ESTIMATION OF CARBON STOCK IN SOUTH OF WESTERN CARPATHIANS FROM MOLDOVA NOUA FOREST DISTRICT USING G.I.S. DATA FROM MANAGEMENTS PLANS

SUMMARY
Analysis of above-ground biomass and carbon stock was performed in South-West of Western Carpathians. Data from two management plans of Moldova Noua Forest District (10 years between) were used. Total above-ground biomass and carbon stock was calculated using allometric equations. Forests from Moldova Noua Forest District stored 1,814,297 tonnes of biomass in 2006 and in 2016 stored 1,706,545 tonnes of biomass. Also, total equivalent of CO2 decreased from 852,720 tonnes in 2006 to 802,076 tonnes in 2016. The theoretical functions Gamma 3P, Lognormal 3P and Weibull 3P have not been suitable to describe the experimental distribution of carbon stock. A GIS based method was used to assess the geographic distribution of quantity of carbon stock and was established the evolution of carbon stock between 2006 and 2016. The results are promising and were obtained with a minimum effort, encouraging further research.

Keywords: Carbon stock, allometric equation, above-ground biomass, South-West of Western Carpathians, Management plans.

INTRODUCTION
Lately, concerns about carbon stored by forest vegetation have intensified since it has an important role in producing climatic changes (Tolunay, 2009).

The negative impact of climatic changes has also been identified in Romania (Pienaru et al, 2009, Ciuvăț et al, 2013). Romania has a commitment to report CO2 emissions to the UNFCCC and to the European Union, and this can be done through forest inventories, yield tables and allometric equations. Allometric equations are recognized as the best method to estimate the amount of atmospheric CO2 stored by forest vegetation (Ciuvăț, 2013).

The purpose of this analysis is to assess the impact of the forest vegetation in the study area on CO2 emissions. The research objective is to determine the CO2 stock stored by forest vegetation using expeditious methods with a minimum cost.

1Șerban Chivulescu (corresponding author: serban.chivulescu@gmail.com), Ionuț Schiteanu, National Institute for Research and Development in Forestry “Marin Drăcea” Bucharest, ROMANIA.
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MATERIALS AND METHODS

The researches were performed in Moldova Noua Forest District area, part of the Caraș- Severin Forestry Direction, with an average altitude of 400 meters (INCDS, 2016) (Fig.1). This district is located in South-West of Western Carpathians.

Climatologically, the research area is framed in the temperate continental climate zone, with Mediterranean influences, generating a particular climate, different from the rest of the country (INCDS, 2016). Phyto-climatologically, the surface of Moldova Noua Forest District is located in the hill-storeys area of sessile oaks, of European beech stands and the hill-storeys of oaks.

The main species is common beech, followed by sessile oak and hornbeam; the mean productivity of the stands is medium, with an average crown density between almost full and full. The research area from Moldova Noua Forest District is 19,300 ha. The data used are from GIS Database of Moldova Noua Forest District’s management plans, editions 2006, 2016. The GIS database has been merged with the management plan database, resulting a complete and very useful tool for these researches. For the statistical analysis of the databases used, PASTECS (Grosjean & Ibanez, 2014) was used in the RStudio software.

Also, ArcGIS ver.10.3 has been used in order for the GIS processing to be carried out in good condition by querying the database and the graphic results to be in good quality.

In order to determine the carbon stock, it was necessary to determine first the above-ground the biomass with following formula:
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\[ B = V \times D \times BEF \] (IPCC, 2003)

Where: \( B \) - above-ground biomass (tonnes)
\( V \) – stand's volume from management plans (m\(^3\))
\( D \) – wood density according to the main species (Giurgiu et al, 2006) (tonnes /m\(^3\))
\( BEF \) – biomass expansion factor. The value used is for temperate climatic forests of 1.4 (IPCC, 2006, Volume 4, Table 4.5)

The carbon stock was determined with the formula:

\[ C = B \times CF \] (IPCC, 2003)

Where: \( C \) - carbon stock (tonnes)
\( CF \) – carbon fraction (value equal to 0.47 from IPCC 2006 GL, V4, CH4, Table 4.3.)

Analysis of carbon stock distributions for the two periods with experimental distributions Gamma 3P, Lognormal 3P and Weibull 3P was done using the EasyFit application.

