

**Proiect IDEI 111/5.10.2011 "FOREST GHG MANAGEMENT"**  
Scientific report (15.12.2011-15.12.2012)

**Institut de Cercetări și Amenajări Silvice**

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**Summary**

The project aims to analyze the carbon storage or greenhouse gas flows in forests and forest management influence on these flows. The research method is based on the project developed within a European project "GHG Europe" ([www.ghg-europe.eu](http://www.ghg-europe.eu)), aimed exclusively beech forests. This project expands and complements the coverage of the European project by analyzing the forests rarely studied: natural forests.

We selected 10 areas of study, of which 4 in natural forests, planted forests appropriated 4 of geographical and environmental conditions, in order to grasp the impact of management on carbon stocks and fluxes of greenhouse gases emitted from ground. The other two areas are special circumstances, such as areas affected by clear cutting and reforestation. Unfortunately, due to severe budget cuts in 2013, research in these areas have been discontinued.

In the remaining areas, the specific measurements have been made, necessary for estimating the carbon stock. In natural forest of spruce, the quantities of dead wood are particularly high, a survey was conducted of wood density (factor needed to estimate biomass, dead wood associated carbon respectively). This study was published in a journal ISI.

Stock biomass dynamics analysis was based on dendrochronological methods and measurements. Dendroecological methods do not fully correspond purpose of the study, so that an adaptation / modification of these was necessary. This topic has been deepened in an international working group, which resulted in the proposal of a new methodology. This study was submitted for assessment in an ISI.

Through collaborations with researchers from Germany, has analyzed the impact on forest management and protection of natural forests naturality or ecological interest, such as forests in an area classified Natura 2000. This study was published in a journal ISI.

Regenerate, which is part of the main mechanisms of development of stands and increases the amount of carbon stored, analyzed the natural forest of spruce. This study was submitted for assessment in an ISI.

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## 1 Introduction. Scientific context.

In Romania, the main forest services are considered to be the forest timber production and protection. Estimating the emissions and removals of greenhouse gases is a very recent issue. Carbon storage functions are not yet considered, but the pressure to be estimated with high precision at European level is likely to increase further, as the recently published Green Paper (<http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=&language=EN> A7-2011-0113). This report points out that "forests make up biospheres not only include trees and providing invaluable ecosystem services including carbon storage, water flow rates, nature conservation and protection against natural disasters, all of which are of great importance for agriculture and rural development and quality of life of European citizens. "It also recognized "the capacity of European forests to act as effective reservoirs of CO<sub>2</sub>, NH<sub>3</sub> and NO<sub>x</sub> is still disregarded, and wood from sustainably managed forests could benefit sustainable mitigation, serving as an alternative recyclable, carbon-rich , energy-intensive materials such as metal alloys, plastics and concrete, widely used in construction and other industries. "Committee on Industry, Research and Energy (12.11.2010) in response to the Green Paper was to welcome "Commission's view that forests should be seen as one of the main tools to neutralize the action of factors contributing to changes climate, for example by capturing CO<sub>2</sub> from the atmosphere; emphasizes that sustainable forest management, including protection of forests and their regeneration, adapted to the different conditions in Europe, is of paramount importance in achieving the EU's climate and protecting forest biodiversity, which provide numerous ecosystem services (supply of wood users and services related to carbon storage and protection against natural disasters) and cultural services (in the form of sustainable tourism) that are essential to society. "

Emissions of greenhouse gases (GHGs) increased in all industrialized countries, despite the fact that these countries have signed international protocols that requires them to reduce emissions. The finding that emissions can be reduced significantly brought to the conclusion that efforts are needed to enhance, where possible, storing carbon. Forest ecosystems, mainly forests and grasslands (pastures and meadows) act as carbon traps. Carbon dioxide gas is right with the largest contribution to greenhouse quantitative role of forest ecosystems in mitigation or mitigation of the effects of GHG emissions has always been considered essential.

The first IPCC report (International Panel on Climate Change), Houghton et al. (1992) suggestat mitiga- that an aggressive strategy by creating forests by planting at large (1 hectare billion, or more than 130 times the forest area of Romania), while stopping logging (deforestation) should bring to absorb carbon at a level of 0.5 Gt of carbon per year by 2050. it was therefore developed the idea that forests and forest ecosystems in general, can be of great help to rebalance GHG emissions.

The idea to balance GHG emissions through forest policy is seductive, but faces many obstacles. The first relates to the contribution of forest ecosystems to carbon storage and that it is not known precisely their ability to capture and sequestration. Second, research in this area have shown demonstrated the dynamic nature of capture and storage capacity, thus potentially affected by climate changes. These unknowns were the main reason why they made several global projects focus on capacity issues capture and storage (eg CarboEurope project, <http://www.bgc-jena.mpg.de/public/carboeur/>). But the most important issue in GHG emissions reduction plan is that forests are managed for carbon capture and storage. Forest management is more optimized for production of wood or present environmental purposes, such as conservation land.

## 2 Aims and scopes of the project

The effect of forest management on carbon stocks and carbon storage capacity, is less documented and is in the global spotlight. FP7 project "GHG Europe" ([www.ghg-europe.eu](http://www.ghg-europe.eu)), funded by the EU, aims to determine how, and to what extent the carbon cycle GHG emissions from terrestrial ecosystems can be managed. The basic idea is to manage GHG fluxes through terrestrial ecosystems management.

In this project, the Forest Research and Management Institute's mission is to study "The impact of land management on regional GHG balance in selected regions rich in information, in Europe". Its task is to establish a gradient of management (management) in beech forests to study the impact on the budget management of GHG. This gradient covers a wide range of management methods, even aged trees from stands at relatively issued of many year and issued of many year, with soil conditions, growth and productivity whose variability is minimized.

The aim of the present project is to complete this rare situations gradient and management relevant to Romania, namely natural forests and wooded pastures. Project management includes specific types of Romania, otherwise quite rare and therefore undocumented. The objective is to obtain data from experimental measurements of flow and fund GHG. The gradient of GHG project management built in Europe is developed for beech, a species widespread in Europe but which is the main species in Romania in terms of standing volume, thus having great relevance both nationally and at European level. Gradient followed currently consists of 12 areas, representative of typical forest management, contrasting with frequency and intensity of silvicultural interventions (care work, silvicultural treatments) executed over the life cycle stands.

However, this management gradient lacks extreme conditions: first, that no natural stands; in this respect, Romania, with over 200,000 ha of natural forests is an appropriate place for such a study. In addition, there is a controversy in the scientific world about the secular forests and natural ability to function as carbon traps (Knohl et al. 2003 Luyssaert et al. 2008 Wirth et al. 2009), many researchers considering these forests as rather neutral on carbon flux. The acquisition of experimental data of the project will allow further clarification of the status of natural forests in Europe and their behavior vis-à-vis GHG fluxes.

### **3 Projects' structure**

The project is divided into two distinct and complementary activities. The first is to estimate the dynamics of carbon stocks in forests studied air. This activity will bring knowledge about forest carbon storage capacity and sensitivity to forest management. In particular, estimates of carbon sequestration in natural forests, a novelty really expected the scientific community in this area, because the rarity of this type of forests limited availability of estimates, despite the fact that they represent a point of reference very useful. The second activity for monitoring greenhouse gas fluxes from forest. This type of monitoring remains relatively rare, because the equipment requires an investment of time. The measurements are complementary, as the analysis described in detail carbon storage and fluxes of carbon storage above ground level, the ground remains discovered without GHG gas emissions from soil analysis.

