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HERBACEOUS PLANT DIVERSITY IN ENERGY TREE CROP PLANTATIONS

Vita Krēsliņa, Kristīne Štikāne, Ieva Bebre, Dagnija Lazdiņa, Guntis Brūmelis

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The study was carried out in an energy tree crop plantation in Skrīveri district in "Pardenči" (56°41 N and 25°08 E). Of the several short rotation tree species planted in the area, we studied plant species composition under four of the planted tree species: *Salix* sp., *Betula pendula*, *Populus tremuloides x Populus tremula,* and *Alnus incana*. The abundance of each herbaceous species was rated in percent cover. The lowest species diversity occurred in the *Alnus incana* plot, and the highest in the *Betula* plot. Diversity of herbaceous species decreased with tree age from third to fifth year after planting, excepting in the *Alnus incana* plot. Five years after planting, the plots were dominated by herbaceous vegetation with typical field species. This vegetation layer can be important for increasing ecosystem services (for example, medicinal plants and for pollinators. The area between rows can be used for livestock feed in the first 5-6 years after planting. Indicator species analysis showed that the most characteristic species for the group of the *Salix* sp. were *Phleum pratense*, *Trifolium pratense*, *Plantago lanceolata*, *Soonchus arvensis*, and *Agrostis gigantea*. The most characteristic species for the group of the *Betula pendula* were *Poa annua*, *Taraxacum officinale*, *Trifolium hybridum, Myosotis sylvatica*, *Leontodon autumnalis, Cerastium holestoides*, *Myosotis sparsiflora*. The most characteristic specie for the group of the *Populus tremuloides x Populus tremula* was *Festuca ovina*. There were characteristic species for the *Alnus incana* group.

Key words: vegetation, short rotation crops, succession, agriculture land.

Vita Krēsliņa, Kristīne Štikāne. Latvian State Forest Research Institute "Silava", Riga street 111, Salaspils, Latvia, LV-2169, University of Latvia, Faculty of Biology, Jelgava street 1, Riga, Latvia, E-mail: kreslinavita@gmail.com, kristinestikanek@gmail.com
Ieva Bebre, Dagnija Lazdiņa. Latvian State Forest Research Institute "Silava", Riga street 111, Salaspils, Latvia, LV-2169; Email: ieva.bebre@silava.lv, dagnija.lazdina@silava.lv
Guntis Brūmelis. University of Latvia, Faculty of Biology, Jelgava street 1, Riga, Latvia, E-mail: guntis.brumelis@lu.lv

INTRODUCTION

The use of fast-growing trees as energy crops in short-rotation plantations for bioenergy production has greatly expanded in the last 10 years and will continue in the furture. There is an increasing demand for renewable energy resources and reduction of CO_2 emmissions (EC Directive on the promotion of the use of energy from renewable sources /2009/28/EK). Use of productive tree plantations can decrease the need for deforestation of natural forest, which is a major reason for global decline in biological diversity (Brockerhoff et al. 2008, Bārdulis et

Table 1. Scheme of the plantation and sampling plots. Shaded boxes denote the studied control plots.

Block	Block 1	Block 2	Block 3	Block 4
Column	Control	Control	Control	Control
	Bp shw	Ag	Ha	Ga
	Bp ln	Ag	Ha	Ga
	Ga	Bp shw	Ag	Ha
	Ga	Bp ln	Ag	Ha
	Ha	Ga	Bp shw	Ag
	Ha	Ga	Bp ln	Ag
	Ag	Ha	Bp shw	Ag
	Ag	Ha	B ln	Ag
	Ag	Ha	Ga	Bp shw
	Ag	Ha	Ga	Bp ln
	Pt 22/4	Pt 22/28	Pt 22/4	Pt 22/28
	Pt 22/28	Pt 22/4	Pt 22/28	Pt 22/4
	Pt 33/4	Pt 33/28	Pt 33/4	Pt 33/28
	Pt 33/28	Pt 33/4	Pt 33/28	Pt 33/4
	S	S	S	S
Forecrops	*Brassica napus/ Phleum pratense*	*Brassica napus/ Phleum pratense*	*Festuca pratense*	*Phleum pratense/ Lolium multiflorum*

