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Study on the natural regeneration of the beech in the "Izvoarele Nerei" Nature Reserve

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Abstract
Natural regeneration in virgin forests is a vital process for the maintenance and healthy development of these exceptional ecosystems. At the heart of these forests, natural processes run their course in a subtle dance of life, in every aspect – from seeds and soil to climate conditions and species biodiversity – contributing to their continued perpetuation and evolution. The study is based on measurements regarding the natural regeneration of beech stands in the "Izvoarele Nerei" Nature Reserve, more precisely on the surface of two plots of one hectare, located at 1350 meters altitude in which 4 sample surfaces were placed in the direction of each point cardinal. On each surface obtained, each seedling with a height of less than 150 centimetres was inventoried. More precisely, following the inventory of the 8 sample areas, a number of 712 saplings were obtained, thus concretizing a fundamental parameter for the characterization and evaluation of the stand. The study of beech regeneration in the virgin forest is considered timely and of great importance for a better understanding of the natural processes and dynamics of the virgin forest as the most important model for the development of a forest management strategy including major aspects related to the sustainable conservation of the natural diversity of forests and the ecological reconstruction of derived forest ecosystems as part of a participatory process with wide social acceptance.

Keywords: virgin forest, biodiversity, plots, development

Introduction

Forests with a high level of naturalness or so-called "virgin forests" represent the last forest ecosystems where nature survives in its pure form, without significant modifications by humans. In virgin forests, trees die of old age, fall, break, or dry up in place, and the dead wood remains there, nourishing the ecosystem for future generations.

In Romania, beech represents the most common forest species, occupying approximately 31% of the country's forested area (about 1,915,600 hectares), which accounts for 11.7% of the total area of Eurasian beech forests. Beech is found in the sub-Carpathian and Carpathian regions, from low hills (around 300-500 meters altitude) to the mountainous region (1200-1400 meters), and exceptionally can descend to about 150-200 meters in wet valleys or even 60-100 meters along the Danube Valley. Also, exceptionally, the upper limit of beech forests can exceed 1400 meters (up to 1650 meters) in the Parang and Apuseni Mountains, and in the Semenic, Cernei, Parang, mountains, it constitutes the upper limit of the forest, in the absence of a coniferous belt.

The existence of genetic diversity at the population level is vital for counteracting climate change and identifying provenances of tree species that adapt to these changes. Beech (*Fagus sylvatica*) and fir (*Abies alba*) forest ecosystems thrive in the Carpathians, covering a wide climate gradient, perpetuating in habitats with continuity that have been recolonized in the post-glacial period [6].

The genetic diversity of these species as well as their potential for expansion during evolution according to their climatic adaptability is less pronounced in the case of long-distance migrations compared to migration over short distances (between stands) within their periglacial refuges.

The regeneration process in virgin forests is periodic and discontinuous, a fact due to the periodicity of tree fruiting, but also to the development phases of the stands [7]. Virgin forest regeneration occurs exclusively from seeds produced by mature trees, a process that takes place exclusively under the influence of natural environmental factors. Forest regeneration occurs both under the canopy and at the edge or outside

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it, on open ground. It has been found that regeneration under the canopy is continuous in forests with a structure close to the polyena one and periodic in those with a structure more or less close to the equine one. Certainly, trees of some species in the virgin forest produce shoots, but the establishment of a new forest vegetative represents very rare exceptions in our temperate forests [3,4].

Essentially, due to the periodicity of tree fruiting and the development phases of the stands, the regeneration process in virgin forests is periodic and discontinuous [5]. Stands with an absolutely polyene structure, composed of trees of all ages in reality, are rare and isolated cases. Stands are usually made up of trees belonging to several generations, appearing after successive fruiting of the mature stand in the disaggregation/regeneration phases or, on restricted areas, after the appearance of gaps - called “gaps” in the specialized literature in English; thus, space is occupied by successive generations of trees (cohorts).