## **4 Material and Methods**

### **4.1 Presentation of the monitoring sites and plots**

The selection of sample plots is an important step, because the plot will determine the measurement performed. Therefore, a great attention was paid to these steps, in close contact with researchers from abroad. Were identified and selected a total of 10 plots (Table 1):

- (i) 4 plots in the southwestern region: 2 natural forests, 2 cultivated (managed) forests
- (ii) 5 plots in the eastern region: 3 in natural spruce stands, 2 in a meadow
- (iii) in the central region, one plot on clear-cut forest.

In the southern region, the experiment was set in a race cut of 0.5 ha, illustration of the situation of land use change. Market sample was placed in a majority of beech stand, even aged trees, at an altitude of 55 m. For comparison, it is near areas used in FP7 namesake, at a distance of approx. 200 m.

**Tabelul 1.** General characteristics of the stand location chosen for the experiment

Region	District	U.P.	u.a.	Sp. comp.	Stand structure	Canopy closure	Age	Forest type	Altitudine mean
SudVest	Nera	II	123 A	10 FA	uneven, natural	0.8	190	Natural, beech	1200
		III	22	10 FA	uneven, natural	0.8	170	Natural, beech	1250
		I	68 A	8 FA 2 BR	uneven, managed	0.8	140	Natural, beech	1050
	Văliug	I	68 B	10 FA	uneven, managed	0.5	130	Cultivated, beech	1250
		I	70 B	10 FA	uneven, managed	0.6	115	Cultivated, beech	1250
		I	71	10 FA	uneven, managed	0.8	70	Cultivated, beech	1100
NordEst	Pojorâta	-	-	MO	Meadow	0	10	-	1050
	Giumalău, rezervația	III	120A	10 MO	uneven, natural	0.8	180	Natural, spruce	1100
Sudică	Mihăiești		212F	7 Fa 3 DT	even, managed	0	0	Cultivated, beech	550

In the South West locations were chosen for the experiment in two locations: in the natural forest, cvasi Reserve "springs Nera" and planted trees equivalent stationary conditions as close to those of natural forest (v. Fig. 1). General location of sites experiment in this region is Semenic Massif, natural stands are located in the southern part of the massif, and stands grown in the northern part of it.

First were investigated in the field of beech stands cvasi Reserve; came to our attention the beech forests of mountain beech forests located lower altitudinal limit, ie forests band located between 1300 and 1350 m altitude. It is known that the reserve "springs Nerei" has a large amplitude so that the surface - 5028 ha, as well as a gradient altitude - from about 650 to about 1400 m; Because of this, the Reserve meet a wide variety of stationary conditions covering three altitude zones from the beech forests of the hill (pure) in the mountainous beech forests and then to the high altitude beech forests (in Semenic Mountains, the upper altitudinal beech forest is by depriving floor and mixtures of conifers).

Given that experimental methodology install required equivalence best possible stationary conditions between natural and planted forests, the site chosen for test plots in natural forest is u 123 A U.P. II and U.A. 22 U.P. III of the O.s. Nera, located at 1300-1350 m altitude, soil conditions of districambisol typically higher productivity and favorable stationary conditions; fundamental natural forest type is Fagetul normal flora mull higher productivity.

Regarding the location of the cultivated reference, the experimental plot was selected from a representative group of u - 68 A, B, 70 B, and 71 - the U.P. I from the district Văliug that are located very close to natural forest, occupying a wide altitudinal range: from 940-1350 m. These management units

have mostly all a districambisol substrate, with only one exception (u 71) which is a lithic soil subtype, but keeping productivity high.

In these stands have been applied since 50 years transformation cuts to change the management type from even-aged to uneven-aged or pluri-aged. The district Văliug is emblematic of Romania, being one of the most important places where the transformation works occurred, with an area of about 9000 ha. This treatment is most intensive possible, while being closest to the natural laws of forest ecosystem functioning ("close-to-nature" forestry). The option chosen for this treatment is that which includes the control method, which requires constant supervision of production through market fund structure standing trial, significantly placed in UP (production units, homogeneous as regards to the forest treatment). Based on information obtained from these control surfaces for each UP calculate the theoretical curve structure and silvicultural interventions aimed as much as possible close to the real structure of the forest curve calculated (theoretical) while yielding main forest products (wood thick enough to harvest diameter-end). Because logging application for conversion to gardening, many of stands belonging UP studied have acquired a structure at least relatively issued of many year. It should be noted that throughout this U.P. treatments are covered trees in the forest regime regularly, eg progressive cuts; however, stands were stimulated to develop relatively issued of many year structure. Although this U.P. part of Semenic-Caras Gorge National Park, silvicultural treatments were applied - gardening, progressive cuts, care work and accidental cuts and hygiene products so that anthropogenic influences are evident and measurable.

The typical forest flora is:

- a) Indicator spontaneous vegetation: *Asperula odorata*, *Athyrium filix-femina*, *Dryopteris filis-mas*, *Oxalis acetosella*, *Dentaria glandulosa*, *Pulmonaria rubra*, *Dentaria bulbifera*, *Geranium robertianum*;
- b) frequent spontaneous vegetation: *Rubus hirtus*, *Mycelis muralis*, *Lamium galeobdolon*, *Actaea spicata*, *Mercurialis perennis*, *Symphytum cordatum*, *Euphorbia amygdaloides*, *Anemone nemorosa*, *Isopyrum thalictroides*.

In the Eastern region were established three plots in natural spruce forest massif, and two abandoned lands in Giupalău (Magura), where afforestation is very active.

Giupalău sample plot is approx. 10 km southwest of the Magura plot, and the Secular Forest Reserve is located in Giupalău, Forest Department Pojorâta. The reserve has a 1700 m elevation and an area of approx. 300 ha, of which 164 ha as strictly protected area, under strict protection status in 1943.

Sample surface corresponding experimental device project (0.5 ha) is part of this (plot 120A) and was installed in 1978, at an altitude of approx. 1200 m, on an exposition NW. Forest type is 1114, which corresponds to the type of ecosystem in 1226 - molidiș with *Oxalis acetosela*. Until now, there were five re-inventory (in 1985, 1988, 2001, 2006 and 2011), except their spatial positions being measured and the following: the trees - diameter at 1.3 m height (incl. Ellagic) status (healthy, debilitated, dead) and the dead wood - diameter at the ends, the length of the class of decomposition.

Plots corresponding sample surface were Magura installs wooded pastures chosen for spatial representativeness of this phenomenon, which has a large in Romania. The limit was artificial forest and grazing off brought to the appearance of disseminated trees, rare, resulting in a very low consistency. Progress is slow, however, and the forest will be considered in a period of just a few decades. Until then, plots will be set up representative areas called "afforestation", which are neither meadows or pastures.

## 4.2 Biometric measurements

### 4.2.1 Estimation of the aerial carbon stock of the stands studied

The measurements required to estimate carbon stock of a stand are classical biometric measurements. To transform the amount of biomass estimated into carbon stocks, in the absence of more specific estimations, we used the classic 0.5 transformation factor. Of course, there is some deviation in the amount of carbon per unit volume of wood (g C per g of biomass). But the error in the estimation of the amount of carbon far exceeds the error resulting from the simplification is the use of a constant coefficient for conversion of biomass carbon (Joosten et al., 2004).

The measurements made on living trees carried out in a systematic inventory typical diameter and tree height were recorded for each area. To estimate the amount of carbon in dead wood, measurements are more complicated because the decay status influences the amount of carbon that remains in the wood (Olajuyigbe et al., 2011). The inventory should be made taking into account the quantity and quality of dead wood, which is done typically by classifying the dead wood into decomposition classes.

In the Giumalău secular forest, the amount of dead wood is very high (Figure 1) and has a high degree of spatial variability within the plot studied. Here, we studied the relationship between the degree of decomposition and the wood density. This study was needed to convert the quantities of carbon stored in the deadwood. The study was published in a scientific article (Teodosius & Bouriaud, 2012).

