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Proiect IDEI 111/5.10.2011 „Forest GHG management”

Instituţia: Institul de Cercetări și Amenajări Silvice

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Conţinut

Summary

Carbon storage has become an new forest management goal taken into account after scientific researches have shown that forests play an important role in the carbon cycle. Storage and storage dynamics are increasingly well documented, but the impact of forest management on storage is not well known. Among others, current researches lack measurements on natural forests, which can constitute a reference or control treatment in studying the impact of forest management. The project aims to bridge to this gap, taking benefit from the existance of natural forests in Romania. The research method is based on the one developed within the European project "GHG Europe" (www.ghg-europe.eu), aimed exclusively at beech forests, but the "Forest GHG management" European project extends and complements the coverage by analyzing forests rarely studied: natural forests, reforestation and clear cuts.

Initially, 10 plots were chosen for this study, of which 4 in natural forests and planted forests 4 appropriated from geographically and ecological conditions, in order to grasp the impact of management on carbon stocks and fluxes of greenhouse gases emitted ground. The other two areas were not considered due to the strong reduction of the project's budget.

In the earlier stages of the project, dead wood density was studied. The density is a key factor to estimate carbon stock, which is very important here since the amounts of dead wood is especially high in natural forests. The results were published in a journal ISI. Was also analyzed the dynamics of biomass stocks, based on dendrochronological methods and measurements in an international working group. Since conventional methods do not fully correspond dendroecological purpose study proposes a new methodology was published in 2014.

The current phase of the project consisted in two activities:

- a first activity was focused on monitoring greenhouse gas fluxes. Monitoring consisted in the collection of samples of gases emitted from forest soils with manual chambers. Chromatography analysis allowed the determination of these fluxes. Results from previous years were presented at an international conference. The measurement of the gaz concentration in the vials was achieved as planned and laboratory data processing is in progress.

- The second activity is to achieve a synthesis of knowledge on forest carbon stock. Synthesis on carbon storage in dead wood was performed in the previous phase, the focus was now on the air live trees with established relationship between diameter and volume. Estimation of carbon stocks is based on the volume of trees in biomass conversion. The relationship depends on the wood density and the rate of growth of trees. The role of each component was studied. The study was valued in a scientific article under evaluation in a journal ISI.

Currently, 2 articles are in evaluation and 3 in progress. The priority at the beginning of the project was given to the measurements. Publications are now possible, since the databases start to be populated.

The funding was reduced by 50% the last 2 years (2013 and 2014) which left barely sufficient funds to run the chromatograph (http://news.sciencemag.org/people-events/2013/04/romania-replace-national-research-council-after-mass-resignation). Apart from the impact on the GHG monitoring, the reduction of costs have also forced the team to invest on other projects to get the necessary funds.

1 Introduction

Forests are recognised as a major carbon pool, highly significant for both terrestrial ecosystems and globally. The estimation of the amount of carbon stored in forest is a priority for all countries signatory to the Kyoto Protocol.

Despite recent efforts, the contribution of forest ecosystems to carbon storage is not precisely known, nor is their ability to capture and sequester at long terms. Forest management is optimized for the production of wood, or for the fulfillment of environmental services such as protecting the land, but not for carbon sequestration.

The aim of this project is to gain insights on the relationship between the forest management and the carbon stocks and sink strength of forests.

2 Project aims and objectives

The effects of forest management on forests' carbon stock and carbon storage capacity is less documented and is in the global objective of this project. FP7 project "GHG Europe" (www.ghg-europe.eu), funded by the EU, aimed to determine how, and to what extent, the carbon cycle and greenhouse gas emissions (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 balance of greenhouse gas emissions in selected regions of Europe". Its task is to establish a gradient of management in beech forests to study the impact on the budget management of GHG. The gradient of management covers a wide range of management types but keeping confounding factors to a minimum.

The aim of the present project is to complete this management gradient with new unstudied situations in Europe, typical and relevant to Romania, namely natural forests and wooded pastures. The objective is to obtain data from experimental measurements GHG stocks and fluxes. 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 executed during the life cycle stands.

