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The effect of living ground cover on the development of the young generation of tree species on post-agrogenic lands of the boreal zone

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Abstract. This study analyzes the influence of living vegetation on the renewal of tree species on post-agrogenic lands. To assess the influence of factors on the development of living ground cover and the renewal of wood vegetation, Ramensky amplitude ecological scales were applied. More than half of the plants in the studied plots are mesophytes and their share in the total projective cover is more than 75%. The emergence of undergrowth of tree species is most influenced by grass. The study shows that the ecological ranges reflect the confinement of the species to certain amplitudes of environmental conditions. A rapid or slow reduction in the abundance of cenopopulation of one or another species is associated with an increase or decrease in the impact of a particular environmental factor. With an increase in the total projective cover of living ground cover, the number of undergrowth is significantly reduced, and vice versa, the formed undergrowth limits the development of the cover vegetation due to advantages in the competition for light, moisture, and nutrients.

1. Introduction

After the agricultural use in anthropogenically transformed territories has been terminated, the soil formation begins to follow a natural biological way, and the plots begin to overgrow first with grassy and then shrub and wood vegetation [1, 2]. The analysis of the differences in plant composition and species among forest stands growing in areas with different land use history and at different stages of succession can improve understanding of the past land use effects on plant communities. The acquired knowledge can serve as a basis for predicting response measures for the maintenance and usage regime of stands. Currently, the information on the natural regeneration of forests on post-agrogenic lands of various fertility levels in the Northwestern District of Russia is limited, making it difficult to develop a scientifically justified system of silvicultural and agrotechnical measures aimed at the formation of highly productive forest stands on former fallow lands [3-5].

When studying plant communities, it has long been noted that vegetation is sensitive to changes in environmental factors. As a result, it was proposed to determine the environmental conditions of a particular habitat according to the specifics of the plant community [4]. The conditions of the ecotope



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in which cenopopulation of a particular species is found lie within the ecological ranges of factors suitable for the existence of this species. Thus, the basis of phytoindication is the environmental characteristics of species populations that constitute specific plant communities. And the narrower is the ecological range of a species, the higher is its indicative importance [6, 7]. The close relationship between the vegetation cenopopulation and its existence conditions allows judging the needs of plants and their ecological positions on a particular factor scale from environmental characteristics. The ecotope characterizes the plant community as a whole even clearer, if considered as a set of plant species it includes, i.e., the plant community is used as an indicator of environmental conditions. However, neither national nor foreign researchers have yet found the optimal solution for quantifying the use of certain factors. The only measure for this is a range of levels or scale points. A comparison of these ranges gives only an approximate idea of the extent of the ecological space of a certain factor for populations of given species. A statistical comparison of such information is extremely difficult. Even more difficult is the task of comparing fragments of ecological niches of species that include the sum of the considered factors. Therefore, ecological scales are often used, which are scoring tables of the characteristics of the species ecology, used to evaluate environmental conditions [7]. Currently there are known ecological scales of more than 20 authors. All are based on estimates obtained in natural conditions. Despite the fact that the information for the development of ecological scales was obtained in different regions, ecological assessments of species on scales of different authors are similar [6, 7].

The process of natural renewal of wood vegetation on old croplands that are not in active agricultural use anymore has been scarcely studied, and the present work is aimed at revealing the basic patterns of this process.

2. Methods and Materials

2.1. Objects of study

The process of natural renewal of wood vegetation on old croplands that are not in active agricultural use anymore has been scarcely studied, and the present work is aimed at revealing the basic patterns of this process.

The study of the effect of living ground cover on the natural regeneration of wood vegetation was carried out on the old croplands of the Gatchina region on the flat interfluves elevations adjacent to the Oredezh river basin. Formerly arable sandy loam-loamy horizon is well humified with a thickness of 30-40 cm and pH level 5-5.6. The underlying mother rock is red-colored boulder loam. The objects of study were selected in accordance with the objectives of the research and had to satisfy the following conditions: there should be a significant density of undergrowth on the object of study allowing to cover the main characteristics of wood vegetation – the height and diameter. At the same time, distinctive features of the objects of study, the agricultural lands that are not in the circulation anymore, were:

- 1) The land plot was not subjected to economic impact for more than 20 years;
- 2) The object of study borders a front of forest located on native forest lands;
- 3) The forest area bordering the object of study has both broad-leaf and coniferous species dominance.

