Vegetation gradients due to management and light intensity in beech stands of the Lviv region (Ukraine)

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Master thesis in Forest management - Euroforester, SLU course code EX0506, Advanced Level (E), 30hp(HEC)

Abstract

Conservation and sustainable use of forest ecosystems is one of the most important environmental goals today. In this work, special attention was directed to the vegetation of beech forests *(Fagus sylvatica L.)* in Ukraine. Beech stands of the Lviv region are among the most productive in Europe and are characterized by species rich herbaceous vegetation.

In this work, the amount and structure of the herbaceous species vegetation in beech stands in Lviv green zone was analysed in relation to gradients in light and management intensity from nature reserve, managed forest and parks.

Research on the sample areas shows, that there is a difference in species composition between forest, natural reserve and park areas in the green zone of Lviv city. Differences mainly depend on the anthropogenic impact on the territory.. Sample areas which are situated far from places of recreation show a higher presence of typical beech forest species, than comparing to places, where the level of recreation is more intense.

Key words: *Fagus sylvatica*, herb layer vegetation, management intensity, species classification, light

Анотація

Збереження та стале використання лісових екосистем є одним із найбільш важливих екологічних цілей сьогодні. У даній роботі, особлива увага була спрямована на рослинність букових деревостанів *(Fagus sylvatica L)* в Україні. Букові насадження Львівської області є одними з найбільш продуктивних у Європі і характеризуються багатим видовим різноманіттям трав'янистих рослин.

У даній роботі кількість та структура надґрунтового трав'яного вкриття букових насаджень у зеленій зоні м. Львова була проаналізована стосовно до показника освітленості та типу лісокористування у заповіднику, лісництві та парках.

Дослідження, проведені на пробних площах вказують на різницю у трав'яному видовому різноманітті у заповіднику, лісництві та парках зеленої зони м. Львова, що здебільшого залежить від антропогенного впливу на територію. Пробні площі, що розташовані далеко від місць рекреації показують вищий рівень присутності типових для букових деревостанів трав'янистих рослин, ніж в порівнянні з місцями, де рівень рекреації є вищим.

Ключові слова: букові насадження, рослинність, тип лісокористування, видова класифікація, освітленість

CONTENTS

1. INTRODUCTION

In the face of intense human impact on beech forest ecosystems, with logging being the main use area, a unique group of beech forests on the Eastern border area is endangered. In this work, we deal with a comprehensive study of the actual geographical distribution, floristic and ecological features in beech forests, natural reserve and parks of the Lviv green zone in Ukraine.

Climatic and geomorphologic factors are very important in the formation and distribution of the vegetation in the study region. Anthropogenization of natural landscapes has led to substantial changes in the vegetation cover of the Lviv region. Fundamental natural vegetation is preserved only in the forests, partly in large parks. Ruderal vegetation is spread everywhere. Exotic species are widely represented in parks, squares, streets, botanical gardens and arboreta.

1.1. Basic biological and ecological features of forest vegetation

Vegetation of beech phytocoenoses in the Lviv green zone (which is located in a 30 km zone around the city) is the most sensitive component in stands connected to changes of environmental factors. In different sample areas the distribution of diverse herb species can show the growing conditions of the whole stand.

Within the green zone of Lviv it is possible to distinguish five groups of vegetation: forest, meadow, marsh, rocky and steppe. The most widely represented are the first three groups. The flora in its composition is represented by typical boreal, taiga (spruce, Scots pine, etc.), Central European or broadleaf forests (European beech, oaks). The main species in broadleaf forests are: *Quercus robur, Fagus sylavtica and Carpinus betulus*. In mixed forests there are: *Pinus sylvestris, Quercus robur, Fagus sylavatica*. Most forests in the described region are natural.

The area in the Lviv green zone has an intensive recreational use, which leads to qualitative and quantitative changes in the fundamental circles of forest biogeocoenose (soil, litter, vegetation and trees). Human activities have a strong impact on an environment of suburban forests depending on forest paths and the level of recreation in the area. One of the main anthropogenic disturbances in the forest or park areas is trampling, which causes a decrease of forest species diversity and frequency *(Dzwonko, Loster 1997).*

Urbanisation of the territory has been confirmed by phytocoenons in the herb layer of the city parks *(Grygora, Aleinikov et al. 2008).* In their structure, except the common *Geum urbanum L., Impatiens parviflora DC., Urtica dioica L.,* etc., are often to be found groups of significant

typical forest species - *Aegopodium podagraria L., Viola odorata L., Geranium robertianum L., Lysimachia nummularia L), Lamium maculatum L.(L.).*

Thus, to understand the influence of urbanization on the vegetation, we need to make a deeper analysis of the major floral representatives of vegetation in beech stands at different management gradients (natural reserve, managed forests and urban parks) of the Lviv green zone.

1.2. Objectives and purpose of the research

The objective of the research is to analyse the vegetation in beech stands with different management goals. The following questions are:

1. Is there any influence of light intensity on frequency and distribution of herbal plants in the forest?

2. Are there any differences in species composition of vegetation in beech stands with different management goals (management forest, natural reserve, city-park and forest-park)?

2. MATERIALS AND METHODS

2.1. Data collection

The survey was carried out in areas of Vynnykivske Forestry (managed forest[1]), natural reserve[2] "Roztochchya", as well as in the forest-park "Pohulyanka" and city-park "Zalizna Voda" in Lviv region, Ukraine *(appendix 1).*

Vynnykivske Forestry is located on Davydovske hills, 7 km from the regional center of Lviv city. The size of forest is 2,799 hectares. The main species in forest stands are pine and beech *(appendix 2).*

Natural reserve "Roztochchya" is located in the northwestern part of the Lviv region in the administrative district Javorovskyi, 25 km from the regional center. The size of the territory from north to south is 8 km and from the west to east is 12 km, with the area of 2,084 hectares *(appendix 3).*

[1] **Managed forest** - forest area, that are not occupied by forest conservation, scientific, historical, cultural, recreational and protective forests.

[2] **Natural reserve** - protected area where the main object of protection is one of the components of the complex.

Forest-park[3] "Pohulyanka" is one of the largest city park systems. Its area is more than 100 hectares. The forest-park was established in 1930 among the slopes and plateaus. And 10 years later, in 1940, it was declared as a protected territory of Lviv city. Basis of the forest-park is a hornbeam-beech forest. Here is the north-eastern border of beech growth in Europe.

City-park "Zalizna Voda" is situated close to the center of Lviv city. It was founded in 1905. The total area of the park is 19.5 ha. In tree composition the main species is beech, but there also occur pine, oak, birch and poplar.

With the assistance of the Ukrainian forest state association "Ukrderzhlisproekt" sample areas were selected with the dominant type of beech forest. The share of beech trees is 95% or more. In these beech stands density[4] of canopy ranged from 0.41 to 0.84, age - 30 to 120 years *(Table 2.1).*

Table 2.1. Characteristics of the sample areas

№	Situation of the sample area on the territory		Species composition	Age, years	Density of canopy	Growing stock, m^3/ha	Characteristic
	quarter	block					
Vynnykivske Forestry							
1	39	4	10 Fg	120	0.7	760	forest-management area
2	40	12	10 Fg	110	0.8	742	
3	40	13	10 Fg	110	0.6	535	
4	19	1	10 Fg	100	0.7	569	
5	52	3	10 Fg	110	0.5	286	
Natural reserve "Roztochchya"							
6	1	10	9 Fg +1Q	70	0.8	388	natural reserve, limited forest-management activities
7	2	12	10 Fg	50	0.8	303	
8	2	11	10 Fg	30	0.8	248	
Parks							
9	-	-	10 Fg	140	0.7	-	city-park, high urbanization of area
10	-	-	10 Fg	90	0.9	-	forest-park, performed for recreational purposes

Note: Density **–** a proportion of surface area of land occupied by projections of crowns of the trees.

[3] **Forest-park** it is an ordered area of forest designated for short-term rest and performed for recreational, landscape, sanitary, educational and forest functions.

[4] **Density –** it is a proportion of surface area of land occupied by projections of crowns of the trees.

Sample areas were chosen by different age, density of canopy and management gradient distribution of the stand and established in pure beech stands of different age, by exposure and lighting of the herb layer. The type of substrate is equal for all sample areas – light gray forest podzolic soil on noncarbonated loam. The type of forest conditions is usual for all 10 sample areas – D_3 (wet grud). Five different sites were selected in Vynnykivske Forestry, three sites in natural reserve “Roztochchya”, one in the forest-park "Pohulyanka" and in the city-park "Zalizna Voda" in Lviv city.

The size of each sample area constitutes 0.5 ha. There was measured diameter of trees *(appendix 4)* and registered by 4-cm classes (materials used: calliper, measuring tape). The height of the trees was estimated by altimeter. The light conditions of the stand were measured by illuminometer U-116. The measurements in the stands were made in the forenoon 1 m above the ground. To compare the data of light intensity, collaterally in the same time of the day, open areas in forests or park territories were chosen and measurements were made in those conditions.

Recording of vegetation in each sample area was carried out in August and September 2009, by accounting plots. For this, plots of 1 m^2 (1x1 m) were layed out along diagonals, and the distance between plots was 1 m *(figure 1).* For the plots was recorded relative density and species composition of vegetation, the dominant species. There were approximately 100 plots.

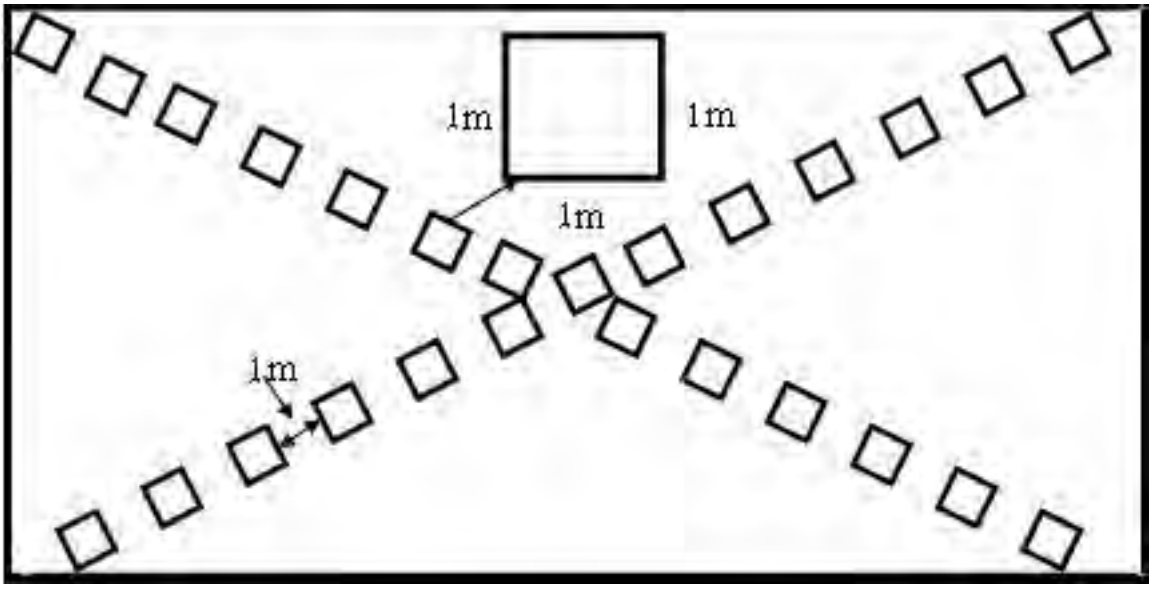

Figure 1. Establishment of plots on a sample area (approximately 100 plots)
Plots were used in each sample area.

Average frequency and average projective coverage are determined by sight estimation (in points) with approximate size of the projective cover (in percentage).
Phytocoenotic value ratio (PVR) was calculated as projective covering multiplied by relative density *(appendix 5).*

2.2. Study area (Lviv region, Ukraine)

Climate. Due to its geographical location, the area of the Lviv region is under the influence of Eurasia and the Atlantic Ocean air masses. In winter and spring, there is an inflow of continental Arctic air, resulting in cold, cloudless sky, with low temperature. In summer though autumn, sea arctic air brings cold, damp weather. Maritime tropical air masses cause warm, cloudy and foggy weather. During the year, the prevailing direction of winds is from the west and south-west *(Herenchuk 1972).*

The average annual humidity is 79%, in winter it reaches 88 – 97%, in the summer time - 56%. The average annual rainfall is 660 mm: in the warm season - 489 mm, and the rest - in the cold. In the winter a more or less stable snow cover is formed in the region, the duration of which ranges from 1.5 to 2.5 months.