3 Project structure

The project is structured in two main activities:

- the first activity is the estimation of the aerial carbon stock dynamics in the forests. This work brings knowledge on forest carbon storage capacity and its sensitivity to forest management. In particular, attention was paid to carbon storage in natural forests, which is rarely assessed yet expected by the scientific community, because of the paucity of this type of forests, despite the fact that they represent a point of reference very helpful.

- The second activity is the monitoring of greenhouse gas fluxes from forest soils. The monitoring is also rarely performed, because the equipment requires a susbtantial investment of time. The two activities are complementary, since the soil remains uncovered by the first activity unless specific tests are performed.

4 Results

4.1 Carbon stock dynamic (sinteza)

4.1.1 Allometric equations

Carbon sequestration in forests is represented in its vast majority by the quantity of carbon deposited in the wood. Quantifications of the aerial forest carbon stocks requires a conversion of the easily assessed tree volume into carbon quantities. Typical measurements in the forest are diameter and tree height. The volume of the tree can be estimated with a sufficient degree of accuracy on the basis of these variables. Carbon mass is not directly related to tree volume, two conversion factors are necessary: first, wood density, and the second is the ratio of the total mass of wood and carbon mass.

The relationship between diameter, volume and wood density were studied on a set of very complete and detailed data. The equations obtained were applied to an independent set of data for estimating errors and error propagation successive models used (volume and density). The study was realized in a scientific article that is submitted for assessment in a journal ISI.

The estimation of the dynamics carbon stocks was based on dendrochronological methods. For typical dendrochronological analyzes, the main purpose is to determining the variability of tree growth in relation to some environmental factors such as climate, and are thus based on specific sampling designs, established long time ago (eg Cook 1987). These studies focus on dominant trees because these trees are, at least in theory, less sensitive to changes in tree density or to changes in the level of competition in the stand. Selecting trees for such analysis was therefore focused on the biggest trees in the stand or in the plot. Recently, it was shown that this type of sampling introduce deviations and even biases om dendroclimatic analyzes (Nehrbass-Ahles et al. 2014).

The sampling and data processing used in this study in order to reconstruct the productivity of the stand was developed and described in an article published in 2014 (Babst, Bouriaud & Frank) stands studied and applied in the project.

Using dendrochronological data carbon cycle research purposes was quite limited and rare (Bouriaud et al. 2005a). Published studies on this topic and have shown how converting biomass growth from dendrochronological measurements were often limited to one experimental site, and did not use a single method or homogeneous sampling. In the article published in the journal

Dendrochronologia, in contrast, we presented a dedicated sampling method estimates biomass carbon storage and comparison of growth estimates based on the base surface, as is done in various works, and increases in biomass. Although the deviations are minor, the study demonstrated a clear advantage for estimates based on biomass as form factor trees that are species-specific and variable, and wood density are integrated to estimate the biomass more properly.

4.1.2 Climate-growth relationships

Inter-annual climate variability has been shown to be the most influential environmental factor of trees productivity. Drought years are marked by a sharp reduction in growth trees, which translates to a low carbon sequestration that year. The impact of a strong climatic event may have implications for several successive years, the phenomenon being called in literature as "carry-over" effects. Some negative effects can be felt even more during the consecutive years than in the growing season when it occurred (delayed or lagged effects).

The study of relations between weather fluctuations and growth of trees is done by two different methods:

- Monitoring growth: meteorological parameters and radial growth of trees is continuously monitored with sensors (dendrometers)
- Dendroclimatological: retrospective analysis of growth based on increment cores.

These two methods differ in the spatial scale and time scale at which they are made. Monitoring growth requires expensive equipment which cannot be implemented on a large scale. However, the temporal precision and the frequency of the measurements allows intra-annual analysis of the relationship between growth and weather forcing, which is not feasible with dendroclimatological method based on retrospective analysis of annual ring width.

4.1.2.1 Continuous monitoring based on dendrometers

In this stage were analyzed some series of growth obtained from automated dendrometers. The dendrometers measured at an hourly or half-hourly step, depending on the model, changes in the diameter of trees sampled. The series of values that come from this type of record containing multiple sources of variation: at a fine time step, water status fluctuations can induce a contraction of the trunk; bark humidity, which is influenced by the air humidity and rainfall; and finally, the radial growth itself. The signal of interest, the radial growth, is not always the highest in comparison with the other sources. A first step to extract the increase in gross dendrometric series consists therefore in signal filtering.