Characteristics of natural regeneration of tree species are presented in table 1.

Table 1. Average characteristics of natural regeneration undergrowth on experimental plots.

Plot number #	Tree species ^a	pcs. per ha	H _{av} , cm	A _{av} , years
1	Pine	2684	151.5	6.0
	Spruce	1105	79.4	10.2
	Birch	58	243.1	-
	Aspen	121	123.5	-
	Willow	8	515.0	-
	Alder	100	121.0	-
2	Pine	3020	102.5	5.3
	Spruce	1160	82.7	6.0
	Birch	16	253.7	-
	Aspen	4	77.0	-
3	Spruce	3142	97.4	5.8
	Birch	2212	640.2	-
	Willow	48	1000.0	-
	Aspen	2807	780.0	-
	Alder	133	873.6	-
	Oak	84	25.0	-
4	Spruce	92	112.2	10.5
	Pine	4642	177.5	10.5
	Birch	2360	238.5	-
	Willow	260	267.0	-
	Oak	4460	187.5	-
5	Spruce	74	144.0	4.4
	Pine	2557	134.5	5.0
	Birch	475	552.5	-
	Willow	656	354.5	-
	Aspen	1623	464.5	-
6	Spruce	772	150.5	9.5
	Pine	20	505.0	6.0
	Birch	88	550.5	-
	Willow	116	516.0	-
	Aspen	6	490.0	-

where, pine – *P. silvestris* L.; spruce – *P. abies* Kr.; aspen – *P. tremula* L.; willow- *Salix* sp; birch – *B. pendula* Rott.; Alder – *Alnus alba* L.; Oak – *Q. rubra* L.

2.2. Experimental part

To assess the characteristics of the natural regeneration of tree species on post-agrogenic lands, we determined the number of undergrowth, its age and height.

The number of undergrowth was determined by the sampling statistical method at the circular areas of 10 square meters created according to the Gryazkin method.

The study of living ground cover was carried out at one-meter registration plots [8].

In order to assess the influence of various factors on the development of living ground cover and the renewal of wood vegetation, we used amplitude ecological scale (points) of L G Ramensky [7]. The determination of the dependence of the abundance of trees and shrubs (A1: B1) on the projective cover of living ground cover (A2: B2) consists in finding the intersection point of the vectors of its upper and lower amplitudes (table 2). Then, the sorted vectors of the upper and lower amplitudes of the factor are used to build the trend lines, applying linear regression formula (1):

$$y = b \cdot x + a \quad (1)$$

Then, using the found values of the regression coefficients (the slope of the trend line and the intersection with the vertical axis), the coordinates of the intersection point of the trend lines are found using the formulas (2, 3):

$$xx = (a_2 - a_1) / (b_1 - b_2) \quad (2)$$

$$yy = b_1 \cdot (a_2 - a_1) / (b_1 - b_2) + a_1 \quad (3)$$

where, a_1 , a_2 , b_1 , b_2 are the regression coefficients ($y_{\text{hat}1} = b_1 \cdot x + a_1$; $y_{\text{hat}2} = b_2 \cdot x + a_2$) for trend lines, xx and yy are the coordinates of the trend intersection point.

Table 2. Creating a series of restrictive levels for the Ramensky scale.

#	Projective cover, %	A1	A2	B1	B2	XX	YY
1	84.64	63	90	64	88	17.2222	76.12
2	81.4	50	55	69	53	11.7241	85.65
3	40.7	52	69	81	95	20.7895	123.12
4	32.51	86	55	97	100	13.7755	83.02
5	86.96	98	86	62	61	11.5152	73.47
6	47.87	50	60	79	90	11.4617	85.16

3. Result and discussion

In conditions of better supply of mineral nutrition elements on the former arable soils, the living ground cover most actively influences the renewal of tree and shrub vegetation. The analysis of the structure of the living ground cover and its species composition in the studied areas indicates the presence of dead cover zones; in all the studied areas the projective cover of the living ground cover is less than 100% (figure 1).

