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Current state of *Picea abies* stands in the Ukrainian Carpathians

Abstract: The paper provides a detailed characterisation of Norway spruce stands in the Ukrainian Carpathians. The majority of natural spruce stands in Ukraine occur in Polesie, while artificial regeneration is spread all over the country. The most densely forested part of Ukraine is the Carpathian region with 41.1% of forest-covered area (2.1 million ha). Spruce-dominated stands occupy about 700 thousand hectares (30%) of the forested area of the state forest fund in the Ukrainian Carpathians, and another 10% of the mixed forests contain 10 to 30% of spruce. Besides pure spruce stands, there are beech-spruce, beech-fir-spruce, and cedar-spruce stands. The most productive stands (750–900 m³ stem wood per ha) grow in the middle and lower parts of slopes at 1100–1200 m a.s.l. which have favourable soil and climate conditions. Since the second half of the 20th century, spruce stands in the substantial part of the Ukrainian Carpathians have declined under the influence of complex anthropogenic and natural factors. Although the present condition of most spruce forests in this region remains satisfactory, the degradation processes and the ban imposed in 2006 on planting spruce on non-spruce forest sites (in state forests) may decrease their area in the longer term.

Additional key words: Norway spruce, environmental functions, Carpathian forest types, composition, productivity

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Introduction

In terms of their purpose and location, Ukrainian forests perform mainly environmental functions, i.e. water-protective, sanitary and hygienic, recreational and other functions, and have limited usage. The total area of the forest fund makes up 10.8 million hectares, of which 9.5 million hectares (15.7% of the country's territory) are covered with forest vegetation.

Norway spruce (*Picea abies* (L.) Karst.) is the only representative of the genus *Picea* occurring in the Ukrainian forests. It constitutes one of the basic forest-forming species both in natural and artificial forests in the country. The total forest area with dominating spruce is close to 700 thousand hectares. By this indicator, the species takes the third place after Scotch pine (*Pinus sylvestris* L.) and oak (*Quercus robur* L.).

Distribution and area of spruce stands in Ukraine

The natural stands of Norway spruce in Ukraine occur in the Carpathian part of the natural habitat of island spruce stands of Ukrainian Polesie. The artificial regeneration of Norway spruce is spread all over the country, with the greatest concentration being in Polesie and the forest-steppe zone. Its total area is close to 50 000 hectares.

The region of Ukrainian Polesie is home to more than 250 island stands of Norway spruce of natural origin, occupying an area of about 2050 hectares in total (Melnik 1993). According to growth, these stands fall mainly into the 1st, and less frequently 2nd, forest capacity class. The average age of spruce in these localities ranges from 65–80 to 120–130 years.

The stands cover an area of 0.5–1 to 330–400 hectares. The majority of island stands of Norway spruce, 1787.4 hectares or 87.2%, are concentrated in the western part of Ukrainian Polesie (Volynska and Rivnenska administrative regions). Further to the east, the frequency of such localities diminishes. In left-bank Polesie (Chernigivska and Sumska administrative regions), only five island spruce stands aged 75–115 years have been preserved with a total area of about 20 hectares.

The remaining spruce stands (93%) are concentrated in the region of Ukrainian Carpathians. The Carpathians, with the proportion of forest-covered areas of 41.4%, constitute the most densely forested region in Ukraine. The total forested area is 2.26 million hectares, and the area of land covered by forest is 2.09 million hectares. The Ukrainian Carpathians forming part of the Eastern Carpathians differ from the neighbouring mountainous areas in Slovakia, Poland and Romania in that they have smaller absolute heights, a typical geologic bedrock (mainly flysch), a more continental climate, and a higher percentage of forest areas. Because of difficult orographic conditions, the ecological factors in the Carpathian area, such as climate, soils and hydrological conditions, and their vertical zoning, are non-uniform. Seventy tree species and 110 shrub species grow in the Carpathian forest stand. The dominant ones are natural and artificial stands of Norway spruce whose area considerably exceeds the areas covered with other main forest species.

