SPECIES COMPOSITION EFFECTS OF FOREST STANDS ON AFFORESTED AGRICULTURAL LAND ON THE SOIL PROPERTIES*

I. Kupka, V. Podrázský

Czech University of Life Sciences, Faculty of Forestry and Wood Sciences, Department of Silviculture, Prague, Czech Republic

Afforestation of agricultural lands took place on different sites and ecological conditions, including lower and medium elevated localities, and continues to present. On the other side, low attention is paid to ongoing soil changes. The study is aiming to fill this gap and documents effects of species composition in stands of Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), birch (*Betula verrucosa*) and Douglas fir (*Pseudotsuga menziesii*). These stands are in the territory of the School Training Forest Kostelec nad Černými lesy, in the altitude 430 m a.s.l., on the site of forest type 4Q1. The plots were compared with the neighboring locality with arable land. During the first roughly 40 years, considerable changes were documented on the afforested plots. The surface humus layers in the coniferous stands were formed, fixing relatively high amounts of carbon. Also the favorable effects on the upper mineral horizons were observed, consisting in the shifts of the soil physical characteristics and in the increased sequestration of carbon. Afforestation increased the carbon fixation not only due to stand biomass and litter necromass accumulation, but also due to increased sequestration in the upper mineral soil.

afforestation of agricultural lands; species composition; Douglas fir; soil physical characteristics; c-sequestration

INTRODUCTION

Afforestation of agricultural lands represents topical problem in the Czech forestry in the last periods. Extended shifts in the land use were common in the past as well as at present, as the consequence of EU agrarian policy. Afforested area increased considerably since the end of the WW II, in 1960ies especially. From this point of view, many authors dealt with this topic (Hatlapatková et al., 2006; Kacálek et al., 2006, 2007; Špulák, 2006), as well as the development of successional stands was studied. There is only limited information concerning the forest soil character restoration on the contrary, as the basic predisposition for complex ecosystem functions (Podrázský, Štefáník, 2002; Podrázský, 2006; Podrázský, Procházka, 2009; Podrázský et al., 2010). Parallel problem is represented by the forest soil restoration on localities degraded by bulldozer site preparation (Podrázský, 2008; Podrázský et al., 2006). Importance of the afforestation/reforestation of different sites is discussed also as the concern of biodiversity and stability of the landscape (Hlaváč et al., 2006).

For consideration of the whole problem, the comparizon with natural and close-to-nature forests it is basic concept in similar site conditions (Podrázský, Remeš, 2007a, b; Podrázský, Viewegh, 2003), even so with the state in intense commercial forests (Novák, Slodičák, 2006; Podrázský, Remeš, 2008; Bílek et al., 2009).

The most important topics in the restoration of forest soil functions are the formation of the functioning holorganic layers, the mineral soil physical structure. These processes document the retention capacity for water as well as for macroelements. Aim of the presented paper is to document of the state of soil physical characteristics after agricultural soils afforestation separately for particular used tree species and to document of the retention capacity for main microelements (C, N, P, K, Ca, Mg).

MATERIAL AND METHODS

The effects of particular species on the selected soil characteristics was evaluated on the series of research plots on the territory of the School Training Forest Kostelec nad Černými lesy, close to Krymlov village. The studies stands were located in the altitude 430 m a.s.l., the mean annual precipitation range about 600 mm, mean annual temperature reaches value 7.5 °C, Forest Site Group is determined as 4Q. The soil type is evaluated as Gleyed Luvisol. The stands were established on the agriculture land by planting of stands of Scots pine, Norway spruce, white birch and Douglas fir in spring 1967.

* Paper originated as a part of the project NAZV QL102A085 Optimisation of Silvicultural Treatments for Biodiversity Increase in Commercial Forests. Preliminary results were presented in the Czech version on local Czech-Slovak seminar, used with accordance of organizers.

The dendrometrical characteristics and stand parameters were determined by standard dentrometrical methods (Podrázský et al., 2009; Šálek, Zahradník, 2008) at the stand age of 39 years (Table 1).