Spring is characterized by a rapid growth of solar radiation and higher temperatures, manifested in the external seasonal changes of the landscape, the rapid development of phenological phenomena - from swelling buds to the development of leaves and blossoms. Comparing with winter, rainfall in spring increases by 1.5 times. Spring is usually characterized by variable weather.
Summer is characterized by high temperatures and high rainfalls. Day time lasts more than 16 hours, the weather in summer is generally warm. There could be years of dry periods with increasing temperature up to $+35^{o}$C.

Soil and hydrological regime. Basic background soils in the region and its surroundings are prevailingly gray and light gray-ash soils.
Hydrological regime is formed on the southern sides of Lviv region by several small rivers: Shchyrets, Zubra and Malechkovychi.

2.3. Data calculation and analysing

The vegetation in beech stands was classified by different classifications connected with the species taxonomic structure, geographical analysis, bioecological characteristics, distribution of the light, life forms and floristic classification *(Aleksandrova 1969).* Division into classifications helps to compare species diversity of vegetation with different management goals of the beech stand in an investigated area.

Taxonomic structure of vegetation in beech stands was studied by Grygora (2005**)**, Poletyka (1967), Prokudin (1987) and others.

Geographical analysis of the herbal vegetation was based on classification scheme, which was developed by Malinovsky (1980). According to this scheme, the zone element is traced to the

division of vegetation and geographical variations such as types of habitats and regional groups of distribution. Distribution of the species vegetation on the sample area was classificated by boreal, nemoral, montan, azonic or arid geographical elements.

Ceonotic distribution of vegetation is related to the places of herb species habitation and they are classified into swamp-meadow, swamp-forest, meadow, forest-shrubbery, ruderal and forest types *(Sukachev, Dylis 1964).*

Bioecological characteristics of each herbal species related to environmental conditions determined by Musienko (2006), Prokopev (2003). They characterized the distribution of the studied species, depending on moisture and soil fertility. Plants have high exaction to humidity and belong to mesophytes type (vegetation which is adapted to neither a particularly dry nor particularly wet environment). In relation to the soil fertility, herbage of beech stands belongs to eutrophes and mesotrophes.

Distribution of the light demanded herbal species was defined by using a modified scale of Tsyganov (1983). It was distributed for 7 types of: ultra shade mode of lighting (Z-type); thicket shade mode (T-type); shady forest (S-type); medium-shaded forest (R-type); densely-light regime (N-type); light treatment (M-type); thin forest (G-type).

The analysis of species by their life forms is the characteristic of form and structure of a mature organism on the basis of which it can be classified; based on the classifications of Serebryakov *(Green book of the Ukrainian SSR 1987)* and Raunkiaer *(Solomakha, Yakushenko, et al. 2004)*. Life forms are determined by genotype and are a combination of certain plant species, similar in appearance, because of anatomic-morphological structure, ecological and physiological characteristics, which have been formed in the process of evolution under a complex influence of environmental factors. Life forms of herbal plants by Serebryakov *(Kramer, Kozlovsky 1983)* are divided by composition of root system on: short-rhizome plants; repens rhizome plants; annual-biennial plants; shrubbery; fibrous root plants; tap root plants.

The principle of Raunkiaer's *(Solomakha, Yakushenko, et al. 2004)* classification is made to take account of all the infinite variety of ecological adjustments. For his classification he took a very important single feature - the adjustments of plants to the unfavourable season. The position of a plant in this system is determined by the location and protection of the perennating organs during the unfavourable season, that is, during the cold winter or the dry summer. On this basis Raunkiaer distinguished: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes.

1. *Phanerophytes* – especially trees and shrubs, bearing their renewal buds upon upright shoots at least 25 to 30 cm. high and therefore more exposed to unfavourable weather condition than any of the tropics and subtropics. The more northern phanerophytes are

characterized by special bud protection, or they make use of the protection of snow by means of low growth. Their resistance to cold is to a large extent due to properties of their protoplasm.

2. *Chamaephytes* – with renewal buds above the surface of the earth; the plants enjoy only such protection as is afforded by the plant itself, either through protective mechanisms on the bud or by dense growth or by dead shoots. Important subgroups are: bryochamaephyta, chamaephyta lichenosa, chamaephyta reptantia, chamaephyta succulenta, chamaephyta pulvinata.

3. *Hemicryptophytes* – plants with perennial shoots and buds close to the earth's surface. They often have the protection of a covering of dead and living scales, leaves or leaf sheaths. The class is marked by great variety in the development of the vegetative shoots.

4. *Cryptophytes* – trunks of this plants in unfavourable season of vegetation are dying, and their buds, which are situated under the substratum (in geophythes) and at the bottom of basins (in hydrophythes) or other substrate. This group has three subgroups: geophythes, helophytes and hydrophytes.

5. *Therophytes* – plants which complete their life cycle, from germination to ripe seeds, within a single vegetative period. Their seeds or spores survive the unfavourable season under the substratum. Due to this habit and their mobility they are widely distributed, even in the unfavourable hot, dry regions of the earth. They include: thallotherophytes, bryotheropthytes, pteridotherothytes, eutheropthytes.

Methodological features of the floristic classification of Braun-Blanquet *(Matuszkiewicz 2002)* are the most important qualification of all the taxonomic units - associations. The characteristic of those species are notable for a certain degree of loyalty or certainty for taxons.
Geobotanical description by the method of Braun-Blanquet (1932) can show a place of which association was formed present stand and to promote the recovery of its initial composition in the future.

3. RESULTS

3.1. Characteristic of the beech stands and vegetation

On the investigated sample areas was counted the distribution of diameter and height of the beech trees in the stand *(appendix 4).* The direction of the slope and light intensity for different sample areas were also different, which has a big influence on the average coverage and average frequency of vegetation in the stand *(appendix 5).*

Table 3.1. Characteristic of the sample areas

№	Average diameter, cm	Average height, m	Exposition of the slop	Luminosity		Average projective coverage of vegetation, %	Average frequency of herbal species, %	Number of families, items	Typical species in beech stands	Untypical species in beech stands
				lux	%				%	%
Vynnykivske Forestry										
1	50.7	30.2	eastern (15^o)	5.1	10.1	27.3	14.4	10	73	27
2	42.6	29.3	eastern (15^o)	4.6	9.2	81.3	31.4	9	33	67
3	31.2	28.6	north (20^o)	3.4	8.0	75.8	15.2	5	40	60
4	39.6	29.5	south - east (25^o)	3.6	7.9	96.1	30.8	12	69	31
5	38.4	28.1	north (30^o)	38.5	64.5	202.7	11.7	20	55	45
Natural reserve "Roztochchya"										
6	31.2	28.3	western (10^o)	6.5	11.2	100.0	28.4	8	50	50
7	20.3	23.7	north- west (10^o)	3.5	6.0	43.6	49.1	8	67	33
8	17.4	19.8	plain	3.3	7.6	173.7	39.6	9	75	25
Parks										
9	72.5	36.5	south - east (15^o)	7.6	12.8	65.9	12.5	16	46	54
10	42.3	26.5	western (30^o)	3.0	4.5	3.0	4.2	8	40	60

Note: by % - it showed the per cent of herbal species presence on the sample area, by items – its number on the area.

Vegetation of beech phytocoenoses of green zone of Lviv city is the most sensitive component in stands connected to changes of environmental factors. In different sample areas the distribution of diverse herb species can show the growing conditions of the whole stand.

On the sample area №1 there is an intensive development of regeneration of maple with height 2.5 – 4.0 m. In spite of the low light luminosity, species diversity of herb vegetation is presented by 11 species, although the average projective cover is low (0.04 – 5.5%). The main species that form vegetation in this sample area is *Galium aparine L., Dryopterix filix max (L.) Schott., Carex pilosa L., Glechoma hederacea L., Asarum europaeum L., Hedera helix L.*

Comparing with the sample area № 1, sample area № 2 has the lower light areas, but the average projective cover for some plants is much higher: *Carex pilosa L.* – 47.85%, *Rubus hirtus L.* – 10.53%, *Glechoma hederacea L.* – 9.45%, *Galium aparine L.* – 5.77%. It reveals, that there is influence of other factors (like direction of slope or age of the stand), which have impact on the growth and distribution of the vegetation in this area.

Species composition of herb vegetation on the sample area № 3 is poor. This is obviously due to the exposure of the slope. In mid-day the light intensity on this territory is higher than on the previous sample areas. The total amount of luminosity during the day is obviously less because of the North exposure of slope. The highest PVR on the area is characterized by *Majanthemum bifolium (L.) FW Schmidt*, which appears in more than 54% of the studied area. Comparing with the previous sample area, species composition of herb vegetation on the sample area № 4 is richer, with almost the same intensity of light. Prevailing species in the area is *Carex pilosa L.*, which occurs on all the plots. Also the sample area characterized by - *Hedera helix L., Asarum europaeum L., Glechoma hederacea L.*, which are typical species for beech stands in this region.

Thus if the sample area № 5 has the highest light luminance, the number of species is high. In addition to plant species, which were studied on the previous sample areas, here is observed more a light demand species of plants represented by *Rubus hirtus L.*, which is occupying more than half of the investigated territory. Also here are presented such species as: *Carex pilosa L., Dryopterix filix max (L.) Schott., Rubus idaeus L.* - they have taken a dominant position and suppress the spread of others. Even in such conditions shade-enduring plants actively took their ecological niche - *Oxalis acetosella L.* (relative frequency - 23.4%), *Glechoma hederacea L.*, (relative frequency - 13.1%).

In the sample area № 6 due to the increased illumination, like on the previous area, also prevails *Rubus hirtus L.*, with the average projective cover of 80.1%. It densely covers the soil and it severely limits distribution of other species. In this regard, the number of other species is much lower, although the density of many plant species is more or less even.

The sample area № 7, which is situated in natural reserve is covered by 9 species of vegetation. Although their average projective cover is not significant (maximal - *Asarum europaeum L.* – 10.42%), but most of the plants on the area are located evenly and their occurrence is very high. The frequency of the species distribution is one of the highest between other sample areas.

The sample area № 8 is characterized by flat territory and younger beech stand, than in previous sample areas. But typical species of vegetation are presented here in big amounts, main of them - *Glechoma hederacea L., Hedera helix L., Carex pilosa L., Oxalis acetosella L., Asarum europaeum L., Galium aparine L.* They are occupying a significant part of the investigated area and their projective cover is 18.4 – 43.2%. These plants have a high coefficient of PVR, indicating its important role in vegetation in beech stands.

Species composition of vegetation on the sample area № 9 (city-park) is much richer comparing to the previous plots. This is primarily due to the increase of light under the tent of trees. Also in connected with the recreational load and appearing of synantropic and ruderal plants: *Plantago major L., Urtica dioica L.;* also meadow species (*Ranunculus acris L.,*

Taraxacum officinale Wigg.). In places where recreational influence is smaller prevail typical forest species, the average projective cover of vegetation is not very significant, but they occur very often.

Vegetation in the sample area № 10 (forest-park) differs significantly from the previous areas. First of all, it should be noted that under a shelter of trees there is low light luminance, which means that vegetation is not rich of different species of plants in this area. Some typical forest species were found in places, with a low recreational impact (*Sanicula europaea L., Aposeris foetida (L.) Less., Glechoma hederacea L.).*

3.2. Differences in the species composition of vegetation along the management gradient (natural reserve, management forests and parks)

The investigation of forests, natural reserve and parks shows difference in herb species composition in beech stands by different factors and conditions of growing.

3.2.1. The distribution of vegetation in investigated areas by geographical elements

The geographic distribution of the vegetation in beech stands, by geoelements is presented in *figure 1* and *appendix 6.*

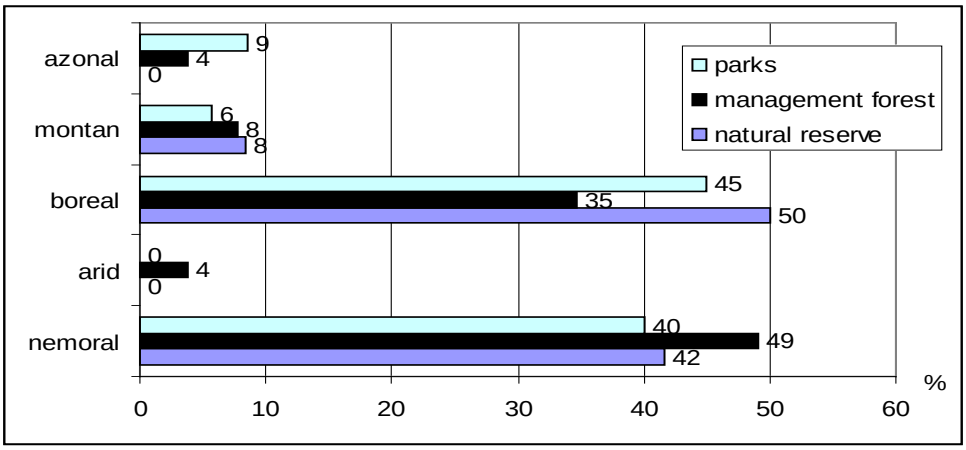

Figure 1. The distribution of vegetation in forests and parks of investigated area by geographical elements

Prevailing number of the species belongs to the boreal and nemoral elements. Moreover, it was determinate, that boreal elements are predominating in the beech stands of natural reserve (50%) and nemoral elements in the management forest (49%). Number of montan species in beech forest, natural reserve and parks is approximately equal (6-8%). Azonal elements among the vegetation in the natural reserve are not presented, but in beech forest its distribution is in twice less amounts comparing with the parks (only 4%). The same number

has the arid elements (4%) in the forests, while in the parks and reserve such vegetation is completely absent.