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Regeneration can be uniform, generating equine stands over large areas, only in the case of catastrophes that destroy the mature stand; however, these only occur in the case of anemochory species, such as spruce, pine, larch, which can easily reoccupy the affected area. In other cases, however, when the regeneration of the original species does not occur immediately, longer successions may occur, with successional phases based on pioneer species [5].

Material and Method

The study conducted in the “Izvoarele Nerei” Natural Reserve primarily aims to examine the regeneration process in virgin forests, which is periodic and discontinuous due to the periodic fruiting of trees and the development phases of the stands.

The purpose of this study is to highlight significant aspects regarding the natural regeneration of beech trees in the “Izvoarele Nerei” Natural Reserve in relation to the height of the beech saplings on the surface of two sample areas delimited by the researchers from INCDS Timisoara.

From a scientific standpoint, regeneration does not refer to the quantitative and qualitative evaluation of regeneration results in forestry practice but rather to an on-site operation conducted through short means. The evaluation of regeneration, the subject of this study, is characterised by international trends documented in such studies. Recent studies addressing this question often focus on the competitive relationship between beech saplings, differences among individuals, spatial distribution patterns of saplings, structural homogeneity of colonies, or the determination of specific distributions at that stage of development.

In terms of the proposed objectives, four levels of practices are defined in the study, which can be overlapped with the main objectives:

- selecting representative sample areas for beech regeneration;
- determining the number of beech saplings per height class;
- determining the average age of saplings per height class;
- determining the correlation between natural regeneration and sapling height.

Through these considerations, this study views the issue of beech sapling regeneration as an operation aimed at identifying certain specifications and characteristics of regeneration that can be quantified through complex analysis of field data.

For this study, the primary source used includes the virgin beech forests located in the “Izvoarele Nerei” forest, protected within the Natural Reserve of the same name. These specific trees are located in the upper region of the Nera River, more precisely in UP II Nergana and UP III Nerganita, in the Caras-Severin County.

For the placement of sample areas, two plots (119 and 120) out of a total of twelve existing ones were chosen, located at an altitude of 1350 meters. On the surface of the two plots, each covering 1 hectare, four polygons in the form of circles with a radius of 7.3 meters were established in each of the four cardinal directions (N, E, S, and W), and each beech sapling with a height between 1-150 centimetres was inventoried.

Regarding the working method, the following steps were followed: on the surface of the “parent” plots (119 and 120), both covering 1 hectare each, four different lengths of 28 meters were established from the centre of each plot using a forestry tape measure along the trajectory of each cardinal point. At the end of each length, a test polygon was delimited using a rope and stakes in the form of a circle with a radius of 7.3 meters.

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In the next step, all that was required was to inventory each beech sapling within the surface area of the 8 created circles. All saplings with a height between 1-150 centimetres were measured using a tape measure, and their diameter was determined using a calliper.

It is worth mentioning that the two plots were chosen for research due to their high altitude and central position within the reserve area, in order to eliminate any suspicions arising from human intervention on the beech saplings. Thus, by distributing them on sample surfaces, their vitality rate, mortality, and other disturbing factors are attributed solely to the "laws of nature" and not human intervention.

Results and Discussion

According to our own research, conducted independently but also within the project coordinated by Tomescu et al. 2012, we found the existence of two main regeneration strategies in the beech forests of the Izvoarele Nerei reserve. A first strategy is encountered at high altitudes, over 1250 m, where there is a more or less continuous seed layer, installed on almost the entire surface; when a gap appears in the canopy of mature trees, the underlying seed layer immediately activates its growth and tends to fill the respective gap. At lower altitudes, meaning much better ecological conditions for tree development, a second strategy appears - the seed layer is installed (as a general rule) only after a gap appears in the parental canopy, then growing steadily to fill the respective gap.

