

Structural research in the natural beech forest, situated at the eastern limit (Humosu Old Growth Beech Forest, Iași county, Romania)

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Abstract. The paper points out the stability of the natural forest due to its structural complexity, reached through millennia of evolution. The „Humosu Old Growth Beech Forest” situated between 450-500m altitude in the Moldavian Plateau is a clear example of a natural structure with a continuous transformation given by the passage through a series of stages (phases) with individual characteristics. Five of these individual phases are identified and described: the initial phase, the optimal phase, the terminal phase, the degradation phase and the regeneration phase. For each of these phases biometric characteristics are indicated, and the general structural profile, as well. The distribution of dead wood volume inside these phases, as part of a natural matter circuit, found in different stages of degradation, shows the complexity of natural ecosystems and their importance to life, in general.

Key words: old growth forest, development phase, structural complexity, biometric characteristics, structural profile.

Rezumat. Lucrarea subliniază stabilitatea pădurii naturale datorate complexității sale structurale, atinsă în milenii de evoluție. Făgetul secular Humosu situat la o altitudine între 450-500m în Podișul Moldovei, este un exemplu clar de structură naturală aflată într-o continuă transformare, ce constă în trecerea succesivă printr-o serie de stagii definite de anumite caracteristici. Sunt identificate și descrise cinci astfel de stagii (faze): faza inițială, faza optimală, faza terminală, faza de degradare și faza de regenerare. Pentru fiecare dintre aceste faze sunt determinate caracteristicile biometrice ale arboretului, precum și profilul structural al acestuia. Distribuția volumului de lemn mort cu diferite stadii de degradare, pentru arboretul aflat într-o anumită fază de dezvoltare, subliniază complexitatea ecosistemelor naturale și importanța lor pentru lumea viului, în general.

Cuvinte cheie: pădure seculară, fază de dezvoltare, complexitate structurală, caracteristici biometrice, profil structural.

Introduction. The concept of sustainable development, widely spread after the Rio Summit in 1992, underlines, among other, the necessity for the increased protection of the natural environment, especially the natural forest ecosystems.

The distribution of natural forests on the Globe varies a lot due to different factors, large areas being located in underdeveloped countries, with low economic potential and large populations (Biriș et al 2002).

In the context of increased resource need for economical growth in underdeveloped countries, any action taken towards protecting these true rivers of knowledge, is becoming more and more difficult. Structural and functional stability of the natural forest was perfected in millenia of evolution. After Mayer H., the correspondent concept for the natural forest is dimax forest (Giurgiu et al 2001).

A detailed analysis can reveal informations about complex mechanisms of self-adjustment and ecosystemical control that can maintain the energetic balance, and a long term biocenotical stability (Bândiu et al 1995).

These forests represent natural laboratories from which we must learn new methods to optimize the functionality of managed forests (Cenușă 1996). So scientists came to the idea that the study of natural forests will unveil a pattern for the future of managed forests (Giurgiu 1995). But, it's a known fact in the science world that studying natural ecosystems is pretty difficult, due to structural and functional complexity related factors.

In 1959, Leibundgut H., in the paper "Über Zweck und Metodik der Struktur und Zuwachsanalyse von Urwäldern" introduces the development phase theory, as a new study methodology, aiming to reflect the structural mosaic of the natural forest and to facilitate it's interpretation. The author defines a number of five phases: young forest phase, optimal phase, maturity phase, regeneration phase and the degradation phase. I.U.F.R.O. uses six development phases for the study of the natural forest: the juvenile phase, intial phase, optimal phase, terminal phase, degradation phase and the regeneration phase. The collocation development phase refers to a development stage evidently different from a structural point of view, inside a forest association (Cenușă 1996). On a international level, authors like Tschermak L. 1950, Frohlich I. 1951, Leibundgut H. 1959, 1970, Mayer H. 1975, 1982, Hofmann A. 1970, Mayer H. and Neumann M. 1981, Schmidt-Vogdt 1981, published a lot of papers after studies conducted on topics concerning the natural forest (Bândiu et al 1995).

A joint effort of Cost Action E4 Programme - Forest Reserves Research Network - initiated by the Cost Commision (part of the European Comission) in 1995-1996, with the participation of over 100 specialists, has the objective of collecting existing data, creating data bases and also finding new research methods for the natural forests of Europe, approximately three million hectares.

