

# Soil cover under *Betula pendula* Roth. Stands growing on the coal mining spoils in the Kuznetsk region, Russia

Vladimir Ufimtsev<sup>1,\*</sup>, Ivan Belanov<sup>2</sup>, and Olga Trefilova<sup>3</sup>

<sup>1</sup>The Federal Research Center of Coal and Coal Chemistry of SB RAS, 18, Leningradsky ave., Kemerovo, Russia, 650065

<sup>2</sup> Institute of Soil Science and Agrochemistry of SB RAS, 8/2, Academic Lavrentyev pr., Novosibirsk, Russia, 630090

<sup>3</sup> Sukachev Institute of Forest SB RAS, Federal Research Center “Krasnoyarsk Science Center SB RAS”, Academgorodok, 50/28, Krasnoyarsk, 660036

**Abstract.** The article presents results of the study on the influence of the white birch *Betula pendula* Roth. stands with varying crown cover (<30, 31-50 and >50%) on the properties of soils developing under these stands on the coal mining spoils in the Kuznetsk hollow (so called Kuzbas region). The studied birch stands were located in two ecotopes, i.e. the northern and southern forest-steppe subzone at Kedrovsk (55°32'33"N 86°04'11"E) and Bungur (54°16'09"N 86°09'00"E) coal mines, respectively. The methodology of the study was based on the concept of plant phytogenic fields. The highest rate of soil organic matter and nutrients accumulation was found under sparse stands in both ecotopes. However, the southern ecotope, as compared to the northern one, was found to have higher organic matter and nutrients content irrespective of the birch stand density.

## 1 Introduction

The white birch (*Betula pendula* Roth.) is well known as a pioneer of natural forest revegetation on coal mining spoils in the Kuzbas region [1]. Trees affect soil organic matter composition and spatial distribution, nutrients forms and their content, soil acidity. Trees also alter chemical composition of precipitating water, mediate the rate of detritus decomposition, as well as microbiota composition and biological activity in general [2-5].

The space that experiences the influence of a tree, is called an ecological field (EF) [Ошибка! Закладка не определена., 6]. There are many studies describing the results of investigating the effect of an individual tree or sparse tree stands on soil properties, and the decreasing effect of a tree on soil properties with increasing distance from the tree trunk is well documented. Therefore the EF vertical projection on soil surface is usually differentiated according to the EF effect. Currently there no standardized common approaches for such differentiation, including the number of differentiated subfields.

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\* Corresponding author: [uwy2079@gmail.com](mailto:uwy2079@gmail.com)

The influence of trees, growing in denser stands with overlapping EF of different trees, on soil properties under them is less studied. The overlapping of individual tree EF is increasing with increasing crown cover, which is manifested by soil cover structure and status [5, 7].

The aim of the study was to compare the influence of white birch stands of different density on the soil properties, developing under the stands during coal mining spoils natural revegetation.

## 2 Materials and methods

The study was carried out on the coal mining spoils, located near 1) the Kedrovsk coal mine in the northern forest-steppe subzone, 55°32'33"N 86°04'11"E, and 2) Bungur coal mine in the southern forest-steppe subzone, 54°16'09"N 86°09'00"E. The studied soils were technosols [8], or embryozems, i.e. young soils, developing under the canopy of class II birch *B. pendula* stands aged 28-35 yrs. In many forest inventories the crown cover (CC), defined as percentage of the ground area covered by the vertical projection of crowns, is the main stand density variable. The study sites were chosen according to the birch stand CC: 20-30% (sparse stands), 50-60% (moderately dense stands) and 80-90% (highly dense stands). Within the area of each study site the below-crown, near-crown and beyond-crown concentric circle areas obtained by vertical projections of individual EF on soil surface [6]. In sparse tree stands the external boundary of the below-crown area was determined by vertically projecting external boundary of a tree crown on soil surface, while near-crown circle was determined according to ground plant cover. The total individual EF area was estimated as 4-times of the area of the crown vertical projection on the ground. In moderately and highly dense stand individual EF areas overlapped.

Soil samples were collected from 0-10 cm layer of the predominating soil type within each phytogenic field zone in triplicates. Total soil carbon (STC) and nitrogen (STN) were determined by 2400 Series II CHNS/O Perkin Elmer elemental analyzer. Labile soil phosphorus content was measured colorimetrically in 0.5N acetic acid extracts; exchangeable potassium was measured in 1N ammonium acetate extracts. Soil pH was measured in water extracts potentiometrically by Hanna Instruments pH-meter. Granulometric composition of soil particles was measured by sieving [9], while  $\leq 1$  mm fraction was determined by laser diffraction using Fritsche Analysette 22.

