soils.

Table 5. The distribution of soil ground vegetation species (%) of *Haplic Arenosols* according to their indicator value in abandoned formerly fertilized (in brackets – formerly non-fertilized) arable land of Perloja experiment (2005–2007)

Environmental factor	Indicator value									
	1	2	3	4	5	6	7	8	9	x
E_L – light					9 (9)	14 (14)	32 (27)	36 (32)	9 (18)	
E_F – soil moisture		5 (9)	9 (9)	54 (41)	14 (23)	5 (5)				13 (13)
E_R – soil reaction (pH)		9(9)	5 (0)	5 (0)	5 (9)	18 (18)	13 (18)	0 (5)		45 (41)
E_N – soil nitrogen	8 (9)	18 (18)	5 (0)	18 (18)	18 (18)	5 (14)	5 (0)	5 (5)		18 (18)

x – indifferent species

Summarizing the data given in Tables 4 and 5, it could be stated that in *Arenosols* in Scots pine plantations and, especially, in abandoned arable land light-demanding plants dominated in ground vegetation cover. According to the soil moisture content, in pine plantations there were mainly the moderate-dry-site plants (54%), meanwhile in abandoned land-dry-site (14–18%) and moderate-dry-site (64–68%) indicator plants were growing. However, in both biotopes the plants of acid and non-fertile soils with low nitrogen content became dominant. Thus, it could be stated that the renaturalisation of ground vegetation was detected in Scots pine plantations as well as in abandoned arable land in Perloja experiment. This was especially true for pine plantations, where the mosses *Pleurozium schreberi*, *Hylocomium splendens* and *Dicranum polysetum*, typical of the *Vaccinio-myrtillosa* forest type (Karazija, 1988) had been distributed.

Conclusions

1. Over a 45-year-period, the former ploughing Ap horizon of *Haplic Arenosols* have been renaturalized in the Scots pine (*Pinus sylvestris* L.) plantations. The increases in the concentrations of Al^{3+} ions and in acidity were detected in 0–20 cm mineral topsoil due to the accumulation and decomposition of acidic (pH_{CaCl2} 3.6) soil organic layer. These changes were followed by the accumulation of organic C under the forest floor in the uppermost 0–10 cm mineral layer.

2. Over 11 years, the renaturalization of *Haplic Arenosols* in abandoned arable land could be also estimated by the decrease in the concentrations of organic C, total N and, especially, mineral N. While in abandoned previously intensively fertilized land, mineral N was leached out: however, the former Ap horizon was still less acid and more saturated with P_2O_5 and K_2O.

3. In afforested by Scots pine and abandoned arable *Haplic Arenosols* the coverage of ground vegetation was very similar and comprised 74–87%. However, plant species composition of ground vegetation differed considerably. In abandoned arable land over the period of 11–13 years, in total 116 species of vascular plants, 9 species of mosses and 4 species of epigeous lichens have become widespread. Compared with abandoned land, the plant diversity in 45–47-year-old Scots pine plantations was about 5 folds lower. *Haplic Arenosols* are almost completely covered by 7 species of the mosses while only 15 species were found in very weak coverage (1%) of vascular plants.

4. The abundance of the plants that indicate acid and non-fertile soils reflects the renaturalization of ground vegetation cover in afforested by Scots pine plantations and in abandoned arable land as well. In Scots pine plantations, due to the accumulation of acidic forest floor, the mosses characteristic of the *Vaccinio-myrtillosa* forest type have distributed. Thus, in abandoned arable *Haplic Arenosols* the renaturalisation of ground vegetation during 11–13-year-period could be explained by the leaching of nutrients, especially, mineral N.

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Smėlžemių renatūralizacija apželdintose paprastąja pušimi (*Pinus sylvestris* L.) ir dirvonuojančiose žemėse

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Santrauka

Tyrimų tikslas – ištirti paprastųjų smėlžemių (SDp), *Haplic Arenosols* (*ARh*), cheminių savybių ir gyvosios dangos renatūralizaciją pušynais apželdintose bei dirvonuojančiose žemėse. Nustatyta, kad padidėjus Al^{3+} jonų koncentracijai ir sumažėjus pH rodikliui 45-erių metų pušų želdynuose buvęs ariamasis Ap horizontas renatūralizavosi. Kaupiantis ir skaidantis miško paklotei arba dirvožemio organiniam sluoksniui (pH_{CaCl2} 3,6), jame išplito samanos, kurios būdingos brukniniam-mėlyniniam miško tipui. Pagal organinės anglies, suminio azoto (N) ir ypač mineralinio N sumažėjusias koncentracijas, paprastieji smėlžemiai renatūralizavosi ir 11 metų dirvonuojančiuose anksčiau intensyviai tręštuose arimuose. Jų gyvojoje dangoje išplito daugiausia nederlingų ir mažo pH rodiklio dirvožemių augalai.

Reikšminiai žodžiai: ariami smėlžemiai, pušų želdynai, dirvonuojanti žemė, cheminės savybės, gyvoji danga.