Retention potential was determined for the topmost part of the soils, i.e. for the humus forms (Green et al., 1993). The holorganic horizons were sampled quantitatively using the steel frame 25x25 cm, by particular holorganic horizons. Dry matter was determined at 105 °C.

The soil samples from top mineral soil layer (upper 10 cm) were taken as so-called Kopecky's cylinders. The samples were processed by standardized methods to get pedophysical characteristics (in horizon Ah – Podrázský, Remeš, 2005). Samples for chemical analysis and holorganic horizons analysis were taken in the autumn 2006, Kopecky's cylinders were taken in 2008, always 4 repetitions for each sample plot. Humus and carbon volume were analysed in Laboratory Tomáš (VULHM VS Opočno) as the volume of COX (Podrázský et al., 2009). Carbon volume was then calculated in humus horizons from its volume and weight of horizons. The carbon volume in 10 cm upper layer was calculated using total carbon volume and weight.

Software STATISTICA v.8.0 was used for statistical evaluation using one factorial ANOVA (after verifying the normality of data) as well as by post-hoc Tukey's test. Results were evaluated on common level of significance i.e. ($p < 0.01$, $p < 0.05$).

RESULTS AND DISCUSSION

The basic characteristics of observed species in the stands are given in Table 1. The research plots were rather small ones and therefore their statistical likelihood are limited but the larger stands were not available in this case. Nevertheless the data confirmed Douglass fir dominance in growth and the beginning of birch stand disintegration. These results were described in other paper (Podrázský et al., 2009) and they are similar to the results of other authors (Kantor, 2008; Podrázský, Remeš, 2008). The publications were cited as they serve as an illustrative example for the main purpose of the paper. However data suggests that above-ground biomass fixing carbon and nutrients have the highest value for Douglass fir stands.

Pedophysical characteristics the top most 10 cm upper mineral layer are given in Table 2. The farm land were different in all pedophysical characteristics on highly significant level with the exception of specific weight (the data have higher values but the differences are not significant) and capillary water capacity. The differences among different tree species stands were not significant in terms of pedophysical variables with the exception of soil humidity in Douglas fir stand which was significantly lower than in the other species stands. The difference is probably caused by higher productivity of Douglas fir and therefore its higher water consumption. On the other hand not significant but the highest specific weight of topmost mineral layer in Douglas fir stand is caused by the lowest humus volume (see Table 3). The same is true for the lowest value of air capillary capacity for the same species.

Upper layer humus volume and total humus volume and carbon volume are given in Table 3. Holorganic volume and carbon content could be compared with data which describe the soil under mature stand (label Mature stand in Table 3) which is in neighborhood of other analyzed stands. The analyses do not compromise the Kopecky's cylindrical soil samples and therefore the volume

Table 1. Comparison of production potential of particular tree species in the stands established on agricultural lands

	Pine	Spruce	Birch	Douglass fir
Plot size (ha)	0.250	0.191	0.134	0.125
Age (year)	39	39	39	39
Number of trees	352	221	59	116
Trees per ha	1408	1157	440	928
Volume (m^3)	88.015	66.73375	21.05625	54.643
Volume per ha (m^3)	352.1	349.4	157.1	438.6
Annual mean increment	9.03	8.96	4.03	11.25
Annual mean increment in % of Douglas fir	80	80	36	100

Table 2. Pedophysical characteristics in topmost 10 cm of mineral soil in the stands of particular tree species

	%	$g.cm^{-3}$	$g.cm^{-3}$	%	%	%
Species	soil moisture	volume weight	specific weight	porosity	capillary water capacity	capillary air capacity
Pine	10.99	1.14	2.55	55.16	25.80	29.36
Spruce	9.30	1.10	2.54	56.63	33.17	23.46
Birch	9.74	1.15	2.54	54.70	29.98	24.72
Douglas fir	6.06 a	1.23	2.57	52.16	32.75	19.41
Farm land	16.43 b	1.46 a	2.60	43.89 a	35.66	8.23 a