Plant litter was sampled in thus established zones and then characterized. Projective cover (PC) of vegetation was determined as the percentage of ground area covered by the vertical projection of the respective aboveground phytomass. Soil cover structure was determined by cartography for every CC-specific circle within a phytogenic field.

## 3 Results and discussion

Individual white birch EF did not have distinct boundaries as judged by their leaf litter, as the latter was found in all 3 concentric circles with its thickness and projective cover in all gradually decreasing with increasing distance from tree trunks.

In highly dense birch stands the horizontal differentiation herbaceous plant cover did not show any differentiation: the projective cover was 8%, being mostly concentrated on elevated microrelief. Overall 32 plant species were recorded, with predominating *Melilotus officinalis* L. (3% PC), *Vicia cracca* L. (2% PC), *Dactylis glomerata* L. (1% PC) and *Medicago lupulina* L. (1% PC), the rest being represented by singletons. The green phytomass standing stock was estimated as  $26 \pm 8$  g/m<sup>2</sup>. Organic matter accumulating

embryozeims (OM-embryozeims) accounted for 95%, while initial embryozeims were found on just 5% of the study site area.

In moderately dense birch stands the below-crown zones had 30% of the ground plant cover, while the near-crown circles were found to sustain 70%, with beyond-crown circles being absent. In below-crown circles 6 cm-thick birch litter covered 100% of the surface area, with bryophytes occupying just 5%. Overall 9 species were found on this zone, the individual plants being sporadically spread. Herbs were absent. In below-crown circles 1% of the vegetation projective cover was formed by self-disseminated plants of *Sorbus sibirica* Held. Organic matter accumulating embryozeims were found to occupy up to 100% of the area. In near-crown circles 1 cm thick birch litter covered 70%, while bryophytes accounted for 10% of the overall projective cover. Herbs and grasses had 10% of the PC, being represented by 19 species. Such species as *Gypsophila perfoliata* L. (10 %), *Melilotus alba* L. (2 %), *Centaurea scabiosa* L. (2 %) displayed distinct preference for the circle. Standing green phytomass was estimated as  $38 \pm 7$  g/m<sup>2</sup>. Organic matter accumulating embryozeims and initial embryozeims accounted for 70% and 30% of the area, respectively.

In sparse stands the below-crown circles accounted for 30% of the area, while near- and beyond-crown zones constituted 30 and 40%, respectively. In below-crown circles the ground was covered with 5-10 cm thick birch litter, while bryophytes could not be found. Overall 8 species were recorded in these stands, with *Populus tremula* forming 1% of the PC. The growth and development of herbs and grasses under the crowns there was hampered, resulting in low standing green phytomass of just  $8 \pm 3$  g/m<sup>2</sup>. Soil cover consisted mostly of OM-accumulating embryozeims (90% of the area), with the rest of the area occupied by soddy embryozeims due to the growth of *Poa angustifolia* L. with projective cover ca. 15%.

Near-crown circles had a developed bryophyte layer on 50% on the area and high projective cover of 1 cm thick forest litter (50%). Projective cover of herbs reached 30%. Overall 19 species were observed, with 5% of the projective cover formed by each of *Melilotus officinalis*, *Amoria hybrida* L. C. Presl., *Medicago lupulina*, *Hippophae rhamnoides* L. and 3% formed by each of *Centaurea scabiosa* and *Gypsophila perfoliata*, the flag species of the near-crown zone. Standing green phytomass was estimated as  $50 \pm 11$  g/m<sup>2</sup>. Initial embryozeims were entirely absent there, and OM-accumulating embryozeims occupied 80-90% of the area. Humus accumulating embryozeims were also found on 5% of the area due to abundant legumes.

The beyond-crown circles had still birch litter on 20% of the surface area, the rest of the litter being produced by herbs and grasses. Bryophytes formed 20% of the projective cover. The projective cover of herbs and grasses was 90%. Overall 26 plant species were found, with dominating meadow species such as *Dactylis glomerata* with its 30 % of the projective cover, *Agrostis gigantea* L. with 20 %, *Achillea millefolium* L. with 20 %, *Amoria hybrida* with 10 % and *Phleum pratense* L. contributing 10 % into PC. Active growth of grasses and herbs resulted in 7-times increase, as compared to the near-crown circles, in aboveground standing phytomass, reaching  $336 \pm 11$  g/m<sup>2</sup>. Up to 80% of the area was occupied by OM-accumulating embryozeims, the rest 20% covered by soddy ones.