In Romania the development phases theory, as a study method for natural forests was introduced by Giurgiu (1979). Research showed that around the year 1984, in Romania, the total area covered by pristine (or natural) forests was around 400000 hectares (Giurgiu et al 2001). In Humosu old growth forest recent studies, were concentrated on aspects like natural beech forest biodiversity, based on structural and phytocenotical stand analysis (Roibu et al 2008). The present paper is based on two main aspects: first identifying spatial repartition of the development phases inside the stand and second analyzing the phase dynamics using certain parameters.

Material and Method. The research was conducted in plot no. 62, part of Humosu 3rd Production Unit (romanian forestry area management system) administrated by the Iași Forestry Direction, in an old growth beech (*Fagus sylvatica* L.) forest stand, part of the natural reservation "Humosu Old Growth Beech Forest". The type of forest according to the romanian classification "is hilly beech (*Fagus sylvatica* L.) forest of superior productivity with mull type flora" (Pașcovschi & Leandru 1958), 1st production class. The location is situated between 450-500 m in altitude, in a hilly area, with slopes up to 15 degrees, oriented north-west. The characteristic type of soil is typical luvosoil. Inside the beech stand a transect was delimited with a total length of 800 meters (divided in 8 segments of 100 m each) and 20 meters in width, according to the methodology for studying forestry ecosystems using structural profiles (Cenușă 1986, 2002).

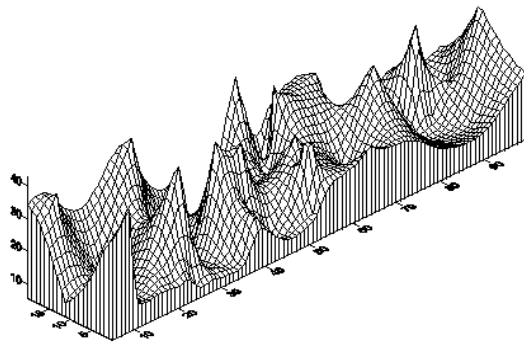


Figure 1. The canopy profile for the 7th segment of the transect.



Figure 2. Stand structural profile for the 7th segment of the transect.

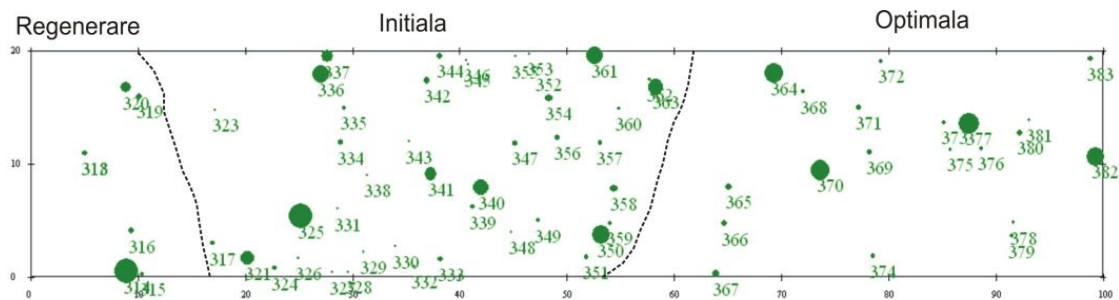


Figure 3. Stand texture for the the 7th segment of the transect (the dotted line indicates the limits of individual development phases).

For each tree inside the experimental plot, with a d_{bh}^1 over 4 centimeters, the following characteristics were registered: specie, two d_{bh} measured on two perpendicular directions, total height, Kraft class, quality class, head shape, defects, head diameter, cartesian coordinates (x,y). Also the dead wood volume was graded, according to the state of degradation. All field data was processed using Microsoft Excel work sheets. For graphic representations of the stand's spatial structure ProArb v.3 , was used (Popa 1999).

Results. Stand observations and statistical filed data analysis showed the following: A succession of five different development phases: initial, optimal, terminal, degradation and regeneration phase, each with a different set of values for the main biometric parameters, that indicate the dynamics of the succession. In table 1 the values for these parameters are presented for each of the five development phases.