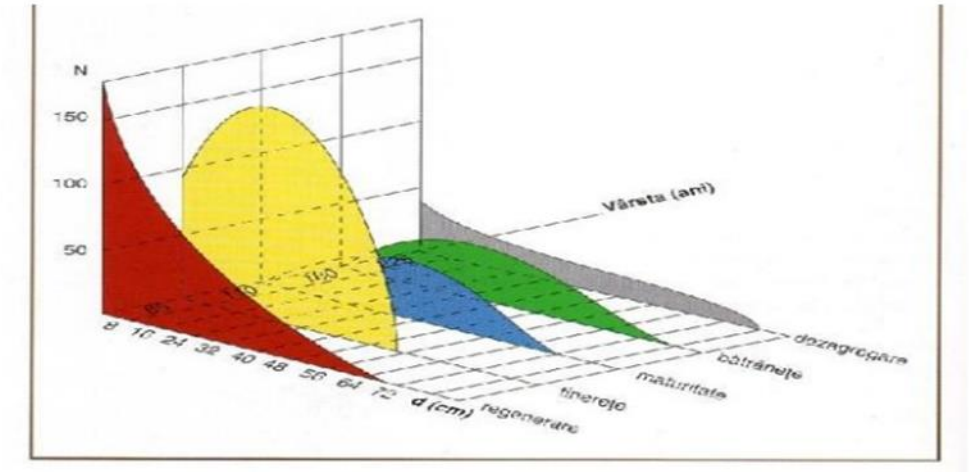

Fig. 1 The distribution of trees by categories of diameters and phases of development (Cenusa 1996, in Giurgiu et al. 2001)

The dimensional structure of the virgin forest has a specific dynamic, passing, in turn, through different development phases (or stages of evolution) [7]. Figure 1 shows the distribution of trees by diameter categories for each of the development phases, this figure illustratively depicting the dynamics of the dimensional structure for a stand that successively goes through these phases.

Bandiu et al., 1995, observe that in virgin beech forests in Banat, both numerically, in terms of density, and as biomass, density (basal area and volume), local variations are large, but these variations fit into the legality determined mainly by the development phase. Three development trends (evolution of dimensional structure) are observed:

- population decrease with increasing ecological age - from youth to optimal phase, then to old age;
- density increase with stabilization at high ages (especially in terms of height);
- increase, with extended maximum at middle age (optimal phase) and subsequent decrease, in the terminal phase, of biomass (volume) [2].

The virgin forest, like any living organism, goes through a succession of development phases over time, which translate into significant morphological and structural changes, which however do not contradict the idea of stability but accentuate it. In the specialized literature, in accordance with the general principles of population eco-ontology, three main phases are considered fundamental: the phase of youth, the phase of maturity, and the phase of old age; when separating into subphases, however, different opinions supported by various authors appear [2].

A true nature laboratory has been preserved untouched in the "Izvoarele Nerei" Natural Reserve, an integral part of the Semenic - Cheile Carasului National Park. The reserve covers approximately 5000 hectares

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and consists of pure virgin beech forests, in various stages of development, with a highly diversified structure along a significant altitudinal gradient (from about 600 m to about 1400 m). The composition is monospecific, represented by beech, with only a few specimens of elm, sycamore, trembling aspen, and birch, which are rare exceptions; the dimensional elements are impressive - the largest trees exceed 1.2 meters in diameter and have heights over 50 meters, and the volume per stand sometimes exceeds the impressive value of 1200 m3/ha. Thick and/or very old trees, as well as dead wood, are very well represented in these ecosystems, constituting key elements of their high naturalness.