**RESULTS AND DISCUSSION**

**Biomass and carbon stock structure distribution**

The research area is statistically covered, due to the relatively large number of observations (2984) with a low coefficient of variation of biomass and carbon stock, indicating high homogeneity (between 1.93 and 1.95).

**Table 1: Main statistic indicator of experimental Biomass and Carbon stock**

| Year | Indicators   | Nbr. Val. | min (T)   | Max (T)   | Sum (T)   |
|------|--------------|-----------|-----------|-----------|-----------|
| 2006 | Biomass      | 2984      | 0.0763    | 9419.99   | 1814297.91|
|      | Carbon stock | 2984      | 0.035     | 4427.39   | 852720.0177|
| 2016 | Biomass      | 2984      | 0.06      | 10049.47  | 1706545.07 |
|      | Carbon stock | 2984      | 0.03      | 4723.25   | 802076    |
| Year | Mean (T)     | Var.      | Std. dev. | Coef. var |
| 2006 | Biomass      | 1411002.66| 1187.85   | 1.95      |
|      | Carbon stock | 311690.489| 558.29    | 1.95      |
| 2016 | Biomass      | 1249118.47| 1117.63   | 1.93      |
|      | Carbon stock | 275930.161| 525.29    | 1.93      |

Regarding to the minimum values of above-ground biomass, it varies from 0.06 (2016) to 0.076 (2006) and the minimum carbon stock values range from 0.03 (2016) to 0.035 (2016). It can also be noticed that the maximum values of above-ground biomass and carbon stock are increasing in 2016 as compared to 2006 due to the aging of the stands.

**Biomass and carbon stock distribution**

For choice of the most suitable theoretical frequency functions necessary to adjust experimental distributions was used Kolmogorov-Smirnov, Anderson-Darling significance testing and the \( \chi^2 \) criterion for a 95% coverage probability
(Table 2). Gamma 3P, Lognormal 3P and Weibull 3P were the theoretical functions for adjusting the experimental distributions used to describe the carbon stock distribution (Fig. 2).

Comparing the two types of distributions (experimental and theoretical) using the three above-mentioned significance tests, can notice that there are differences between theoretical and experimental values, and the stand not having any of the studied theoretical distribution laws. This is due to the silvicultural operations that took place on the forest district territory between 2006 and 2016, as well as the post-communist retrocession of forest areas.

**Table 2: Main indicators of theoretical distributions**

| Year | Theoretical Function | Theoretical values | Experimental values |
|------|----------------------|--------------------|---------------------|
|      | **Kolmogorov – Smirnov** |                    |                     |
| 2006 | Lognormal3P          | 0.024              | 0.033               |
|      | Weibull3P            | 0.024              | 0.057               |
|      | Gamma3P              | 0.024              | 0.098               |
| 2016 | Weibull 3P           | 0.024              | 0.033               |
|      | Lognormal 3P         | 0.024              | 0.037               |
|      | Gamma 3P             | 0.024              | 0.078               |
|      | **Anderson – Darling** |                  |                     |
| 2006 | Lognormal3P          | 2.501              | 10.083              |
|      | Weibull3P            | 2.501              | 11.02               |
|      | Gamma3P              | 2.501              | 50.43               |
| 2016 | Weibull 3P           | 2.501              | 9.897               |
|      | Lognormal 3P         | 2.501              | 11.818              |
|      | Gamma 3P             | 2.501              | 30.122              |
|      | **χ² Criterion**     |                    |                     |
| 2006 | Lognormal3P          | 19.675             | 10.083              |
|      | Weibull3P            | 19.675             | 80.868              |
|      | Gamma3P              | 19.675             | 74.245              |
| 2016 | Weibull 3P           | 19.675             | 44.254              |
|      | Lognormal 3P         | 19.675             | 59.52               |
|      | Gamma 3P             | 19.675             | 200.31              |

**Map of evolution of carbon stock in Moldova Noua Forest District**

The carbon stock's evolution in Moldova Noua Forest District was based on data from the two management plans, 2006 and 2016 editions, and the graphical representation (Fig. 3) was performed using GIS techniques. These GIS techniques have also been successfully used in other research as a dynamic power tool useful for identifying and quantifying the parameters that may affect the carbon stock (Gil et al, 2011).
For a detailed analysis, the carbon stock was divided into 6 categories, by size. It can be seen that the carbon stock drops in 2016 compared to 2006.

