DOI: 10.17707/AgricultForest.62.3.03

Șerban CHIVULESCU, Ștefan LECA,
Diana SILAGHI, Ovidiu BADEA [1]

GROWTH OF VIRGIN FORESTS IN THE SOUTHERN CARPATHIANS

SUMMARY

In the beginning, all forests were represented by natural virgin forest stands. These kinds of ecosystems stand for a model representation for the managed forests. The research area is situated in Western Romanian Carpathians. To understand the functioning baseline principles of the virgin forests the radial growth of beech in relation to breast height diameter (DBH) was studied. The experimental growth distribution was determined using Beta, Gamma and Weibull theoretical frequencies functions. For the dendrochronological series, 36 samples were used. The average time span is 361 years with a mean growth of 0,999 and standard deviation (SD) of 0,482. The pointer years of this dendrochronological series were determined and the radial growths were correlated with climatic data such as temperatures and precipitations. Once the trees' volumes determined, it has been concluded that the virgin beech stands have high eco-productive characteristics (6,33 $m^3 \cdot year^{-1} \cdot ha^{-1}$) , despite the age and climatic influences.

Keywords: virgin forest, primeveral ecosistems' growth, old-growth forest dendrocronology pattern, virgin forest autoregulation, *Fagus sylvatica* virgin forest

INTRODUCTION

Initially, all the forest ecosystems were represented by natural virgin forest stands featuring uneven age structure and obvious ecological, silvicultural and economic advantages (Giurgiu, 1988). Also, the virgin forests represent a model for their durability and high efficient eco-productivity that people strive to achieve (Bândiu, 2013). Therefore, the analysis of this types of forests is important for developing in-depth knowledge. Regarding the forest ecosystems evolution and their natural dynamics the virgin forests are considered inestimable sources of information (Motta et al., 2010) that can be used as scientific basis for improving the forest management economy (Giurgiu, 2013). During the time, various researches highlighted the structural and functional characteristics of the virgin forests. Although such studies failed to meet the requirements and to reveal their natural potential level, they are still a sound groundwork for

[1] Șerban Chivulescu, (corresponding author: serban.chivulescu@gmail.com), Ovidiu Badea, Faculty of Silviculture and Forest Engineering, Brașov; National Institute for Research and Development in Forestry "Marin Drăcea", Voluntari,077190, ROMÂNIA, Ștefan Leca, Diana Silaghi, National Institute for Research and Development in Forestry "Marin Drăcea", Voluntari,077190, ROMANIA.
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

furthering the research scope of primary ecosystems. Preliminary research has highlighted the virgin forests' characteristics in relation to the managed forests, and has referred, inter alia, to the stand structure relative to age as well as to the correlation between DBH and DBH growth (Giurgiu, 1974). Recent researches have focused on statistical based knowledge of a natural forest's spatial structure, concluding that these ecosystems are characterized by high amplitude of DBH (Popa, 2013).

For the reconstruction of the climate spanning the last centuries, as well as the analysis of the forest ecosystems' dynamics, researches on dendrochronological series for fir, spruce (Popa, 2013) and beech (Roibu, 2013) had been carried out. The present research study is a continuation within the afore-mentioned topic.

The most important researches related to the structure, dynamics, cause of death and regeneration progress, for the studied area, had been carried out by Tomescu and Turcu from 2004 to 2006, and others from 2009 on. The purpose of these researches was to determine the trees' age by tree sampling.

In Romania the broadleaf forest covers 69,3 % of the afforested land, of which beech comprises 30,7%, oaks - 18,2% and other broadleaf species –20,4 %. The present investigations subject to this paper have a special importance and they aim, primarily, to develop in-depth knowledge on the peculiarities of the tree growth in the primary forests. The objectives of the present research are twofold: evolution and analysis of a virgin beech stand from the growth point of view and elaboration of a dendrochronological series for beech. The aims of the dendrochronological series are as follows: radial growth and DBH tree variability; stand structure relative to tree radial growth; dendrochronological aspects; correlation between the tree radial growth and the environmental conditions; volume growth.

