Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 8 (57) No.1 - 2015

THE INTER - ANNUAL DYNAMICS OF BASAL AREA INCREMENT DERIVED FROM PERMANENT GIRTH BAND MEASUREMENTS IN INTENSIVE FOREST MONITORING NETWORK

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Abstract: *Knowledge of intra-annual tree growth dynamics allow a better understanding of tree reaction to short term climate variation. The main objective of our study was modelling intra-annual dynamics of basal area increment (BAI) in four level II plots in Romania, composed of pedunculate oak (Quercus robur L.), sessile oak (Q. petraea [Matt.] Liebl.), Norway spruce (Picea abies [L.] Karst.) and European beech (Fagus sylvatica L.), which are placed in representative forest ecosystems, as well as in climatic and altitudinal conditions. Between 2010 and 2014, for a number of 60 trees (15 for each plot and species), the growth variations of the selected trees were recorded bimonthly using permanent girth bands. Seasonal dynamics of radial increment were modelled using Gompertz functions. Results confirm that each year the growing season period is different for each location. For pedunculate and sessile oak a common onset of the growth was observed during the whole period, except 2012. The same situation was emphasized for European beech (situated at 1300 m altitude) and Norway spruce. For these species located in mountainous regions the maximum growth rate is recorded in the same period (late of June). In general, in all studied plots the values recorded on permanent girth bands regarding the onset and maximum growth rate are confirmed by the data recorded on continuous point dendrometers.*

1. Introduction

Since its implementation in the 1990's, the forest monitoring system has been one of the most reliable and consistent scientific sources of information on the state of forest ecosystems affected by air pollution and other stress factors. One of the most important activities entailed by this system is the monitoring of the trees and forest stands growth. Periodical and seasonal growth is a synthetic indicator that reveals highly important information concerning the trees' reaction to the

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climate and vegetation condition changes, as revealed by their growth pattern [8].

Numerous methods and types of equipment have been developed and tested throughout time, with the purpose of monitoring tree growth. Certain methods, such as the sample extraction (increment cores) using Pressler borer are believed to be destructive and are more often used in dendrochronology studies that require long time series to conduct an analysis. The use of continuous measurement bands for automatic data recording or permanent reading girth bands enable the collection of short term data sets in a non-destructive way and allow for the recording of daily variations in the stem's circumference, thus enabling the identification of the onset and cessation of the growth. However, there are evidences [10] that the data provided by permanent girth bands does not reveal the seasonal dynamics in the wood cells formation, but only the variations in the stem's circumference. More recent findings [11] have revealed that, according to the measurements conducted by means of the girth bands, the start of the growing season was recorded at the beginning of May, while the formation of early wood was identified around June 1st, according to the micro-core and xilological methods.

A detailed analysis of the advantages and disadvantages of the various methods used for measuring the dynamics of radial growth was conducted by [5].

The objective of this paper is to identify and analyse the inter-annual dynamics of tree growth based on the data provided by the permanent girth bands, as well as the beginning and end of the growth periods and their duration, which may vary, depending on tree species, climate conditions or altitude.

2. Materials and methods

The research has been conducted during 2010-2014 across four of the 12 intensive forest monitoring plots (Level II) in Romania (Fig. 1). These plots, so called *core-plots,* have been selected during the IM1 (*Intensive Monitoring action 1*) action group developed as part of the international project *Further development and implementation of an EU-Level Forest monitoring System* (FutMon), and are located in representative forest ecosystems of pedunculate oak (Ştefăneşti – stejar), sessile oak (Mihăeşti – gorun), beech (Fundata – fag) and spruce (Predeal – molid) [1]. In order to meet the objectives set in the FutMon project, these *core-plots* have been equipped with modern forest monitoring equipment and instruments that enable researchers to conduct permanent and continuous measurements. The aim of recording accurate data was to assess the expansion and development of polluting factors in relation to the main parameters used to characterise the state of forest ecosystems.

The Romanian intensive forest monitoring *core-plots* are located in representative forest ecosystems in different bio-geographical areas. The Stefăneşti – stejar core-plot is placed at 86 m altitude in the forest plain area, in a 63 year old tree stand consisting mainly of oak mixed with linden and hornbeam. The Mihăeşti – gorun core-plot is located in the sub-Carpathian hills, in a 64 year old sessile oak tree standmixed with beech at an altitude of 500 m. The Fundata – fag and Predeal – molidcore-plots have been selected as relevant for the mountain areas, located at an altitude of 1300 m and 1100 m, respectively. The Fundata - fag stand is a pure 52 year old beech stand. The Predeal-molid stand is approximately 97 years old and is a mixture of coniferous trees and beech, the main predominant species being Norway spruce.