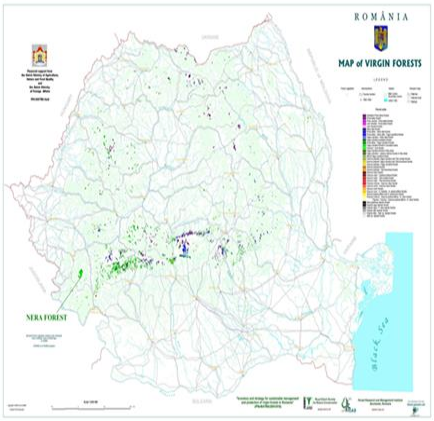

Fig. 2 The distribution of virgin Forest in Romania (Veen and Biris, 2004)

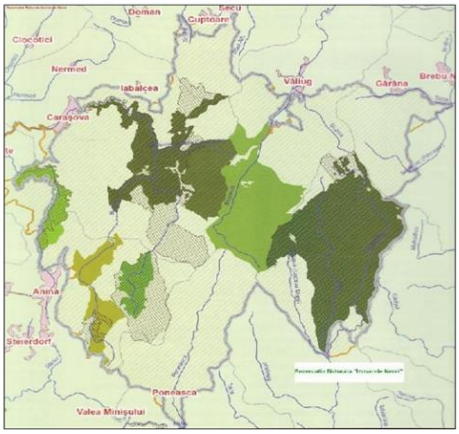

Fig. 3 The location of "Izvoarele Nerei" Natural Reserve within the Semenic-Cheile Carasului National Park (dark green) (Badescu and Vlaicu, 2011)

Forests are complex systems of forest ecosystems. Their structure and dynamics are controlled by specific cybernetic mechanisms. Identifying specific structural attributes is one of the actions that characterize forestry research and studies to determine the characteristics of the tree population in the analysed area. One of the objectives of this study is to identify these characteristics, which will be very useful for interpreting further analyses.

An important element of this structure is the density of the beech sapling layer, which is a fundamental parameter for characterizing and evaluating tree regeneration. A total of 712 saplings were inventoried in the eight sample plots, and the data regarding the number of saplings are presented in the following table.

Table 1. The situation of the number of saplings in the eight sample plots

Height classes	Number of trees affected	Number of dead trees	Number of trees with broken tops	Total number of trees
1-5 cm	37	6	-	43
6-10 cm	207	24	-	231
11-15 cm	40	1	-	41
16-20 cm	14	-	1	15
21-25 cm	23	-	3	26
26-30 cm	28	1	-	29
31-35 cm	24	1	2	27
36-40 cm	19	-	1	20
41-45 cm	15	-	2	17
46-50 cm	15	1	1	17
51-55 cm	18	-	4	22
56-60 cm	13	-	-	13
61-65 cm	19	-	2	21
66-70 cm	16	-	1	17
71-75 cm	12	-	1	13
76-80 cm	6	-	3	9
81-85 cm	6	-	1	7
86-90 cm	7	-	1	8

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91-95 cm	5	-	1	6
96-100 cm	6	-	1	7
101-105 cm	8	-	1	9
106-110 cm	7	-	1	7
111-115 cm	2	-	-	3
115-120 cm	5	-	1	8
121-125 cm	8	-	3	9
126-130 cm	2	-	1	3
131-135 cm	7	-	1	8
136-140 cm	4	-	-	4
141-145 cm	5	-	-	5
146-150 cm	1	-	1	2
>150 cm	65	-	-	65
TOTAL	644	34	34	712

Another important aspect regarding the height of the saplings analysed in this chapter pertains to the variation in height classes present in the lower canopy layer. To better observe the spatial variation and characteristics of the sapling populations, we have graphically represented the entire sapling population captured across the entire surface of the eight sample plots.