¹ d_{bh} - diameter at breast height

Table 1

Stand main biometric parameters for each development phase

Parameter	Development phase				
	Initial	Optimal	Terminal	Degradation	Regeneration
Tree number (N/ha)	54	61	99	56	11
Base area (m ² /ha)	10.52	13.46	30.37	15.73	4.97
Average diameter dg (cm)	39.49	42.04	49.33	47.46	59.33
Diameter variation coefficient (%)	61.24	50.01	53.19	62.38	57.66
Volume (m ³ /ha)	154	174	463	208	74

Tree number distribution per diameter categories is a often used indicator of horizontal stand structure. In the natural forest this distribution has some unique features for each development phase.

The initial phase is defined by the presence of a large number of trees situated mainly in the inferior diameter categories (Figure 4), a high level of competition for space inside the stand and a consequential high rate of natural elimination. Production potential is maximum at this stage. Because the trees have small diameters, the base area per hectare is small, despite high density.

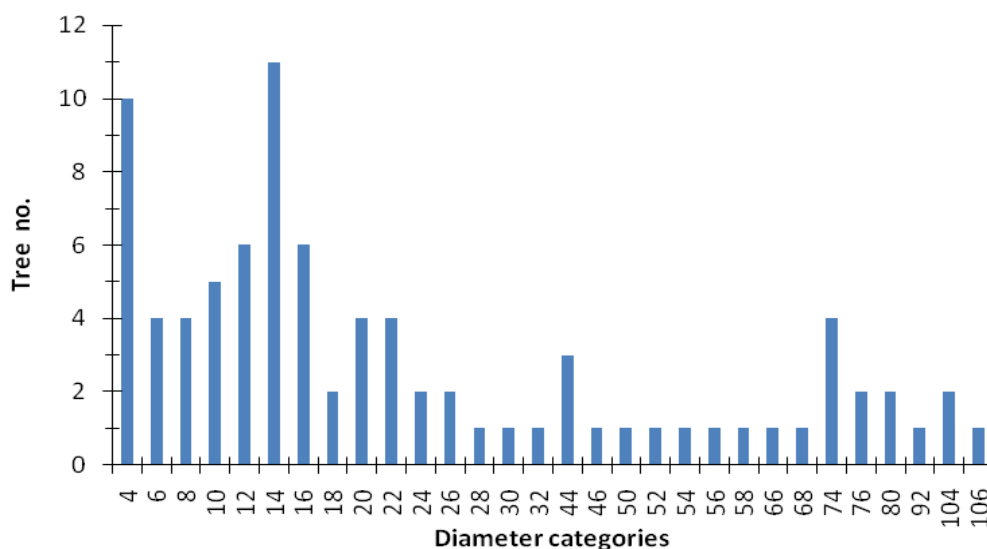


Figure 4. Distribution of tree number per category of diameter in the *initial* phase.

The optimal phase is defined by the presence of a relatively large number of trees, with a high growth potential. At superior levels in the canopy the presence of high vitality specimens is noted, assuring a high degree of stability. The base area per hectare and volume are increased, related to the previous phase (Table 1).

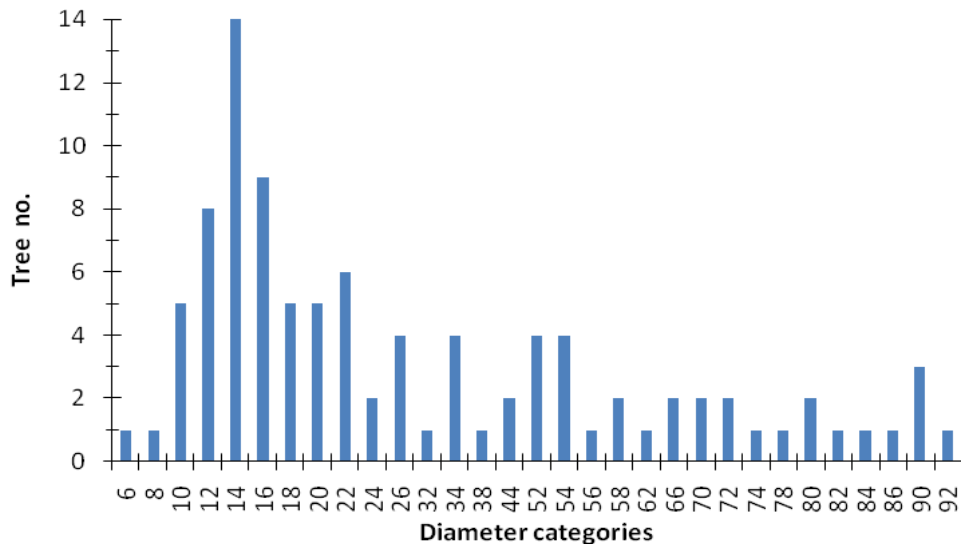


Figure 5. Distribution of tree number per category of diameter in the optimal phase.