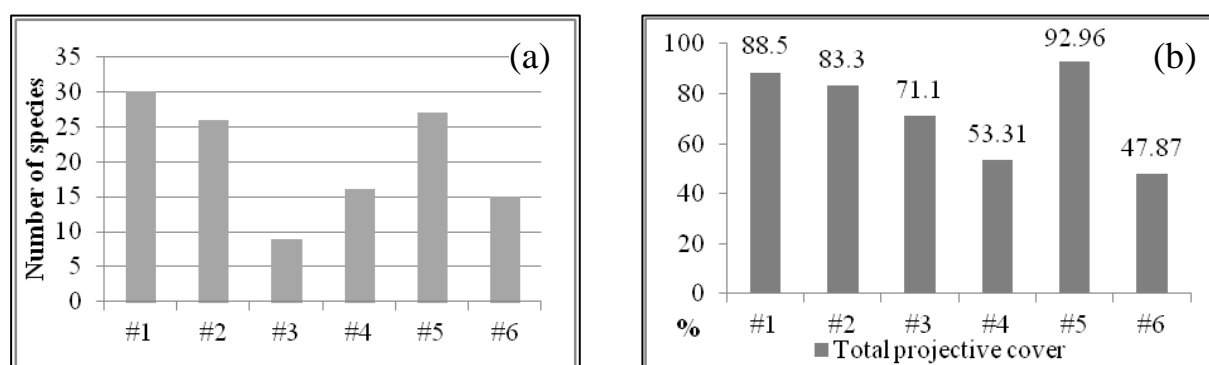


Figure 1. The number of species and the total projective cover of living ground cover at the experimental sites.

Stratification is not expressed. The total projective cover of living ground cover at the objects of study varies from 47.87% to 92.96%. The analysis of the obtained data indicates that the emergence of undergrowth is most affected by grass. Depending on the study area, the proportion of grass varies from 56.7 to 99.2%. Grass, as mesotroph, is actively involved in the competition with other elements of the living ground cover and get enough mineral nutrition elements, which creates favorable conditions for its growth, but at the same time, the development of undergrowth is actively restrained. Herbs, being mesotrophs, are actively involved in the competition with other elements of the living ground cover and get enough mineral nutrition elements, which creates favorable conditions for their growth, but at the same time, the development of undergrowth is actively restrained. Thus, the study shows that living ground cover, in particular grass, adversely affects the emergence and development of undergrowth, which is confirmed by the fact that undergrowth on all experimental plots is either thin or of medium density. At the same time, there is also a reverse relation: the formed undergrowth has a dominant influence on the nature of the development of living ground cover. The share of grass in the studied plots has a dominant position and varies from 30.8% (# 4) to 90% (# 6). Crops and carex

grass are represented in much smaller proportions – from 0.4% (# 3) to 36.3% (# 6). The amount of moss on the analyzed plots is negligible. Their share increases on the plot 3 – 42.8% and plot 4 – 39.0%. These plots are less drained, which allows active development of mosses. This suggests a slow biocirculation on these plots. This may indicate the saturation of these plots with mineral elements, which allows quite active development of mesotrophs.