Abbreviations: Ga – *Alnus incana*; B – *Betula pendula*; Ha –*Hybrid alnus* sp.; Ah – *Alnus glutinosa;* Pt 22/4 – *Populus tremuloides x Populus tremula* (clone 4 planted 2x2m); Pt 22/28 – *Populus tremuloides x Populus tremula* (clone 28 planted 2x2m); Pt 33/4 –*Populus tremuloides x Populus* tremula (clone 2 planted 3x3m); Pt 33/28 –*Populus tremuloides x Populus tremula* (clone 28 planted 3x3m); S – *Salix sp.*

al. 2015, Bardule et al. 2016). This type of forest management first developed in southern regions due to a great demand for more efficient wood production, and later became popular in northern regions (Weih 2004). Land-use transformation of low-productive agricultural land to forest use is a rational choice and sustainable (Weber 2000; Liepins et al. 2008, Rytter et al. 2015). Fast-growing tree plantations can be established on marginal land (Dimitriou, Rutz 2015, Rutz et al. 2016), such as on polluted soil, in flood zones, along railway tracks, under overhead electrical power lines and in erosion risk areas. These species tend to withstand variable environmental conditions, and can be productive also in unfavourable conditions. To be economically effective, fast-growing trees are used in energy plantations. *Salix* species are often used in Europe as they grow fast in the temperate climate zone (Dickmann & Stuart 1983, Abolina et al. 2015, Ryter et al. 2015), and are easily cultivated and vegetatively propogated (Makovskis & Lazdina 2015, Rytter 2016).

Land-use transformation to fast-growing energy crops can alter pesticide use, erosion, and CO_2 sequestration. Biological diversity will also be affected (Weih et al. 2003), which can be positive due to increased structural diversity and ecotone area (Christian et al. 1997, Pucka et al. 2016). It can be expected that biological diversity in fast-growing tree plantations will be higher than in intensively managed agricultural land, but perhaps lower than in non-intensively used fields. In comparison to meadows, biological diversity can be predicted to be higher or lower in fast-growing tree plantations, depending on management practices employed. However, biological diversity in plantations is lower than in forest (Dimitriou, Rutz 2015) and depends on factors like canopy openness (Mestre et al. 2017).

Establishment of short-rotation plantations causes changes in the habitat and vegetation composition, in relation to plantation age and increasing tree canopy cover and the associated shift from sun-loving to shade-tolerant herbaceous plant species, and from annual to perennial species (Baum*et al.*2009). Vegetation composition is also related to past land-use (Baum*et al.* 2009). Vegetation composition also is heterogenous within plantations, with less diversity in the core area of a plantation than at its edges (DTI 2004).

MATERIAL AND METHODS

The study was carried out in the Skrīveri municipality in the land holding "Pardenči" – coordinates 56.689538; 25.138470. Soil texture was mostly loam and sandy loam. Soil reaction was slightly acidic. Organic material content was 18 – 20 g kg^{-1}. P and K concentrations were normal (Rancāne *et al.* 2014). In the experimental area, trees were planted in rows, and between rows different species were seeded (Rancane *et al.* 2015, Rancane *et al.* 2017). The grass between rows was cut.

In 2011, trees were planted in rows in the NW–SW direction with four replicates of rows for each tree species (*Salix sp., Betula pendula, Populus tremuloides x Populus tremula* and *Alnus incana*). The rows were delineated into blocks. Four fertilizer treatments were used, but in this study only the control blocks were examined. Block length was 10 m. Vegetation was first surveyed in summer 2014. Cover of each herbaceous species was assessed in classes: very low, low, moderate and high. In further analysis, species with moderate and high cover were considered as dominant species, as reported in a preliminary report (Anonīms 2014). A second survey was conducted in autumn 2015. Then vegetation was assessed in two plots with 2-m length in each block. Plots were located 2 m from each end of the block and thus distance between plots was 2 m. Plot width was 2 m, i.e, under the tree canopy. The arrangement of control plots is shown in Table 1. Percantage cover of each plant species was estimated in 2015. A third survey was conducted in autumn 2016. One plot with 1 m length was established in each block. Percentage cover of each species was determined. Plant nomenclature follows Gavrilova and Šulcs (1999). Due to differences in methods of assessment of plant cover between years and between authors, in qualitative analysis we use only dominant species (moderate of high cover, or percentage cover over 50 %). Quantitative analysis of vegetation composition employed only presence/absence data for species.