MATERIAL AND METHODS

The permanent research plot (Semenic P20) is situated at an altitude of 1352 m in the "Izvoarele Nerei" Natural Reserve which is located in the "Semenic-Cheile Carasului" National Park , which is a part of Western Romanian Carpathians (Figure 1).

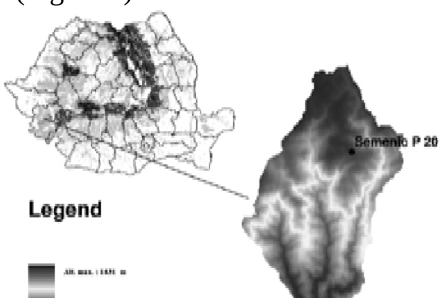

Figure 1. Semenic P20 research plot localization in the " Semenic–Cheile Carasului" National Park.

The choice of this research plot is based both on the consideration of the identification and delineation criteria of virgin forest, adopted by Romanian Government (Minister Order no. 3397/2012), and on the fact that the beech forests from the Banat Mountains are the largest and most compact century-old forests from Europe (Toader, 2004). In addition, the economical quality of this beech forest is acknowledged internationally. From the climatic point of view, the “Semenic - Cheile Carasului” National Park is located in the continental temperate region, with strong Mediterranean influences. Winters are long and cold, with a snow cover range between 60 and 100 cm, and a duration between 80 and 120 days (Tomescu, 2013), resulting in a short vegetation season (3 months). There is a tree growth variability from year to year depending on the vegetation conditions (Popa, 2004) on the one hand, and on the competition relationships between trees, on the other hand. The growth is materialized via the annual tree ring which holds important information about the time evolution of the tree growth.

For the radial growth determination, all 372 trees were sampled by means of the Pressler driller, 1,3 m above the ground, by following the cardinal points (N, E, S, V), in order to reduce the influence of the transversal form section and the radial growth, respectively. For highlighting the annual tree ring pattern, the increment cores were mounted on special wood supports and were grounded with different abrasive belts. Samples were processed by using CooRecorder 7.4, a software meant to register data from scanned pictures in order to measure tree-ring widths by registering boundary coordinates. The quality of crossdating and measurement accuracy of the tree-ring series has been assessed by the computer programme COFECHA. The ASTRAN application was used for the growth indexing of dendrochronalogical data series.

The volume growth is determined by means of one-inventory method using radial increment cores extracted from the living trees (Giurgiu, 1979, Leahu, 1994, Badea, 2008). This method allows to determine the volume growth by diameter classes based on the radial tree growth adjusted to the radial tree samples and was calculated as follows:

$$p_{iv} = p_{ig} + p_{ihf} - 0{,}01\, p_{ig} p_{ihf}$$

(Giurgiu, 1979).

Where : p_{iv} - volume growth in volume percent by diameter classes; p_{ig} - basal area growth percent by diameter classes; p_{ihf} – reduced average height growth percent.

The basal area growth percent by diameter classes was determined as follows :

$$p_{ig} = \frac{400\, i_r}{d}\,(1 - \frac{i_r}{d})$$

(Giurgiu, 1979).

Where: i_r is average radial growth; d - diameter class.

Average height growth percent is determined using the relationship:

$$p_{ig} = n\,\lambda \quad \text{(Giurgiu, 1979).}$$

Where: n number of years spanning the period on which the radial growth sampled had been averaged; λ - annual percent of tree reduced height growth.