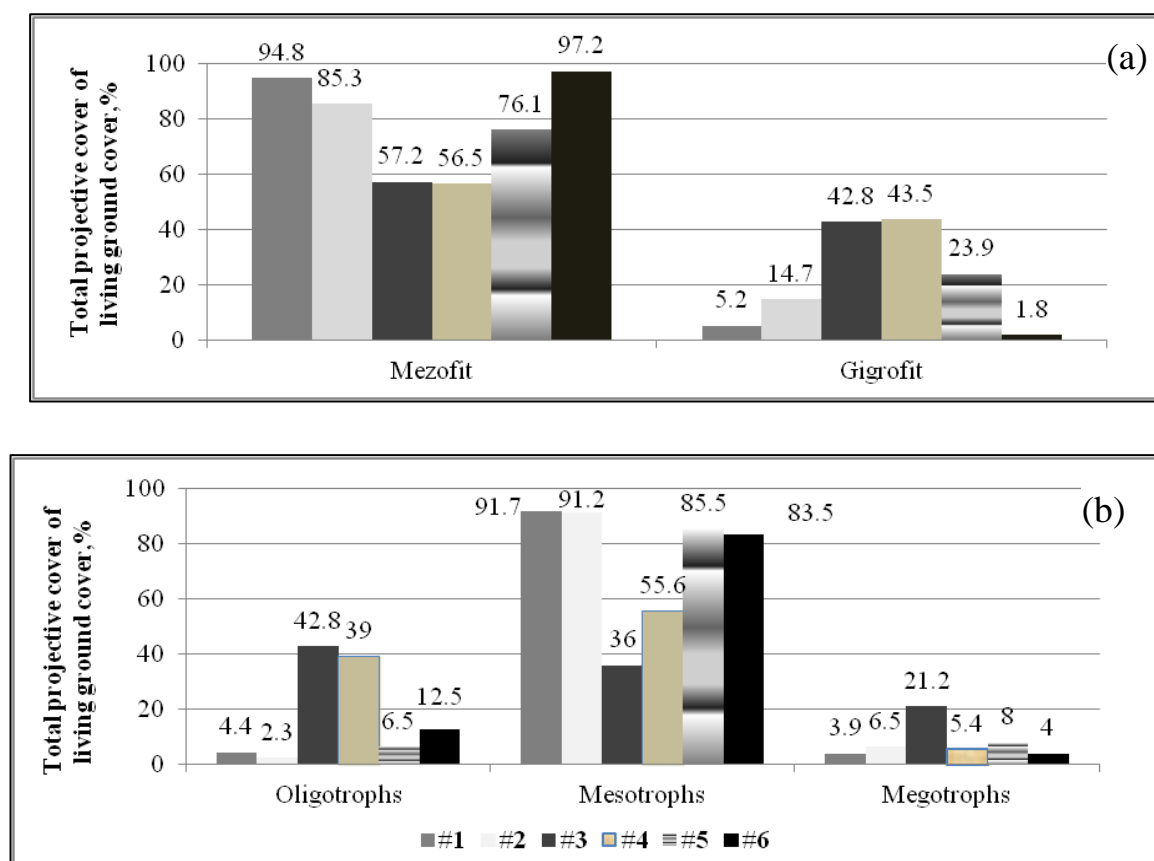


Figure 2. Ecological plant groups in relation to soil and hydrological conditions at the experimental sites.

The basis for constructing environmental tables was the projective cover scale. According to the plot 1 data, it can be concluded that there is an almost linear relationship between the upper (A) and lower (B) boundaries of the amplitudes of the abundance of living ground cover and the number of undergrowth on the analyzed plot (XX, YY) expressed in points (figure 3). The intersection point of the trend lines gives the factor level (72.03) at the maximum total projective cover of the living ground cover for a given plant community and a prediction of the effect of living ground cover on the development of the young generation of tree species in these plots. The hypothesis that the higher the projective coverage of the plot, the lower the number of undergrowth at a given age in conjunction with the environmental factors of a particular cenosis on plot 1 is confirmed.

The data for plot 2 also confirm a virtually linear relationship between the abundance of the living ground cover and the number of undergrowth on the analyzed plot. The intersection point of the trend lines gives the factor level (54.27) at the maximum total projective cover of the living ground cover for a given plant community and the analysis of the effect of living ground cover on the development of the young generation of tree species in this plot. For plot 3, it can be concluded there is no linear relationship between the upper (A) and lower (B) boundaries of the amplitudes of the abundance of living ground cover and the number of undergrowth on the analyzed plot. The amplitude boundaries

have different directions. We assume that at this stage, the formed undergrowth (8426 specim. per ha) has a dominant influence on the living ground cover and limits its development. This conclusion is confirmed by the indicators of projective cover (71.1) and the number of undergrowth on the studied plot.