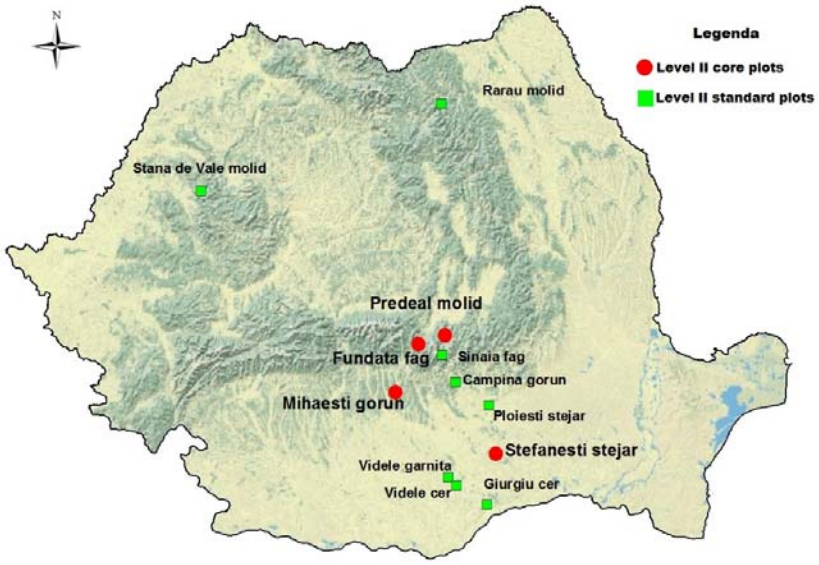

Fig. 1. *Romanian intensive forest monitoring network (Level II)*

A number of 60 permanent girth bands have been installed across the 4 core-plots in 2010, as the FutMon international project was launched in Romania. The bands were fitted on 15 trees of the main species, with different diameter categories, three such trees being selected in each of the five subplots of the core-plot (Fig.2).

The permanent girth bands are UMS-GmbH [16] type, and their measuring unit is in π/1(cm), thus directly providing the tree diameter value with a reading precision of 0,05 πcm up to 0,01 πcm. The readings frequency was monthly during October-March and bi-monthly during the vegetation season (April-September). The data has been recorded in standardized files [6].

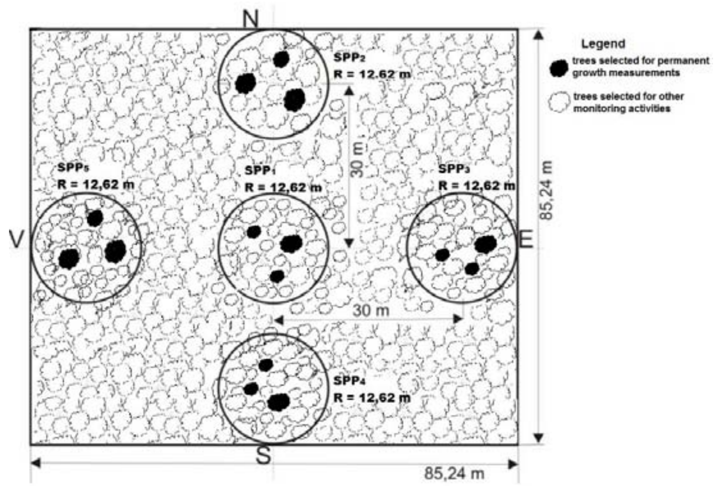

Fig. 2. *Intensive monitoring Level II plot design and the location of the 15 trees selected for permanent growth measurements*

The permanent girth bands measurements sometimes proved to be difficult to analyse, due to the sensitivity manifested during contraction and expansion processes in frost/defrost or hydration/dehydration processes. These phenomena cause variations in the tree bark and, implicitly, the recording of values bear considerable errors that cannot be accounted as actual growth.

Unlike continuous stem circumference measurements (e.g. using circumference band and point dendrometers), the temporal resolution and measurement precision do not allow permanent girth bands to measure the daily dynamics of the stem circumference caused by changes in the water content of wood tissues [18].

Basal area increment (BAI) was computed from the tree diameter variation, adopting the circular pattern of the stem cross sectional area. The cumulated BAI values were calculated by adding the periodical BAI values over time. The radial growth dynamics modelling was performed using the Gompertz model [9] and [14]. All the statistical analyses were conducted using the R programme [13].