The terminal phase is characterized by the highest number of trees per hectare and in consequence a maximum volume and base area (Table 1) with growth rate still high, due to favourable light conditions. A slight tendency of decrease in density is noted at the high levels of the canopy. The number of trees is distributed in all diameter categories, according to the stand structure.

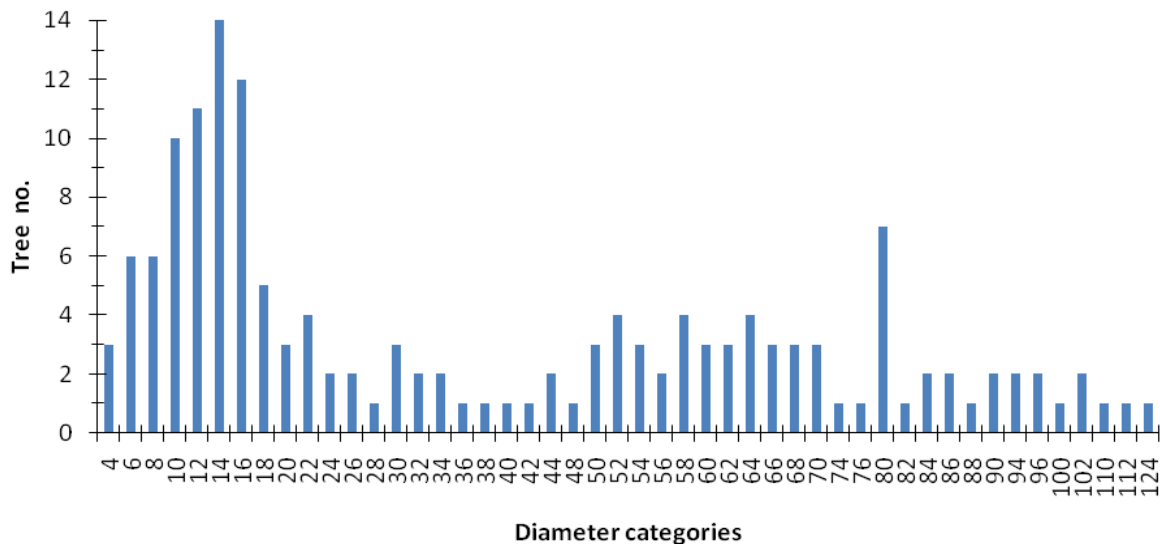


Figure 6. Distribution of tree number per category of diameter in the terminal phase.

The degradation phase marks a notable decrease in the number of trees per hectare (Table 1) due to a high degree of mortality. The remaining specimens, randomly distributed inside the stand, are part of the superior diameter categories, which explains the big

volumes and base area. In certain spots, the process of natural regeneration is initiated, this fact being reflected by the number of trees in inferior diameter categories (Figure 7).

