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Impact of Timber Harvesting on Vegetation in the Ural Mountains

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Abstract

Transformation of vegetation, which takes place in dark-coniferous forests under the action of clear timber harvesting in dominating forest habitats of the mountains of the Middle Urals, Russia, was studied. Harvesting was conducted 65 years ago. Research objects were 190-year-old spruce forests with domination in herbaceous layer of Oxalis acetosella L., 65-year-old birch forest with undergrowth of thick spruce, 65-year-old birch forest with undergrowth of sparse spruce and hay meadow. The plots were studied with regard to tree stand, understory and grass layer. Sample plots included no less than 200 woody plants. The undergrowth of trees on the tapes 20x4 m^2 was studied. In order to determine the productivity of grass-dwarf shrub layer 10 to 20 record subplots of 1x1 m^2 over period of maximum grass stand were established. The plants were cut at soil level, sorted by species, dried to an absolutely dry condition at the temperature of 105 °C and afterwards weighed. It was found that strong anthropogenic effects lead to appearance of a wide spectrum of vegetation communities within a single forest habitat (one type of indigenous forests). For a long time these vegetation communities differ by the structure of all vegetation layers, conditions of soil formation, and, consequently, by the direction and intensity of restoration processes. Age of spruce undergrowth was 65 years or more for most of the recorded trees. This undergrowth survived during harvesting. The reforestation direction was determined by the number of spruce undergrowth, which was stored in the timber harvesting.

Keywords: Forest, timber harvesting, vegetation, Ural mountains, Russia

1. Introduction

The problem of biodiversity is becoming very relevant due to the increase in the rate of transformation of natural ecosystems (Noss, 1999; Zobel, 2016). Large-scale reduction of natural ecosystems will inevitably lead to a decrease in their regulatory powers and the destruction of the planet's biodiversity (Pavlov et al., 2010). In the past, the consequences of anthropogenic disturbance of ecosystems led only to locally or regionally environmental damages; presently, however, a global scale of this process is becoming more apparent (Foley et al., 2005; Chen et al., 2011; Westgate et al., 2013). Timber harvesting is a major factor in the transformation of structure and function forest ecosystem. The huge scale of timber harvesting in various countries is the cause of global effects (Achard et al., 2006; Young et al., 2006). Detailed quantitative studies are needed to further advance theoretical foundations of the concept of sustainable forest management (Maiti et al., 2016).

More than 20% of the world's forest ecosystems are in Russia. They are of paramount importance to maintain the stability of the biosphere (Global Biodiversity Outlook, 2006). In the Ural Mountains region of Russia, industrial logging has been carried out for approximately 300 years. Intensive cutting and other forms of industrial disturbance of the mountain forests have brought about a highly mosaic structure of vegetation represented by various types of forests at different stages of regeneration and age succession (Shirokikh et al., 2013; Ivanova, 2014).

Numerous studies were carried out in connection with the problem of reforestation on clear-cuts. Reforestation features in Western and Central Europe, in Scandinavia and Canada are considered in numerous publications (Thomasius, 1990; Fitzsimmons, 2003; Ibbe et al., 2011; Gray and Hamann, 2011; Fisichelli et al., 2014). Much attention is paid to this problem in Russia (Melehov, 1933; Pobedinskiy, 1966; Sannikov, 2004; Davydychev, 2006). However a lot of questions have not been decided by this day (Ivanova, 2012; Gauthier et al., 2015; Lankin and Ivanova, 2015; Cusack et al., 2016; Kuuluvainen, 2016). Regional features of the manifestation of this global process are not determined until.

2. Research Area

The research area is located in the Ural Mountains, Russia.

The Ural Mountains are located on the border between Europe and Asia, at the junction of two floras. Ural forests (Russia) are part of the belt of coniferous forests in the Northern Hemisphere. They are one of the 200 hot spots of biodiversity, the preservation of which is necessary for the future survival of mankind on the planet Earth. The research site is situated in the Zauralsky (Trans-Ural) hilly piedmont province (Middle Ural, Russia) between 57°00´–57°05´N; 60°15´–60°25´E. It is divided in foothills formed by the alternation of meridian heights and ridges (Kolesnikov et al., 1973). Absolute heights are 200–500 m amsl. The climate is temperately cold, temperately damp. A frostless period lasts from 90 to 115 days, average annual temperature is +1 °C, and the average snowfall is between 40 and 50 cm (Kolesnikov et al., 1973).