Mainly there are two methods to estimate radial growth dendrometric series: the first is to use the maximum daily values (Bouriaud et al. 2005b), the second is the method by which one phase is associated to each of the variations (Deslauriers et al. 2011).

The second method was implemented in SAS program that describes each step of the calculation (Deslauriers et al. 2011). Unfortunately, SAS software is a very expensive and, therefore, used only in research. In contrast, R is free software and is becoming more widespread, with the advantage of being evolutionary and enable sharing data and code. Given the progress made in the analysis of time series and trends mentioned above, the work done in this phase was proposed and managed transcript of the SAS program in R, and improve it to make it fully functional.

By working with top researchers in this field, we are developing a new data processing program for dendrometers. Initial results were presented at the annual conference of COST STReESS

(Studying Tree Responses to Extreme Events: a Synthesis) dedicated to the study of the impact of climate extremes trees through an oral presentation entitled "Analyzing the time series of dendrometer Using date routines in SAS and R ". In addition, an article is developing Dendrochronologia magazine (ISI).

The functions programmed in basic R series permit processing and filling data gaps. An example is provided below (Figure 1), which presents variations in the diameter of a tree where some data are missing due to defects (the devices are very sensitive and any malfonction is sanctioned by loss of data). The first step in processing is to fill-in the incomplete series.

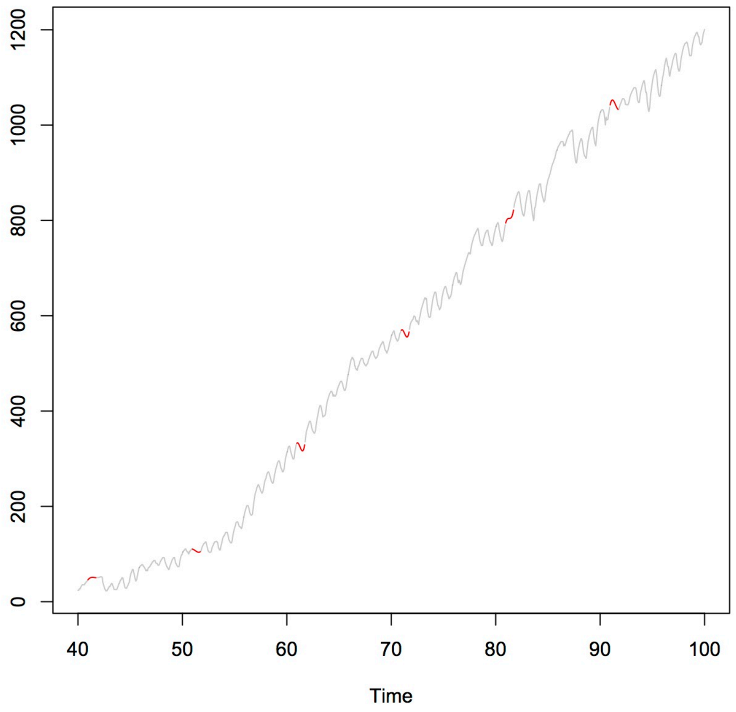

Figura 1. Changes in radial position as recorded by the dendrometers. Missing values are filled in red. The correspondence between the measured and interpolated to fill gaps is very good.

Once completed, the series are processed by a complex algorithm to distinguish the phases of growth (in gray in figure 2) and those of decrease. Phases of decreasing diameter are the result of contractions due to evapotranspiration, water discharging from the trunk faster than water entering through the roots.