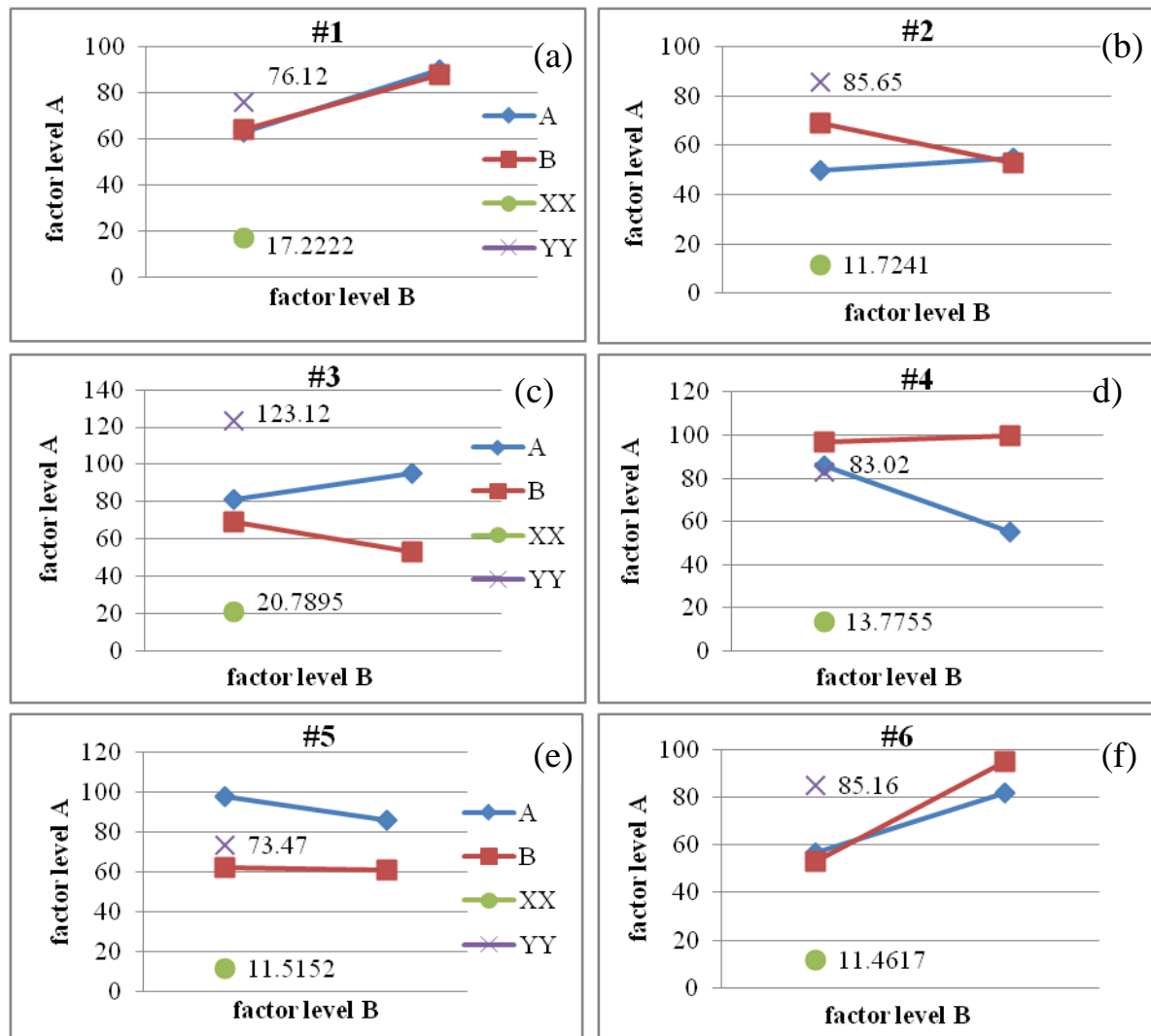


Figure 3. Dependence of the abundance of trees and shrubs (A1: B1) on the projective cover of living ground cover (A2: B2).

Regression trend lines do not intersect. On plot 3, an inverse relationship is observed: a large number of formed undergrowth has a dominant effect on the living ground cover and limits its development. In the future the projective cover of the living ground cover will not exceed 60% of the area. For plot 4, a relationship between the upper (A) and lower (B) boundaries of the amplitudes of the number of undergrowth and the abundance of vegetation is also observed. The amplitude boundaries have different directions. We assume that at this stage, the formed undergrowth (11814 specim. per ha) has a dominant influence on the living ground cover and limits its development. This conclusion is confirmed by the indicators of projective cover (53.31%) and the number of undergrowth in the studied plot. The regression trend lines intersect only the lower (B) boundary of the undergrowth number fluctuations amplitude.

On plot 4, an inverse relationship is observed: a large number of formed undergrowth has a dominant effect on the living ground cover and limits its development.

On plot 5, a linear relationship between the upper (A) and lower (B) boundaries of the amplitudes of the abundance of ground cover species and the number of undergrowth (XX, YY) is observed. The amplitude boundaries are unidirectional. The hypothesis that the higher the projective coverage of the plot, the lower the number of undergrowth at a given age in conjunction with the environmental factors of a particular cenosis is confirmed. This conclusion is confirmed by the indicators of the total projective cover (92.96%) and the number of undergrowth (4385 pcs. per ha).