The main soil properties for the white birch EF specific circles are shown in Table 1. In sparse stands STC content was the highest, with a minimum in the near-crown circles (4.5-4.8%) and gradually increasing to a maximum at the EF periphery (5.3-6.6%). Such STC spatial distribution is most likely due to the meadow species growth, providing easily decomposable phytomass input with above- and belowground litter and rhizodeposition, which increased with increasing plant performance at some distance from the tree trunks. Irrespective of the stand density, the southern forest-steppe study site had 1.0-1.6% higher STC content, most likely due to 30-50 mm higher yearly precipitation in the area as compared to the northern forest-steppe study site

The STN, generally correlating positively with STC, showed similar pattern of spatial distribution, being maximal in sparse stands and minimal in highly dense stands (Tab.1). Labile P and K contents can be rated as low and medium, respectively. Nevertheless, the tendency of P and K decrease in the below-crown zone is quite clear for all EF-specific circles and both ecotopes studied.

**Table 1.** Soil properties in the white birch phytogenic field zones, differing in crown cover

Biotope	EF* circle	Dominant soil type	STC, %	pH	K <sub>2</sub> O, mg/kg	P <sub>2</sub> O <sub>5</sub> , mg/kg	STN, %
Sparse stands (crown cover < 30 %)							
Southern Forest-steppe (Kedrovsk coal mine)	near*	OM-accumulating embryozem	4.8	7.49	77	56	0.25
	below	OM-accumulating embryozem	4.6	8.25	53	49	0.29
	beyond	Soddy embryozem	5.3	7.25	112	74	0.31
Northern forest-steppe (Bungur coal mine)	near	OM-accumulating embryozem	4.5	7.01	110	76	0.36
	below	OM-accumulating embryozem	4.9	6.34	93	39	0.34
	beyond	Soddy embryozem	6.6	6.38	132	92	0.35
Moderately dense stands (crown cover < 50%)							
Southern Forest-steppe (Kedrovsk coal mine)	near	OM-accumulating embryozem	3.8	7.25	78	21	0.23
	below	OM-accumulating embryozem	4.1	7.56	66	18	0.21
Northern forest-steppe (Bungur coal mine)	near	OM-accumulating embryozem	4.4	6.17	71	34	0.28
	below	OM-accumulating embryozem	4.8	5.88	59	28	0.35
Highly dense stands (crown cover <90%)							
Southern Forest-steppe (Kedrovsk coal mine)	near	OM-accumulating embryozem	3.4	7.15	92	46	0.15
	below	OM-accumulating embryozem	4.2	7.32	84	25	0.20
Northern forest-steppe (Bungur coal mine)	near	OM-accumulating embryozem	5.1	7.53	87	51	0.25
	below	OM-accumulating embryozem	4.8	8.02	66	62	0.28

\*Phytogenic field circles: near-, below- and beyond-crown ones.

Small size particle were found to contribute 18-47% into soil solid particles under sparse stands with 30% CC, the percentage increasing by 3-12% from the near- to beyond-crown circles. The gravel ( $\geq 10$  mm) percentage, ranging 18-25%, practically did not change in different CC-specific circles. The main shift of 5-12% occurred in the intermediate size fraction from the bigger (10-5 mm) towards the smaller one (3-1 mm). The granulometric composition of the < 1 mm size fraction for all concentric circles can be described as medium loam with physical clay contributing 37.5-41.2%. The fact that granulometric composition was not dependent on the CC-specific circles of the phytogenic field most

likely results from the homogeneity of technogenic eluvium. Soil pH also did not vary much, being neutral or slightly alkaline in all study sites.

In other CC circles increased (23-38%) >10 mm particles content and <28% of < 1 mm particles was found. The intermediate fractions (10-5, 5-3 and 3-1 mm) were rather evenly distributed, accounting for 10-20%. The granulometric composition of <1 mm particle can be identified as medium loam.

## 4 Conclusions

The observed pronounced patchiness of plant cover and soil organic matter accumulation in areas under sparse birch stands suggested that the environment there was most favourable for soil formation and development. Increased soil carbon, soil nitrogen and physical clay content manifested increased quality of soil environment in areas with birch crown cover less than 30% in both northern and southern forest-steppe subzones. The areas with denser crown cover soil were still quite satisfactory in terms of environment quality, albeit somewhat poorer. The obtained results necessitate more critical approach to determine the density of white birch tree stands during reforestation.

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