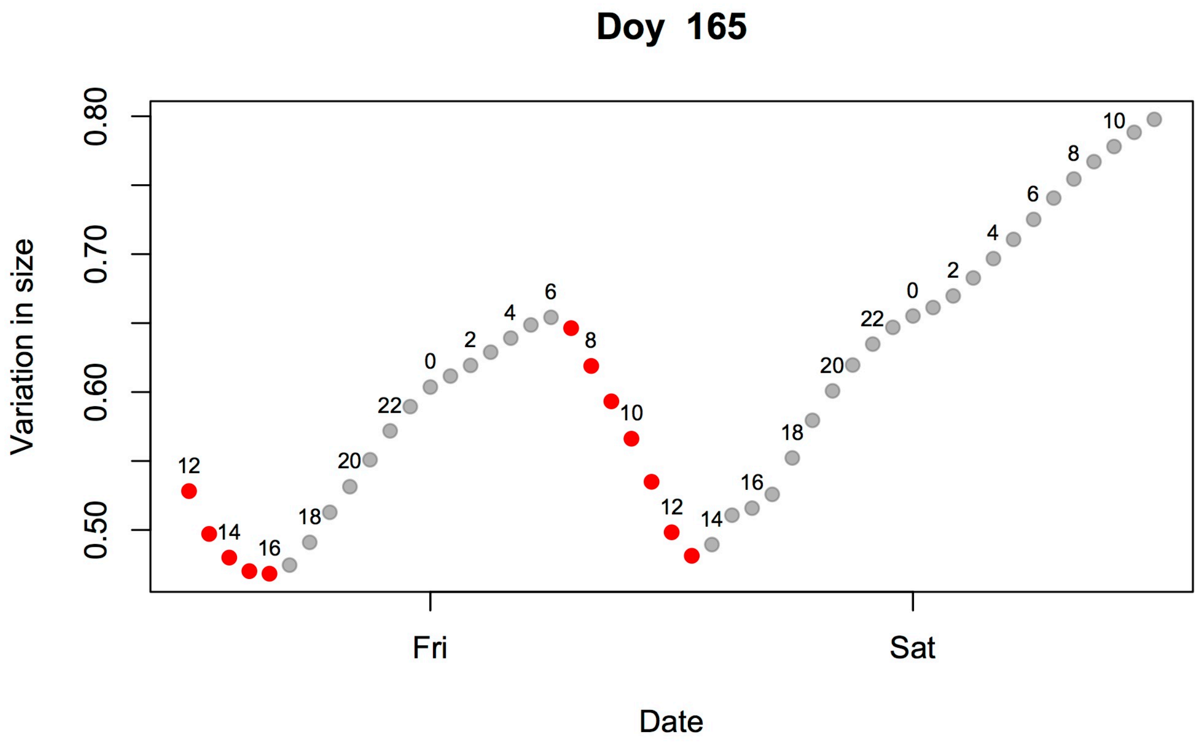

Figura 2. Example of intra-daily variations in diameter with two visible phases: growth, gray, and decrease in red. The numbers represent the hours (hourly average values are shown).

4.1.2.2 Dendroclimatology

Both methods are dependent on the purchase of weather and climate data quality. Some interpolated climatological data are available from (ex. Climate Research Unit, University of East Anglia) but because the accuracy of this data can be interpolated below the required limit analysis is required in addition to actual data and cofruntare measured. For this purpose were installed temperature sensors that record air temperature and soil with a very high frequency (every 15 minutes) and provide with high precision values of temperature variations (Figures 3-5). The sensors were calibrated before being installed in the field.

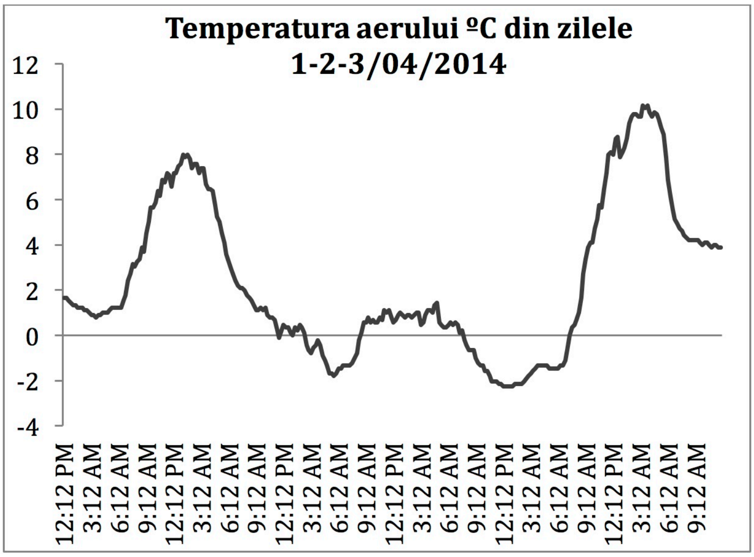

Figura 3. Example of intra-daily temperature variations recorded in step 15 minutes.