3. Results and discussions

The average BAI for the studied *Quercus spp.* were of 11.5 $cm^2 year^{-1}$in the case of the sessile oak stand in Mihăeşti –

stejar core - plot and 19.6 $cm^2 year^{-1}$, for the pedunculate oak in the Ştefăneşti – stejar core – plot (Fig.3). For both species, the lowest increments were recorded in 2012, when the sessile oak had a growth rate of 10.9 cm^2 $year^{-1}$, while oak grew with 16.9 $cm^2 year^{-1}$.

The average BAI for the spruce and beech stands in the mountainous region had values of 14.88 cm^2 $year^{-1}$ and 7.68 $cm^2 year^{-1}$, respectively. As in the case of the oak species, the lowest increments have been recorded in 2012, beech reaching a value of 6.11 cm^2 $year^{-1}$, while spruce grew by 13.4 cm^2 $year^{-1}$. The low values recorded in 2012 may be caused by low precipitation during the previous autumn and winter (2011), and at the beginning of the current growing season. The effects of water deficits have been widely debated by numerous authors ([2], [15] and [17]), whose findings have proved that a proper onset of the growth is mainly conditioned by the quantity of resources accumulated at the end of the previous season.

As for the onset, maximum and flattening of the growth curves, differences have been revealed depending on each species under analysis (Fig.3). Thus, for the Ştefăneşti– stejar core – plot, the start of the growing season was identified in the first part of April, while the maximum growth was recorded in the first decade of May (Fig.4), with a flattening of the growth curve at the beginning of July. Proximate periods, but with a nearly 10 day delay have also been observed for sessile oak (Mihăeşti – gorun).The growth onset of the two species overlap with the flushing observed through phenological observations conducted across each core-plots ([7] and [12]).

In the case of beech and spruce from Fundata - fag and Predeal – molid core – plots, respectively, there were visible differences from the *Quercus spp.* in terms of the altitude level concerning the start of the radial increment periods. In the case of beech, located at a high altitude, there was a two months delay of growth onset as compared to the pedunculate and sessile oak species. The systematic positive BAI for beech is consistent with phenological observations, the first leaves flushing having been identified at the beginning of May. This species has reached a maximum increment during the second decade of July, and the wood mass build-up process continued until the beginning of

September. In the case of the beech from Slovenia, the xylology analyses have revealed a maximum radial increment in the first week of June [4].

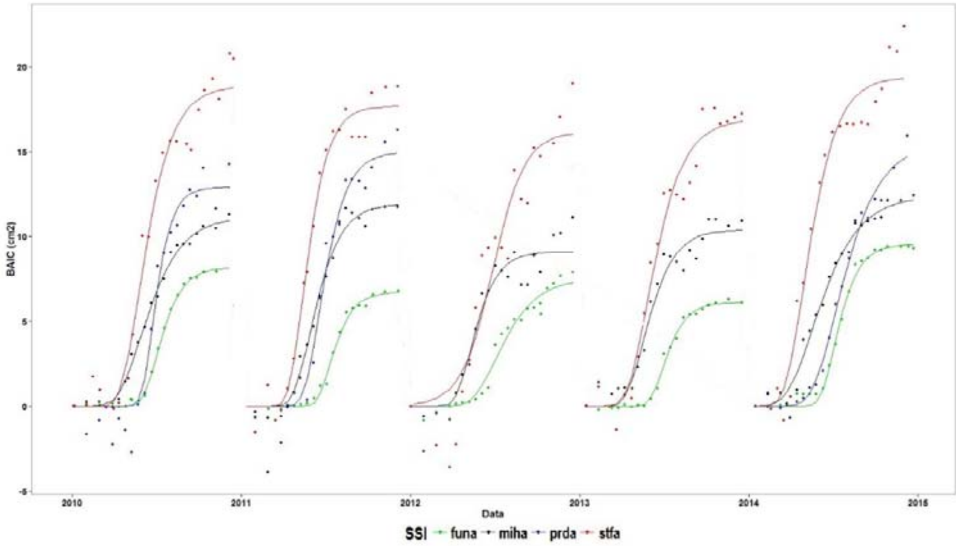

Fig. 3. *Estimated cumulative BAI for sessile oak (miha), pedunculate oak (stfa), spruce (prda) and beech (funa)*