Two categories were distinguished: deadwood on the ground and standing deadwood. Wood density for each of the 5 classes of degradation is unknown, but it is not documented in European beech neither. After Mund and Schulze (2006), we assumed a decreasing linear density from class 1 to class 5, of 558 kg / m<sup>3</sup> to 62 kg / m<sup>3</sup>. The volume was deduced from the dimensions recorded in the inventory circle of 200 m<sup>2</sup>. The diameter of each piece was measured at the middle of the pieces. Standing dead wood was recorded in the same manner as living trees (diameter, height). Stocking density was the same as the one used for living trees.

### 4.2.2 Estimating the carbon stock dynamic

#### Retrospective analysis for the recent period

Estimating the amount of carbon stored and its dynamics was based solely on dendrochronological methods. In the case of permanent areas, the estimation of the growth of trees is made by a simple comparison of the size of the tree (especially the diameter and total height) in the sample plot. This method has proven to be the safest, but requires the use of permanent plots (pre-established), which was not the case in the project. Dendrochronological measurements arise in this context, as the best way to make estimates of tree growth. The purpose of the measurements is to estimate the diameter at each remeasurement occasions, usually 5 years. Increment cores all trees were sampled (at breast height - 1.3 m, considered standard). The methods and purpose of the dendrochronological analyzes implemented here differ substantially from those generally pursued- to get long series of wide growth rings, which are processed to extract an annual or multi-annual signal common trees studied. To this end, often oriented towards climatology, dendrochronological techniques aim to extract information about climate variations by converting annual growth in some indices with specific characteristics such as the absence trends, constant variance etc. Here, the research did not focus on one type of trees (e.. dominant), but on all trees, because each has a specific contribution to the biomass or carbon growth of the stand. A new method was applied here and developed in a scientific article under review: Babst et al. (Dendrochronologia log evaluation).

#### Long-term retrospective analyses

In the context of a short-term carbon stock analysis, the carbon input is the trees recruitment and growth, while the output is mortality. Tree mortality is one of the most difficult factors to consider since dead wood is an element that degrades quickly. Previous studies have demonstrated the importance of timber harvest losses, and the inclusion of studies related mortality of a forest carbon budget. For the natural stands studied, tree losses by cuts are zero. Standing dead trees will be included easily in the inventory survey.

Detection of disturbance that could have occasioned a change in the number of trees in an area can be made based on dendrochronological data analysis. More details in the method can be found in Bouriaud & Popa (2007) and Svoboda et al. (2013).

### 4.2.3 GHG Monitoring

Studied gases are the main ones, usually issued by a forest soil: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O. The method chosen for this project is one based on respiration chambers, four for each sample site.

In strict terms of physical properties, nitrous oxide is, among these three gases, the one with the greatest capacity to capture ultraviolet radiation: global warming potential (GWP) is 298 times higher than the dioxide carbon (Lashof & Ahuja 1990). The carbon dioxide is, in absolute terms, the second-most important molecule in the greenhouse effect, after water vapor, despite a low global warming potential. Methane has a GWP's value much higher than CO<sub>2</sub>.

The fluxes of carbon dioxide and methane are part of the carbon cycle. The ecosystems' carbon budget is based on three main streams: the input, through photosynthesis, the allocation and the output. The carbon budget can be estimated by monitoring the fluxes, this method being used on a large scale through the "Eddy covariance". In this method, the gas flows exchanged (emitted or absorbed) between ecosystems and the atmosphere is measured directly using concentration analysis devices above the canopy of the trees, in addition to expensive micro-meteorological measurement devices. These devices - and their tower - are very expensive and do not allow to be analyzed more surfaces. Although this method was considered as the reference method to estimate carbon balance at the stand, recent research has demonstrated the limits of the method, especially its tendency to overestimate the amount of carbon absorbed (Curtis et al., 2011).

The budget can be expressed as the difference between the stock observed at two different times. This approach is the least expensive and currently only allowing analysis of a great amount of plots. The principle is to convert the measurable characteristics of the trees in a stock of carbon.

## 5 Results

### 5.1 Carbon stock estimations

In the Giurnalău secular forest, the amount of dead wood is very high (Figure 1) and has a high degree of spatial variability within the plot. Here, we studied the relationship between the degree of decomposition and the wood density. This study was needed to convert accurately the quantities of carbon stored in dead wood in this natural forest. The study resulted in a scientific article (Teodosius & Bouriaud 2012). Specifics of natural mountain spruce forests is given great quantities of dead wood, and support biodiversity mediator.

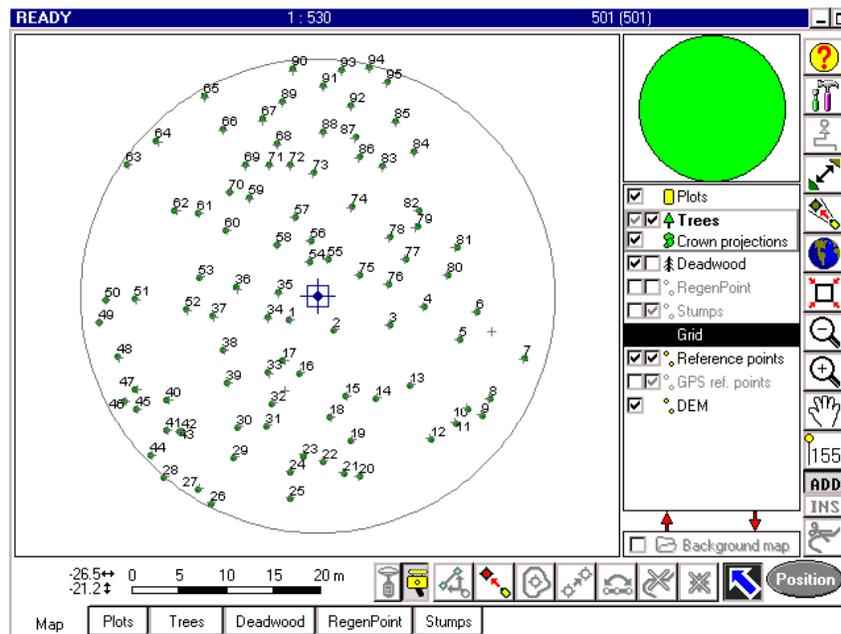
Dead wood is a key component of primary forests, which plays an important role in carbon sequestering and its cycle. The estimation of the deadwood stock is based on volumes - easy to measure - into dry weight using conversion factors associated with the level of decay. Little is known about the specific dry density of dead wood in primary forests of spruce (*Picea abies* (L.) Karst), especially in temperate mountain areas. For such forest were studied changes in specific density and standing dead wood on the ground in northern Carpathians. Using a balanced sampling (15 samples) were recorded piece size, the percentage of rot and decayed degree in two classes for standing timber and 8 classes to the ground. The sampling position (top, middle, bottom) and the contact with the soil were considered as additional explanatory factors. Classification of dead wood degradation was intentionally high ground in order to test an optimal number of classes degradation. The results of this study were published in Teodosiu and Bouriaud, 2012.