Note: letters indicate statistically significant differences at level of significance $p < 0.01$

weight soil was just only assessed as comparable with the data for horizon Ah under Norway spruce stand. The data proved the highest upper layer humus accumulation and carbon content under mature stand. The other sites i.e. under other tree species stands were not significantly different but within these stands the highest volume of upper layer humus was under Norway spruce stand. The humus layer is not yet created under birch stand. The figures in upper layer of mineral soil are similar (not significantly different) under all forest stands as well as in farm land. Top layer of mineral soil under birch stands has more or less the same volume of carbon accumulation as the other soils. Lower volume in layer Ah was significant under Douglas fir stand because the litter is decomposed much more quickly than under the stand of Norway spruce or Scots pine and in farm land where the volume was the lowest. Similar results for relationship among spruce, Douglas fir and broadleaved species were found in the paper of Podrázský and Remeš (2008). Significantly higher enrichment of mineral layers under forest stands in comparison with arable land was described by Podrázský and Procházka (2009). The comparison with the soil characteristics under "mature stand", the carbon volume in upper humus layer of farm land afforested 39 years ago was only 1/5 of carbon volume in soils under mature forest stands or only 50% of the soils under stands with more natural species composition (Podrázský, Remeš, 2007b).

CONCLUSIONS

Afforestation of farm land has changed significantly the basic soil characteristics. Our research proved dramatic changes in pedophysical characteristics, namely the decrease of volume weight as the results of soil structure changes and the increase of humus volume caused by new forest stands. The other changes are the increase of air capillary volume for the same reasons as above.

It could and should be repeated that the main reason for these pedophysical soil changes is different use of land i.e. afforestation and therefore the interruption of plaughing. The main driving force is a process of increasing organic material in soil as a consequence of litter fall on the surface and within upper soil layer as well as soil fauna activities.

Afforestation significantly influenced the carbon fixation in forest soil of forest ecosystems. First of all it should be mentioned the accumulation of organic materials in the holorganic layers i.e. in upper humus layers. The important is at the same time enrichment of upper mineral layer. The phenomenon is most probably common for these processes.

Carbon accumulation in holorganic layers during the first forty years could be observed and its volume is equal to about 20% of carbon volume in the soils under coniferous stands in the area or/and 50% of carbon volume in the soil under broadleaved species. Afforestation of farm land

Table 3. Dry matter of the surface humus layers and total amount of humus and carbon

Species		t/ha	%	%	t/ha	
	horizon	weight	total humus	carbon volume	carbon stock	carbon stock in Ah
Pine	L + F1	9.44	65.80	38.17	3.60	
	F2 + H	22.58a	57.30ab	33.24	7.50	
	Ah		4.10 b	2.38		**27.13**
		32.02			**11.1**	
Spruce	L + F1	11.57	58.30	33.82	3.91	
	F2	8.74	59.60	34.57	3.02	
	H	17.49 a	49.40 b	28.65	5.01	
	Ah		3.80 ab	2.20		**24.20**
		37.80			**11.94**	
Birch	0–10		3.50 ab	2.03		**23.34**
	10–20		1.90	1.10	0.00	
Douglas fir	L + F1	13.40	57.80	33.53	4.49	
	F2 + H	20.51 a	48.80 b	28.31	5.81	
	Ah		2.70 ab	1.57		**19.31**
		33.91			**10.30**	
Mature stand	L + F1	9.71	54.70	31.73	3.08	
	F2	16.46	70.60	40.95	6.74	
	H	112.12 b	64.60 a	37.47	42.01	
	Ah		3.80 ab	2.20		**24.20**
		138.29			**51.83**	
Farm land	0–10		1.80 a	1.04		**15.18**
	10–20		1.80	1.04	0.00	

could be seen as one of the important vehicle to increase retention capacity of the landscape and at the same time to increase sequestration of carbon in forest ecosystems.