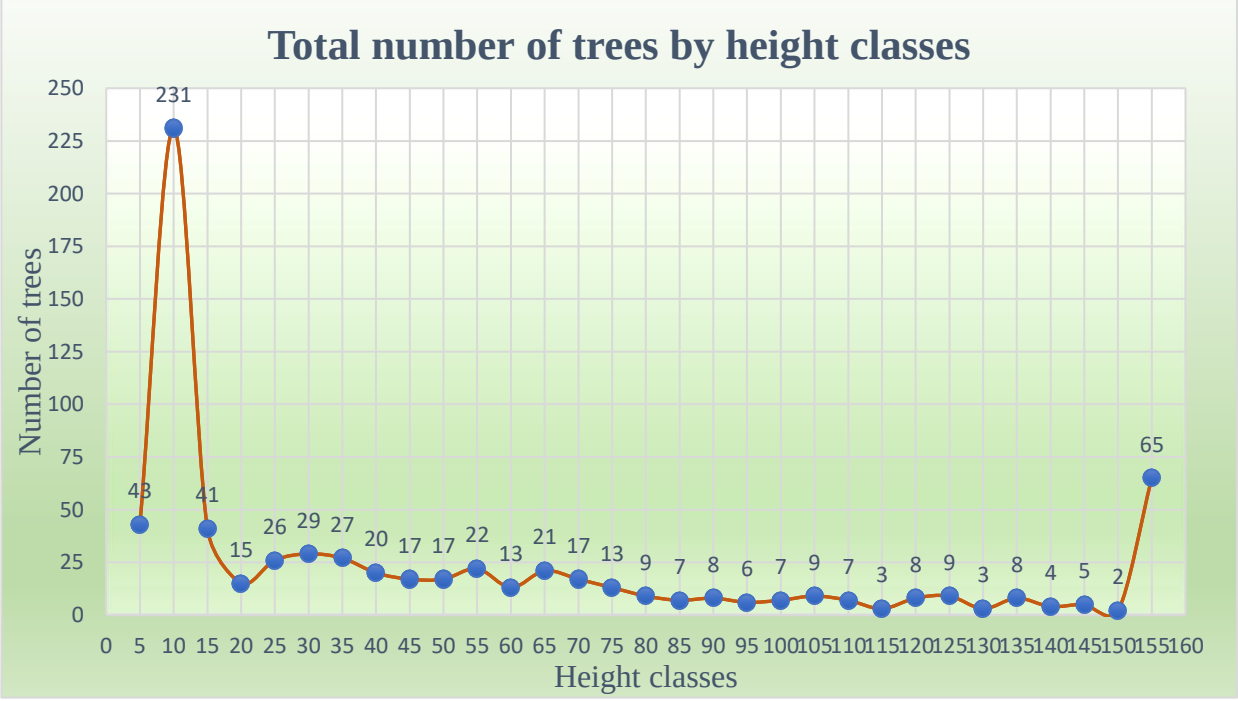

Figure 4. The graph of the total number of saplings per height class

For better observation regarding the statistics of the number of saplings exhibiting certain defects, such as broken tops, and also their mortality rate in relation to height classes, we have depicted their current status in the following graphs.