The spruce-dominated forests occupy 33% of the forested area belonging to the state forest fund of the Ukrainian Carpathians (Table 1). Another 10% of the mixed forests contain from 10 to 30% of spruce. The exploitation of spruce forests during the last two centuries and the widespread cultivation of Norway spruce in beech-, fir-, and oak-logging areas resulted in a considerable increase in the area covered with spruce (Golubec 1988).

Types of spruce stands in the Ukrainian Carpathians

Currently, the Ukrainian Carpathian spruce forests fall into three categories: natural, derivative, and mixed. Natural stands have been formed in the process of natural regeneration, derivative stands are the result of artificial afforestation, whereas mixed stands combine the elements of natural and artificial reforestation.

At present, three types of cones are observed in the Carpathian spruce forests: cones with pointed scales, with obtuse scales, and with wide scales. The pointed-scale form is considered to be native to the Carpathians, while the other two forms are typical of introduced trees. Imported spruces produce lower mass of wood per unit area, with a high percentage of large branches. Native spruces have a good form of the trunk, high-heaved up crown, and good self-pruning ability. The stands originating from imported seeds occupy considerable areas and are susceptible to destruction by wind, to fungal infections, and damage by pests.

The native stands of Norway spruce are concentrated in three out of eleven silvicultural districts in the Ukrainian Carpathians. The derivative spruce stands occupy a considerable area (about 150 thousand ha) and grow in all silvicultural regions. The largest portion of such stands (55% by area) grows in the Ivano-Frankivska region, the rest occurs in the Zakarpatska region (18%), Lvivska region (16%), and Chernivecka region (11%).

The derivative spruce stands are most common in beech and fir types of forest (54 thousand ha or 30.9%). In their age structure, saplings (60%) and middle-aged forest stands (17–20%) prevail.

Norway spruce is the main typological forest species in the conditions of the Ukrainian Carpathians that forms about 30 types ranging from spruce-pine forest to beech-fir-spruce forest. Moist beech-fir subspruce forests (53%), moist highly-elevated subspruces (23%), moist beech-fir spruce forests (15%), and moist pure spruce forests (5%) are the most widespread types of forest. Other forest types are less frequent (Ostapenko and Tkach 2002).

Table 1. Distribution of forest fund lands across administrative-territorial units of Carpathian region

Administrative-territorial units (regions)	Area (thou. km ²)	Forest fund lands			
		total area (thou. ha)	area covered with forest vegetation		
			all stands (thou. ha)	Norway spruce stands	
				(thou. ha)	%
Zakarpatska	12.8	695.8	652.9	196.2	30.1
Ivano-Frankivska	13.9	626.0	576.7	305.7	53.0
Lvivska	21.8	682.8	626.4	113.4	18.1
Chernivecka	8.1	261.8	237.8	72.1	30.3
Total	56.6	2266.4	2093.8	687.4	–

Norway spruce forests mixed with *Pinus cembra* L. of preglacial origin are very unique. They belong to such types of forest as moist cedar-spruce forest, moist and raw cedar-spruce subforest, moist larch-cedar-spruce subforest, moist cedar-mountain pine subforest, and moist cedar subspruce. These rare types of forest occupy an area of 8.29 thousand hectares.

The zone of spruce forests in the Ukrainian Carpathians lies within 1140–1500 m a.s.l. on the southwestern macroslope, and within 920–1420 m a.s.l. on the northeastern macroslope of the mountains (Ukrainian Carpathians Nature 1988).

Norway spruce forms both mixed and pure stands of different productivity. The most productive forests occur in the middle and lower parts of slopes at 1100–1200 m a.s.l. on strong subclay and subloamy soils. The stock volume of spruce stand reaches 750–900 m³ stem wood per hectare (Fig. 1).