3. Research Objects

Test sites were located in similar geomorphological elements, namely at the bottom of draining gentle slopes, which represent the most widely occurring group of forest conditions. Stable fresh loamy soils are formed on gruss eluvium-talus deposits of crystalline rocks. As a result, podsolization and gleying processes are limited and brown-type soils become more frequent in these forest conditions (Firsova, 1977). Dark coniferous forests are indigenous to these conditions (Figure 1). The study was classified by use of spruce forests as *Vaccinio-Piceetea* class (boreal dark coniferous and light coniferous forests), as *Piceion exelsa* union (mesophytic coniferous forests with dominance in the tree layer of *Picea obovata* Ledeb.), as *Melico-Piceenion* subunion. The dominant herbaceous layer is *Oxalis acetosella* L. We studied the vegetation transformation after timber harvesting in these forests. Harvesting was conducted 65 years ago. The study was carried out in the spruce forest (Figure 1), birch forest with undergrowth of thick spruce (Figure 2), birch forest with undergrowth of sparse spruce (Figure 3) and hay meadow (Figure 2, 4). Hay meadows are anthropogenic in origin and their existence is supported by mowing.

4. Sampling Procedures

The work was based on the methodological approach of geo-genetic (geodynamical) forest typology (Ivanova, Zolotova, 2014). A geo-genetic classification is a classification based on forest origin and evolution patterns which take into account all of the developmental stages of the forest ecosystem and can be used to predict their future changes. B.P. Kolesnikov and his colleagues (Kolesnikov et al., 1973) published a fundamental work on typology of the Sverdlovsk region forest which is still used both for scientific purposes and forestry. However, differences in the composition of plants and soils in different forest types, especially in sub-mountain and mountain areas remained little studied until very recently. This lacuna had been filled by the present study (Ivanova, 2012a; Ivanova, Zolotova, 2013a, 2013b, 2015). These studies were the basis for this study.

Figure 1: Indigenous spruce forest with *Oxalis acetosella* in the Ural mountains under study

Figure 2: The foreground photo depicts a meadow, which was formed on the site of the spruce forest after felling with birch forest – in the background under study

Figure 3: Birch forest with undergrowth of sparse spruce in the Ural mountains under study

Figure 4: Study of the productivity of herbaceous layer in the meadow, which was formed on the site of the spruce forest after harvesting

The 0.2–0.5 ha sample plots were laid according to commonly used methods (Forest Communities Study Methods, 2002). Sample plots included no less than 200 woody plants. The plots were studied with regard to their tree stand, understory, and grass layer. All the trees on the sampling plot were counted, their diameter and height were also measured. The age by the annual rings was identified. The undergrowth of trees on the tapes 20×4 m^2, which had been divided into 2×2 m^2 subplots was studied. For characteristic shrubs, the projective cover was defined. Totally dry biomass as an integral role of plants was taken. In order to determine the productivity of grass-dwarf shrub layer, 10 to 20 record subplots of 1×1 m^2 over period of maximum grass stand (July) were established. The subplots were situated on two perpendicular lines. The plants were cut at soil level, sorted by species, dried to an absolutely dry condition at the temperature of 105 °C and afterwards weighed.

5. Results and Discussion

Timber harvesting caused changes in structure of vegetation communities: the species composition and gross productivity of lower layers. The structure of the stand, the undergrowth of woody plants and the herbaceous layer are shown in Table 1. The quantitative ratio of species was altered most (Table 2). The correlation coefficients are shown in

Table 1: Differentiation of structure of vegetation communities in a single forest type