3.2.2. The distribution of vegetation in investigated areas by ceonotic structure

The numbers of separate taxons in the forest, natural reserve and park phytocoenoses and the number of species are correlating by ceonotic structure. Ruderal and meadow species have a significant advantage in the parks and a big per cent of forest and forest-shrubbery species is presented in managed forest and natural reserve areas (*figure 2).*

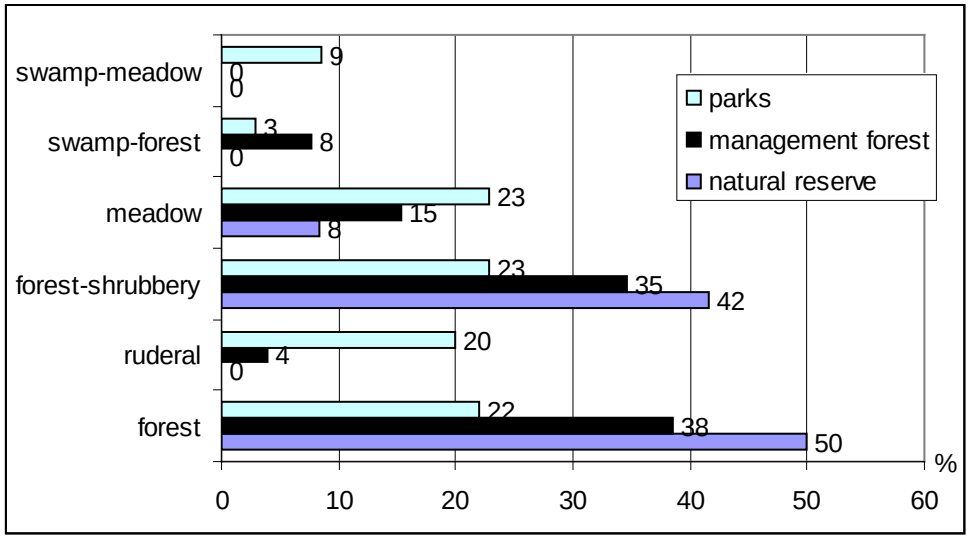

Figure 2. The distribution of vegetation in forests and parks of investigated area by ceonotic structure

In the *figure 2* vegetation of the natural reserve is mainly generated from the forest and forest-shrubbery species (respectively 50% and 42%). The same distribution in ceonotic structure of vegetation is presented in the beech stands of managed forest: 35% forest-shrubbery and 38% of forest species. High representation, especially in parks, is characterized by meadow (23% species) and ruderal (20% of species) types of vegetation. Between swamp-meadow and swamp-forest types the presentation of herbal species is minimum or totally absent.

3.2.3. The distribution of vegetation in investigated areas by the soil humidity and fertility

Bioecological characteristics of each species are determined by ratio of vegetation comparing to the environmental conditions. In *figure 3* and *appendix 7* they are characterized by the distribution of the studied species, depending on moisture and soil fertility.

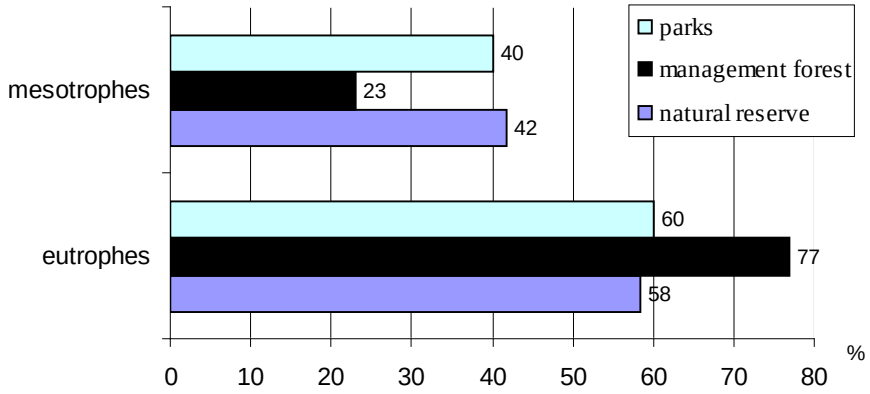

Figure 3. The distribution of vegetation in forests and parks of investigated area by the soil fertility

The vast majority of plants has high exaction to humidity and refers to mesophytes. In relation to the soil fertility, vegetation of beech forests has some differences from the parks and natural reserves. 77% of vegetation in managed forest belongs to eutrophes and 23% to mesotrophes. Such bioecological features of vegetation fully comply with the nature of the beech forests. Representation of eutrophes and mesotrophes in parks and natural reserve is approximately equal. In the parks, the share of mesotrophes is increasing to 40%, which clearly proves the deterioration in growth conditions.

3.2.4. The distribution of vegetation by the light regimes in classification of Tsyganov

Another determining factor is the lighting conditions of the studied plants. Based on the classification of Tsyganov (1983), it was investigated by the distribution of vegetation at the different light regimes *(figure 4* and *appendix 8).*

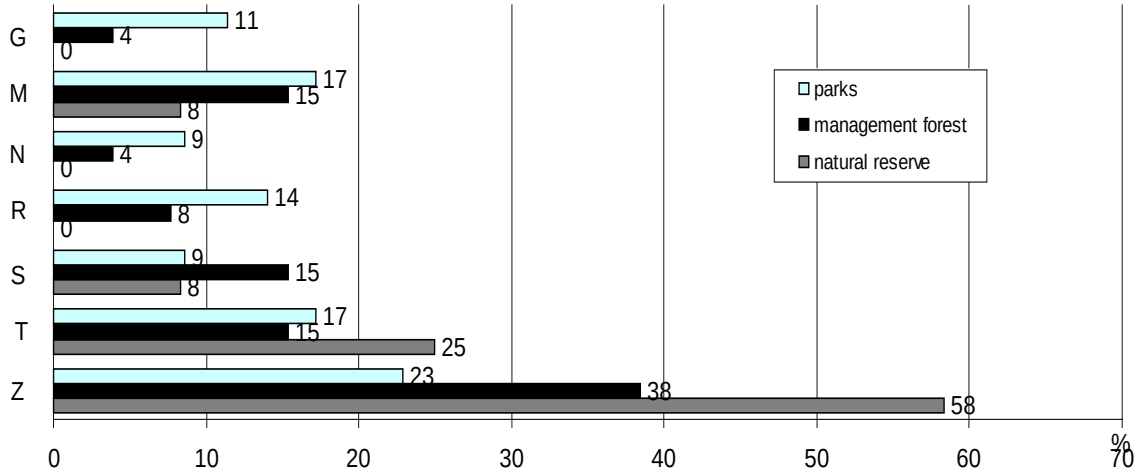

Figure 4. The distribution of vegetation by the light regimes in classification of Tsyganov

Note: ultra shade mode of lighting (Z-type); thicket shade mode (T-type); shady forest (S-type); medium-shaded forest (R-type); densely-light regime (N-type); light treatment (M-type); thin forest (G-type).

The vegetation in the beech forest, natural reserve and parks by the scale of Tsyganov (1983) shows that the dominant types of vegetation are species of shady forests, which are growing on the poor soils - very rich with salt, weak-acid - neutral, rich by nitrogen. The density of the vegetation layer in the beech stands of the investigated areas ranges from the "dead cover" to the continuous thickets of vegetation.

3.2.5. Life forms of vegetation by classification of Serebryakov

An important feature of the distribution and competitive ability of plants are their life forms. The most common classifications of plant life forms are methods of Serebryakov and Raunkiaer.

Figure 5 and *appendix 9* show the distribution of the vegetation studied by Serebryakov *(Kramer, Kozlovsky, 1983).*

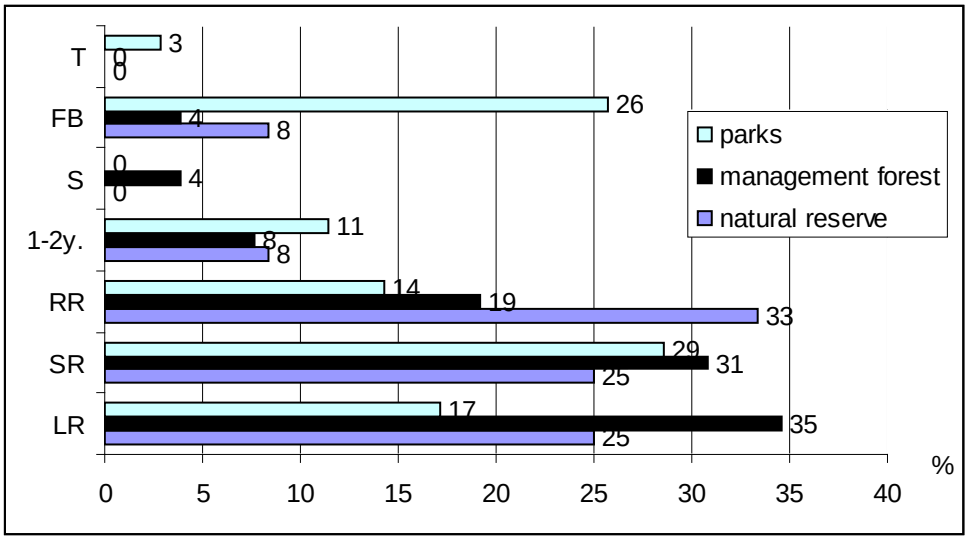

Figure 5. Life forms of vegetation by classification of Serebryakov

Note: LR – long-rhizome plant;
SR – short-rhizome plant;
RR – repens rhizome plant;
1- 2 y. – annual-biennial plant;
S – shrubbery;
FB – fibrous root plant;
T – tap root plant

Among the studied species the largest number of types belongs to the long-, short-rhizome and repens rhizome plants, with an obvious advantage of them in the management forest and natural reserve areas. These species in the largest extent adapted to the conditions of the shady beech forests and they basically are the most typical. 26% of fibrous root species are presented in park sample areas. Other life forms of Serebryakov are usually not typical for the forest vegetation and they are mostly not spread under the beech trees in parks.

3.2.6. Life forms of vegetation by classification of Raunkiaer

Figure 6 and *appendix 10* show the system of the life forms of investigated vegetation by Raunkiaer *(Solomakha, Yakushenko, et al. 2004*).

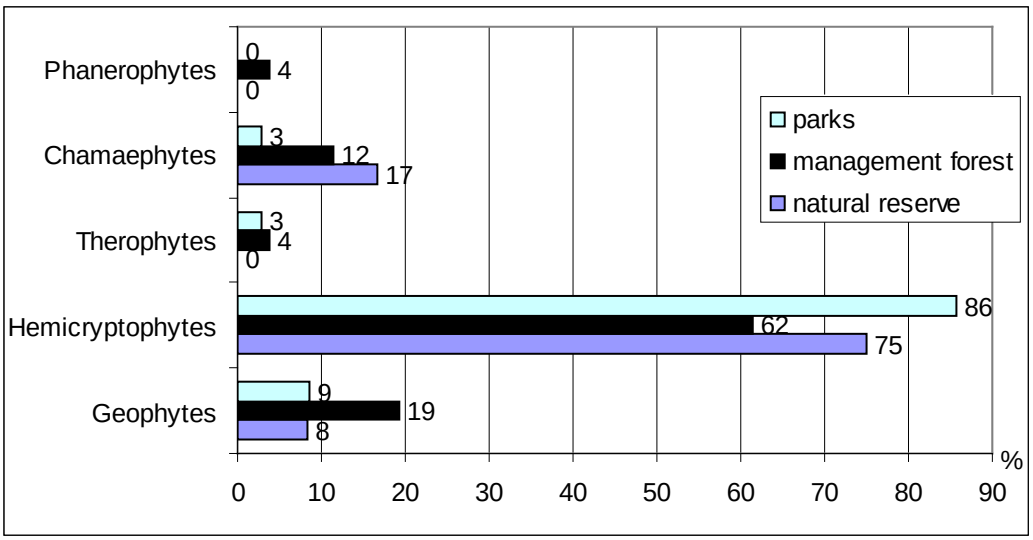

Figure 6. Life forms of vegetation by classification of Raunkiaer

Vegetation of the beech phytocoenoses is represented by phanerophytes; chamaephytes; hemicryptophytes; geophytes; therophytes. The vast majority of the vegetation species at the forest (62%), natural reserve (75%) and in the parks (86%) are hemicryptophytes. However, phytodiversity of forests and natural reserves is represented more widely, in the same time when the herbaceous plants in parks are practically concentrated in two groups of life forms - hemicryptophytes and geophytes.