The high growth indexes of spruces in the middle and lower parts of slopes (from 700 to 1150–1200 m) can be explained by favourable soil and climatic conditions. The soils are deeper and contain considerably more nutrients because of a higher intensity of the processes of humification and mineralisation of organic substances. Compared to the higher parts of slopes, these locations have also better hydration and aeration conditions and more favourable thermal regimes of soils.

At altitudes higher than 1200 m a.s.l., the spruce stand productivity decreases with increasing elevation, by one class of forest capacity per 100 m.

The less favourable conditions for spruce forest growth in the upper part of slopes (above 1200 m) are caused by a cold and moist climate, less fertile soils, and a short vegetation period. Undoubtedly, high winds and a thick snow cover (up to several meters) have a restraining influence on the growth of spruce.

Beech, Norway spruce, and cedar pine can play a role of co-dominants in mixed spruce forests, while sycamore maple, Norway maple, and Witch elm (rarely Scotch pine or Polish larch) are admixtures. According to structure, the spruce stands in the

Ukrainian Carpathians are divided into the following types:

- pure spruce (Chornogora (Black Mountain), Gorgany, Chyvyhynski, Marmoroski Mts. and north macroslope of Svydovec),
- cedar-spruce (Gorgany),
- beech-spruce (Beskydy, Gorgany, Pokutsko-Bukovina Mts.),
- beech-silver-fir-spruce (Rachivska and Jasynska cavities).

Compared with natural forests, derivative spruce forests, which occupy about half of the area of spruce forests in the Carpathians (Fig. 2), have a simplified structure, high productivity at an early age, and low resistance to winds, diseases and pests (Golubec 1988).

Norway spruce stands in the Ukrainian Carpathians occupy an area of about 354 thousand hectares (Kolosok 2002). As a rule, they exhibit intensive growth (I–I^b class of forest capacity) and a high productivity (Table 2). Some of the artificial spruce stands have been created on sites where natural stands of Norway spruce were logged, so they represent the artificial regeneration of native stands.

The remaining stands are artificial derivative spruce stands outside of the spruce types of forest. It is noteworthy that more than 94% of artificial spruce forests grow at elevations not exceeding 1150 m a.s.l.

Conclusion

Since the second half of the 20th century, it has become obvious that spruce stands in substantial areas of the Ukrainian Carpathians, especially derivative spruce forests (Fig. 3) created on original beech-, oak-, or fir-forest-logging places, have been increasingly degrading. The degradation of spruce stands is accompanied by their mass drying which begins at the age of 30–40 years and is caused by a complex of anthropogenic and natural factors.

The present condition of spruce forests in the Ukrainian Carpathians can be considered as satisfactory. In the future, however, their area is likely to diminish. The principal causes include the progress of

Table 2. Area and average indexes of forest valuation for artificial Ukrainian spruce stands of Carpathian Mts. (Kolosok 2002)

Forest capacity (class)	Area (ha)	Average indexes of forest valuation				
		age, A (years)	height, H (m)	diameter, D (cm)	plenitude, P	stocked, M (m ³ ha ⁻¹)
I ^b	23075.3	59	27.5	28.5	0.75	577
I ^a	128117.3	54	22.6	24.0	0.75	442
I	142409.5	37	13.9	14.7	0.74	225
II	45932.6	33	10.7	11.2	0.71	144
III	12499.5	29	7.3	8.0	0.70	74
IV	1596.8	26	4.9	5.4	0.62	33
Total	353631.0	44	17.5	18.4	0.74	315



Fig. 1. Highly productive native stands of Norway spruce in Ukrainian Carpathians



Fig. 2. Derivative spruce stands in Transcarpathian beech forests at elevations of 450–500 m a.s.l.



Fig. 3. Example of degradation of derivative spruce stands

spruce forests degradation and the ban imposed in 2006 on creating spruce stands on non-spruce types of forest sites in the area managed by state forest enterprises. As this process seems long-lasting, the accuracy of our forecast will only be known in a few years.

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