Multiple response permutation procedure with Sorenson distance measure (MRPP) was used to determine significant differences in vegetation composition between blocks with planted tree species (*Salix sp., Betula pendula, Populus tremuloides x Populus tremula, Alnus incana*). Indicator species analysis with a randomization test was conducted to determine species that significantly differed in occurrence between the planted tree species blocks. The statistical analysis was conducted using PCORD version 5.0.

RESULTS

Composition of species differed depending on tree canopy and between years, particularly under a *Salix* canopy. However, some species were observed in all plots in all survey times: *Elytrigia repens*, *Phleum pratense*, *Stellaria graminea*, *Vicia cracca* (dominant species) and *Achillea millefolium*, *Artemisia vulgaris*, *Hypericum perforatum*, *Medicago lupulina*, *Taraxacum officinale*, *Trifolium pratense* (Table 2).

Many species were lost during the examined 3-year succession. These included graminoids of fields like *Urtica dioica*, *Galeopsis terahit*, *Ranunculus acris*, *Stellaria holostea* and other annual or biennial field and weed species. The

Table 2.The abundance of herbaceous plants in each sampling time

Trees planted	***Salix* sp.**			***Betula pendula***			***Populus tremuloides x Populus tremula***		***Alnus incana***	
Year observed	3	4	5	3	4	5	4	5	4	5
Vegetation										
Achillea millefolium L.	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	x	x
Acinos arvensis (Lam.) Dandy	x									x
Aegopodium podagraria L.	x									
Agrostis gigantea Roth	**D**	x	x							
Agrostis stolonifera L.	**D**	x	x							
Agrostis tenuis Sibth.		**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Alchemilla vulgaris L. S.l.	x			x	x	x	x			x
Anthriscus sylvestris (L.) Hoffm.	x									
Anthylis baltica(L.) Hoffm.	x									
Artemisia vulgaris L.	x	x	x	x	x	x	x	x	x	x
Barbarea stricta Andrz.	x									
Calamogrostis arundinacea (L.) Roth.	x			x	x					
Calamogrostis epigejos (L.) Roth	x			x	x		x			
Campanula patula L.	x			x	x	x		x		
Carex rostrata Stokes				x	x					x
Centaurea diffusa Lam.	x									
Centaurea jacea L.										x
Cerastium holestoides Fr.	**D**			**D**	**D**		x	x		
Chamaenerion angustifloium (L.) Scop.	x				x	x				x
Cirsium arvense (L.) Scop.	**D**	x	x	x	x	x	x	x		x
Cirsium vulgare (Savi) Ten.	x			x						
Coronaria flos-cucculi (L.) A. Br.	x				x		**D**			
Dactylis glomerat a L.				x	x			x	x	
Decschampsia caespitosa(L.) P. Beauv.					x					
Dianthus deltoides L.	x								x	
Elytrigia repens (L.) Nevski	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Epilobium hirsutum L.	x									
Epilobium montanum L.	x	x		x	x					
Equisetum arvense L.	**D**	x		**D**	x		**D**		x	x
Equisetum pratense Ehrh.	x					x		x		
Equisetum sylvaticum L.								x		