**Tabelul 1.** Comparative values of the quantities of carbon stored in trees studied:

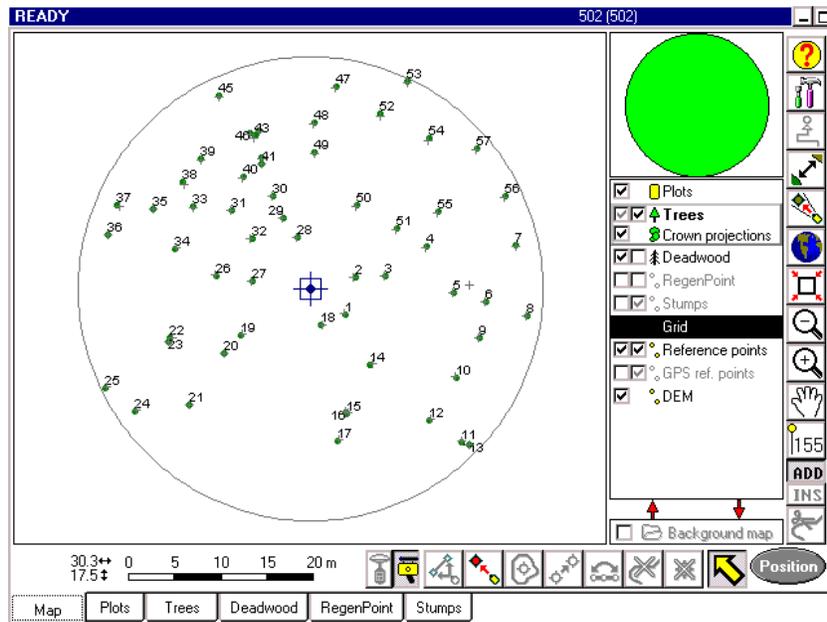
Region	Plot type	Max biomass of a single tree (t)	Biomass mean/tree	Biomass living trees (t.ha <sup>-1</sup> )	Biomass dead wood (t.ha <sup>-1</sup> )	Total biomass (t.ha <sup>-1</sup> )
Vest (Nera)	1 - natural	9.36	1.48 ± 1.63	458.35	20.78	479.13
	2 - natural	8.63	1.21 ± 1.43	488.77	52.61	541.38
Vest (Văliug)	3 – cultiv.	1.95	0.91 ± 0.39	306.72	9.13	315.85
	4 – cultiv.	2.42	0.93 ± 0.53	166.98	7.52	174.50
Est (Giumălău)	1 - natural	4.89	1.55 ± 1.43	228.82	84.59	293.41
	2 - natural	5.95	1.26 ± 1.19	245.54	74.42	309.96

From biomass estimates made it is noticeable that the stock is largest in natural beech stands.

In the forests of the southern region, the focus was put on the natural beech stands. In thies stands were placed two circular sample plots with size of 2000 m<sup>2</sup> each, where the inventory and and the increment core extraction of all trees was undergone. FieldMap inventories were made using equipment consisting of computer field (Tablet PC) Laser equipment (for measuring horizontal distances and vertical angles) and electronic compass (for measuring horizontal angles). Fig. 1. și Fig. 2. present the spatial distribution of the trees inventoried within each plot:



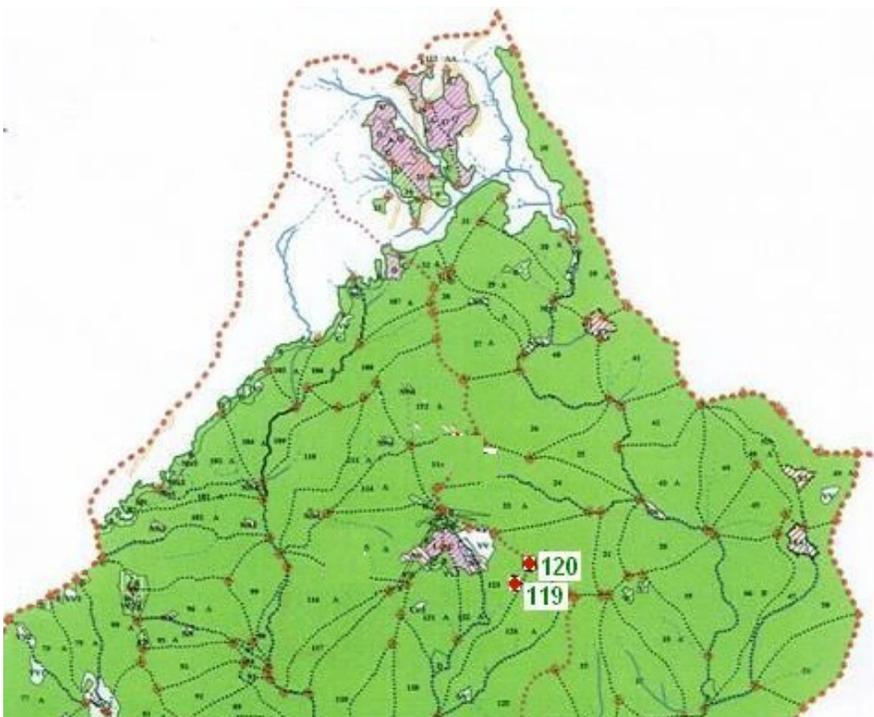
**Figura 1.** Stand map for plot 1



**Figure 2.** Stand map for plot 2

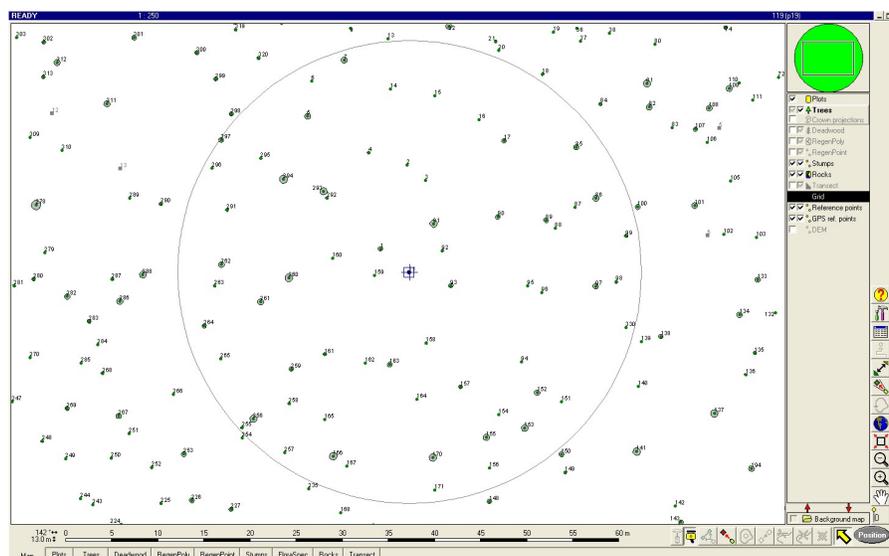
### Measurements made in natural beech forests

One of the most important locations of the project is the natural beech forests of the Nera springs contained in the nature reserve of the same name. In the Nera Springs Nature Reserve was installed monitoring plots that present as many similarities as possible with the cultivated forest in terms of exposition, slope, soil and elevation.