3.2.7. Ecological-floristic classification of Braun-Blanquet

To the classification of Braun-Blanquet (1932) of forests in the investigated region belongs the class Querco-Fagetea represented by associations and variants of associations that are formed at the strict accordance with the location of exposure *(Table 3.3).*
Appendix 11 presents a typical for beech stands distribution of vegetation species by classification of Braun-Blanquet.

Table 3.3. Phytocoenotic characteristic in beech stands, forest-park and park of Lviv area by the method of Braun-Blanquet

Number of sample area	1	2	3	4	5	6	7	8	9	10
Area, ha	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Number of species	11	9	5	13	22	9	9	8	24	15
		Average projective coverage, %								
D.sp. Ass.: 1 Dentario glandulosae-Fagetum, 2 – Carici pilosae-fagetum										
1 Dentaria glandulosa L.	0.04	-	-	0.04	-	-	-	-	-	-
2 Carex pilosa L.	5.50	47.85	0.21	52.93	42.38	7.23	2.00	25.3	2.31	-
D.Sp. Cl.: a - QUERCO-FAGETEA; b - Fagetalia sylvaticae, c – Carpinion betuli										
a Anemone nemorosa L.	0.08	0.09	0.09	-	-	0.60	-	-	4.57	-
a Aegopodium podagraria L.	0.52	-	-	0.87	1.00	-	-	-	4.48	-
a Hedera helix L.	2.48	-	-	14.02	4.00	-	8.94	35.8	1.01	-
a Hepatica nobilis Mill.	-	-	-	8.15	3.00	1.51	9.16	-	2.78	-
a Mycelis muralis (L.) Dumort.	-	-	-	-	1.00	-	-	-	2.11	-
a Lathyrus vernus L.	-	-	-	2.07	-	-	-	-	-	-
b Aposeris foetida (L.) Less.	-	-	-	-	-	-	-	-	2.06	0.05
b Asarum europaeum L.	4.12	-	-	13.8	5.00	-	10.42	18.6	3.12	-
b Dryopterix filix max (L.) Schott	5.14	3.47	-	-	38.00	1.02	-	5.7	-	-
b Lathyrus vernus L.	-	-	-	-	5.00	-	-	-	-	-
b Paris quadrifolia L.	0.10	-	-	-	-	-	-	-	-	-
b Pulmonaria obscura Dum.	-	-	-	1.41	4.00	-	9.16	4.8	1.96	-
b Sanicula europaea L.	-	-	-	-	-	-	-	-	-	0.15
b Viola reichenbachiana Jord. ex Boreau	-	-	-	0.15	2.00	0.09	0.06	-	0.71	-
c Stellaria holostea L.	-	-	-	1.00	-	-	-	-	-	-
D.Sp. Cl.: a – MOLINIO-ARRHENATHERETEAE; b-Trifolio fragiferae-Agrostietalia stoloniferae, Agrostietalia stoloniferae, Agropyro-Rumicion crispi; c-Calthion palustris; d – Arrhenatheretalia										
a Vicia cracca L.	-	-	-	-	-	-	-	-	-	0.06
a Plantago major L.	-	-	-	-	-	-	-	-	0.03	-
a Trifolium repens L.	-	-	-	-	-	-	-	-	-	0.06
a Juncus effusus L.	-	-	-	-	-	-	-	-	-	0.07

Area, ha	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Amount of species	11	9	5	13	22	9	9	8	24	15
b Ranunculus acris L.	-	-	-	-	-	-	-	-	0.80	-
c Myosotis palustris L.	-	-	-	-	-	-	-	-	0.31	-
d Taraxacum officinale Wigg.	-	-	-	-	-	-	-	-	1.01	0.41
D.Sp. Cl.: a – EPILOBIETA ANGUSTIFOLII, Atropetalia, Sambuco-Salicion										
a Chamaerion angustifolium (L.) Scop.	-	-	-	-	1.00	-	-	-	-	0.02
a Rubus idaeus L.	-	-	-	-	5.00	-	-	-	-	-
a Fragaria vesca L.	-	-	-	-	-	-	-	-	-	0.85
a Rubus hirtus L.	-	10.53	-	-	65.30	80.10	-	-	-	-
D.Sp. Cl.: a – ARTEMISIETEA VULGARIS; b – GALIO-URTICENEA; c – Glechometalia hederaceae, Alliarion										
a Festuca rubra L.	-	-	-	-	-	-	-	-	-	0.71
a Glechoma hederacea L.	4.64	9.45	0.03	9.85	2.00	1.26	7.23	43.2	7.40	0.12
a Urtica dioica L.	-	-	-	-	2.00	-	-	-	0.02	-
a Geum urbanum L.	-	-	-	-	-	-	-	-	0.47	-
a Ranunculus acris L.	-	-	-	-	-	-	-	-	-	-
b Galium aparine L.	4.58	5.77	0.06	4.57	5.00	5.41	4.77	18.4	7.13	-
c Impatiens parviflora DC.	0.05	0.72	-	0.04	2.00	-	-	-	-	-
D.Sp. Cl.: a – FESTUCO-BROMETEA; b-Festucetalia valesiacae										
b Salvia verticillata L.	-	-	-	0.65	2.00	-	-	-	0.14	-
D.Sp. Cl.: a – STELLARIETEA MEDIAE; b – Polygono-Chenopodietalia; c – Polygono-Chenopodion										
b Galinsoga parviflora L.	-	-	-	-	-	-	-	-	-	0.08
b Stellaria media L.	-	-	-	-	5.00	-	-	-	0.53	-
c Sonchus arvensis L.	-	-	-	-	-	-	-	-	-	0.15
D.Sp. Cl.: a – VACCINIO-PICEETEA; b – Dicrano-Pinion										
a Polytrichum commune Hedw.	-	-	-	-	-	-	0.06	-	-	-
b Solidago virgaurea L.	-	-	-	-	-	-	-	-	-	0.09

Area, ha	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Amount of species	11	9	5	13	22	9	9	8	24	15
Other species:										
Athyrium filix-femina (L.) Roth.	-	-	-	-	-	-	-	-	5.74	-
Majanthemum bifolium (L.) F. W. Schmidt	-	3.28	2.06	-	1.00	-	-	-	-	-
Geranium sylvaticum L.	-	-	-	-	-	-	-	-	1.48	-
Oxalis acetosella L.	-	0.11	-	-	2.00	0.43	-	19.5	3.21	-
Juncus tenuis Wild.	-	-	-	-	5.00	-	-	-	-	0.10
Daucus carota L.	-	-	-	-	-	-	-	-	0.53	0.12

Note: syntaxons are marked by numbers: 1 – Dentario glandulosae-Fagetum; 2 – Carici pilosae-fagetum

By a phytosociological descriptions of forests (where mainly beech stands are presented) we determined, that the beech forests belong to the class *Querco-Fagetea* order *Fagetalia sylvaticae,* which combines meso- and hydrophilic deciduous forests in Western, Central and Eastern Europe. Union *Fagion sylvaticae* include beech, spruce-beech and fir, typical for Central Europe. Forests of this alliance are typical for temperate zone; they are natural and have very resistant types of vegetation. This union is divided into sub unions.

1 - Dentario glandulosae-Fagetum - classic beech "Carpathian" type, there are many variations and differences of it in the region.
Ceonotic structure of such stand is different. There are several layers in the stand, where the dominant species is *Fagus sylvatica L.* Crown density is usually high (90%). Shrubby layer is often dense, and quite immature. The development of vegetation depends of illumination in this stand. Characteristic of this sub union is also underdeveloped moss layer.

Phytosociological structure of this sub union is characterised by diversity of species in the vegetation. There are presented such species as: *Dentaria glandulosa Waldst. et Kit., Symphytum cordatum Waldst. et Kit. ex Willd., Polystichum aculeatum (L.) Roth.* In our research, on sample areas the dominant species is *Dentaria glandulosa Waldst. et Kit.* Generally, in the formation of such phytocoenoses the most dominant species are types of union *Fagion sylvaticae,* order *Fagetalia sylvaticae*.

2 - Carici pilosae-Fagetum - one of the most common associations of beech forests among Ukrainian forests, particularly in its south-eastern part.
The structure of the beech forests of the association is simplified. Pure beech stands, often with additives of hornbeam or maple-sycamore. Shrubby layer with low density presented by *Sambucus nigra L., S. racemosa L., Euonymus verrucosa L*. Dense vegetation layer formed by *Carex pilosa Scop., Sanicula europaea L., Viola reichenbachiana Jord. ex Boreau, Mercurialis perennis L., Galeobdolon luteum L., Actaea spicata L.*

Phytosociological characteristics. Sub union is formed by a typical species of *Carex pilosa L.*, which almost always takes a large area of such forests. There are poorer variants of association with the exclusive dominance of *Carex pilosa L.* and ferns. It is usually expressed in mature stands without glades and with formed layer structure.

Description of vegetation (column 10 in *table 3.3*) belongs to the original group of indigenous associations of beech forests.

3.3. Influence of light intensity on the projective coverage and frequency of the species in vegetation

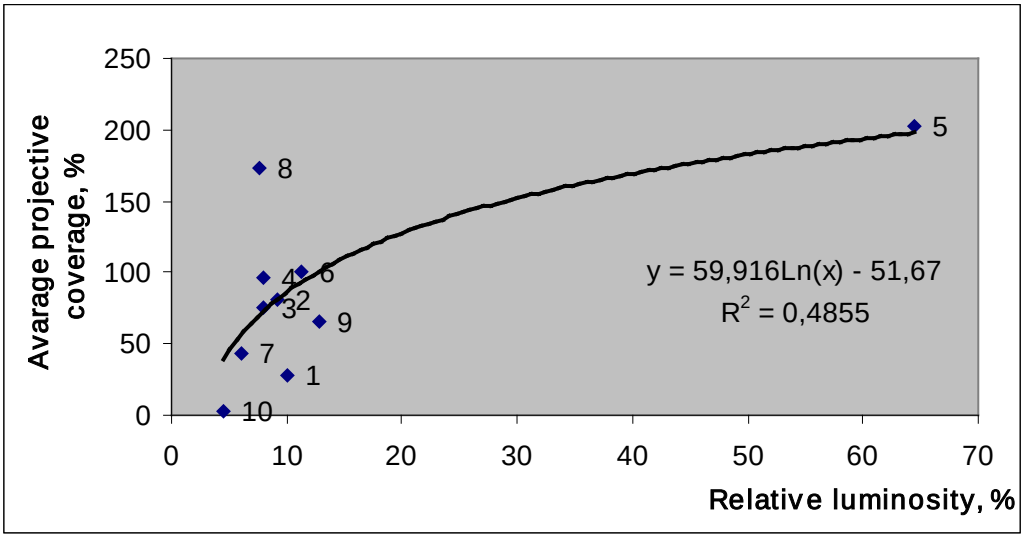

Figure 7. Relative luminosity and projective coverage of vegetation

Increasing of light intensity assists for increasing number of herbal species and its projective coverage on the area. Development of species competition can lead to the formation of layers in vegetation, as it is learned from the 5th and 8th sample areas *(Figure 7).*

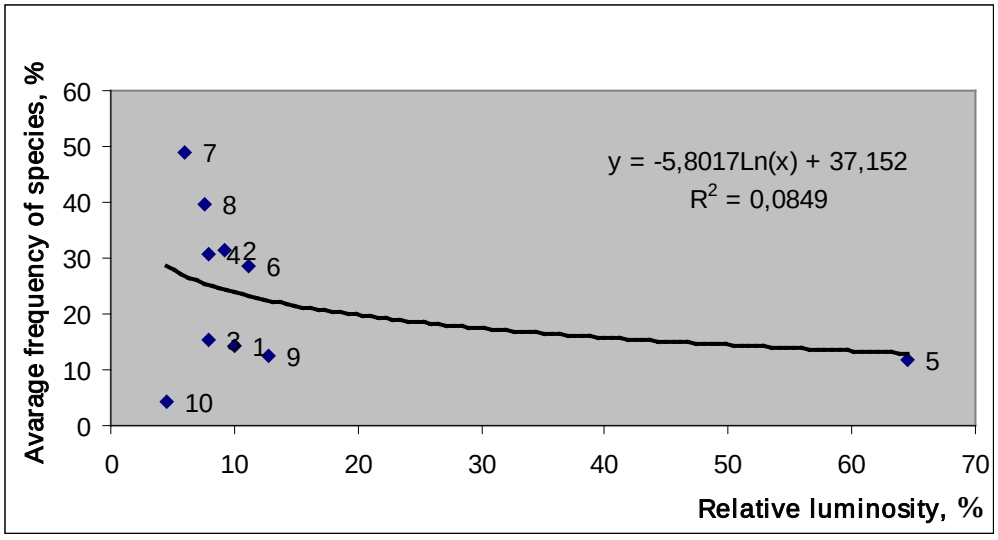

Figure 8. Relative luminosity and frequency of species in vegetation

On the *figure 8* there is a tendency of decreasing of average frequency of vegetation with the increasing of light intensity. It is connected with the increasing of amount of herbal plants and level of concurrence between them. High luminosity is not optimal for existing of forest vegetation. Its durable influence will provocate a colonization of territory by light demanded meadow plants or weeds, thus to decreasing of number of forest species.