Trees planted	***Salix* sp.**			***Betula pendula***			***Populus tremuloides x Populus tremula***		***Alnus incana***	
Erigeon acris L.	x			x	x		x			
Erigeon annuus (L.) Pers.				**D**						
Erigeon canadensis L.	x			x			x			
Festuca ovina L. s.str.				x				x	x	x
Festuca pratensis Huds.	x					**D**	**D**	**D**		
Fragaria vesca L.		x	x				x	**D**		
Galeopsis tetrahit L.									x	
Galeopsis bifida Boenn.				x	x					
Galeopsis speciosa Mill.	x									
Galium aparine L.	*x*			x						
Gnaphalium sylvaticum L.	x				x		x			
*Hieracium sp.*L.	**D**		x							
Hypericum perforatum L.	**D**	x	x	x	x	x	x	x	x	x
Juncus compressus Jacq.	x			x						
Juncus conglomeratus L.	x			x	x					
Juncus effusus L.	*x*	x		x	x	x	x	x		
Lapsana communis L.	x			x				x		
Lathyrus pratensis L.	x			**D**	x	x	x	x		
Leontodon autumnalis L.	x				x	x				
Leontodon hispidus L.	*x*			**D**	x		x	x		x
Leucanthemum vulgare L.		x	x	**D**	**D**		x	x	x	x
Lolium perenne L.	x	x	x				**D**		x	
Lotus corniculatus L.s.str.	x									
Luzula multiflora (Ehrh.) Lej.	x									
Matricaria perforata Merat	x	x	x	**D**	x		**D**	x		
Medicago lupulina L.	x	x	x	**D**	x	x	x	x	x	**D**
Meliandrum album (Mill.) Garcke		x		x	x		x			
Meliotus albus Medik.	x			x	x		x	**D**		
Mentha arvensis L.		x	x	**D**	x		x	x		
Myosotis sparsiflora Pohl	x				x	x				
Myosotis sylvatica Ehrh.ex Hoffm.				x	x		x			
Phleum pratense L.	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Plantago lanceolata L.		x	x		x					
Plantago major L.				x						
Poa annua L.					x					
Poa pratensis L.	**D**			**D**	x	x	x	x	x	**D**

Trees planted	***Salix* sp.**			***Betula pendula***			***Populus tremuloides x Populus tremula***		***Alnus incana***	
Potentilla anserina L.	**D**	x	x	**D**	**D**		x			
Potentilla argentea L.	x	x	x		x	x	x	x	x	x
*Potentilla erecta (*L.) Raeusch.	x									
*Potentilla reptans*L.	**D**	x		x	**D**		**D**			
Prunella vulgaris L.	x	x	x	x	x		x			
Ranunculus acris L.		x	x	x	x	x	x	x	x	
Rubus idaeus L.	*x*									
Rumex acetosa L.	*x*		x	**D**	**D**		x			
Rumex confertus Willd.	x			x	x	x	x	x	x	x
Senecio jacobaea L.	*x*			x	x		x	x	x	x
Silene vulgaris (Moench) Garcke							x			
Solidago canadensis L.	x					x	x	x		x
Solidago virgaurea L.		x	x	x	x		x			
Sonchus arvensis L.	**D**	x	x	**D**	**D**		**D**		x	x
Sonchus oleraceus L.	*x*					x	x	x		x
Stellaria graminea L.	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Stellaria holostea L.	x								**D**	
Stellaria media (L.) Vill.		x	x		x	x	x	x	x	x
Taraxacum officinale F. H. Wigg.s.l.	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Thlaspi arvense L.				x						
Trifolium hybridum L.	x	x	x	**D**	**D**		**D**			
Trifolium medium L.		x	x							
Trifolium pratense L.	x	**D**	**D**	x	**D**	**D**	**D**	**D**	x	x
Trifolium repens L.		x	x	**D**	x	x	**D**	**D**	x	
Tussilago farfara L.	x	x	x	**D**	x	x	x		**D**	**D**
*Urtica dioica*L.	*x*			x					x	
Valeriana officinalis L.				x	x					x
Veronica chamaedrys L.	x	x	x	x	x		x		x	x
Vicia cracca L.	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**	**D**
Vicia sylvatica L.	x			x						
Viola arvensis Murray				x						
Total	**62**	**37**	**34**	**60**	**59**	**28**	**48**	**33**	**28**	**31**

Abbreviations: x – species found in the sampling plot; **D –** species found in the sampling plot and is dominant (covers more than 50%).

Table 3. Changes in the composition of herbaceous plant communities (from the third to the sixth year)