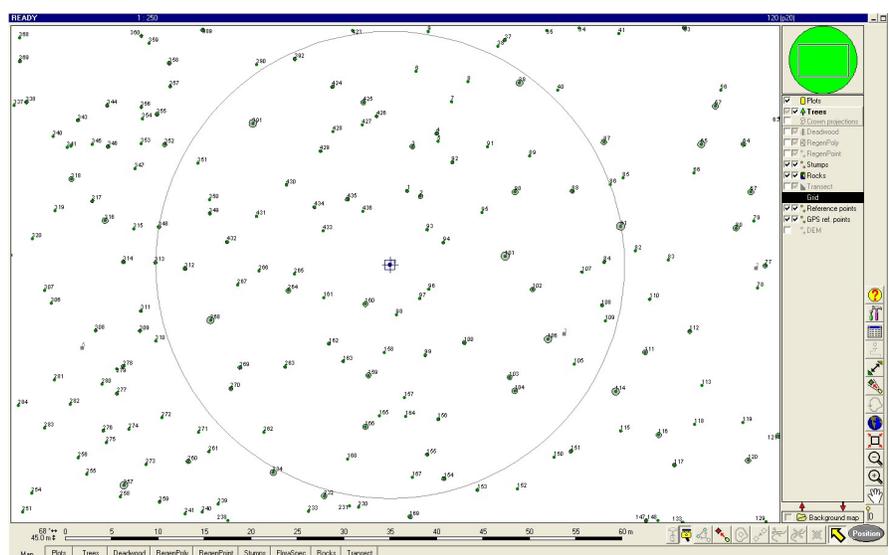


**Figure 3.** Location of the experimental plots in the Nera Forest Reserve

Au fost efectuate măsurători biometrice în cele două suprafețe de probă folosind echipamentul FieldMap:



**Figura 4.** Distribuția spațială a arborilor cuprinși în suprafața de probă GHG, ca sub-plot al suprafeței de probă permanentă P119



**Figura 6.** Distribuția spațială a arborilor cuprinși în suprafața de probă GHG, ca sub-plot al suprafeței de probă permanentă P120

For the natural forest, we obtained the following estimations:

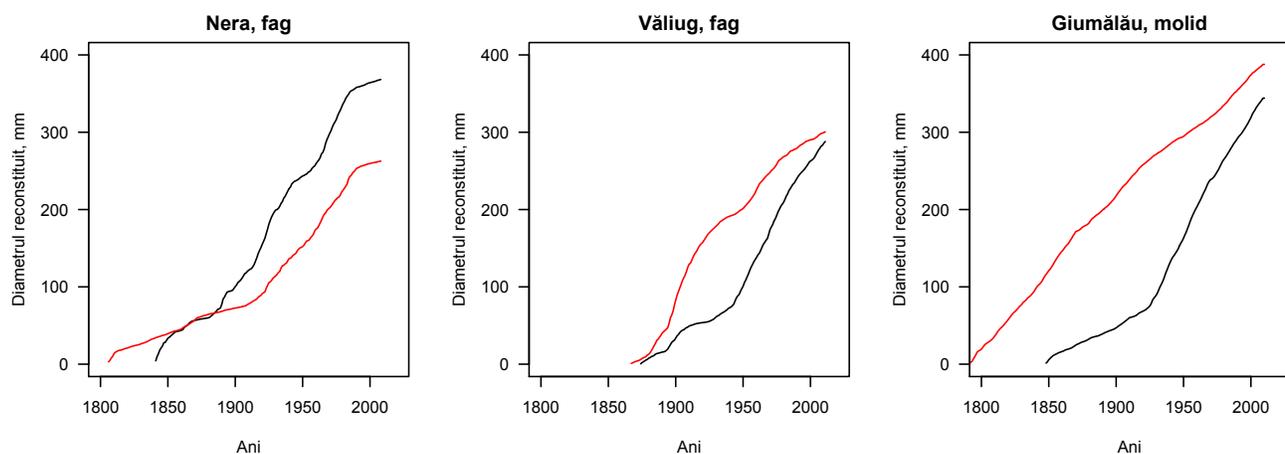
**Tabelul 3.** Valorile la hectar ale numărului de arbori, suprafeței de bază și al volumelor

Plot	Trees/ha	Bazal area, m <sup>2</sup> /ha	Standing volume, m <sup>3</sup> /ha
119	311	44	715
120	406	43	589
Media	359	44	652

## 5.2 Carbon stocks dynamics

### 5.2.1 Retrospective analysis

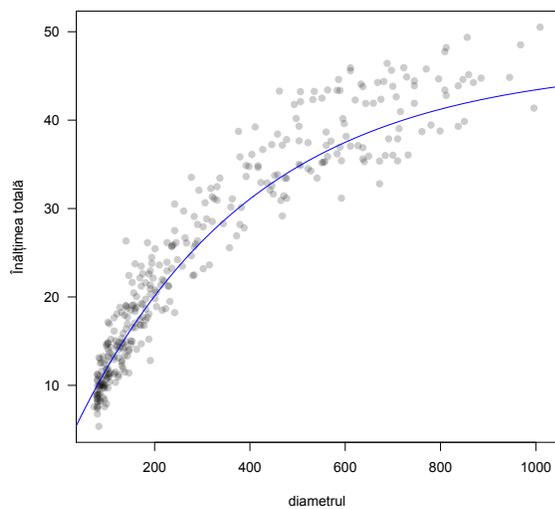
The estimations of carbon stocks in the forests studied used a methodology based on dendrochronology (Cook 1987). Unlike the classical dendrochronological studies, the estimation of the carbon stock dynamics do not focus on dominant trees and the variations reflected by the annual ring width variability are not standardized to remove some internal factors such as age. The sampling conducted in the reconstruction of radial growth at the stand must take into account the high degree of differentiation in the growth rate of trees that are not focused on a small number of large trees, but trees include all sizes. Systematic sampling is the most appropriate, in this case. An adequate method of sampling and data processing devoted to reconstruct the productivity of stands (in the carbon balance) was therefore developed and is described in detail in Babst, Bouriaud & Frank (2012) and applied in the project stands studied (Fig 5).



**Figura 5.** Examples of retrospective diameter reconstruction with different growth rates of the 3 regions studied

The reconstruction of the carbon stock dynamic in a stand involves the application of biomass equations, which are generally depending on the diameter of the tree (including bark). In our case (beech), it was observed that the bark width variability can induce errors in historical reconstruction external diameter trees. Indeed, the method of reconstitution of the diameter is based on either the assumption of (i) the width of the bark is proportional to the diameter, or either that (ii) increasing the bark is proportional to the radial width of the ring. These two hypotheses were proved to be documented beech, being specifically studied in the project. In this respect, were taken 240 samples of bark, to see which of the two hypotheses is the most plausible. The study results led to writing a scientific article nearing completion, submitted for evaluation: Turcu, Bouriaud & Ponnette 2013 (in preparation).

The retrospective estimation of trees biomass (or converted into carbon stocks) requires the reconstitution of the total tree height - the second input element in the functions applied (volume or biomass directly). The increase in height must be deducted from the radial growth as growth trees is not documented. For stands studied was established curve heights depending on the diameter, using an exponential model derived from logistic models. Adjustment method is presented for Parresol et al. (1999) for nonlinear models showing a heterogeneity of variance (heteroscedasticity) and are based on weighted iterative adjustments according to heteroscedasticity observed at each step. The equation is adjusted with Gauss-Newton iterative algorithm based on likelihood optimization. As for models with predictive purposes, it is necessary to establish statistical estimates to meet the essential criteria: absence of bias, residual variance constant. The analysis of the residuals PRESS was performed.



**Figura 6.** Height-diameter observation points and modeled height for the plot 1 Izvoarele Nerei

### 5.2.2 Disturbance analysis

The results have been published partially in Svoboda et al. 2013 (publicat 2013/8/1 în *Journal of Vegetation Science*):

[Landscape-level variability in historical disturbance in primary \*Picea abies\* mountain forests of the Eastern Carpathians, Romania,](#)

Authors: Miroslav Svoboda, Pavel Janda, Radek Bače, Shawn Fraver, Thomas A Nagel, Jan Rejzek, Martin Mikoláš, Jan Douda, Karel Boublík, Pavel Šamonil, Vojtěch Čada, Volodymyr Trotsiuk, Marius Teodosiu, Olivier Bouriaud, Adrian I Biriş, Ondřej Sýkora, Petr Uzel, Jiří Zelenka, Vít Sedlák, Jiří Lehejček.

Minor disturbances are predominant in Giumalău, the major ones being detected in about 36% of the plots studied. Beyond the variability between plots, common periods of disturbance occurrence were identified (1800 – 1830, 1820 – 1850, 1840 – 1870, 1900 – 1930, 1950 – 1980).