From the graph for plot 6, it can also be concluded that there is no linear relationship between the upper (A) and lower (B) boundaries of the amplitudes of the abundance of living ground cover and the number of undergrowth on the plot. The intersection point of the trend lines gives the factor level (62.13%) at the maximum total projective cover of the living ground cover for a given plant community and the analysis of the effect of living ground cover on the development of the young generation of tree species in this plot. We assume that at this stage, the formed undergrowth (1002 specim. per ha) has a dominant influence on the living ground cover and limits its development. This conclusion is confirmed by the indicators of projective cover (47.87%) and the number of undergrowth on the studied plot. From the data on figure 4, it can be concluded that there is a relationship between the projective cover of the vegetation and the number of naturally renewed young generation of tree species.

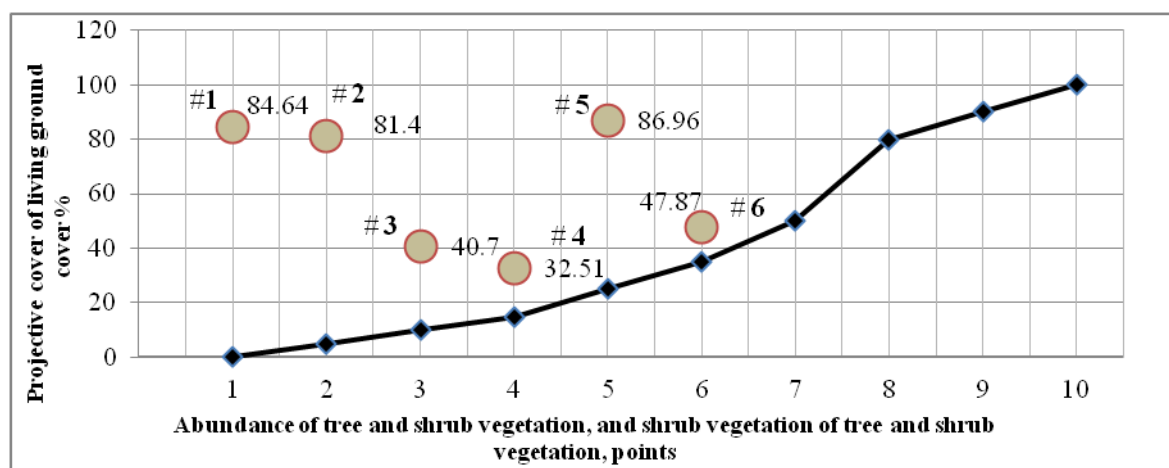


Figure 4. A relationship between the abundance of tree and shrub vegetation and the projective cover of living ground cover on the analyzed plots. Where, abundance, points: 1 – single distribution, 2 – small number: up to 1000 specim., 3 – moderate number: between 1000-3000 specim., 4 – abundance: 3000-5000 specim.; 5 – mass representation: over 5000 specimens.

Considering in conjunction the environmental factors of a particular cenosis: on the studied plots with abundant projective cover of vegetation, a moderate number of undergrowth is observed (# 1, 2, 5, 6). With a decrease in the share of living ground cover to 32.51% in the projective cover, an increase in the number of undergrowth is observed up to massive on plot 4–11814 pcs. per ha. The study shows that ecological ranges reflect the confinement of a species to certain amplitudes of environmental conditions, as well as a rapid or slow reduction in the abundance of cenopopulation of a particular species due to an increase or decrease in the impact of a particular environmental factor.

4. Conclusion

The results of the study allow concluding that:

- In the studied areas, more than 50% of plants are mesophytes and their share in the total projective cover ranges from 76.1% to 94.8%.

– The development of living ground cover is significantly affected by the number and density of undergrowth. The lower the number and density of undergrowth, the greater the percentage of the total projective cover of living ground cover.

– A linear relationship between the number of undergrowth and living ground cover was found: the higher the proportion of ground cover, the lower the proportion of the young generation of tree species.

– In areas with a large share of grassy vegetation, young undergrowth is either thin or of medium density.

– With an increase in the total projective cover of living ground cover, the number of undergrowth is significantly reduced, and vice versa, the formed undergrowth limits the development of the living ground cover vegetation due to advantages in the competition for light, moisture, and nutrients.

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