	Disappeared species	New species
Salix sp.	*Acinos arvensis, Aegopodium podagraria, Alchemilla vulgaris, Anthriscus sylvestris, Anthylis baltica, Barbarea stricta, Calamogrostis arundinacea, Calamogrostis epigejos, Campanula patula, Centaurea diffusa, Cerastium holestoides, Chamaenerion angustifloium, Cirsium vulgare, Coronaria flos-cucculi, Dianthus deltoides, Epilobium hirsutum, Epilobium montanum, Equisetum arvense, Equisetum pratense, Erigeon acris, Galeopsis speciosa, Galium aparine, Gnaphalium sylvaticum, Juncus compressus, Juncus conglomeratus, Juncus effusus, Lapsana communis, Lathyrus pratensis, Leontodon autumnalis, Leontodon hispidus, Lotu scorniculatus, Luzula multiflora, Meliotus albus, Myosotis sparsiflora, Poa pratensis, Potentilla erecta, Rubu sidaeus, Rumex confertus, Senecio jacobaea, Solidago canadensis, Sonchus oleraceus, Urtica dioica, Vicia sylvatica*	*Agrostis tenuis, Fragaria vesca, Meliandrum album, Plantago lanceolata, Ranunculus acris, Solidago virgaurea, Trifolium medium, Trifolium repens*
Betula pendula	*Calamogrostis arundinacea, Calamogrostis epigejos, Care xrostrata, Cerastium holestoides, Cirsium vulgare, Dactylis glomerate, Epilobium montanum, Equisetum arvense, Erigeon acris, Erigeron annuus, Erigeron canadensis, Festuca ovina, Galeopsis bifida, Galium aparine, Juncus compressus, Juncus conglomeratus, Lapsana communis, Leontodon hispidus, Leucanthemum vulgare, Matricaria perforate, Meliandrum album, Meliotu salbus, Mentha arvensis, Myosotis sylvatica, Plantago major, Potentilla anserina, Potentilla reptans, Prunella vulgaris,Raphanus raphanistrum, Rumex acetosa, Senecio jacobaea, Solidago virgaurea, Sonchus arvensis, Thlaspi arvense, Trifolium hybridum, Urtica dioica, Valeriana officinalis, Veronica chamaedrys, Vicia sylvatica, Viola arvensis*	*Chamaenerion angustifloium, Coronaria flos-cucculi, Decshampsia caespitosa, Equisetum pratense, Festuca pratensis, Gnaphalium sylvaticum, Leontodon autumnalis, Plantago lanceolata, Poa annua, Potentilla argentea, Solidago canadensis, Sonchus oleraceus, Stellaria media*
Populus tremuloides x Populus tremula	*Alchemilla vulgaris, Calamogrostis epigejos, Erigeon acris, Erigeon canadensis, Gnaphalium sylvaticum, Lolium perenne, Meliandrum album, Myosotis sylvatica, Potentilla anserina, Prunella vulgaris, Rumex acetosa, Silene vulgaris, Solidago virgaurea, Sonchus arvensis, Trifolium hybridum, Tussilago farfara, Veronica chamaedrys*	*Campanula patula, Dactylis glomerata, Equisetum pratense, Equisetum sylvaticum, Festuca ovina, Lapsana communis*
Alnus incana	*Achillea millefolium, Agrostis tenuis, Artemisia vulgaris, Elytrigia repens, Equisetum arvense, Festuca ovina, Hypericum perforatum, Leucanthemum vulgare, Medicago lupulina, Phleum pratense, Poa pratensis, Potentilla argentea, Rumex confertus, Senecio jacobaea, Sonchus arvensis, Stellaria graminea, Stellaria media, Taraxacum officinale, Trifolium pratense, Tussilago farfara, Veronica chamaedrys, Vicia cracca*	*Dactylis glomerata, Dianthus deltoides, Galeopsis tetrahit, Ranunculus acris, Stellaria holostea, Trifolium repens, Urtica dioica*

new species in the succession included *Fragaria vesca*, *Equisetum sylvaticum*, and *Festuca ovina*. These were the only new species in the field which are characteristic of forest. There were new species which were characteristic of fields: *Campanula patula*, *Cirsium arvense*, *Solidago canadensis*, *Plantago lanceolata* and others (Table 3).

Indicator species

MRPP analysis showed significant difference in vegetation composition among planted tree species blocks, except between *Alnus incana* and *Populus tremuloides x Populus tremula.*

Indicator species analysis identified characteristic species that had significantly higher occurrence under a particular planted tree species canopy. For each tree species, no significant indicator species were identified for particular survey years, and thus all years were considered together in further analysis. More characteristic species were found under *Salix sp.* (*Phleum pratense*, *Artemisia vulgaris*, *Trifolium pratense*, *Plantago lanceolata* and *Sonchus arvensis*) and *Betula pendula* (*Poa annua*, *Taraxacum officinale*, *Trifolium hybridum*, *Myosotis sylvatica*, *Leontodon autumnalis* and *Cerastium holestoides*). The only characteristic species under a *Populus tremuloides x Populus tremula* canopy was *Festuca ovina*, and *A. incana* lacked an associated indicator species.