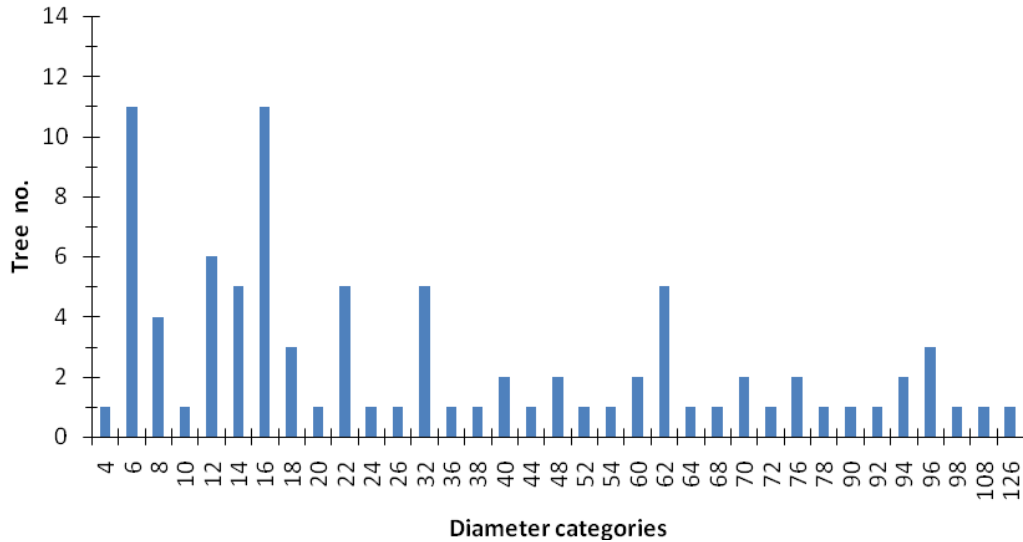


Figure 7. Distribution of tree number per category of diameter in the degradation phase.

The terminal and degradation phases are responsible for creating the stand's uneven aged character, being also known as maturity phases (Cenușă 1986).

The regeneration phase is defined by the presence of a small number of big sized trees, a obvious drop in base area and volume per hectare. Gaps in the canopy, left by the elimination of dead trees enables an acceleration of the regeneration process, light being available at ground level for the seedlings.

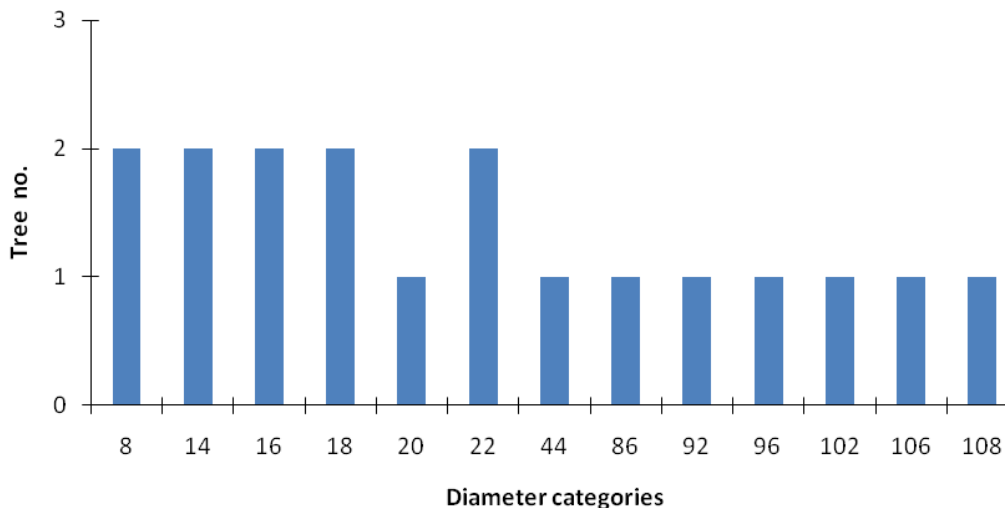


Figure 8. Distribution of tree number per category of diameter in the regeneration phase.