The annual percent of tree reduced height growth is found in the production tables depending on the species, index class and in relation to the stand age (Giurgiu, 2004). In the next stage the volume growth is determined as follows:

$$i_v = 0{,}01\; v\; p_{iv} \quad \text{(Giurgiu, 1979).}$$

Where: v is the volume of the diameter category.
The volume is established with the following regression equation:

$$\log v = a_0 + a_1 \log d + a_2 \log^2 d + a_3 \log h + a_4 \log^2 h \quad \text{(Giurgiu, 2004).}$$

RESULTS AND DISCUSSION

Tree radial and diameter growths variability:

Based on the information obtained by measuring the radial tree ring samples (increment cores) the chart showing the variability of the radial tree ring samples in relation to their diameters had been recorded (Figure 2). One may observe that the spread field generated by the experimental values are grouped along a second degree polynomial curve, very specific to uneven- age stand and by default, to virgin stands (Giurgiu, 1979).

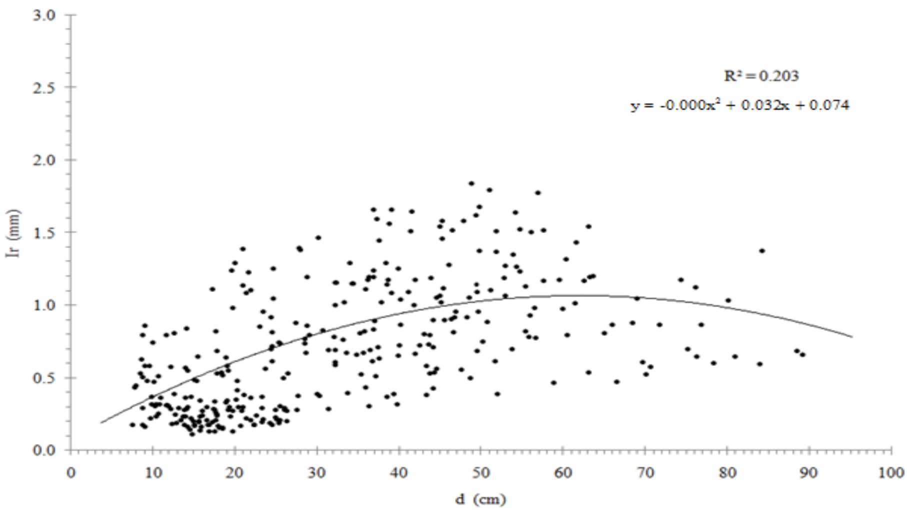

Figure 2. Variation of the radial tree growth average in relation to tree diameter, time period recorded 2003-2013.

An important characteristic pertaining to the virgin forest stands is the variation of the radial tree growth average in relation to the tree diameter, that is to say that the correlation coefficient has lower values (r<0.4) in case of the virgin forest stands as compared to the managed stands (Giurgiu, 1979).

In the case study the correlation coefficient is 0.40. Due to this power of self-regulation, in case of these types of ecosystems, the radial tree growth decreases for bigger trees, the correlation field being recorded as a second order parabola shaped curve.

Distribution of values of the radial growth variation coefficient in relation to the tree diameter:

The radial growth variation coefficient in relation to diameter for the Semenic P20 virgin forest stand has a descending trend line (Figure 3), high values for the lower diameter classes being recorded, and gradually declining to the superior diameter classes.