REFERENCES

BÍLEK, L. – REMEŠ, J. – ZAHRADNÍK, D.: Natural regeneration of senescent even-aged beech (*Fagus sylvatica* L.) stands under the conditions of Central Bohemia. J. Forest Sci., *55* (4), 2009: 145–155.

GREEN, R. N. – TROWBRIDGE, R. L. – KLINKA, K.: Towards a taxonomic classification of humus forms. Forest Sci., *39*, 1993, Monograph Nr. 29, Supplement to Nr. 1. 49 pp.

HATLAPATKOVÁ, L. – PODRÁZSKÝ, V. – VACEK, S.: Výzkum v lesních porostech na bývalých zemědělských půdách v oblasti Deštného a Neratova v PLO 25 – Orlické hory. In: Zalesňování zemědělských půd – výzva pro lesnický sektor, Kostelec n. Č. l., 17. 1. 2006, pp. 185–192.

HLAVÁČ, V. – HOFHANZL, A. – ČERVENKA, M. – BERAN, V.: Zalesňování zemědělských půd z hlediska ochrany přírody. In: Zalesňování zemědělských půd – výzva pro lesnický sektor, Kostelec n. Č. l., 17. 1. 2006, pp. 43–46.

KACÁLEK, D. – BARTOŠ, J. – ČERNOHOUS, V.: Půdní poměry zalesněných zemědělských pozemků. In: Zalesňování zemědělských půd – výzva pro lesnický sektor, Kostelec n. Č. l., 17. 1. 2006, pp. 169–178.

KACÁLEK, D. – NOVÁK, J. – ŠPULÁK, O. – ČERNOHOUS, V. – BARTOŠ, J.: Přeměna půdního prostředí zalesněných zemědělských pozemků na půdní prostředí lesního ekosystému – přehled poznatků. Zpr. lesn. Výzk., *52* (4), 2007: 334–340.

KANTOR, P.: Production potential of Douglas fir at mesotrophic sites of Křtiny Training Forest Enterprise. J. Forest Sci., *54* (7), 2008: 321–332.

NOVÁK, J. – SLODIČÁK, M.: Opad a dekompozice biomasy ve smrkových porostech na bývalých zemědělských půdách. In: Zalesňování zemědělských půd – výzva pro lesnický sektor, Kostelec n. Č. l., 17. 1. 2006, pp. 155–162.

PODRÁZSKÝ, V.: Effect of thinning on the formation of humus forms on the afforested agricultural lands. Scientia Agric. Bohem., *37*, 2006: 157–163.

PODRÁZSKÝ, V.: Tvorba povrchového humusu při zalesňování zemědělských ploch a po buldozerové přípravě v Krušných horách. Zpr. lesn. Výzk., *53* (4): 2008: 258–263.

PODRÁZSKÝ, V. – PROCHÁZKA, J.: Zalesnění zemědělských půd v oblasti Českomoravské vysočiny a obnova vrstvy nadložního humusu. Zpr. lesn. Výzk., *54* (2), 2009: 79–84.

PODRÁZSKÝ, V. – REMEŠ, J.: Retenční schopnost svrchní vrstvy půd lesních porostů s různým druhovým složením. Zpr. lesn. Výzk., *50* (1), 2005: 46–48.

PODRÁZSKÝ, V. – REMEŠ, J.: Změny kvality a množství nadložního humusu při přirozeném zmlazení bukových porostů na území Školního lesního podniku Kostelec nad Černými lesy. Zpr. lesn. Výzk., *52* (2), 2007a: 39–43.

PODRÁZSKÝ, V. – REMEŠ, J.: Humus form status in close-to-nature forest parts comparing to afforested agricultural lands. Lesnícky časopis – Forestry Journal, *53*, 2007b: 99–106.

PODRÁZSKÝ, V. – REMEŠ, J.: Půdotvorná role významných introdukovaných jehličnanů – douglasky tisolisté, jedle obrovské a borovice vejmutovky. Zpr. lesn. Výzk., *53* (1), 2008: 27–33.