Structural parameters	Spruce forest	Birch forest with undergrowth of thick spruce	Birch forest with undergrowth of sparse spruce	Hay meadow
Tree stand				
Age, years	190	65	65	-
Mean height, m	26	24	20	-
Soil				
Name	mountain-forest brown	mountain-forest podsolized brown	mountain-forest brown	meadow-forest turf pale-yellow podsolic
Forest litter capacity of, sm	4	2	2	2
Soil capacity, sm	120	95	150	95–100
Undergrowth of *Picea obovata*				
No. , thousands units ha^{-1}	+	4.0	0.5	+
Predominant height, m	0.1– 0.5	5–10	2–7	-
Undergrowth of *Pinus sylvestris*				
No. , thousands units ha^{-1}	-	-	-	+
Predominant height, m	-	-	-	0.1– 0.3
Lower layer (herb layer)				
Species, total	23	21	44	55
Projective cover/coefficient of variation, %	21.0 26.6	14.4 56.9	66.3 27.5	100 19.5
Average height, cm	7	7	47.9	60
Aboveground biomass (g^{-2} in absolutely dry state)/coefficient of variation, %	17.7 33.2	4.4 66.2	100.9 7.0	280.6 7.7

Table 2: Dominant change and biomass dynamics of species of herbaceous layer

Species	Spruce forest		Birch forest with undergrowth of thick spruce		Birch forest with undergrowth of sparse spruce		Hay meadow	
	A	B	A	B	A	B	A	B
Oxalis acetosella L.	8.07	16.5	1.7	4.4	0.28	0.6	-	-
Calamagrostis arundinacea (L.) Roth	1.16	4.9	0.41	0.8	55.18	67.9	-	-
Gymnocarpium dryopteris (L.) Newm.	1.65	14.4	0.04	0.3	-	-	-	-
Fragaria vesca L.	0.42	1.8	0.38	2.2	0.51	1.1	-	-
Asarum europaeum L.	0.72	4.1	0.08	0.2	0.33	1.3	-	-
Rubus saxatilis L.	0.53	5.4	-	-	-	-	0.03	0.1
Athyrium filix-femina (L.) Roth	0.75	5.5	-	-	0.6	3.6	-	-
Linnaea borealis L.	0.16	1.3	-	-	0.55	1.6	0.22	0.6
Maianthemum bifolium (L.) F. W. Schmidt	0.45	1.4	0.24	1.4	0.48	1.2	0.1	0.3
Aegopodium podagraria L.	0.31	1.7	-	-	6.78	9.9	-	-
Viola selkirkii	0.62	2.9	-	-	0.02	0.05	-	-
Equisetum sylvaticum L.	0.33	1.4	-	-	-	-	-	-
Cerastium pauciflorum Stev. ex Ser.	0.59	2.7	0.4	0.8	1.17	1.9	-	-
Dryopteris expansa L.	0.17	1.9	0.12	0.8	-	-	-	-
Luzula pilosa (L.) Willd.	0.11	0.7	0.26	0.7	0.03	0.2	0.8	2.3
Pyrola rotundifolia L.	0.06	1.4	0.47	3	0.02	0.1	-	-
Stellaria holostea L.	0.23	1.5	0.11	0.7	2.1	4.4	-	-
Aconitum septentrionale Koelle	-	-	-	-	4.67	14.1	-	-
Cirsium heterophyllum (L.) Hill	-	-	-	-	0.88	2.8	39.43	65.4
Thalictrum minus L.	0.05	1.1	-	-	3.13	8.1	-	-
Geranium sylvaticum L.	0.15	2.7	-	-	5.67	10.5	11.77	27.6
Pulmonaria mollis Wulf.	0.05	1.1	0.03	0.1	3.09	7.0	-	-
Carex nigra (L.) Reichard	0.23	1.5	0.01	0.05	9.47	20.9	0,03	0.05
Lathyrus vernus (L.) Bernh.	0.04	0.4	0.04	0.2	1.28	2.8	0.02	0.05
Vicia sepium L.	-	-	-	-	1.0	2.4	0.83	1.5
Senecio nemorensis L.	-	-	-	-	1.37	3.8	-	-
Deschampsia cespitosa (L.) Beauv.	0.04	1.0	-	-	-	-	23.97	26.9
Bistorta *carnea* (C. Koch) Kom.	-	-	-	-	-	-	30.97	47.7
Carex pallescens L.	-	-	-	-	-	-	21.97	28.0
Carex leporina L.	-	-	-	-	-	-	9.73	23.2
Agrostis tenuis SIBTH.	-	-	-	-	-	-	34.03	48.5
Alchemilla vulgaris L.	-	-	-	-	-	-	19.67	26.6
Filipendula ulmaria (L.) Maxim.	-	-	-	-	-	-	29.8	84.5
Trollius europaeus L.	0.01	0.3	-	-	-	-	8.70	15.3
Ranunculus auricomus L.	-	-	-	-	-	-	12.37	17.2
Myosotis L.	-	-	-	-	-	-	6.60	10.7