The coefficient of the intensity of light under the shelter of the trees is ranged from 1.1% to 64.5% *(figure 8)* of full illumination (direct sunlight), which in absolute terms equals to 3.0-38.5 thousand lux. The highest quantitative index of species in vegetation with sufficient light is on the 5th and 8th sample areas, but the distribution of species types is different. Sample area № 5 is dominated by typical forest vegetation; on sample area № 8 is a significant number of meadow grass species.

3.4. Impact of the age and density of canopy on the vegetation

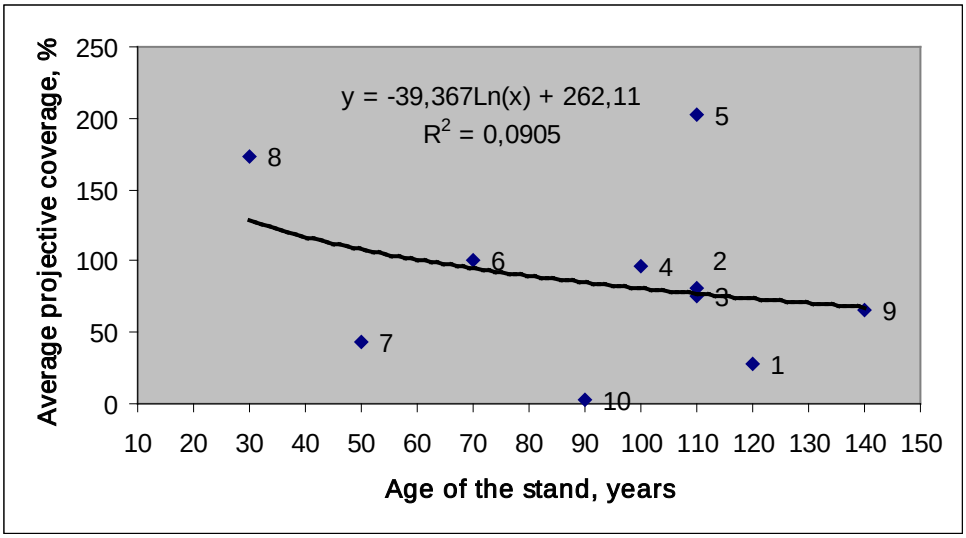

Figure 9. Age of the stand and projective coverage of vegetation

At the age from 30 to 140 years quantitative and species representation of vegetation at the beech stands shows, that there is no differences between their characteristics.

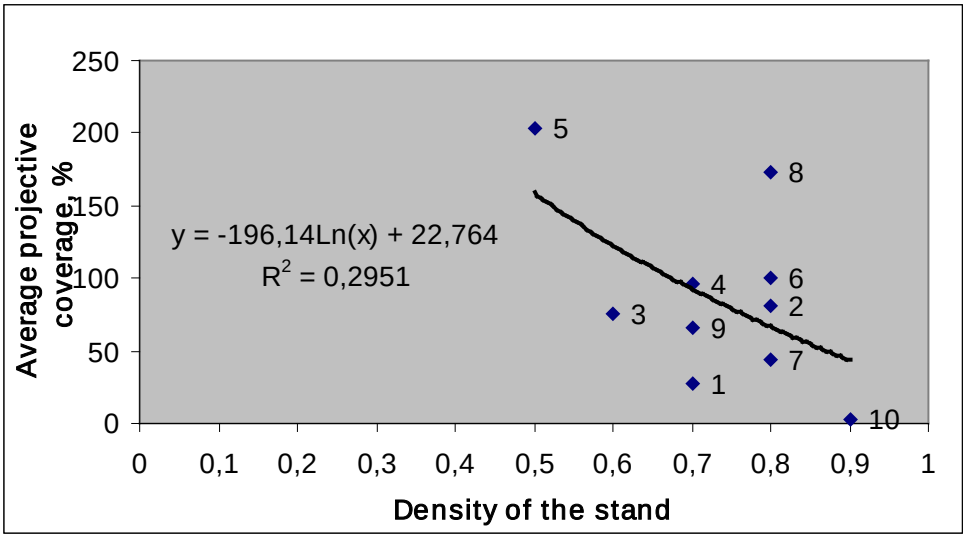

Figure 10. Density of canopy of stand and projective coverage of vegetation

Increasing of the density of canopy leads to decrease of illumination under the shelter of the trees, thus to decrease of projective coverage and wise versa, if the density of canopy is higher - the index of projective coverage will be higher *(figure 10).*

At lower levels of light intensity on the research areas of direct correlation between the intensity of light at the time of measurement and quantitative characteristics of the vegetation could not identify.

3.5. Influence of direction of the slope on the vegetation

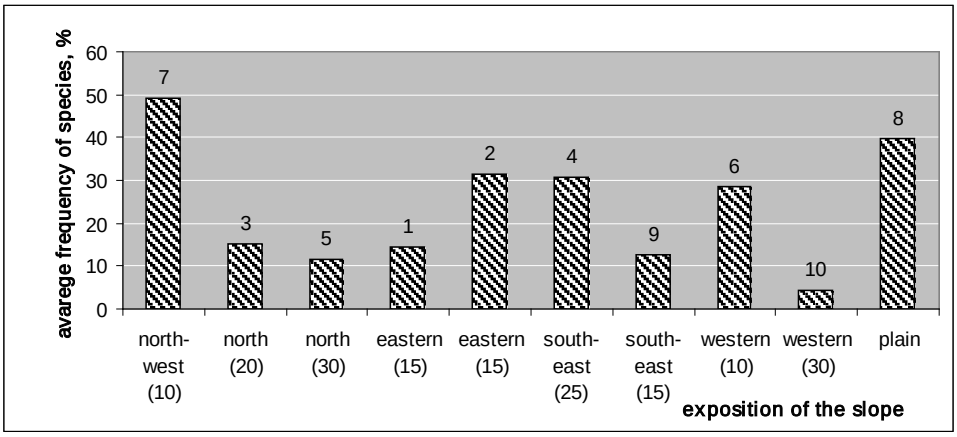

Figure 11. Changes in vegetation comparing to the exposition of the slope (numbers within brackets are showing the inclination of the slope; numbers on the column show the number of sample area)

There is a greater correlation with the exposure of the slope *(figure 11).* At approximately the same intensity of light, in time of measuring, a greater number of species was presented on the south-eastern, eastern and western slopes of the hills (sample areas - 4, 6, 2) and the lowest - on the northern (sample area – 3, 5). It obviously can be explained by the fact that on the southern and south-eastern exposition in the day time angle of incidence of light is close to straight. The northern slopes, however, receive less total dose of light through more reflection of surface and self shading.

4. DISCUSSION

4.1. Differences in the species composition of vegetation comparing to management gradients (natural reserve, management forest and parks)

A significant impact on the species diversity of the vegetation has the urbanization level of the area *(Cole, Bayfield, 1993; Liddle, 1991).* Prevailing plants in urban conditions are represented by typical forest species, especially area in older parks, sometimes reminds of a

forest area. All other vegetation is growing near the trails and on the small meadows, where it is sufficient illumination. These plants mostly belong to meadow and forest-meadow types.

The number and distribution of different herb species is higher in the places of disturbance, in parks it is an impact of recreation and trampling; in the forest – it's mainly of management activities. The results of scientists show that thirty years without management on the forest territory are sufficient to change species composition significantly *(Brunet, Falkengren-Grerup, et al., 1996; Graae, Sunde 2000).* When comparing managed forest and natural reserve, the species distribution of vegetation will be higher in managed area, it mainly is the result of different disturbances at the territory (*Aude, Lawesson, 1997).* The richness of species in vegetation starts to decline at territories where the active management activities are not accomplished *(Schmidt 2005).*

4.2. Influence of light intensity on the projective coverage and frequency of the species in vegetation

In this investigation were made the calculations of light conditions under the shelter of the beech stand and on the open space territory. Percentage that equalled luminosity in the stand shows that the most powerful determinant of qualitative and quantitative characteristics of vegetation is lighting under the shelter. This index ranged from 1.1% to 64.5% full light (direct sunlight). However, the influence of light intensity significantly starts to occur in a large increase tension – 11.2 – 64.5% of the full coverage. In the places where the density of the stand is lower and especially in gaps the occurrence of herb species and its richness is higher (*Galhiby, Mihok, et al., 2005).* Despite the highest quantity of herbaceous plants with the sufficient luminosity on different sample areas, species diversity of this area has a different nature. At the same time, when on sample areas in the managed forest, there is presence of typical beech forest species of vegetation, on the plots of parks area is a significant admixture of meadow herbs. It clearly shows the impact of not only light influence, but also recreational and digression processes.

4.3. Impact of the age and density of canopy on the vegetation

Comparing the quantity and species representation of vegetation cover under the parent trees in the range of 30-140 years, was studied that accurate dependence between them is not found. In this section of ontogenesis, the vegetation of beech stands in the studied region is formed around the same types and numbers of species, age of the stand is not correlating.

Bigger dependence was found between the projective cover of vegetation and density of the stand. On other sample areas the dependence of density of the stand was found in a considerable extent, because of the influence of other environmental factors on the stand.

4.4. Influence of direction of the slope on the vegetation

If density of the stand is high and luminosity is low, an important role in a shaping of the vegetation layer plays the direction of the slope. If the stand is not dense, then luminosity is important and the role of the direction of slope in such case is negligible.

Comparing the sample areas at different levels of forest use, was studied, that on the flat territory - the number of projective cover is higher. This is primarily due to low stand density and low luminosity under the shelter of the trees. Also, this area is characterized by different layers of vegetation cover, where the first layer belongs to typical shade-enduring species of vegetation, and the second one to blueberries (the projective cover of the area is more than 100%).

5. CONCLUSIONS

5.1. Characteristic of the beech stands and vegetation on sample areas

Examinated vegetation under the beech stands in suburban forests, parks and natural reserve in total consists of 44 species from 25 families. In parks, the complex of species in vegetation is much wider and is shaped by 35 species, comparing with the management forest, where the same figure is only 26 species and for natural reserve its only 12 species. Species representation of typical vegetation, at the forests and parks, is the largest in the following families: *Asteraceae, Ranunculaceae, Apiaceae.*

The dominant and typical species of beech forests are: *Glechoma hederacea L., Galium aparine L., Carex pilosa L., Asarum europaeum L., Hedera helix L., Oxalis acetosella L., Dryopterix filix max (L.) Schott.*

5.2. Differences in the species composition of vegetation comparing to management gradients (natural reserve, management forest and parks)

Research on the sample areas shows, that there is a difference in species distribution between forest, natural reserve and park areas in the green zone of Lviv city. It mainly depends on the anthropogenic impact on the territory. Sample areas which are situated far from places of recreation, the presence of typical for beech stands species is higher there, than in places, where the level of recreation is more intense.

5.2.1. Distribution of vegetation in investigated areas by geographical elements

Geographical analysis of herbaceous flora of the beech stands in the Lviv green zone shows a significant participation of European, Euroasiatic, North African-Holarctic geoelements

related to panboreal and arcto-boreal groups. This indicates on a genetic connection of flora of beech forests, not only with the Carpathian and Balkan forests, but also with other areas of the beech stands.

5.2.2. Distribution of vegetation in investigated areas by ceonotic structure

Major groups of parks in Lviv city, are mainly generated by meadow and ruderal vegetation. Especially this factor was observed in the forest-park "Pohulyanka". With its high competitive ability and aggressiveness grass species can easily remove typical species of beech stands from the park area.

Ceonotic structure of vegetation in the beech stands is mainly generated from the typical forest and forest-park types. High representation of species, especially in parks, is characterized by meadow and ruderal types of vegetation. Between swamp-meadow and swamp-forest types the presentation of herbal species is minimum or totally absent.

5.2.3. Distribution of vegetation in investigated areas by the soil humidity and fertility

In relation to the soil moisture major amount of plants in vegetation has an average exaction and applies to mesophytes. In relation to the soil fertility vegetation of beech forests has some differences from the parks and natural reserves. 77% of vegetation in managed forest belongs to eutrophes and 23% - to mesotrophes. In the parks, the share of mesotrophes is increasing, which clearly proves the deterioration in growth conditions.