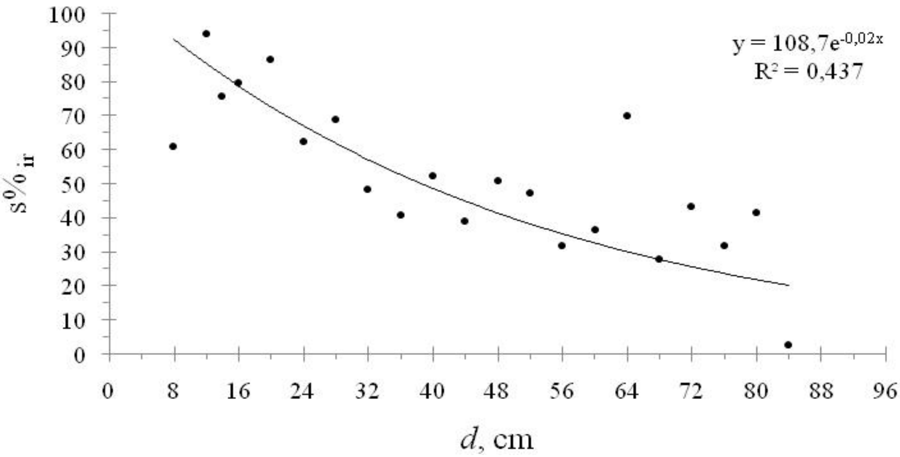

Figure 3. Distribution of values of radial growth variation coefficient in relation to the tree diameter.

The radial tree growth, as well as the diameter variation are influenced by the stand structure in relation to their age, vegetation conditions, trees health and the presence of gaps in the stand caused by windfall, snowfall or tree fall due to tree physiological death, issue specific to the virgin stands.

Virgin beech stands structure from the Semenic P20 in relation to their radial growth:

Similar to the tree diameter distribution, in the virgin forest stand the Semenic P20, the tree distributions relative to their radial growth is of exponential descending type (Figure 4), with “J” shaped allure, where trees from the lower diameter classes record the highest radial growths.

The experimental radial growth distributions were adjusted using the theoretical frequency functions: Beta, Gamma 3P and Weibull 3P.

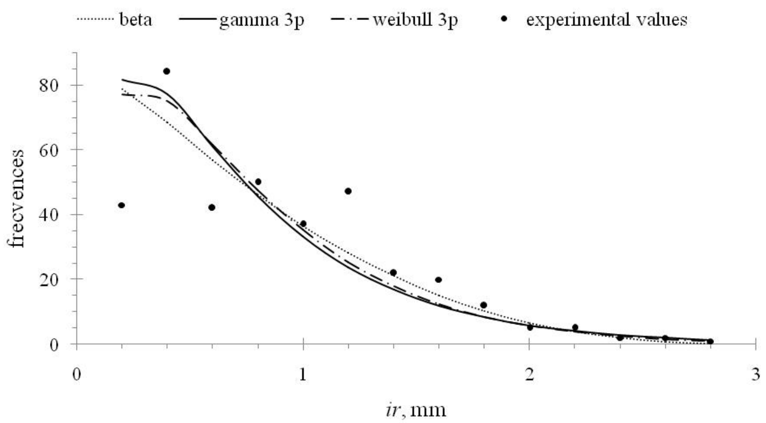

Figure 4. Tree distribution in relationship with their radial growth.

The goodness of fit was tested using $\chi 2$, anderson – darling (ad) și kolmogorov – smirnov (ks) tests (table 1).

Table1. Experimental values of specific goodness-of-fitness.

Distribution	Kolmogorov-Smirnov test (K-S)		Anderson-Darling Test (A-D)		χ^2 Criterion (χ^2)	
	experimental values	theoretical values	experimental values	theoretical values	experimental values	theoretical values
Beta	0,062	0,07	1,198	2,501	18,614	15,507
Gamma 3p	0,063	0,07	2,646	2,501	29,22	15,507
Weibull 3p	0,072	0,07	2,403	2,501	26,079	15,507

As the results of the komogorov – smirnov test show (table 1) one may observe that the theoretical distributions laws beta and gamma 3p are adjusting the semenic p20 virgin stand while the anderson – darlig test shows no significant differences between the experimental and theoretical values of the distributions beta and weibull 3p. In addition, the $\chi 2$ criterion showed that no studied theoretical laws adjust the stand. These differences, between the experimental and the theoretical values, are both explained by the development stages of the stand and by the environmental factors (competition relationships) of the stand as well as natural factors (windfall, snowfall, drought, insects attack), showing once again that the primeval ecosystems have a higher structural complexity (pach and podlaski, 2015).