A: Average aboveground biomass (g^{-2} in absolutely dry state); B: Maximum above ground biomass (g^{-2} in absolutely dry state); “-“: species is not found

Table 3. Species forming the main background of lower layers in spruce forests (*Oxalis acetosella*, *Gymnocarpium dryopteris, Asarum europaeum*, *Fragaria vesca, Equisetum sylvaticum, Dryopteris expansa, Viola selkirkii*) lost sharply in their biomass in secondary birch forests and were absent altogether in meadows. Some species are

Table 3: Variation coefficient (%) of herbaceous biomass

Species	Spruce forest		Birch forest with undergrowth of thick spruce		Birch forest with undergrowth of sparse spruce		Hay meadow	
	A	B	A	B	A	B	A	B
Oxalis acetosella L.	54	83.0	84.3	-	0.28	0.6	-	-
Calamagrostis arundinacea (L.) Roth	123.7	176.6	18.4	-	55.18	67.9	-	-
Gymnocarpium dryopteris (L.) Newm.	226.0	264.6	-	-	-	-	-	-
Fragaria vesca L.	142.2	212.9	95.2	-	0.51	1.1	-	-
Asarum europaeum L.	174.7	115.4	153.2	-	0.33	1.3	-	-
Rubus saxatilis L.	240.7	-	-	173.2	-	-	0.03	0.1
Athyrium filix-femina (L.) Roth	216.1	-	244.9	-	0.6	3.6	-	-
Linnaea borealis L.	206.4	-	120.5	153.7	0.55	1.6	0.22	0.6
Maianthemum bifolium (L.) F. W. Schmidt	94.3	218.3	83.9	173.2	0.48	1.2	0.1	0.3
Aegopodium podagraria L.	161.9	-	56.9	-	6.78	9.9	-	-
Viola selkirkii	144.8	-	118.3	-	0.02	0.05	-	-
Equisetum sylvaticum L.	148.3	-	-	-	-	-	-	-
Cerastium pauciflorum Stev. ex Ser.	118.8	124.2	60.8	-	1.17	1.9	-	-
Dryopteris expansa L.	294.0	246.9	-	-	-	-	-	-
Luzula pilosa (L.) Willd.	192.0	101.7	244.9	162.5	0.03	0.2	0.8	2.3
Pyrola rotundifolia L.	479.6	237.7	244.9	-	0.02	0.1	-	-
Stellaria holostea L.	188.2	244.6	68.1	-	2.1	4.4	-	-
Aconitum septentrionale Koelle	-	-	132.6	-	4.67	14.1	-	-
Cirsium heterophyllum (L.) Hill	-	-	125.3	78.29	0.88	2.8	39.43	65.4
Thalictrum minus L.	479.6	-	114.7	-	3.13	8.1	-	-
Geranium sylvaticum L.	226.0	-	67.8	119.6	5.67	10.5	11.77	27.6
Pulmonaria mollis Wulf.	479.6	170.8	87.4	-	3.09	7.0	-	-
Carex nigra (L.) Reichard	200.1	264.6	74.6	86.6	9.47	20.9	0,03	0.05
Lathyrus vernus (L.) Bernh.	248.4	196.6	91.1	173.2	1.28	2.8	0.02	0.05
Vicia sepium L.	-	-	110.6	91.7	1.0	2.4	0.83	1.5
Senecio nemorensis L.	-	-	144.1	-	1.37	3.8	-	-
Deschampsia cespitosa (L.) Beauv.	479.6	-	-	12.8	-	-	23.97	26.9
Bi*storta carnea* (C. Koch) Kom.	-	-	-	73.4	-	-	30.97	47.7
Carex pallescens L.	-	-	-	41.8	-	-	21.97	28.0
Carex leporina L.	-	-	-	120.1	-	-	9.73	23.2
Agrostis tenuis SIBTH.	-	-	-	36.8	-	-	34.03	48.5
Alchemilla vulgaris L.	-	-	-	33.3	-	-	19.67	26.6
Filipendula ulmaria (L.) Maxim.	-	-	-	159.2	-	-	29.8	84.5
Trollius europaeus L.	479.6	-	-	71.7	-	-	8.70	15.3
Ranunculus auricomus L.	-	-	-	34.3	-	-	12.37	17.2
Myosotis L.	-	-	-	53.9	-	-	6.60	10.7