PODRÁZSKÝ, V. – ŠTEFÁNÍK, R.: Vývoj půd na zalesněných zemědělských plochách – oblast LS Český Rudolec. Zpr. lesn. Výzk., *47* (2), 2002: 53–56.

PODRÁZSKÝ, V. – VIEWEGH, J.: Vliv hospodářských zásahů a dynamiky porostů na stav půd a přízemní vegetace lesních ekosystémů ve zvláště chráněných územích. Příroda, Special Issue, 2003 (1): 311–316.

PODRÁZSKÝ, V. – REMEŠ, J. – ULBRICHOVÁ, I.: Rychlost regenerace lesních půd v horských oblastech z hlediska kvantity nadložního humusu. Zpr. lesn. Výzk., *51* (4), 2006: 230–234.

PODRÁZSKÝ, V. – REMEŠ, J. – HART, V. – MOSER, W. K.: Production and humus form development in forest stands established on agricultural lands – Kostelec nad Černými lesy region. J. Forest Sci., *55*, 2009: 299–305.

PODRÁZSKÝ, V. – REMEŠ, J. – TAUCHMAN, P. – HART, V.: Douglaska tisolistá a její funkční účinky na zalesněných zemědělských půdách. Zpr. lesn. Výzk., *55* (1), 2010 (in print).

ŠÁLEK, L. – ZAHRADNÍK, D.: Wedge prism as a tool for diameter and distance measurement. J. Forest Sci., *54*, 2008: 121–124.

ŠPULÁK, O.: Příspěvek k historii zalesňování zemědělských půd v České republice. In: Zalesňování zemědělských půd – výzva pro lesnický sektor, Kostelec n. Č. l., 17. 1. 2006, pp. 15–24.

Received for publication on October 20, 2010
Accepted for publication on January 24, 2011

KUPKA, I. – PODRÁZSKÝ, V. (Česká zemědělská univerzita, Fakulta lesnická a dřevařská, Praha, Česká republika):

Vliv druhového složení lesních porostů založených na zemědělských půdách na jejich charakteristiky.

Scientia Agric. Bohem., *42*, 2011: 19–23.

K zalesňování zemědělských půd docházelo v minulosti a dochází v současnosti v nejrůznějších podmínkách, včetně nižších a středních poloh, na druhé straně poměrně malá pozornost je přitom věnována probíhajícím změnám v půdním prostředí. Předkládaný příspěvek proto dokládá vliv druhového složení v porostech borovice lesní (*Pinus sylvestris*), smrku ztepilého (*Picea abies*), břízy bradavičnaté (*Betula verrucosa*) a douglasky tisolisté (*Pseudotsuga menziesii*) na území ŠLP v Kostelci nad Černými lesy, v nadmořské výšce 430 m n. m., na stanovišti odpovídající LT 4Q1. Plochy byly srovnávány se sousedním pozemkem s ornou půdou, lokalizovaným v bezprostředním sousedství. Během prvních zhruba 40 let došlo na zalesněných lokalitách ke značným změnám, zejména došlo k tvorbě nadložního humusu, ve kterém bylo poutáno značné množství uhlíku. Rovněž byly patrné příznivé vlivy na nejsvrchnější vrstvy minerálního půdního profilu, které spočívaly v úpravě pedofyzikálních charakteristik a ve zvýšení obsahu poutaného uhlíku. Zalesnění se tedy v oblasti sekvestrace uhlíku projevuje příznivě nejen díky akumulaci biomasy porostu a nekromasy nadložního humusu, ale na řadě lokalit i obohacením svrchních minerálních horizontů.

zalesnění zemědělských půd; druhové složení; douglaska; pedofyzikální vlastnosti; poutání uhlíku

Contact Address:

Prof. Ing. Ivo K u p k a , CSc., Česká zemědělská univerzita v Praze, Fakulta lesnická a dřevařská, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, e-mail: kupka@fld.czu.cz