Dendrochronological aspects in the semenic p20 stand:

For the dendrochronological series 36 increment cores extracted with the pressler driller were used, this method being less destructive as compared to the tree cutting and sample analysis method. The graph representation of the dendrochronological series (figure 5) shows the stand evolution in time revealing the main life events as stages with high and low radial growth, influenced by other factors such as competition relationships and multi-annual variation of the environmental conditions.

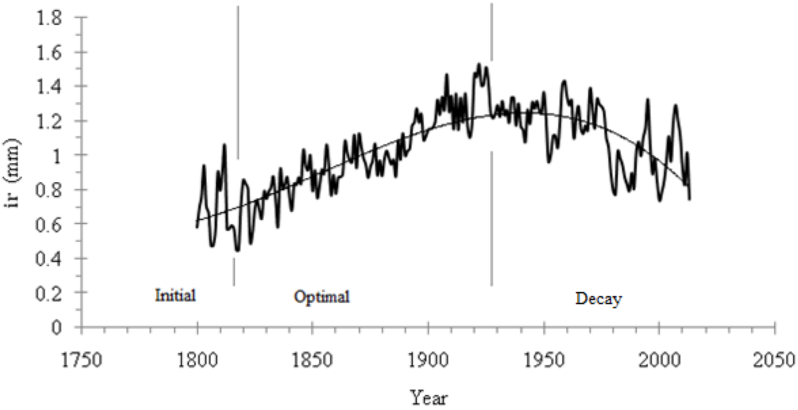

Figure 5. Standardization of polynomial model growth series.

The allure of the average radial growth curve is specific to the virgin forest stands, featuring a unimodal character, with an ascending growth until 1970 (initial and optimal development stages), followed by a decreasing trend of growth induced by the decay development stage, issue characteristic to the virgin forest stands (trotsiuk et al., 2012). Also, this decay can be explained by an increase in sulphur pollution in the 80s (castagneri et al., 2014). The average span is 361 years, time period covered is 1651-2013, mean growth is 0,999, with a standard deviation of 0,482 and mean sensitivity of 0,390 (table 2).

Table 2. Statistical parameters of the dendrocronological series (Semenic beech stand).

Parameters	STD	RES
Average length (years)	361	361
Period covered	1651-2013	1800-2013
Number of radial samples	36	36
Average radial growth	0,999	1,001
Standard deviation	0,482	0,404
Average sensitivity	0,390	0,454
First-degree autocorrelation	0,465	-0,004
Average R bar	0,068	0,034

First-degree autocorrelation is 0,465 and mean correlation coefficient is 0,068. Positive characteristic years are: 1811, 2006, 2012. Negative characteristic years are: 1805, 1836, 2010 (year characterized by drought). Further the growth is correlated with the climatic data such as temperatures and precipitations (figure 6), using cru ts3.22 climatic database for the time period 1901-2013 (ceda, 2014).

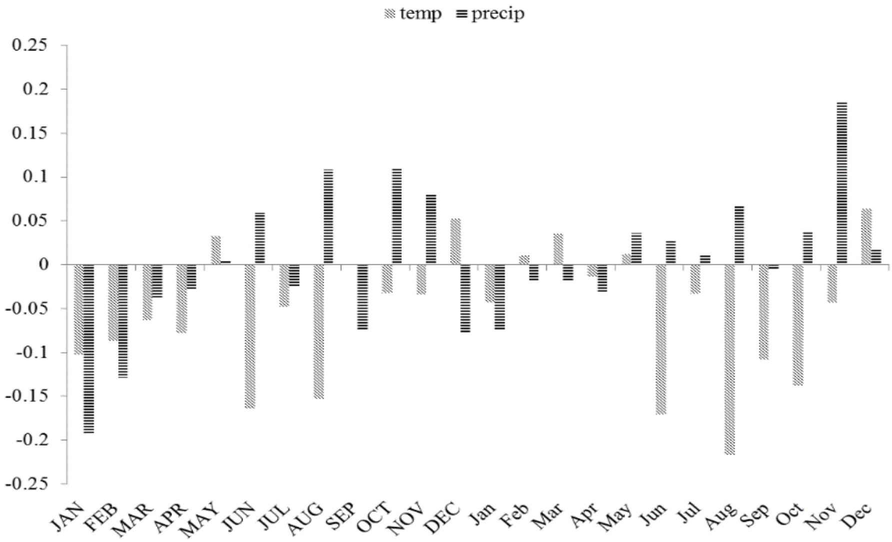

Fig. 6. Correlation between the radial tree growth and the temperatures, precipitations.