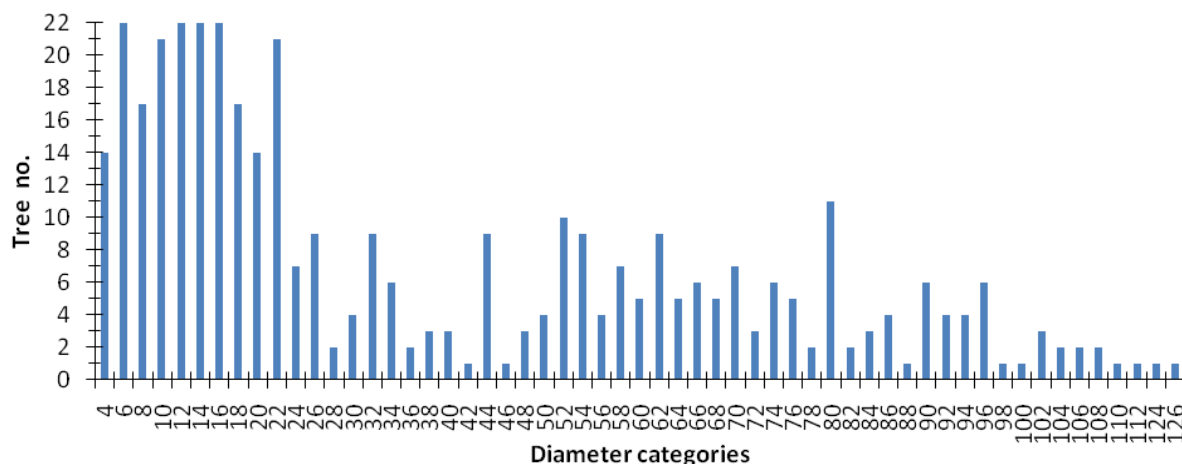


Figure 9. Distribution of tree number per category of diameter for the whole transect.

After analyzing the distributions for each development phase and for the whole transect, a conclusion has been reached. The distribution for the whole transect resembles that of a terminal phase.

Table 2
Main parameters for the experimental distribution of tree number per diameter category

Parameter	Development phase					Whole transect
	Initial	Optimal	Terminal	Degradation	Regeneration	
Average	28.58	33.69	38.87	36.16	45	35.49
Variance	751.09	639.36	928.25	955.69	1580.19	872.31
Standard deviation	27.41	25.29	30.47	30.91	39.75	29.53
Coefficient of variance (%)	95.89	75.05	78.39	85.5	88.34	83.23
Average Standard Deviation	2.96	2.57	2.42	3.28	9.37	1.39
Coefficient of Skew	1.33	0.96	0.71	0.96	0.65	0.94
Kurtosis	0.63	-0.49	-0.72	-0.22	-1.42	-0.33

This type of distribution reflects the horizontal stand structure and the level of competition, effects of the tree's placement inside the stand (Gurgiu 1979). The coefficient of skew has positive values for all development phases, this being a characteristic of the natural forests, with un-even aged structure.

The phases are randomly spread, forming a mosaic that gives the uneven-aged character of the forest. This structural pattern assures the integrity of the forest and also a high degree of ecosystemical vitality. A remarkable fact is the immediate response to the creation of favourable light conditions (gaps appear in the canopy, created by the natural elimination of old trees), which leads to a succession of generations that assures an effective use of biologic potential. Beech has the special quality of reviving its growth rate when exposed to sunlight after a long period in the shade. Studies conducted in old beech forests (Papavă 1977, quoted by Cenușă 1986) showed similar growth rates at specimens of 200 years and 80-100 years. Due to this fact inside the same diameter category age differences range from 25 to 150 years.

Lorentz curve was used to express the degree of heterogenesis of the forest, based on the distribution of tree number per diameter category, for each development phase. The high degree of heterogenesis found confirms a characteristic of the natural forest.