The multivariate analysis of the disturbances show occurrences widely distributed in space, with no distinct groups that reflect similar stories. The ordering explained 96% (non-metric compensation) of the variance of the raw data and confirmed their high spatial variability.

The assessment of the physiographic attributes explaining the disturbances history has shown that elevation was correlated weakly but with axes ordering ( $r^2=0.29$ ,  $P<0.001$ ).

The results of this analysis were compared with the records of history disturbances recorded in forestry archives, especially those with high severity in the last 200 years. Historical data suggest that storms and bark beetles are the most important agents of these disturbances.

The highest peaks of disturbances in this study (1800 – 1830, 1820 – 1850, 1840 – 1870, 1900 – 1930, 1950 – 1980) coincided with major storms and insect outbreaks.

Previous studies have shown a tendency to a spatial aggregation of the disturbances with high severity at landscape level, when these are determined mainly by wind (Frelich & Lorimer 1991; Foster & Boose 1992; Kulakowski & Veblen 2002; D'Amato & Orwig 2008). This may explain the predominance of low synchronicity at major disturbance levels (Panayotov et al. 2011, Foster & Boose 1992; Frelich & Reich 1995; Kulakowski & Veblen 2002; Stueve et al. 2011).

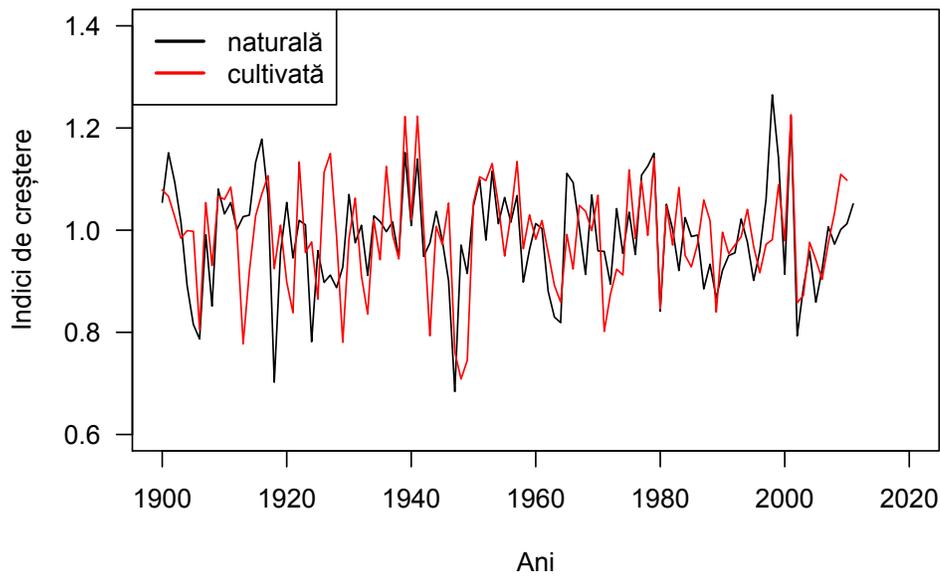
Many areas of the landscape in the studied site did not show the presence of severe disturbances, but rather a disturbing history of low and intermediate severity. An example is the 1950-1980 period, when a significant number of low-disturbed areas showed moderate to considerable spatial variation in the stand.

In conclusion, the base scenario is a regeneration of the forest based on small gaps (gap recruitment) for over 80% of the area studied. More than half of the plots has experienced severe disturbances in the past, but these events were not synchronized in time or space.

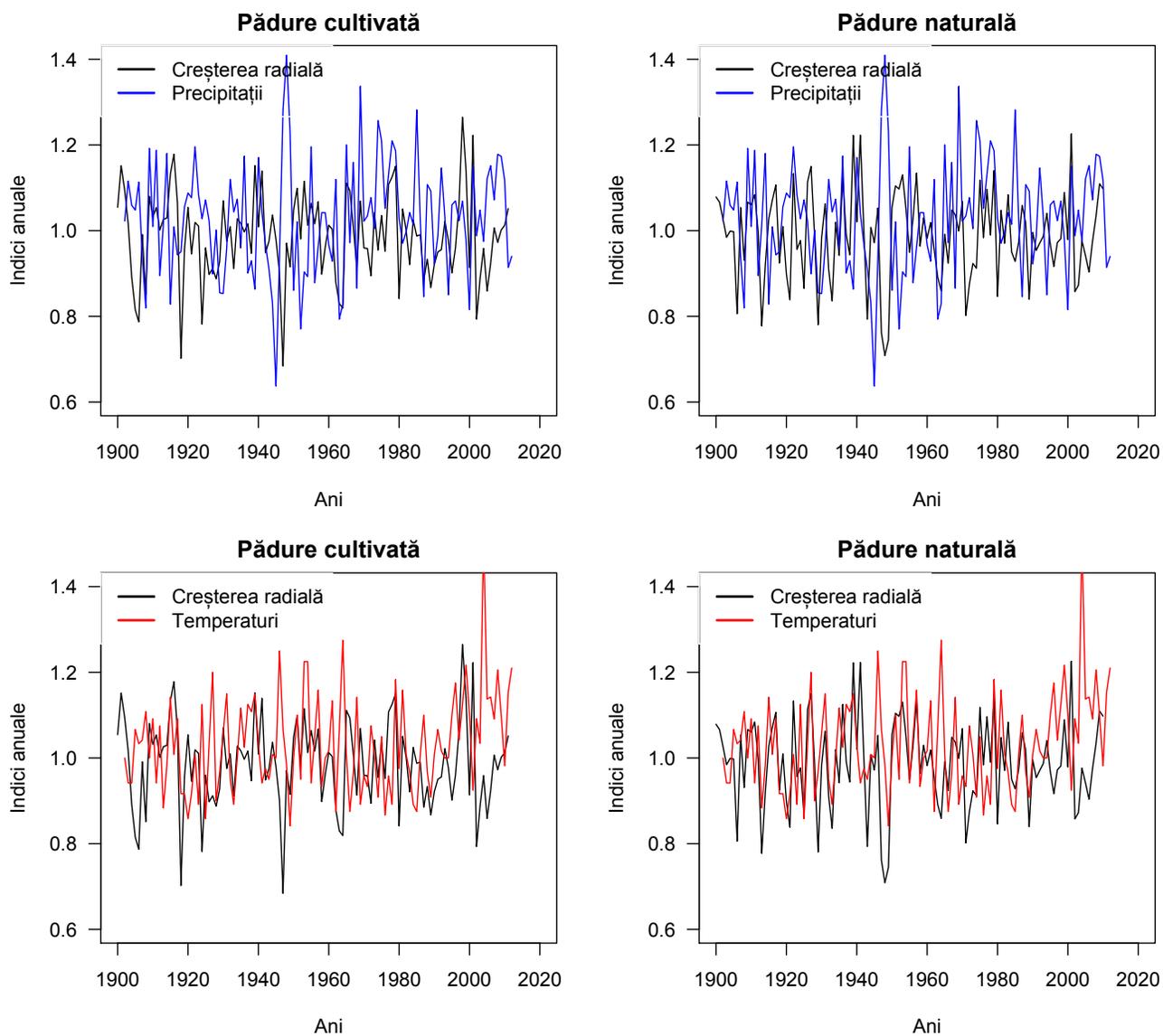
### 5.2.3 Climate-growth relations

The climate is a key determinant of forest productivity. Fluctuations in weather and climate determine annual to multiannual variations of tree growth, which is further reflected in carbon stocks through several mechanisms.