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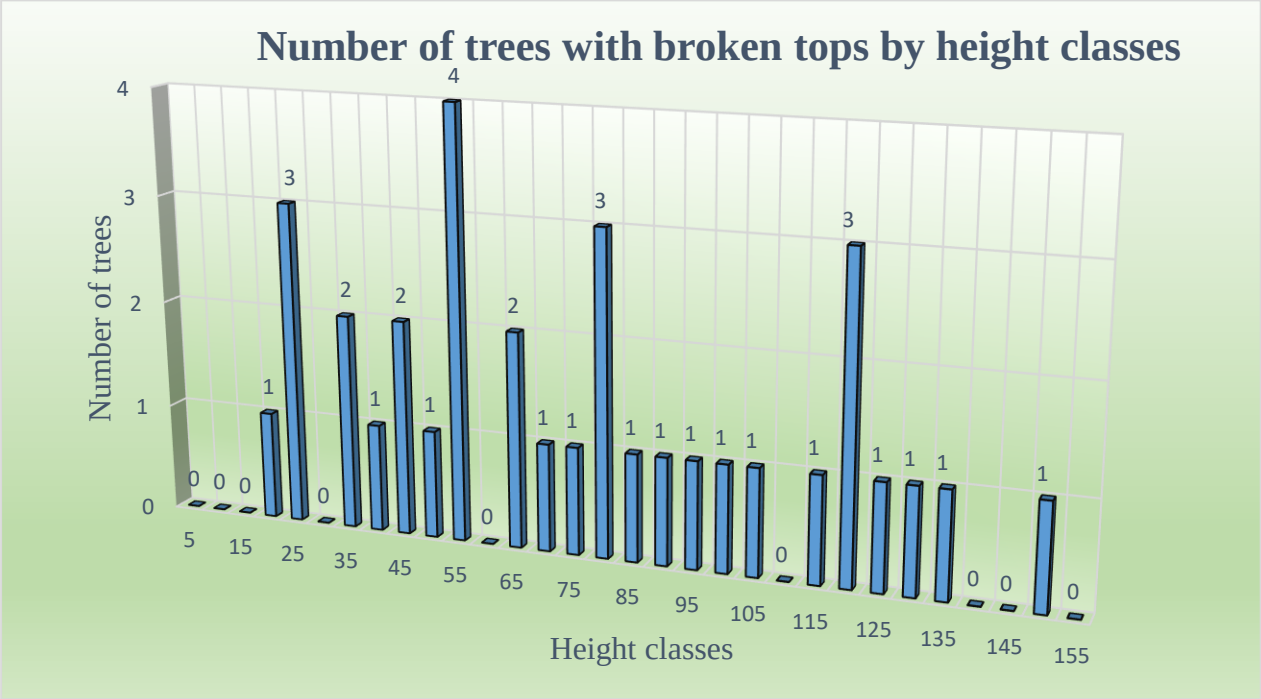

Fig. 5 The graph of the number of saplings with broken tops in relation to height classes

The following graph presents a thorough analysis of the current situation regarding the number of dead saplings encountered within the created sample plots.