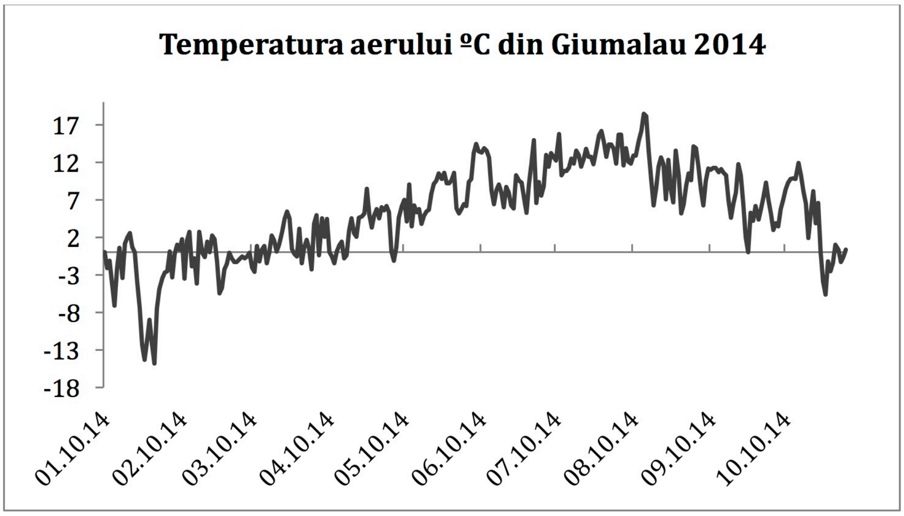

Figura 4. Example of intra-annual variations of air temperature.

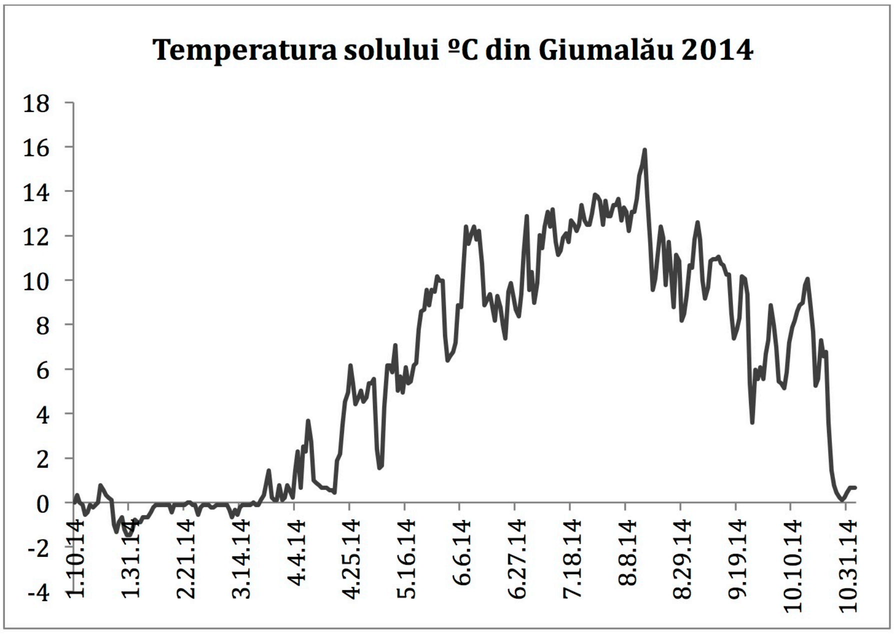

Figura 5. Series of soil temperature at a depth of 5 cm, automatic sensors recorded a 15 minute step

The local climatological data were calibrated based on the temperature series, needed to complete the comparative analysis of natural and cultivated forests growth series obtained in a previous phase of the project.