5.2.4. Distribution of vegetation by the light regimes in classification of Tsyganov

Modified scale of the light conditions by Tsyganov of the vegetation shows that most of types of species belong to ultra-shadow Z-type of lighting regime, and in the natural reserve they comprise a maximum numbers. Notably, for P, N, M and G-types of lighting modes on observed areas prevalence number of species are concentrated in park conditions comparing to the forest and natural reserve areas. The larger light luminosity in the beech stands explains the situation of appearing of the ruderal and meadow species of plants: *Ranunculus acris L., Urtica dioica L., Taraxacum officinale Wigg., Plantago major L.* and others.

5.2.5. Life forms of vegetation by classification of Serebryakov

Life forms of species studied by Serebryakov show that most of the herbal species belong to the long-, short- and repens-rhizome plants. These species in the largest extent adapted to the conditions of the shady beech stands and they basically are the most typical representatives of it. They can absorb a big amount of nutrients from the soil and concur with woody plants. Other life forms are usually not typical and they spread under the beech trees in parks.

5.2.6. Life forms of vegetation by classification of Raunkiaer

The system of life forms of vegetation of Raunkiyer is represented by hemicryptophytes, geophytes, terophytes, hamephytes and fanerophytes. The vast majority of the species in vegetation in the forest, natural reserve and in the parks are hemicryptophytes. The phytodiversity of managed forest and natural reserve is represented more widely, comparing to the vegetation in parks, which is practically concentrated in to two groups of life forms - hemicryptophytes and geophytes.

5.2.7. Ecological-floristic classification of Braun-Blanquet

Beech stands in the investigated area are one of the most interesting elements of the natural vegetation in terms of complex history of formation and specific floristic composition, where the dominating rare species from the montane region are presented. A beech forest has one of the few complexes of vegetation, which are marked by the high degree of self-regulation and reproduction that allowed identifying the species by the method of Braun-Blanquet.

An important factor, which influences the formation of beech coenoses, is recreation, that's because in Lviv region it's almost impossible to find indigenous beech stands.

5.3. Influence of light intensity on the projective coverage and frequency of the species in vegetation

The most powerful determinant of qualitative and quantitative characteristics of vegetation in a beech phytocoenoses is illumination under the shelter of trees. The highest quantitative indexes of vegetation with sufficient light are observed on the sample areas, where the territory is flat and the density of the stand is low. On these areas the greatest number of species was found.

5.4. Impact of the age and density of canopy on the vegetation

Analyzing the quantitative and species representation of vegetation in beech stands at the maternal age from 30 to 140 years, a reliable difference between their characteristics was not found. In this section ontogenesis of vegetation at the investigated area is formed by approximately the same number of species and their amount is not correlated by the age of the stand.

5.5. Influence of direction of the slope on the vegetation

At the time of measurement on the sample areas, a direct correlation between the intensity of the light and quantitative characteristics of the vegetation was not detected. It shows a greater correlation with the exposure of the slope. At approximately the same intensity of lighting a

bigger number of herb species is presented, which occur in the south-eastern, eastern and western slopes of the hills and the lowest - on the northern ones. The northern slopes, however, receive less total dose of light through more reflection of surface and self shading.

ACKNOWLEDGEMENTS

My sincere thank to my supervisor ***Eric Agestam*** for great help and excellent support in guidance me with the Master thesis. Great thanks to examinator Jörg Brunet for helpful comments on the work, and SLU for giving this opportunity of writing thesis in Alnarp, Sweden.

Also big thanks to ***prof. V.P. Kucheriavyj, M.I. Soroka and V.V. Pavlyuk*** from Ukrainian national forestry university, for the reviewing and giving excellent advices in preparing of the manuscript.

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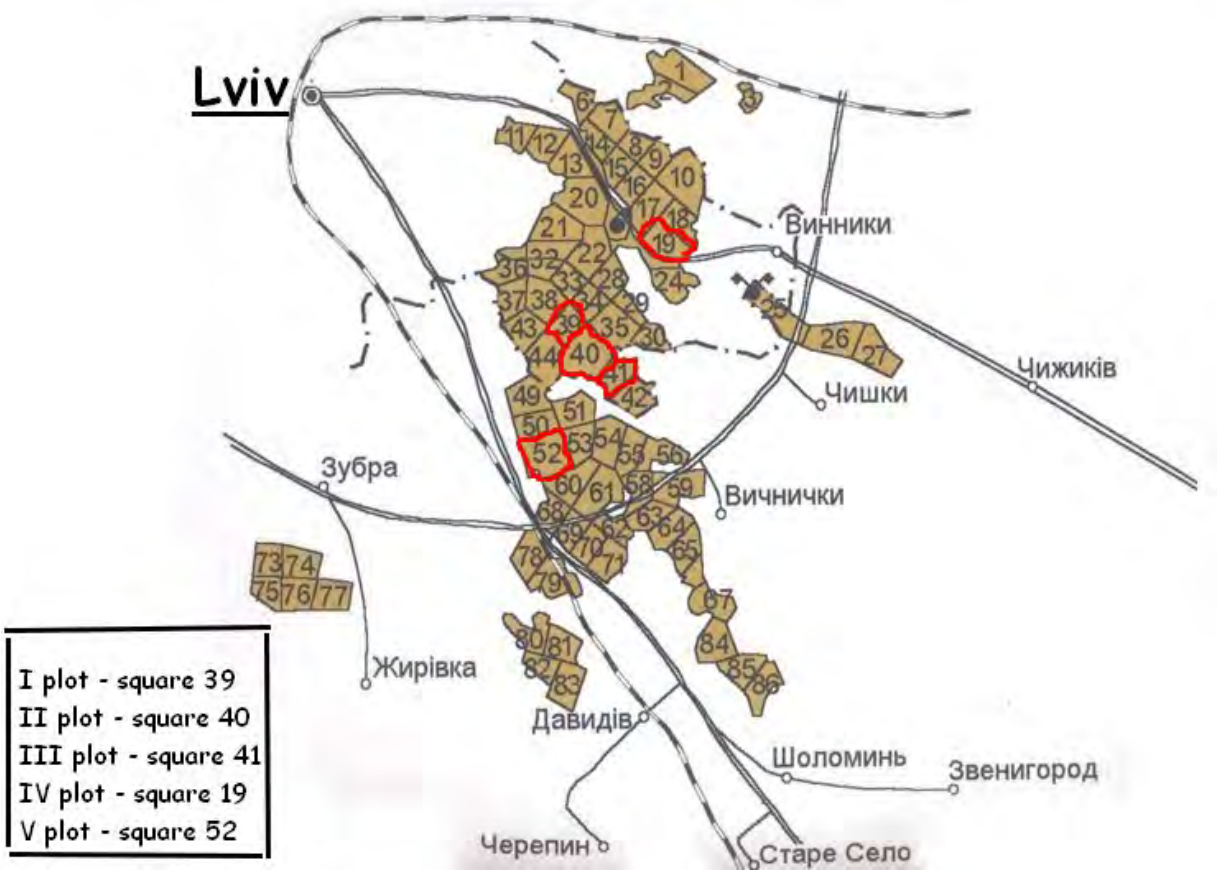
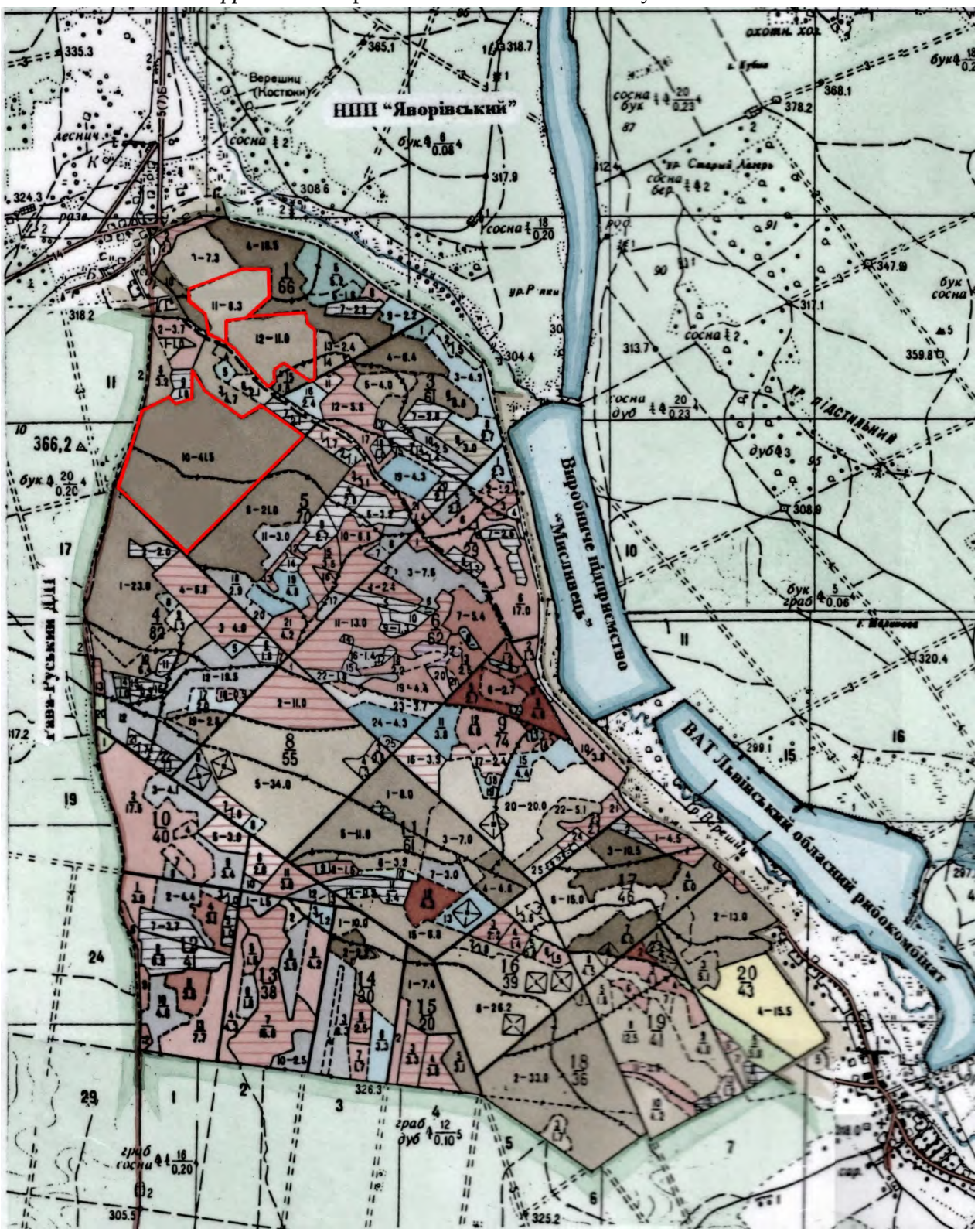
APPENDIX