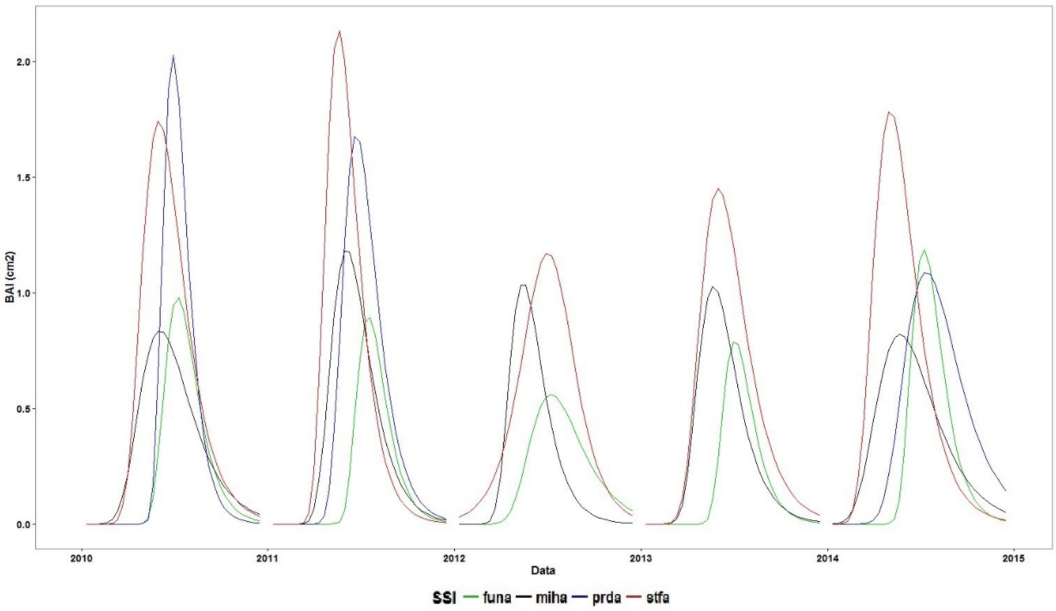

Fig. 4. *Daily growth dynamics during the 2010-2015 period*

Spruce, which is located at optimum altitude for its habitat, has recorded a systematic positive stem circumference growth starting with the first half of April, while its maximum increment in 2014 was recorded during the first half of July. Using similar information, derived from permanent girth bands, [3] identified a maximum growth rate for spruce in the first half of June, while beech reaches its maximum growth during the last week of June and the first week of July.

In the case of the Fundata–fag stand, there has been an obvious change in the growth rhythm, as it has had a slightly declining trend before 2013, when stand thinning were conducted and thus favoured a higher growth rate in 2014. High growth rates in 2014 have also been recorded in the case of the Ştefăneşti - stejar where the highest growth rhythm throughout the entire period under analysis was observed. The inter-annual growth dynamics in the case of this stand does not undergo visible changes from one year to another.

However, two groups of trees with different growth rhythms have been observed, which can be due to their position in the canopy. Trees with accelerated growth rhythms have well established positions within the canopy of the stand their crowns being in direct contact with sunlight.

The Fundata-fag and the Predeal-molid core-plots, located at higher altitudes, have shorter growth periods, as the start of the growing season is identified around late May for beech and beginning of May for spruce. Similar results regarding the influence of altitude on the beginning, end and duration of the growing seasons for spruce have been presented in certain studies conducted in the Italian Alps region [5].

4. Conclusions

Across all permanent plots under analysis, a similar trend in the growth rhythm of the trees, both during growing seasons, as well as in dormancy periods was observed. Thus, the growth rhythm has been clearly outlined, as well as the development cycles of the annual rings for each species included in the research. Throughout the period under analysis, beech and spruce on the one hand, and pedunculate and sessile oak on the other, have had highly similar maximum growth periods.

The development of the annual ring differs from one species to another, except for pedunculate and sessile oak, whose common growth season has been identified as starting at the beginning of April.

The inter- and intra-specific differences identified in terms of the annual ring formation period, as well as the quantity of built-up biomass may be due to the yearly variations of the climate conditions, to the health status of trees, to the vegetation conditions or to the altitude difference.

Even some specialists criticised the results provided by permanent girth bands due to errors recorded during frost/defrost periods or in terms of hydration and dehydration of the tree bark, our findings lead to the idea that the use of such bands should not be abandoned. The sufficiently precise information provided by these instruments is highly important as evidence is supplied on the state of the tree stands, as well as on the technical adjustments that can be implemented in these areas.

Acknowledgements

This study was supported by EU (LIFE+ - FutMon Project), Romanian Authority for Research in Core Program for Forestry – GEDEFOR, projects PN09460110 and PN09460116.

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