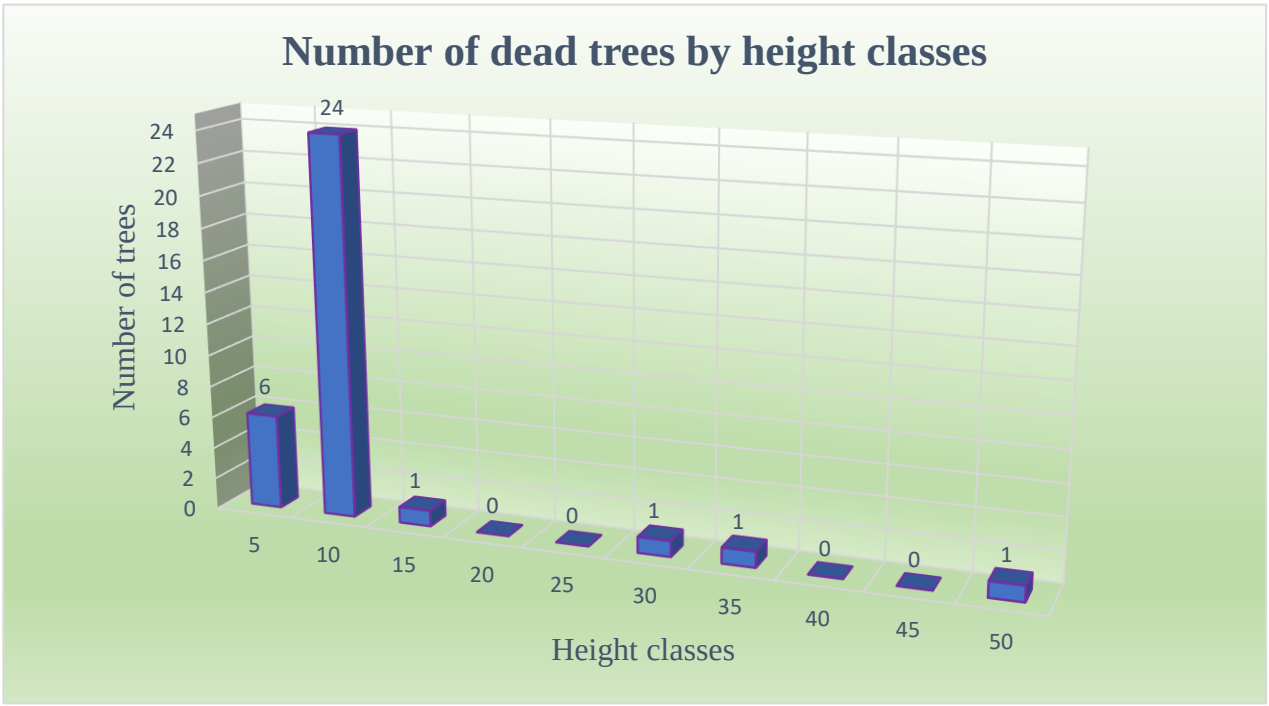

Fig. 6 The graph of the number of dead saplings in relation to height classes

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Regarding the health and vigour of the saplings, as well as their chances of reaching full development and desired maturity, the following graph has been prepared.