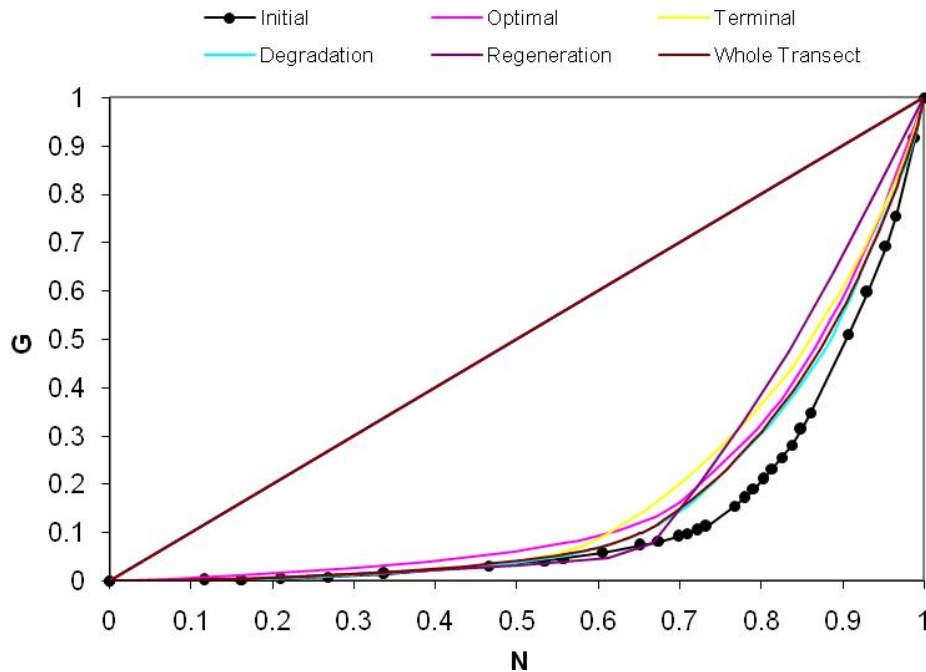


Figure 10. Lorentz curve (for each development phase).

Table 3

GINI index values the development phases

Development phase	Initial	Optimal	Terminal	Degradation	Regeneration	Whole Transect
GINI index value	0.74	0.65	0.64	0.68	0.67	0.67

GINI index, calculated for each of the five development phases has values close to 1, and this fact is characteristic for the un-even aged forests. The initial phase has the highest degree of heterogenesis, due to the presence of both big mature trees (seed sources) and small ones resulted from the regeneration process.

Because of the natural selection phenomenon and the restrictions for human interventions in the natural forest, a certain volume of dead wood is accumulated in time, being of great importance for biodiversity. The quantity and degradation state of the dead wood can be indicators of the complex matter circuits that take place in the natural forest. Modern science hasn't yet figured out entirely these mechanisms, that apparently assure the dynamic balance of natural forestry ecosystems. Part of the circuit are also the trees that reached maximum physiologic longevity. So dead wood analysis can be an indicator for the dynamics inside each development phase, and was made using a grading system with 6 degradation classes, 1st class being a low degradation level, and 6th class – the highest level of degradation (Van Hees et al, quoted by Christensen 2003).

Big dead wood volumes are concentrated in the degradation phase (Figure 11), as a result of the intense natural elimination process of trees that have reached maximum physiological longevity. A relatively large dead wood volume is found in the terminal phase, as a result of the elimination of large dominated specimens from the superior levels of the canopy, due to different causes, their place being taken by trees from inferior levels of the canopy.

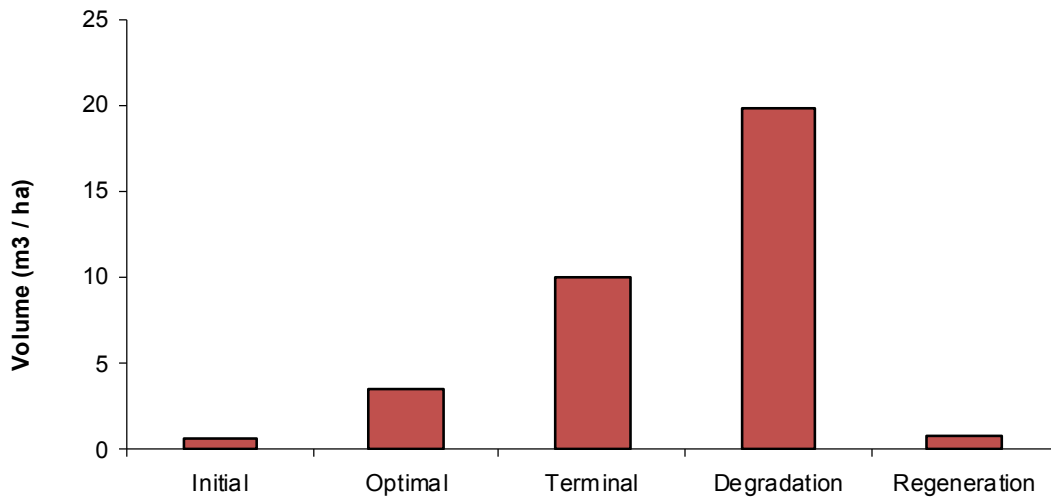


Figure 11. Dead wood volume distribution for each development phase.

In the degradation phase dead wood is at the beginning of the decomposing process, which is indicated by the presence mainly of the 1st and 2nd degradation classes, but big volumes can be found also in the 6th degradation class, as a result of regeneration initiated at the end of the terminal phase. Dead wood from the optimal phase comes from a previous regeneration process and it's almost entirely integrated in the 6th class (Figure 12).