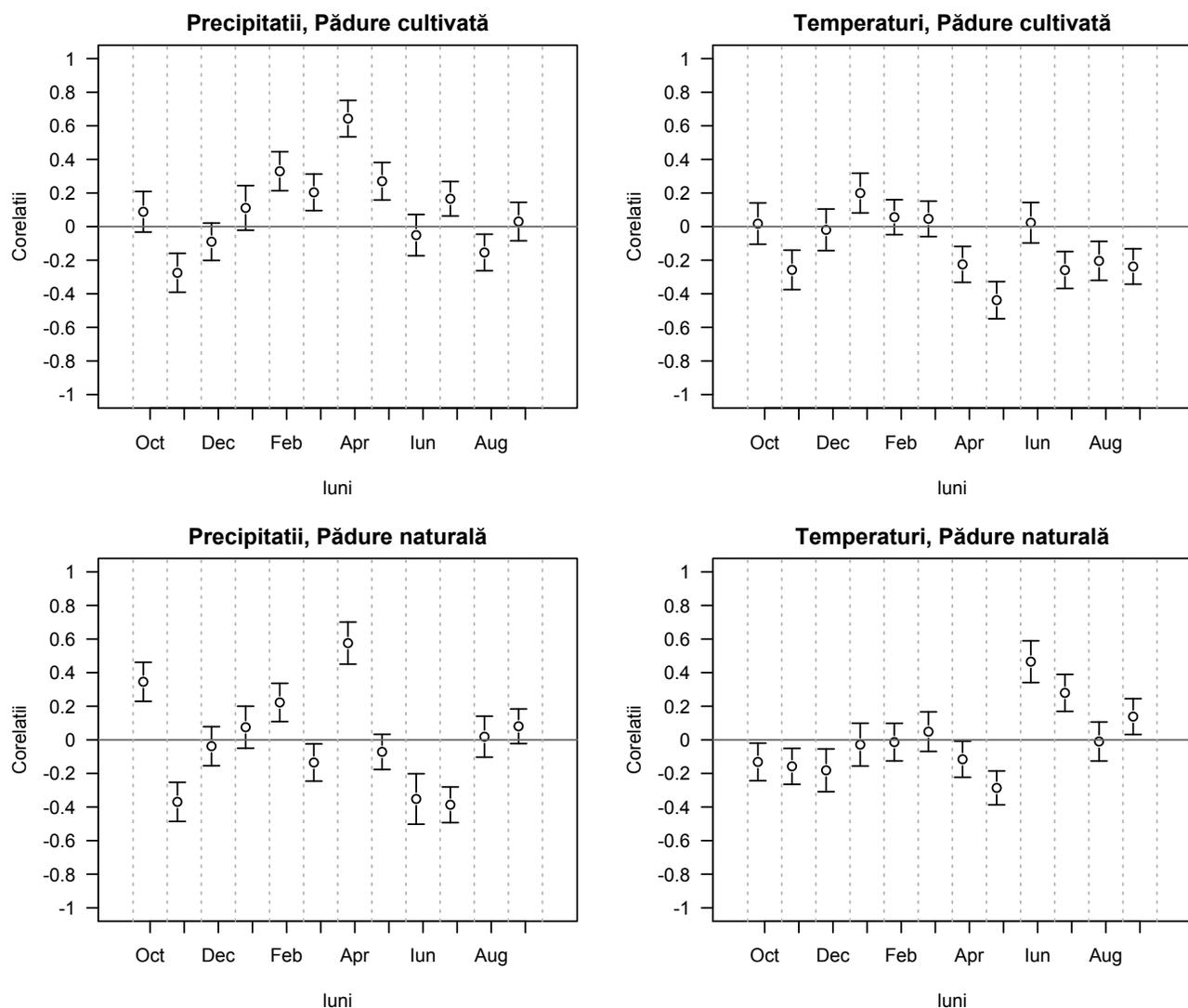
Standard dendrochronological methods are long-established (eg Cook 1987) and very well documented: individual series gross growth ring width are processed to extract only annual variations. It thus generates a set of indexed individual series, which vary around 1 and with constant variance over time. This series of indices of growth, reflecting the variation of radial growth of trees one year to another, are further assembled to constitute a so-called timeline. The usual method is to calculate an average index (a value for each year), using a weighted average iterative, whose aim is to reduce the influence of extreme values we considered plausible. Chronologies developed (eg Fig 7) is such variability average growth of trees in a experimental site. In the project, 4 such chronologies were developed: two for each monitoring area, one in natural forest, one in forest cultivation. Chronologies are correlated with local climate data by simple linear correlation, calculated on subsamples of 66 random (bootstrap method), the entire length of climate series (1901-2012).



**Figura 7.** Comparison of growth indexes obtained for natural and managed or cultivated forests of beech in the NW experimental sites.



**Figura 8.** Comparison of the growth variations and climate fluctuations for natural and managed forests of the NE region (spruce stands)



**Figura 9.** Response to climate of the natural vs cultivated spruce stands (Giurnalău, NE experimental plots)

As the correlations of monthly climate data, April is one of the most important precipitation month, which is explained by substantial water demand at the start of the growing season. Later, temperatures become more important and positive influence on tree growth. The forests studied are indeed located at altitudes where temperature is the most limiting. One can see a clear difference between natural forest and cultivated forest, although altitudes are appropriate. This element is fundamental to explain the differences in dynamic development stands.

This study will be further deepened because it has a high potential for publication.

### 5.3 GHG flux monitoring

Using manual respiration chambers, the monitoring was conducted in the 10 areas established under the project. The collection of gas samples was performed according to accessibility and weather conditions: at least one series per month was collected at each plot.

The year 2012 was a very special year in terms of climatological and unfortunately very unfavorable monitoring. The soil was too dry for the respiration to be monitored. In addition, drought has induced problems the tightness of the rings, some cracks in the soil being already visible in June. Insufficient rains led to a rapid drying of the soil. The soil is dry faster even after heavy rains, which were too few, the wind quickly dried top soil so that the top 5 cm were almost always dry. The temperature is described as the main element in determining the intensity of respiration. Decomposition of organic matter is indeed known to be temperature dependent. But in severe

drought conditions such as those encountered in 2012, the drastically reduced moisture probably hampered the biological activity. In contrast, in 2013 growing season was very wet and will highlight a significant increase in emissions.

The gas field sampling is accompanied by detailed measurements of soil temperature and humidity (Fig. 10), necessary for the conversion of concentrations into fluxes.