Appendix 1. Map of the green zone of Lviv city

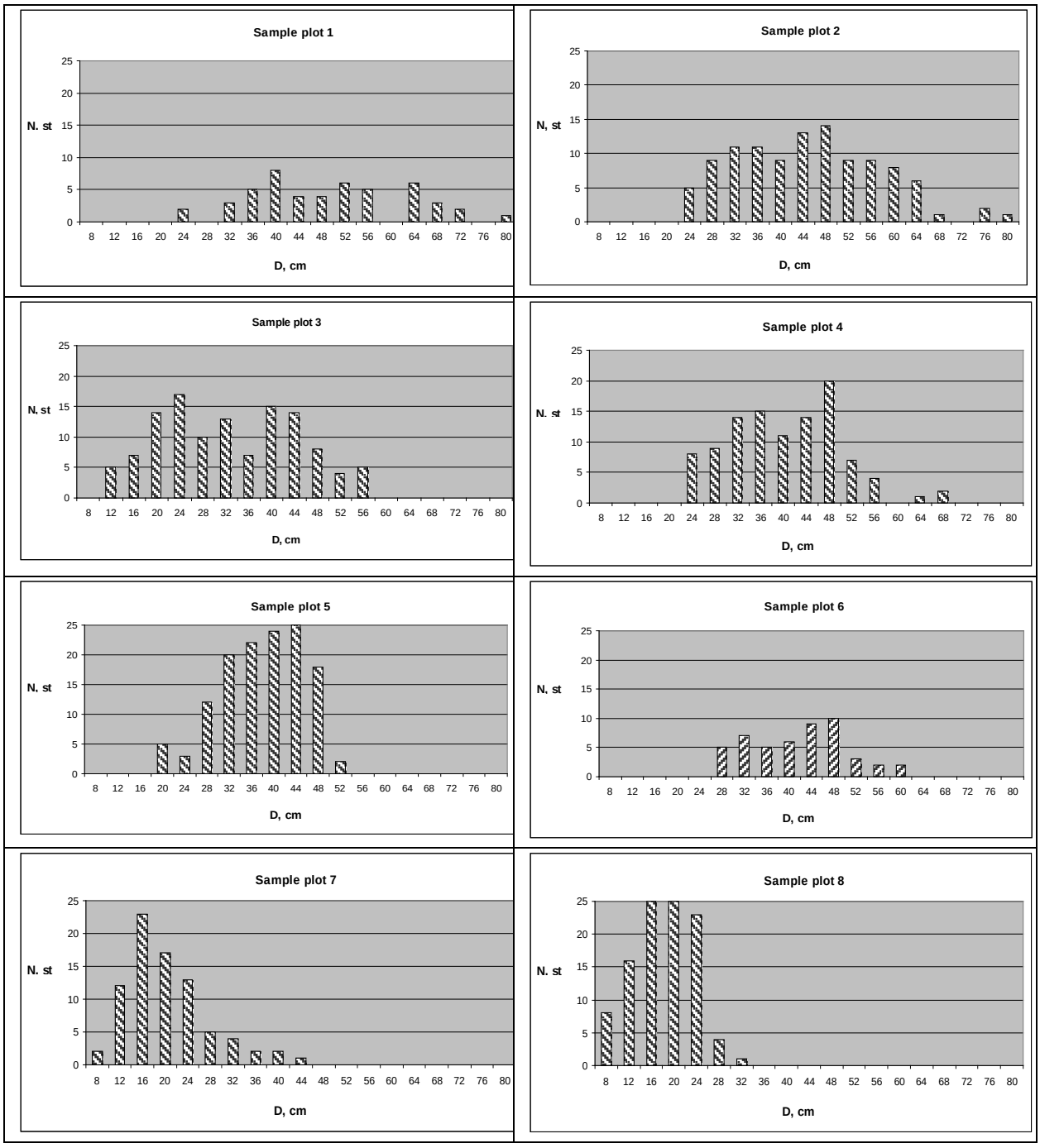
Appendix 2. Map of Vynykivske Forestry



Appendix 3. Map of natural reserve "Roztochchya"



Appendix 4. Diameter distribution of the beech trees in the forest sample areas



Appendix 5. Characteristic of the vegetation in the sample areas

№	Species	Average projective coverage, %	Relative frequency, %	Phytocoenotic Value Ratio (PVR)
Sample area № 1				
1	*Carex pilosa L.*	5,50	18,0	99,0
2	*Dryopterix filix max (L.) Schott.*	5,14	26,0	133,6
3	*Glechoma hederacea L.*	4,64	16,0	74,2
4	*Galium aparine L.*	4,58	36,0	164,9
5	*Asarum europaeum L.*	4,12	16,0	65,9
6	*Hedera helix L.*	2,48	22,0	54,6
7	*Aegopodium podagraria L.*	0,52	4,0	2,1
8	*Paris quadrifolia L.*	0,10	4,0	0,4
9	*Anemone nemorosa L.*	0,08	6,0	0,5
10	*Impatiens parviflora DC.*	0,05	4,0	0,2
11	*Dentaria glandulosa L.*	0,04	6,0	0,2
Sample area № 2				
1	*Carex pilosa L.*	47,85	89,4	4277,8
2	*Rubus hirtus L.*	10,53	23,4	246,4
3	*Glechoma hederacea L.*	9,45	38,3	361,9
4	*Galium aparine L.*	5,77	66,0	380,8
5	*Dryopterix filix max (L.) Schott*	3,47	14,9	51,7
6	*Majanthemum bifolium (L.) F. W. Schmidt*	3,28	25,5	83,6
7	*Impatiens parviflora DC.*	0,72	19,1	13,8
8	*Oxalis acetosella L.*	0,11	2,1	0,2
9	*Anemone nemorosa L.*	0,09	4,3	0,4
Sample area № 3				
1	*Majanthemum bifolium (L.) F. W. Schmidt*	2,06	54,5	112,3
2	*Carex pilosa L.*	0,21	6,1	1,3
3	*Anemone nemorosa L.*	0,09	6,1	0,5
4	*Galium aparine L.*	0,06	6,1	0,4
5	*Glechoma hederacea L.*	0,03	3,0	0,1
Sample area № 4				
1	*Carex pilosa L.*	52,93	100,0	5293,0
2	*Hedera helix L.*	14,02	52,2	731,8
3	*Asarum europaeum L.*	13,8	60,9	840,4
4	*Glechoma hederacea L.*	9,85	58,7	578,2
5	*Hepatica nobilis Mill*	8,15	39,1	318,7
6	*Galium aparine L.*	4,57	43,5	198,8
7	*Lathyrus vernus L.*	2,07	19,6	40,6
8	*Pulmonaria obscura Dum.*	1,41	8,7	12,3
9	*Stellaria holostea L.*	1,00	6,5	6,5
10	*Aegopodium podagraria L.*	0,87	4,3	3,7
11	*Salvia verticillata L.*	0,65	2,2	1,4
12	*Viola reichenbachiana Jord.*	0,15	2,2	0,3

№	Species	Average projective coverage, %	Relative frequency, %	Phytocoenotic Value Ratio (PVR)
13	*Impatiens parviflora DC.*	0,04	2,2	0,1
Sample area № 5				
1	*Rubus hirtus L.*	65,30	50,1	3271,5
2	*Carex pilosa L.*	42,38	73,6	3119,2
3	*Dryopterix filix max (L.) Schott.*	38,00	10,3	391,4
4	*Stellaria media L.*	5,00	6,6	33,0
5	*Asarum europaeum L.*	5,00	5,6	28,0
6	*Juncus tenuis Willd.*	5,00	2,0	10,0
7	*Galium aparine L.*	5,00	8,9	44,5
8	*Rubus idaeus L.*	5,00	23,5	117,5
9	*Lathyrus vernus L.*	5,00	4,3	21,5
10	*Hedera helix L.*	4,00	3,5	14,0
11	*Pulmonaria obscura Dum.*	4,00	8,7	34,8
12	*Hepatica nobilis Mill*	3,00	6,8	20,4
13	*Oxalis acetosella L.*	2,00	23,4	46,8
14	*Urtica dioica L.*	2,00	2,0	4,0
15	*Glechoma hederacea L.*	2,00	13,1	26,2
16	*Viola reichenbachiana Jord. ex Boreau*	2,00	0,5	1,0
17	*Salvia verticillata L.*	2,00	0,6	1,2
18	*Impatiens parviflora DC.*	2,00	8,6	17,2
19	*Majanthemum bifolium (L.) F. W. Schmidt*	1,00	0,9	0,9
20	*Mycelis muralis (L.) Dumort.*	1,00	0,5	0,5
21	*Chamaenerion augustifolium L.*	1,00	0,4	0,4
22	*Aegopodium podagraria L.*	1,00	3,3	3,3
Sample area № 6				
1	*Rubus hirtus L.*	80,10	62,3	4990,2
2	*Carex pilosa L.*	7,23	32,4	234,3
3	*Galium aparine L.*	5,41	48,3	261,3
4	*Hepatica nobilis Mill.*	1,51	38,3	57,8
5	*Glechoma hederacea L.*	1,26	52,9	66,7
6	*Dryopterix filix max (L.) Schott.*	1,02	18,6	19,0
7	*Anemona nemorosa L.*	0,60	11,2	6,7
8	*Oxalis acetosella L.*	0,43	8,6	3,7
9	*Viola reichenbachiana Jord. ex Boreau*	0,09	3,1	0,3
Sample area № 7				
1	*Asarum europaeum L.*	10,42	93,5	974,3
2	*Pulmonaria obscura Dum.*	9,16	80,6	738,3
3	*Hepatica nobilis Mill.*	9,16	80,6	738,3
4	*Hedera helix L.*	8,94	32,3	288,8
5	*Glechoma hederacea L.*	7,23	71,0	513,3
6	*Galium aparine L.*	4,77	61,3	292,4
7	*Carex pilosa L.*	2,00	16,1	32,2

№	Species	Average projective coverage, %	Relative frequency, %	Phytocoenotic Value Ratio (PVR)
8	*Viola reichenbachiana Jord. ex Boreau*	0,06	3,2	0,2
9	*Polytrichum commune Hedw.*	0,06	3,2	0,2
Sample area № 8				
1	*Glechoma hederacea L.*	43,2	56,36	2434,8
2	*Hedera helix L.*	35,8	56,48	2022
3	*Carex pilosa L.*	25,3	75,68	1914,7
4	*Oxalis acetosella L.*	19,5	55,47	1081,7
5	*Asarum europaeum L.*	18,6	44,91	835,3
6	*Galium aparine L.*	18,4	33,81	622,104
7	*Dryopterix filix max (L.) Schott.*	5,7	12,36	70,5
8	*Pulmonaria obscura Dum.*	4,8	15,45	74,2
Sample area № 9				
1	*Glechoma hederacea L.*	7,40	62,33	461,2
2	*Galium aparine L.*	7,13	43,51	310,2
3	*Athyrium filix-femina (L.) Roth.*	5,74	18,16	104,2
4	*Anemona nemorosa L.*	4,57	13,57	62,0
5	*Aegopodium podagraria L.*	4,48	11,85	53,1
6	*Oxalis acetosella L.*	3,21	6,27	20,1
7	*Asarum europaeum L.*	3,12	23,62	73,7
8	*Hepatica nobilis Mill.*	2,78	0,72	2,0
9	*Carex pilosa L.*	2,31	38,10	88,0
10	*Mycelis muralis (L.) Dumort.*	2,11	2,38	5,0
11	*Aposeris foetida (L.) Less.*	2,06	15,44	31,8
12	*Pulmonaria obscura Dum.*	1,96	1,23	4,9
13	*Geranium sylvaticum L.*	1,48	3,25	4,8
14	*Hedera helix L.*	1,01	15,35	15,5
15	*Taraxacum officinale Wigg.*	1,01	1,15	1,2
16	*Ranunculus acris L.*	0,80	3,22	2,6
17	*Viola reichenbachiana Jord. ex Boreau*	0,71	1,02	4,8
18	*Daucus carota L.*	0,53	1,87	1,0
19	*Stellaria media L.*	0,53	0,33	0,2
20	*Geum urbanum L.*	0,47	1,52	0,7
21	*Myosotis palustris L.*	0,31	2,30	0,7
22	*Salvia verticillata L.*	0,14	28,46	174,7
23	*Plantago major L.*	0,03	1,94	0,1
24	*Urtica dioica L.*	0,02	2,36	0,05
Sample area № 10				
1	*Fragaria vesca L.*	0,85	7,12	6,1
2	*Trifolium repens L.*	0,06	2,37	0,1
3	*Festuca rubra L.*	0,71	4,95	3,5
4	*Taraxacum officinale Wigg.*	0,41	5,14	2,1
5	*Sonchus arvensis L.*	0,15	1,26	0,2
6	*Juncus tenuis Willd.*	0,10	0,10	0,0

№	Species	Average projective coverage, %	Relative frequency, %	Phytocoenotic Value Ratio (PVR)
7	*Juncus effusus L.*	0,07	0,09	0,0
8	*Sanicila europaea L.*	0,15	0,72	0,1
9	*Daucus carota L.*	0,12	0,64	0,1
10	*Aposeris foetida (L.) Less.*	0,05	0,06	0,0
11	*Solidago virgaurea L.*	0,09	0,06	0,0
12	*Vicia cracca L.*	0,06	0,05	0,0
13	*Glechoma hederacea L.*	0,12	0,87	0,1
14	*Galinsoga parviflora L.*	0,08	0,75	0,1
15	*Chamaerion angustifolium (L.) Scop.*	0,02	0,12	0,0

Appendix 6. Geographic and coenotic structure of herbal vegetation in beech stands