This correlation spanned 112 years and highlights the fact that the radial growth is more influenced by precipitations than by the temperature. Hence, it is demonstrated the high stability of virgin forests. Same results were found in a study conducted in Lom forest reserve in Bosnia Hertegovina (Castagneri et al., 2014).

Volume growth: To determine the volume growth of the stand, the first step was to determine the volume for each tree (*v*) and the growth volume percent (*piv*). Once the volume growth for each tree was determined, then by summing the values, the volume growth for the entire forest stand (Iv) results for the time period 2003 – 2013 (63,32 $m^3 \cdot year^{-1} \cdot ha^{-1}$). The average of the annual growth is 6,33 $m^3 \cdot year^{-1} \cdot ha^{-1}$.

In comparison with the managed beech stands from the selection forests, where the volume growth is between 4,2 and 6,7 $m^3 \cdot year^{-1} \cdot ha^{-1}$ (Guiman, 2007),the Semenic P20 virgin stand has the characteristics of a stand with high volume growth (even for the virgin forests). Despite the influences of the environmental and climatic factors (the stand is situated at 1532 m altitude, above the beech altitudinal limit, where the vegetation season is short and strong winds occur) as well as the age influence (there had been found trees aged over 200 years) on the volume growth, the Semenic P20 stand proves high eco-productive characteristics of virgin stands.

Thanks to their high adaptive and survival capacity in varied and heavy (even extreme) conditions, the virgin forests, which are complex ecosystems, are net superior to the managed forests, proving time and again the high stability they offer to the ecosystem to which they belong, regardless of the culture system.

CONCLUSIONS

Virgin forests represent a model for sustainability and a high efficient eco-productivity.

The graphical representation of tree radial and diameter growth variability displays the shape of a second order parabola, specific to uneven- age stand and by default, to virgin stands.

For the dendrochronological series 36 samples have been used and the graph representation shows the forest stand evolution in time. The length of this series has 361 years, first dated year being 1631. The average radial growth is 0.999 and standard deviation is 0.482. Also the first degree autocorrelation is 0.465 and average R bar is 0.068.

Climatic data as temperature and precipitations, for the time period 1901 – 2013, in correlation with radial growth show that the stand is not strongly influenced by precipitations and temperatures (with small exceptions generated by precipitations). This fact demonstrates the high stability of virgin forests;

The volume growth of Semenic P20 stand, for the period 2003 – 2013, is 63,32 m3ha-1 and the annual growth is 6,33 m3 year -1 ha-1. In comparison with the managed beech stands from the selection forests, where the volume growth is between 4,2 and 6,7 m3 year -1 ha-1 the Semenic P20 virgin forest stand has the characteristics of a stand with high volume growth (even for the virgin forests);

REFERENCES

Badea, O. (2008). Manual privind metodologia de supraveghere pe termen lung a stării ecosistemelor forestiere aflate sub acțiunea poluării atmosferice și modificărilor climatice. Bucuresti: Tehnica Silvică. 98 pp.

Bândiu, C. (2013): Pădurea virgină arhetip de structurare și funcționalitate pentru pădurea cultivată, Păduri virgine și cvasivirgine ale Romaniei, sub redacția Victor Giurgiu, Editura Academiei Române: 177-181.

Castagneri, D., Nola, P., Motta, R., Carrer, M. (2014): Summer climate variability over the last 250 years differently affected tree species radial growth in a mesic Fagus-Abies-Picea old-growth forest. Forest Ecology and Management 320:21-29.