4.2 GHG flux monitoring

Activitaty 1.1 and 1.2: monitoring in natural forests of spruce and beech

The monitoring is based on manual chambers built by the team and used for the project FP-7 "GHG Europe". The project was set up 10 new monitoring areas which are rare and cases of interest to the scientific community worldwide. Collection of samples of gas was initialized by the end of 2011, but some areas were destroyed (in Campulung Moldovenesc, by a forest fire) and atypical constraining weather conditions in 2012 resulted in reducing greenhouse gas studied. Year 2014 was more favorable in this respect and monitoring was provided with an optimum rhythm.

During the gas collection are registered several parameters that allow analyzing the concentrations. Factors determining the emission gas field study are therefore measured at the start and stop collection: ambient air temperature and humidity, air temperature in the chamber breathing, soil temperature at two depths (Figure 6), soil moisture in the top 20 cm.

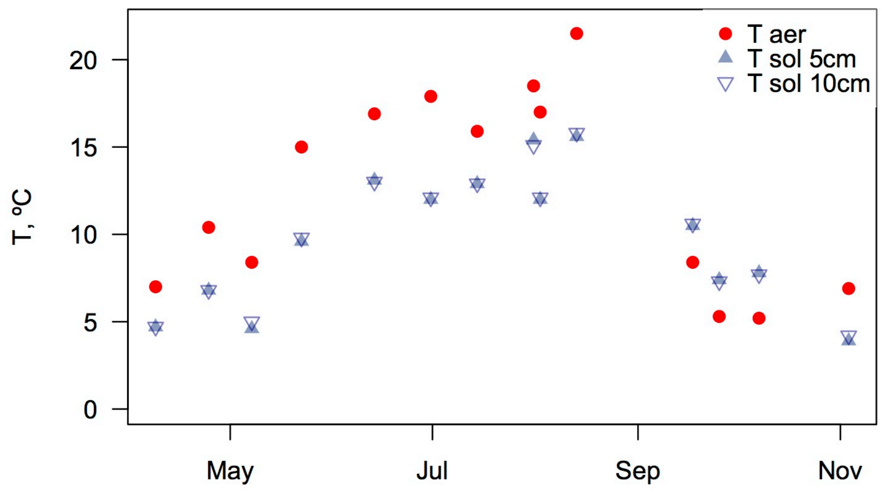

Figura 6. Changes in air temperature and soil from two depths at the time of sampling data in an plot of natural forest of spruce, Giumalău.

Vials of gas collected in the field are sent for chromatography analysis to the laboratory (ICAS Mihăeşti). The chromatograms produced are used to convert the successive gas concentrations observed in the vials into fluxes. Increasing concentrations studied gas chamber breathing, contained in vials taken at regular intervals and predetermined to be converted into flux. The chromatograms should be processed to deduce the flow by applying two corrections:

- First transformation is a correction that depends on the chromatograph. A correction factor between the concentration and the actual concentration reported in the chromatogram was calculated in a specific stage of calibrating the device. This ratio reflects the degree of absorption gas chromatograph studied (loss in the columns);
- The second processing unit of measurement. Values expressed in ppm or ppv must be converted into mass concentrations for flux calculations. Great transformation equation depends on gas-studied, and the conditions at the time of sampling (air pressure, air temperature). For carbon dioxide, the following formula was applied:

$$[CO_2]_g = [CO_2]_{ppm} \times P \times \frac{\frac{273.15}{22.4136}}{1013.25} / (273.15 + T)$$

where P is the atmospheric pressure expressed in hPa, and the air temperature T (ºC).

Once adjusted, the concentration may be used to calculate the effective flow, if any. Was used in this software package from the HMR R (Pedersen et al. 2010).

In this program, two types of relationships between concentration and time of sampling can be fit: a linear relationship and a non-linear. The difference between these two models is represented only in their form: non-linear model (Hutchinson and Mosier, 1981) is based on a hypothesis generating saturation retro-negative control manifested by inflection point and reaching a threshold:

$$C_t = \varphi + f_0 e^{-kt}$$

where k is the only parameter to be determined for exponential, f0 is the initial flow and steady-state concentration phi.