№	Latin name of species	Geographic structure		Coenotic structure
		element	areal	
1	*Juncus effusus L.*	Boreal	Eurasiatic	Swamp meadow species
2	*Geum urbanum L.*	Nemoral	Eurasiatic	
3	*Ranunculus acris L.*	Boreal	Eurasiatic	
4	*Impatiens parviflora DC.*	Arid	Eurasiatic	Swamp-forest species
5	*Chamaerion angustifolium (L.) Scop.*	Boreal	Eurasiatic	
6	*Vicia cracca L.*	Boreal	Eurasiatic	Meadow species
7	*Trifolium repens L*	Boreal	Panboreal	
8	*Festuca rubra L.*	Boreal	Arcto-boreal- Montan	
9	*Daucus carota L.*	Boreal	Eurasiatic	
10	*Taraxacum officinale Wigg.*	Boreal	Eurasiatic	
11	*Glechoma hederacea L.*	Boreal	Eurasiatic	
12	*Juncus tenuis Willd*	Boreal	Holarctic	
13	*Lathyrus vernus L.*	Nemoral	Eurasiatic	
14	*Salvia verticillata L.*	Nemoral	European	
15	*Anemone nemorosa L.*	Nemoral	European	Forest species
16	*Aposeris foetida (L.) Less.*	Nemoral-Montan	European	
17	*Majanthemum bifolium (L.) F. W. Schmidt*	Boreal	Eurasiatic	
18	*Paris quadrifolia L.*	Nemoral	Eurasiatic	
19	*Stellaria holostea L.*	Nemoral	European	
20	*Dentaria glandulosa L.*	Montan	Eurasiatic	
21	*Asarum europaeum L.*	Nemoral	Eurasiatic	
22	*Rubus hirtus L.*	Boreal	Eurasiatic	
23	*Carex pilosa L.*	Boreal	Eurasiatic	
24	*Sanicula europaea L.*	Nemoral	Eurasiatic	

№	Latin name of species	Geographic strucutre		Coenotic structure
		element	areal	
25	*Hedera helix L.*	Montan	European	
26	*Fragaria vesca L.*	Boreal	Eurasiatic	
27	*Viola reichenbachiana Jord. ex Boreau*	Nemoral	European	
28	*Athyrium filix-femina (L.) Roth.*	Azonal	Eurasiatic	Forest-shruberry species
29	*Geranium sylvaticum L.*	Nemoral-Montan	Eurasiatic	
30	*Oxalis acetosella L.*	Boreal	Panboreal	
31	*Rubus idaeus L.*	Boreal	Eurasiatic	
32	*Pulmonaria obscura Dum.*	Nemoral	Eurasiatic	
33	*Mycelis muralis (L.) Dumort.*	Nemoral	European	
34	*Hepatica nobilis Mill*	Boreal	Eurasiatic	
35	*Galium aparine L.*	Boreal	European	
36	*Dryopteris filix max (L.) Schott*	Nemoral	Holarctic	
37	*Aegopodium podagraria L.*	Nemoral	Eurasiatic	
38	*Stellaria media L.*	Nemoral	Pannemorose	Ruderal
39	*Solidago virgaurea L.*	Montan	Eurasiatic	
40	*Galinsoga parviflora L.*	Azonal	-	
41	*Sonchus arvensis L.*	Boreal	Eurasiatic	
42	*Myosotis palustris L.*	Nemoral	European	
43	*Urtica dioica L.*	Azonal	-	
44	*Plantago major L.*	Boreal	Eurasiatic	

Appendix 7. Ecological characteristics of herbal vegetation in beech forests

№	Latin name of species	Relation to	
		humidity	**fertility**
1	*Aposeris foetida (L.) Less.*	mesophyt	eutrophic
2	*Impatiens parviflora DC.*	mesophyt	
3	*Athyrium filix-femina (L.) Roth.*	mesophyt	
4	*Majanthemum bifolium (L.) F. W. Schmidt*	mesophyt	
5	*Aegopodium podagraria L.*	mesophyt	
6	*Vicia cracca L.*	mesophyt	
7	*Geum urbanum L.*	mesophyt	
8	*Dentaria glandulosa L.*	mesophyt	
9	*Viola reichenbachiana Jord. ex Boreau*	mesophyt	
10	*Lathyrus vernus L.*	mesophyt	
11	*Salvia verticillata L.*	mesophyt	
12	*Glechoma hederacea L.*	mesophyt	
13	*Galium aparine L.*	mesophyt	
14	*Paris quadrifolia L.*	mesophyt	
15	*Galinsoga parviflora L.*	mesophyt	
16	*Rubus idaeus L.*	mesophyt	
17	*Pulmonaria obscura Dum.*	mesophyt	
18	*Mycelis muralis (L.) Dumort.*	mesophyt	
19	*Daucus carota L.*	mesophyt	
20	*Carex pilosa L.*	mesophyt	
21	*Myosotis palustris L.*	gigrophyt	
22	*Hepatica nobilis Mill*	mesophyt	
23	*Sanicula europaea L.*	mesophyt	
24	*Hedera helix L.*	mesophyt	
25	*Urtica dioica L.*	mesophyt	eutrophic, nitrophytes
26	*Stellaria holostea L.*	mesophyt	eutrophic, calciephobes
27	*Stellaria media L.*	mesophyt	
28	*Anemone nemorosa L.*	mesophyt	mesotrophic
29	*Geranium sylvaticum L.*	mesophyt	
30	*Solidago virgaurea L.*	mesophyt	
31	*Ranunculus acris L.*	mesophyt	
32	*Chamaerion angustifolium (L.) Scop.*	mesophyt	
33	*Oxalis acetosella L.*	mesophyt	
34	*Trifolium repens L*	mesophyt	
35	*Asarum europaeum L.*	mesophyt	
36	*Festuca rubra L.*	mesophyt	
37	*Taraxacum officinale Wigg.*	mesophyt	
38	*Rubus hirtus L.*	mesophyt	
39	*Sonchus arvensis L.*	mesophyt	
40	*Plantago major L.*	mesophyt	
41	*Juncus effusus L.*	gigrophyt	
42	*Fragaria vesca L.*	mesophyt	mesotrophic, calciephobes
43	*Dryopteris filix max (L.) Schott*	mesophyt	
44	*Juncus tenuis Willd*	gigrophyt	

Appendix 8. Distribution of herbaceous plants referring to the light regimes by Tsyganov

№	Latin name of species	Light regimes by Tsyganov
1	*Vicia cracca L.*	G- type
2	*Chamaerion angustifolium (L.) Scop.*	
3	*Daucus carota L.*	
4	*Sonchus arvensis L.*	
5	*Galinsoga parviflora L.*	M- type
6	*Urtica dioica L.*	
7	*Ranunculus acris L.*	
8	*Mycelis muralis (L.) Dumort.*	
9	*Glechoma hederacea L.*	
10	*Myosotis palustris L.*	
11	*Lathyrus vernus L.*	
12	*Taraxacum officinale Wigg.*	N- type
13	*Rubus idaeus L.*	
14	*Plantago major L.*	
15	*Aposeris foetida (L.) Less.*	
16	*Festuca rubra L.*	P- type
17	*Stellaria media L.*	
18	*Solidago virgaurea L.*	
19	*Trifolium repens L*	
20	*Juncus tenuis Willd.*	
21	*Impatiens parviflora DC.*	S- type
22	*Dentaria glandulosa L.*	
23	*Rubus hirtus L.*	
24	*Juncus effusus L.*	
25	*Salvia verticillata L.*	
26	*Fragaria vesca L.*	
27	*Athyrium filix-femina (L.) Roth.*	T- type
28	*Paris quadrifolia L.*	
29	*Anemone nemorosa L.*	
30	*Geranium sylvaticum L.*	
31	*Carex pilosa L.*	
32	*Hepatica nobilis Mill*	
33	*Sanicula europaea L.*	
34	*Majanthemum bifolium (L.) F. W. Schmidt*	Z- type
35	*Galium aparine L.*	
36	*Pulmonaria obscura Dum.*	
37	*Geum urbanum L.*	
38	*Stellaria holostea L.*	
39	*Oxalis acetosella L.*	
40	*Asarum europaeum L.*	
41	*Hedera helix L.*	
42	*Viola reichenbachiana Jord. ex Boreau*	
43	*Dryopteris filix max (L.) Schott*	
44	*Aegopodium podagraria L.*	

Appendix 9. Characteristics of herbaceous plants by the life forms of Serebryakova

№	Latin name of species	Life forms by Serebryakov
1	*Anemone nemorosa L.*	long-rhizome plant
2	*Majanthemum bifolium (L.) F. W. Schmidt*	
3	*Paris quadrifolia L.*	
4	*Dentaria glandulosa L.*	
5	*Asarum europaeum L.*	
6	*Urtica dioica L.*	
7	*Pulmonaria obscura Dum.*	
8	*Sonchus arvensis L.*	
9	*Aegopodium podagraria L.*	
10	*Geum urbanum L.*	short-rhizome plant
11	*Athyrium filix-femina (L.) Roth.*	
12	*Geranium sylvaticum L.*	
13	*Chamaerion angustifolium (L.) Scop.*	
14	*Mycelis muralis (L.) Dumort.*	
15	*Hepatica nobilis Mill*	
16	*Juncus tenuis Willd*	
17	*Juncus effusus L.*	
18	*Viola reichenbachiana Jord. ex Boreau*	
19	*Lathyrus vernus L.*	
20	*Salvia verticillata L.*	
21	*Dryopteris filix max (L.) Schott*	
22	*Stellaria holostea L.*	repens rhizome plant
23	*Oxalis acetosella L.*	
24	*Trifolium repens L*	
25	*Rubus hirtus L.*	
26	*Hedera helix L.*	
27	*Glechoma hederacea L.*	
28	*Fragaria vesca L.*	
29	*Galinsoga parviflora L.*	annual-biennial plant
30	*Impatiens parviflora DC.*	
31	*Stellaria media L.*	
32	*Plantago major L.*	
33	*Galium aparine L.*	
34	*Rubus idaeus L.*	shrubbery
35	*Vicia cracca L.*	fibrous root plant
36	*Ranunculus acris L.*	
37	*Taraxacum officinale Wigg.*	
38	*Festuca rubra L.*	
39	*Solidago virgaurea L.*	
40	*Aposeris foetida (L.) Less.*	
41	*Myosotis palustris L.*	
42	*Carex pilosa L.*	
43	*Sanicula europaea L.*	
44	*Daucus carota L.*	tap root plant

Appendix 10. The system of life forms by Raunkiyer

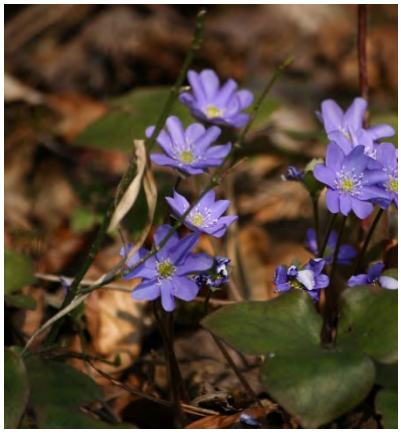
№	Latin name of species	Life forms by Raunkiyer
1	*Rubus idaeus L.*	phanerophyt
2	*Stellaria holostea L.*	chamaephyt
3	*Rubus hirtus L.*	
4	*Hedera helix L.*	
5	*Impatiens parviflora DC.*	therophyt
6	*Galinsoga parviflora L.*	
7	*Anemone nemorosa L.*	geophyt
8	*Majanthemum bifolium (L.) F. W. Schmidt*	
9	*Paris quadrifolia L.*	
10	*Dentaria glandulosa L.*	
11	*Chamaerion angustifolium (L.) Scop.*	
12	*Juncus effusus L.*	
13	*Aposeris foetida (L.) Less.*	hemicryptophyt
14	*Athyrium filix-femina (L.) Roth.*	
15	*Geranium sylvaticum L.*	
16	*Vicia cracca L.*	
17	*Geum urbanum L.*	
18	*Ranunculus acris L.*	
19	*Stellaria media L.*	
20	*Solidago virgaurea L.*	
21	*Oxalis acetosella L.*	
22	*Trifolium repens L*	
23	*Asarum europaeum L.*	
24	*Festuca rubra L.*	
25	*Urtica dioica L.*	
26	*Taraxacum officinale Wigg.*	
27	*Pulmonaria obscura Dum.*	
28	*Mycelis muralis (L.) Dumort.*	
29	*Daucus carota L.*	
30	*Myosotis palustris L.*	
31	*Carex pilosa L.*	
32	*Sonchus arvensis L.*	
33	*Hepatica nobilis Mill*	
34	*Sanicula europaea L.*	
35	*Galium aparine L.*	
36	*Plantago major L.*	
37	*Glechoma hederacea L.*	
38	*Juncus tenuis Willd*	
39	*Fragaria vesca L.*	
40	*Viola reichenbachiana Jord. ex Boreau*	
41	*Lathyrus vernus L.*	
42	*Salvia verticillata L.*	
43	*Dryopteris filix max (L.) Schott*	
44	*Aegopodium podagraria L.*	

Appendix 11. Typical species for beech stands in investigated areas

Anemone nemorosa L.

Aegopodium podagraria L.

Hedera helix L.



Hepatica nobilis Mill

Mycelis muralis (L.) Dumort

Lathyrus vernus L.

Aposeris foetida (L.) Less.

Asarum europaeum L.

Dryopteris filix max (L.) Schott.

Paris quadrifolia L.

Pulmonaria obscura Dum.

Sanicula europaea L.

Viola reichenbachiana Jord. ex Boreau

Stellaria holostea L.

Dentaria glandulosa L.

Carex pilosa L.