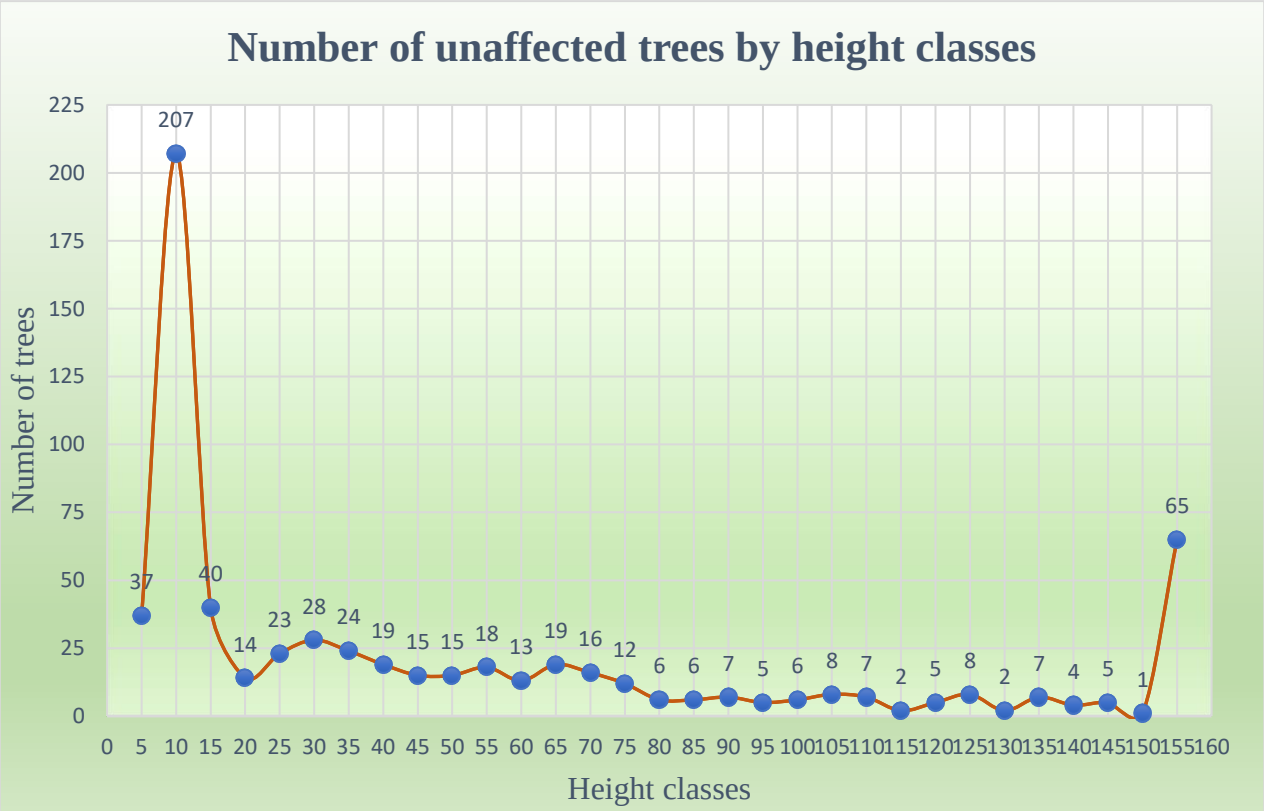

Fig. 7 The graph of the number of unaffected saplings in relation to height classes

From the analysis of the above graphs, a close interdependence relationship can be observed regarding the number of individuals present in the sample plots and the ecosystem factors of regeneration involving the growth and development of young specimens. In the case of mature trees, the basal diameter is a central parameter of the structure and is considered the easiest property to measure. However, for saplings, the central diameter is often impossible to measure due to their small height, so height becomes the easiest measurable parameter and can be considered a much more statistically stable parameter. Moreover, it is particularly sensitive to documenting the relationships between saplings due to the intense competition characterizing this stage of forest ecosystem development.

Conclusions

Romania harbours the largest remaining virgin forests in the temperate zone of Europe, hosting approximately 13,000 species, including the largest population of bears in Europe. However, less than half of the initially estimated 250,000 hectares in 2005 remain today, but even these represent approximately 60% of Europe's virgin forests.

Romania's virgin forests have remained untouched mainly because they are geographically isolated and inaccessible. Therefore, these forests are not uniformly distributed throughout Romania but are mainly concentrated in mountainous areas. Approximately 40% of the virgin forests are beech forests or mixed beech forests, which are generally found in mountainous areas.

Regarding the present study, a significant advantage was the existence of a set of structural measurements and the delimitation of existing sample plots previously carried out in previous years [14]. By creating new sample plots within the existing ones, new databases were created that highlighted the natural regeneration of beech trees.

Studying the regeneration of beech trees in virgin forests is considered opportune and of great importance for a better understanding of natural processes and the dynamics of virgin forests as the most important model for developing a forest management strategy including major aspects related to the sustainable conservation of forest natural diversity and the ecological reconstruction of derived forest ecosystems as part of a participatory process with broad social acceptance.

1. The complexity of forest ecosystem dynamics is difficult to describe in models even for a pure beech forest. The complexity of the ecosystem is largely determined by the level of existing natural biodiversity.

2. Natural diversity expressed through a large number of species at all trophic levels of the analysed forest ecosystem is highlighted in various ongoing studies conducted in the "Izvoarele Nerei" beech virgin forest. The exceptional morphological diversity at the level of the basic species, namely beech, is also explained by some studies of genetic variability conducted here.

3. Preliminary studies conducted in the beech virgin forest on the sample plots within the two plots show a natural regeneration present at all height levels and very well dispersed in the tree stand. The number of saplings present in the sample plots is inversely proportional to their height and ensures continuous regeneration of the tree stand in all situations existing in the virgin forest.

4. A high concentration of individuals is observed at a relatively low height class, followed by an oscillation in the number of individuals present at medium height classes, and finally, there is again a significant increase at a higher height class. Thus, a high degree of seedling germination and, at the same time, a fierce struggle for survival and development at the sapling level can be observed.

5. The age of the beech specimens forming the seedling layer and the equivalent layer with a sub-canopy is difficult to determine and apparently does not have a relationship with the number, height, or diameter of the specimens. Further research on seedlings across the entire surface of the plots where observations, auxometry determinations, and other nature observations have been made, as well as biodiversity observations, will provide more clarification in this regard.

6. An inquisitive approach to all research in the "Izvoarele Nerei" Natural Reserve is imperative, both for a full understanding of the forest ecosystem dynamics here and for considerations related to the future of forestry as a science in the current general context.

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