DICSUSSION

Herbaceous plant diversity depends on competition for light and other resources under a developing tree canopy, with replacement of ruderal species by shade tolerant species (Mestre *et al.* 2017). The most common species were *Elytrigia repens*, *Phleum pratense*, *Agrostis tenuis* and *Trifolium repens*, all of which also tended to be dominant in the species cover. These species are common in well conditions in abandoned fields (Pucka *et al.* 2016) and *Phleum pratense* was planted as fore-crop. In a similar study in Sweden, after four years the vegetation was dominated by different ruderal species: *Cirsium arvense*, *Galeopsis tetrahit*, *Urtica dioica* (Gustaffson 1986). These differences in dominating species can be explained by differing site conditions and fore-crop. However, in both studies in the short term up to five years the herbaceous layer was still dominated by field species. Nevertheless, we observed a general decrease of annual and biannual species like *Medicago lupulina*, *Erigeron annuus*, *Cirsium arvense*, *Cerastium holosteoides*, *Matricaria perforata*. This can be explained by unsuccessful establishment from seed in increased shade conditions and competition from perennial species (Belsky 1992). However, the shift from annual to perennial species occurs in old field succession before tree establishment and colonisation of forest herbaceous species (Lepš 1987).

In our study, herbaceous plant diversity decreased under all tree species canopies. The initial plant composition depends on seed bank composition (Egler 1954, Pucka et al. 2016). During development of a tree canopy, field species are lost and biological diversity can decrease due to shading by the tree canopy (Laquerbe 2000). However, previous studies have contrasting results in regard to species richness in short-rotation plantations. In a study conducted in western North America, in a bioenergy plantation of *Populus tremuloides x Populus tremula*, herbaceous species diversity was observed to be lower than in forests (Halpern, Spies 1995), but in Sweden richness was higher under *Populus tremuloides x Populus tremula* was higher at three to five years after planting than on agricultural land and in coniferous forest (Gustafsson 1987). In France, herbaceous plant diversity was observed to decrease with tree age, and effects of past land-use rapidly decreased in the first years after plantation establishment (Archaux *et al.* 2010). Therefore, short-rotation plantations can improve or decrease biological diversity, and on a landscape level the effect depends on the area of the plantations (Weih 2003). The species in the plantation can be used for livestock feed (Pruchniewicz 2017), biogas production (Bauer *et al.*2014) and granule production (Kirsten *et al.* 2016). Some of the species can be used for medicinal purposes, but usually in plantations their distribution is not suitable for commercial purposes (Zechmeister *et al*. 2003).

The planted tree species can be expected to have effect on species richness and composition. In the fifth year after planting, species richness was similar under the planted tree species canopies. The identified indicator species for tree species canopies might suggest different vegetation composition, but all of the indicator species were field species, and the differences can be explained random establishment and different fore-crops seeded between tree rows. Although we showed a loss of some ruderal annual species, very few typical forest species had colonised the plantation in the five years of study. This suggests that a major change in light conditions probably had not yet occurred, due to the average spaces (2 m) between tree rows creating side lighting. Also, the distance to forest might have been too far for seed dispersal of forest plant species.

CONCLUSION

The lowest species diversity occurred in the *Alnus incana* plot, and the highest in the *Betula pendula* plot.

Diversity of herbaceous species decreased with tree age from third to fifth year after planting, excepting in the *Alnus incana* plot. In the fifth year after planting, herbaceous species richness decreased in the *Salix sp*. block by 55.5 %, in the *Betula pendula* block by 39.7 %, in the *Populus tremuloides x Populus tremula* block by 71.7 %, and under *Alnus incana* only by 7%, compared to richness in the second year. Five years after planting, the plots were dominated by herbaceous vegetation with typical field species and had a general lack of forest species. The *Alnus incana* blocks lacked characteristic indicator species, while some differences in plant composition was noted in the other tree species blocks.

This vegetation layer can be important for increasing ecosystem services (for example, medicinal plants and for pollinators. The area between rows can be used for livestock feed in the first 5-6 years after planting.

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