Gonzalez, I. G. (2001). Weiser: a computer program to identify event and pointer years in dendrochronological series. Dendrochronologia, 19(2), 239-244.

Giurgiu, V.(1974): Particularități de creștere a arboretelor pluriene, comparativ cu cele echiene, ICAS, București.

Giurgiu, V. (1979): Dendrometrie și auxologie forestieră, Editura Ceres, București, 691 pp.

Giurgiu, V.(1998): Amenajarea pădurilor cu funcții multiple. Editura Ceres, București, 287 pp.

Giurgiu, V., & Draghiciu, D. (2004). Modele matematico-auxologice si tabele de productie pentru arborete. Editura Ceres, Bucuresti. 607 pp.

Guiman, G.(2007), Optimizarea structurii arboretelor prin aplicarea tratamentului codrului grădinărit în fogete din Bazinul Mijlociu și Superior al Argeșului, Teză de doctorat, Universitatea Ștefan cel Mare, Suceava, 225 pp.

Giurgiu, V. (2013): Pădurile virgine și cvasivirgine ale României, Ed. Academiei Române, 390 pp.

Leahu, I.(1994): Dendrometrie, Editura Didactică și Pedagogică, R.A., București, 374 pp.

Motta, R., Berretti, R., Castagneri, D., Lingua, E., Nola, P., & Vacchiano, G. (2010). Stand and coarse woody debris dynamics in subalpine Norway spruce forests withdrawn from regular management. Annals of forest science, 67(8), 803.

Pach, M. and Podlaski, R. (2012): Tree diameter structural diversity in Central European forests with Abies alba and Fagus sylvatica: managed versus unmanaged forest stands. Ecological Research 30: 367-384.

Popa, I. (2004). Fundamente metodologice şi aplicaţii de dendrocronologie. Editura Tehnică Silvică. 200 pp.

Popa, I., Sidor, C.G.(2013): Serii dendrocronologice seculare pentru pădurile virgine din lanțul Carpatic din Romania, Păduri virgine și cvasivirgine ale Romaniei, sub redacția Victor Giurgiu, Editura Academiei Române: 310-318.

Popa, I., Sidor, C.G.(2013): Structura spațială a unei păduri naturale de limită altitudinală superioară în Munții Calimani, Păduri virgine și cvasivirgine ale Romaniei, sub redacția Victor Giurgiu, Editura Academiei Române: 257-276.

Roibu, C.C. (2013): Dinamica structurală și dendrocronologie din pădurea cvasivirgină ”Făgetul Secular Humosul”, Păduri virgine și cvasivirgine ale Romaniei, sub redacția Victor Giurgiu, Editura Academiei Române: 277-309.

Toader T., Dumitru I., et. al. (2004): Pădurile Romaniei. Parcurile naţionale. Tipografia Intact, Bucureşti.

Tomescu, R, et al.(2013): Contribuții la cunoașterea dinamicii structurii făgetelor virgine din Rezervația Naturală Izvoarele Nerei-Semenic. Păduri virgine și cvasivirgine ale Romaniei, sub redacția Victor Giurgiu, Editura Academiei Române: 209-257

Trotsiuk, V., Hobi, M. L., Commarmot, B. (2012): Age structure and disturbance dynamics of the relic virgin beech forest Uholka (Ucrainian Carpathians). Forest Ecology and Management 265: 181-190.

Winter, S., Fischer, H. S., & Fischer, A. (2010). Relative quantitative reference approach for naturalness assessments of forests. Forest ecology and management, 259(8), 1624-1632.

*** Centre for Environmental Data Archival, 2014, Climatic Research UNIT (CRU) time-series data sets of variation in climate with variations in other phenomena

*** OM 3397/2012 privind stabilirea criteriilor si indicatorilor de identificare a pădurilor virgine și cvasivirgine.