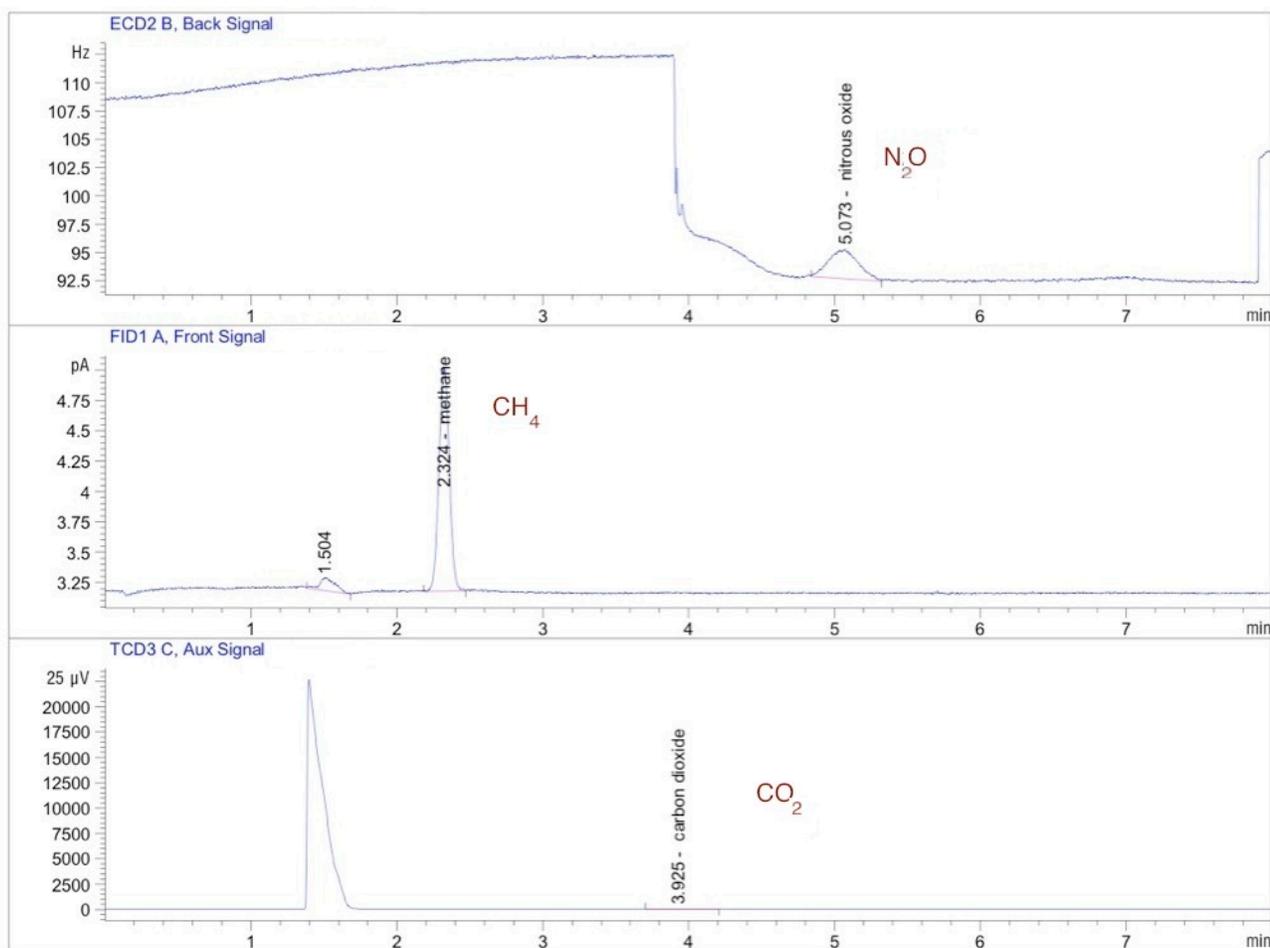
**Figura 10.** Left, closed respiration chamber for gas sampling. Right, locating the four rings used for monitoring each in the natural spruce forest Giumalău.

The samples obtained are sent to the laboratory for analysis (ICAS Mihăiești), where the concentration of gas contained in the vials is estimated by chromatography (Figure 11). There are therefore four chambers or repetition for each sample plot, and five successive vials are taken per chamber.



**Figura 11.** The gaz chromatograph Agilent, installed in the laboratory, housing 3 sensors: ECD, FID and TCD.

After installing and calibrating the chromatograph were obtained first chromatogram (Figure 4) , by using the information processing chromatograph specific chromatograph from Agilent ChemStation, USA, but the gas concentration in vials was initially not trustable. A number of technical problems occurred with continued measurements, such as power surges. These problems have caused the shutdown chromatograph for a longer period. The vials obtained through field monitoring are stored and inert, so it will not cause problems such as the loss of measurements, but only delays to be recovered.



**Figure 4.** Example of chromatograms obtained from a sample of gas collected in the field. Each sensor generates a specific graphic element.

## 5.4 Dissemination and collaborations

### 5.4.1 Collaboration with Max Planck Biogeosciences, Jena, Germania

A tight collaboration has established with Professor E.-D. Schulze, director of the Max Planck Institute Biogeosciences, known as one of the leading researchers in the field. Professor Schulze is studying a forest located in a Natura 2000 site, in Fagaras, which has similar characteristics to those studied in the project: much of the forest has been undisturbed in recent centuries. Thus, an exchange of experience and discussions about the ability of these forests to store biomass and carbon. The rich discussions led to writing a scientific article published in the only ISI forest journal in Eastern Europe: *Annals of Forest Research*.

### 5.4.2 Collaboration with the Institut National de la Recherche Agronomique, Nancy, France

During summer 2013 we organized a monitoring visit to eastern areas (Giumălău), involving researchers from the Institut National de la Recherche Agronomique: André Granier and Charlotte Grossiord. André Granier is the inventor of the method of monitoring the flow of sap in trees. Sap flow is the main element that determines trees evapotranspiration, and hence photosynthesis. This visit was to promote the research conducted within the project and to discuss the possibility to undergo sap flow measurements in the future.

### 5.4.3 Collaboration with the institute Wald Schnee und Landschaft WSL, Zurich, Elveția

In October 2013 organized a monitoring sampling in areas of west (Nera) and eastern (Giumălău) in an informal collaboration with researchers from the Swiss Institute WSL (Swiss Federal Research Institute) and David Frank, head of the dendroclimatological team. The aim of the collaboration is to contribute to a European-level project aiming at collecting cores for isotopic discrimination trees. Carbon Isotope Discrimination for  $^{13}\text{C}$  is, indeed, a synthetic indicator of the physiological activities of trees. Discrimination varies in terms of water during photosynthesis, the fine indicator of the occurrence of water stress caused by drought. These measurements will be complementary to those planned and carried out under the current project. Contribution was to provide data and the creation of plots on which were extracted the increment cores.

### 5.4.4 Publications

#### - Articles in ISI journals

Teodosiu M & Bouriaud O. 2012. Deadwood specific density and its influential factors: A case study from a pure Norway spruce old-growth forest in the Eastern Carpathians. *Forest Ecology and Management*, 283, 77-85.

Walentowski et al. 2013. Sustainable forest management of Natura 2000 sites: a case study from a private forest in the Romanian Southern Carpathians. *Annals of Forest Research*, 56(1), 217-245.

Svoboda et al. 2013. Landscape-level variability in historical disturbance in primary *Picea abies* mountain forests of the Eastern Carpathians, Romania. *Journal of Vegetation Science* 25 (2), 386-401.

#### - Articles in IDB

Turcu et al. 2013. Litter and humus amounts in a beech natural forest. *Journal of Horticulture, Forestry and Biotechnology*, 17(2):181-184.

Turcu D. in press. Tree mortality processes in natural forests. *Journal of Horticulture, Forestry and Biotechnology*.

#### - Articles in evaluation

Teodosiu & Bouriaud. *Oikos*

Babst F, Bouriaud O, Ross A, Trouet V & D Frank. Towards consistent measurements of carbon accumulation: A multi-site assessment of biomass and basal area increment across Europe. *Dendrochronologia*

## 6 Conclusions

Analysis and monitoring were established as planned and all proposed measurements were made. Scantlings implementation had to assess carbon stock in stands dominated by beech or spruce forest areas and forest vegetation.

Estimates of stock and dynamics are still in phase of realization, but more elements have already been published.

We studied specifically the density of dead wood in forests of spruce, because the quantities of dead wood are very important in terms of quantity (and quality to the relationship with biodiversity).

Monitoring greenhouse gas fluxes benefited from more favorable conditions, 2013 was a more rainy year, which followed a dry year, thus providing an important contrast. Emissions are expected to be higher in 2013, allowing discrimination of the forest types studied. Difficulties related to the operation chromatograph are also pending but we the measurements of all the samples collected will be done in time.

More articles are in progress. A fair share of the project was to collect data since the project covers original and undersampled situations. The first years of the project had, therefore, to be devoted to realizing measurements, obtaining the data sought. The last parts of the project will be more favorable to publications since the data bases start to be populated. Publishing will remain the priority of the team.

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