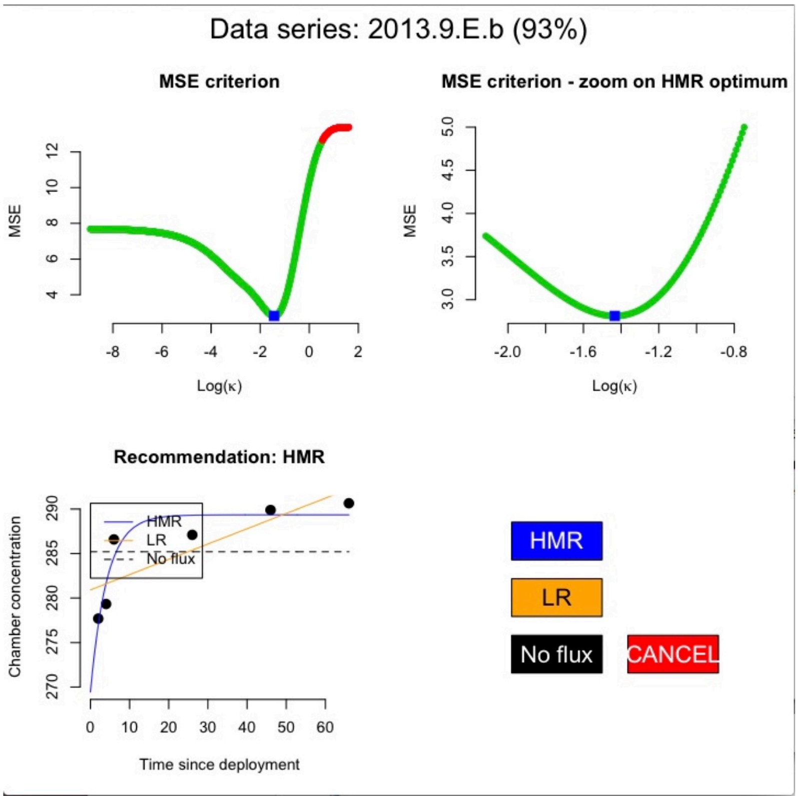

Figura 7. Example of the non-linear adjustment to the model in the measurement of the concentration of CO_2.

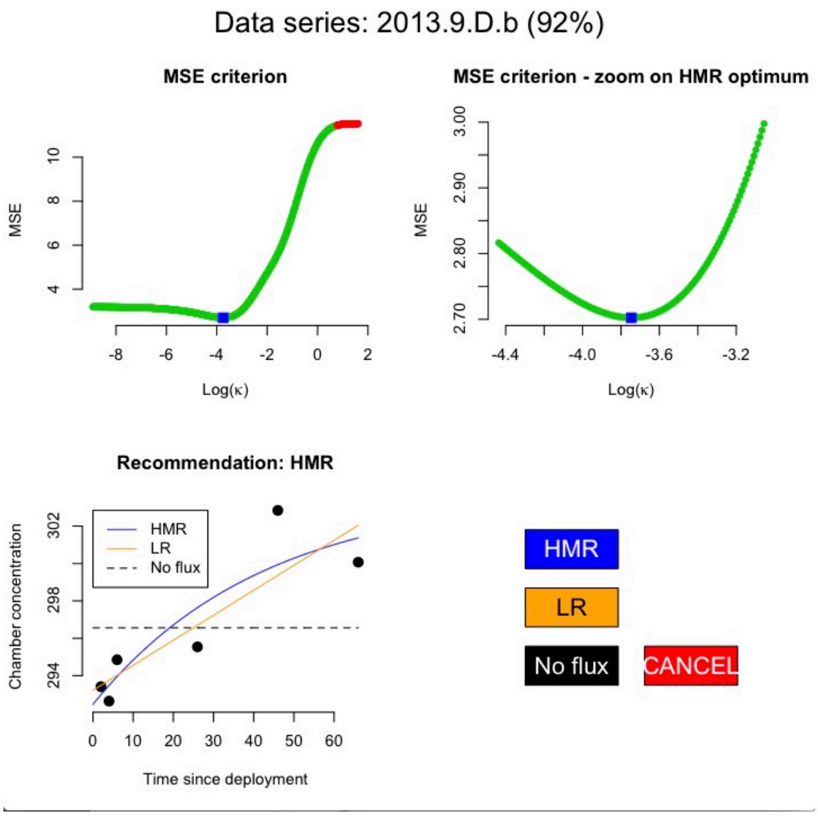

Figura 8. Example of the non-linear adjustment to the model in the measurement of the concentration of CO_2.