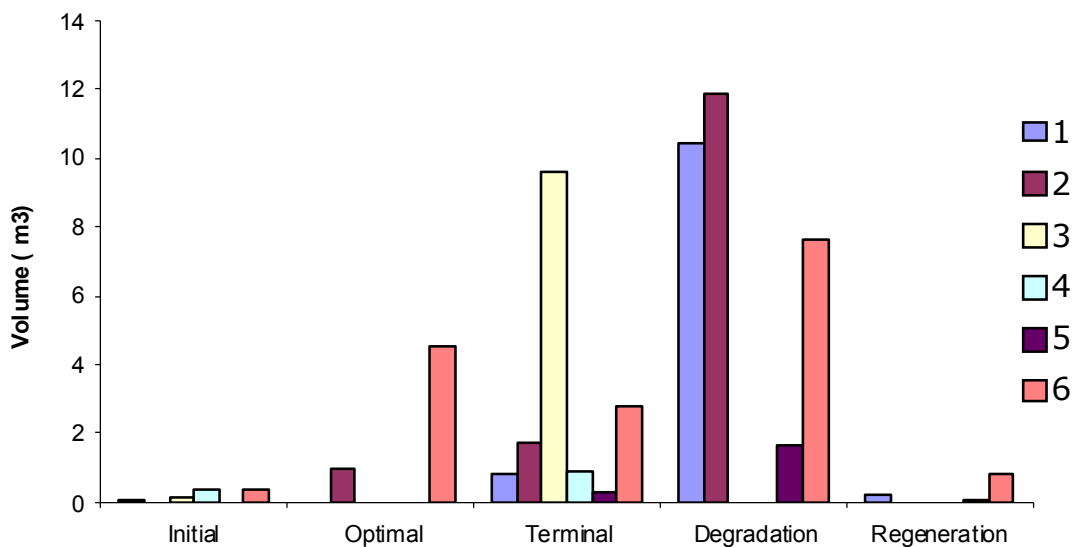


Figure 12. Dead wood degradation classes (1-6), for each development phase.

Conclusions. Stand texture and spatial configuration of the old growth beech (*Fagus sylvatica* L.) forest, subject to the present paper, confirms the structural complexity of the natural forests, given mainly by the alternation of different development phases in a relatively small area. The tree size, forest mosaic and fast development phase alternation are the signs of high ecosystemic vitality, strong dynamics and active regeneration/natural elimination. Every phase has different parameter values, indicators of internal changes that take place. GINI index for tree number per diameter category distribution, calculated for each development phase, shows a high degree of heterogenesis, maximum in the initial phase, as a consequence of the un-even aged structure. Stand structural analysis took also into consideration the distribution of dead wood volume for each phase, and the decomposing state it was found in. Mainly the dead wood is at the beginning (1st, 2nd degradation class) or in an advanced state of the decomposing process (6th class). In the optimal phase the significant dead wood volume, in a high state of decomposing is due to a previous regeneration cycle. The complex circuit of matter inside the natural forest, partly still a mystery to the science world, is very important to life, as the forest itself, and it is the best argument for conserving this natural heritage.

Acknowledgements. This study was supported partially by the project POS - DRU/88/1.5/S/52946 co-funded by the European Social Fund through the Sectoral Operational Programme - Human Resources and Development 2007-2013.



Figure 13. Aspects from "Humosu Old Growth Forest": a)- optimal phase b) - Natural elimination; c) - Newly formed gap; d) - Seedlings; e) - High productivity stand; f) - initial phase; (original).



Figure 13. Aspects from "Humosu Old Growth Forest" (continued): a)- optimal phase b) - Natural elimination; c) - Newly formed gap; d) - Seedlings; e) - High productivity stand; f) - initial phase; (original).

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Received: 21 June 2010. Accepted: 26 July 2010. Published online: 25 September 2010.

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How to cite this article:

Barbir C. F., Roibu C. C., Flutur G., 2010 Structural research in the natural beech forest, situated at the eastern limit (Humosu Old Growth Beech Forest, Iași county, Romania). *AES Bioflux* **2**(2):203-214.