**Figure 2:** Fitting experimental carbon stock distribution using Gamma 3P, Lognormal 3P and Weibull 3P functions.
Figure 3: Distribution of carbon stock from year 2006 to year 2016 in Moldova Noua Forest District
The stand's volume evolution, the above-ground biomass evolution and the carbon stock evolution, in Moldova Noua Forest District, have a downward trend (Table 3) between the two analyzed periods.

**Table 3:** Volume, Above-ground biomass and Carbon stock evolution between 2006 and 2016

| Year | Volume (m³) | Above-ground biomass (Tonnes) | CO₂ stock (Tonnes) |
|------|-------------|-------------------------------|-------------------|
| 2006 | 2376182     | 1814297                       | 852720            |
| 2016 | 2234466     | 1706545                       | 802076            |

The previous table shows that the volume has decreased by 141.716 m³, this decrease being due to the silvicultural operations that took place on the forest district territory like the exploitation forestry works. During this decade 188.710 m³ were exploited, the current volume increment of about 4,8 m³·year⁻¹·ha⁻¹ didn't fully cover this deficit. This fact was also found in above-ground biomass and carbon stock, with lower values in 2016 compared to 2006. This deficit is due to the imbalance produced in forest administration/management, through management plans, by the post-communist retrocession of forest areas failing to fully fulfil one of the most important principles of forest management activities, namely the principle of continuity.

**CONCLUSIONS**

Due to global warming, concerns about carbon stored by forest vegetation have intensified, materializing through high-level commitments with institutions such as the EU and the UNFCCC to report CO2 emissions. The best method of estimating carbon stocks in forest vegetation was found to be allometric equations, the method used in this research.

The researches were performed in Moldova Noua Forest District area, in South-West of Western Carpathians, data used to make this research from two management plans, 2006 and 2016 editions (management plans in Romania are made once every 10 years) for identical areas.

The data used for this research indicated high homogeneity values, the above-ground biomass mean values are between 576 and 608 tonnes. The quantity from 270 to 285 tonnes were determined for the carbon stock stored by forest ecosystems average.

The frequency theoretical functions Gamma 3P, Lognormal 3P and Weibull 3P were used, for the two researched periods, to describe better the carbon stock distribution. Following the goodness of fit test (K-S, A-D and χ² Criterion), the carbon stock distribution did not follow any of the theoretical distributions studied. This is due to silvicultural operations carried out during this period and to the imbalance produced by post-communist retrocession of forest areas from the Moldova Noua Forest District.
This also indicates a decrease in carbon stocks in 2016 compared with 2006 observed through representation of the carbon stock evolution maps.

Through this research we have been able to determine and analyze the carbon stock for two different periods of 10 years between them, through a process with minimum effort but with promising results.

REFERENCES

Ciuvat, A. L., Abrudan, I. V., Blujdea, V., Dutca, I., Nuta, I. S., & Elena, EDU. (2013): Biomass Equations and Carbon Content of Young Black Locust. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 41(2), 590.

Ciuvăţ, A.L.(2013): Producţia de biomasă şi stocarea carbonului înarboreteletinere de salcâm (Robiniapseudoacacia L.) din sudul României, Teză de doctorat, Universitatea Transilvania din Brașov, 142p.

Gil, M. V., Blanco, D., Carballo, M. T., & Calvo, L. F. (2011): Carbon stock estimates for forests in the Castilla y León region, Spain. A GIS based method for evaluating spatial distribution of residual biomass for bio-energy. Biomass and Bioenergy, 35(1), 243-252.

Grosjean, P., & Ibanez, F. (2014): Package for Analysis of Space-Time Ecological Series. PASTECS version 1.3-18 for R v. 3.1.1

ICAS (2006): Studiu General O. S. Moldova Nouă, 230 p.

INCDS (2016): Studiu General O. S. Moldova Nouă, 203 p.

IPCC (2003): Good Practice Guidance for Land Use, Land-Use Change and Forestry, Chapter 3, Section 3.2, equation 3.2.3, 590p.

IPCC (2006): Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2, Forest Land, 46p.

Pienaru A, Iancu P, Căzănescu S (2009): Desertification and its effects on environment and agricultural production in Romania. Annals of Food Science and Technology 10(2):624-629.

Tolunay, D. (2011): Total carbon stocks and carbon accumulation in living tree biomass in forest ecosystems of Turkey. Turkish Journal of Agriculture and Forestry, 35(3), 265-279.