present in small amounts in forest, but is dominated in secondary ecosystems. *Calamagrostis arundinacea*, *Carex nigra, Aegopodium podagraria, Aconitum septentrionale, Pulmonaria mollis, Lathyrus vernus* dominated under the canopy of birch forests. *Cirsium heterophyllum*, *Trollius europaeus*, *Deschampsia caespitosa*, *Bistorta carnea*, *Alchemilla vulgaris, Filipendula ulmaria, Ranunculus auricomus* and *Agrostis tenuis* dominated in hay meadows. Hay meadows were also distinguished for largest floristic diversity (55 species of vascular plants). The aboveground biomass increased. The aboveground biomass decreased only under the canopy of birch forests with undergrowth of thick spruce. Fellings in spruce forests of the Middle Ural region did not alter the type of soil formation in short-term derivative birch forests (Zubareva, Firsova, 1963; Ivanova et al., 2000). These plant communities were characterized by brown mountain-forest soils (Ivanova, Zolotova, 2011; Zolotova, 2013).

Previously, studies in the Southern Urals had been conducted. Indigenous and secondary forests, forest succession dynamics after timber harvesting, conjugacy of dynamics in forest layers and individual species in the succession series were studied (Ivanova, 2000, 2012b, 2014). Similar results, such as for the Middle Urals were obtained. Succession dynamic trend were not uniform for the stand or subordinate layers. Within a single natural forest, a whole range of alternative succession series were formed–spruce forests, fir forests, birch forests, and aspen forests (short-term, long-term, and stable-term secondary). The dynamics of the stand and subordinate layers differed in the succession series, with the differences remaining for a considerable time period.

The age of the young spruce trees in the birch forests of Middle Urals was determined. Age of spruce undergrowth was 65 years or more for most of the recorded trees. That is, spruce undergrowth appeared in the spruce forests, and it survived during harvesting. Young spruce was found in small quantities. Status of spruce undergrowth was good. Symptoms of oppression were mild. Spruce undergrowth grew well. Fatalities young spruce were marked only in birch forest with undergrowth of thick spruce. Thus, the reforestation direction was determined by the number of spruce undergrowth, which was stored in the timber harvesting.

In previous research, reforestation in the Southern Urals was studied (Ivanova, 2014; Maiti et al., 2016). For the western low mountains of Southern Urals the dynamics of the population structure of *Picea obovata* during the formation of short-term secondary birch forests, long-term secondary birch forests, and stable-term secondary aspen forests was analyzed. Similar results, such as for the Middle Urals were obtained. In short-term secondary birch forests, the initial recovery-age shifts of the emergence of new generations of *Picea obovata* were completely suppressed. In the formation of tree communities, only preliminary generation of *Picea obovata* was involved. At later stages of recovery and age, shifts restored the ability to form new generations of coniferous species, multilayers of tree stands, and age differences in undergrowth, but failures in regeneration remained (Ivanova, 2014). In the long-term secondary birch forest (throughout their formation) the age structure of spruce populations was severely impaired: new generations of *Picea obovata* appeared unstable, in most cases only a few were marked as numerically small generations. *Picea obovata*, located in the main layer of the tree stand acted as a source of semination. The restoration of conifer species tree stand dominance was greatly retarded and was possible only after the natural decay of birch over 120 years of age (Ivanova, 2014). These results were in good agreement with literature data (Pobedinskii, 1966; Isayeva, Lougansky, 1981; Sannikov, 1992).

6. Conclusion

Timber harvesting causes appearance of a set of vegetation communities within a single habitat (one indigenous forests type). For a long time these communities differ sharply by the structure of all vegetation layers. They differ by the direction and intensity of restoration processes. The results of this research are fundamental to understanding the evolution of modern ecosystems under anthropogenic impact and climate change.

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