Flux estimates obtained from vials collected in previous years were used in a presentation in a conference organized in the UK (details in Chapter 4 on enhancement of research results).

4.3 Punerea în valoare a rezultatelor proiectului

- **Article in ISI journals published in 2014**

  - Babst F, Bouriaud O, Ross A, Trouet V, Frank D. 2014. Towards consistent measurements of carbon accumulation: A multi-site assessment of biomass and basal area increment across Europe. *Dendrochronologia*, 32(2), 153-161

  http://www.sciencedirect.com/science/article/pii/S1125786514000034

  - Schulze ED, Bouriaud O, Wäldchen J., Eisenhauer N., Walentowski H., Seele C., Heinze E., Pruschitzki U., Dănilă G., Marin G., Hessenmöller D., Bouriaud L., Teodosiu M. 2014. Ungulate browsing causes species loss in deciduous forests independent of community dynamics and silvicultural management in Central and Southeastern Europe. *Annals of Forest Research*, DOI:10.15287/afr.2014.273

- **Articles in IDB published in 2014**

- Merce O, Borlea GF, Turcu DO. 2014. Definitions and structural attributes of the ecosystems from natural forests - short review. *Journal of Horticulture, Forestry and Biotechnology*, 18 (2) 2014 114-120.

- Teodosiu M. 2014. Naturalitatea pădurii: concepte, caracteristici şi implicaţii asupra conservării. *Bucovina Forestieră,* 14(1): 68-76, *in press.*

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- Turcu DO, Merce O, Cantar IC, Cadar N. 2014. Specific management measures for the beech forest habitats from Western Romania. *Journal of Horticulture, Forestry and Biotechnology*, *in press*.

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- **internationale conferences**

  - COST Action FP1305 Biolink: linking belowground biodiversity to function in European forests. University of Reading, UK, 4-7 noiembrie, 2014.

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  - COST Action STReESS: Studying Tree Responses to extreme Events: a SynthesiS. Estoril, Portugal, 22-23 October, 2014.

  Analyzing the time series of dendrometer data using routines in SAS and R.

  Bouriaud O., Deslauriers A., Rossi S., Simard S., Teodosiu M., van der Maaten E.

  - International Symposium "Forest and Sustainable Development" Braşov, Romania 24-25 October, 2014.

  Turcu D.O., Merce O. Densities of large trees in natural forests - a key structural characteristic. Case study from “Izvoarele Nerei” Nature Reserve, SW Romania.

  Merce O., Borlea G.F., Turcu D.O., Cantar I. C., Biris I.A., Deadwood volume and its correlation with stand composition in the 'Runcu Grosi' Nature Reserve

  Astracts: http://www.unitbv.ro/Portals/16/fisiere_silvic/cercetare/simpozion2014/Book%20of%20abstracts.pdf

5 Conclusions

The project aims to provide information on carbon stocks and their dynamics in natural forests of spruce and beech. The project quantified essential processes that determine the emission and absorption of greenhouse gases in the woods. The scarcity of natural forests prevent these phenomena from being studied in other countries. Consequently, a large part of the project is to make measurements. Thus the early years of the project were dedicated measurements, and the first stage of synthesis was made, to be published several articles, one being in the evaluation, two in an advanced stage of drafting.

We continue to work with teams from abroad to develop new scientific publications. For one of the essential aspects of the project, ie monitoring greenhouse gas flows, optimum operating conditions have not yet been met due to budget cuts which resulted in delayed delivery of results in the form of publications. Participation in the international conference in the UK has shown great interest held by foreign teams for measurements performed in this project.

6 References

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