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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.

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MATERIALS AND METHODS

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

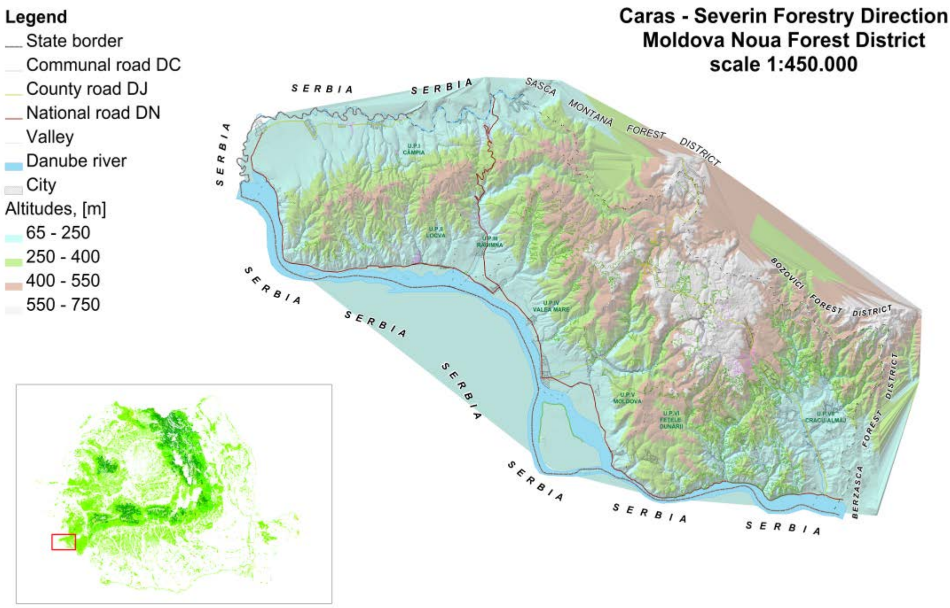

Figure 1: Moldova Nouă Forest District localization

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:

B = V x D x 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 x 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
χ^2 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).

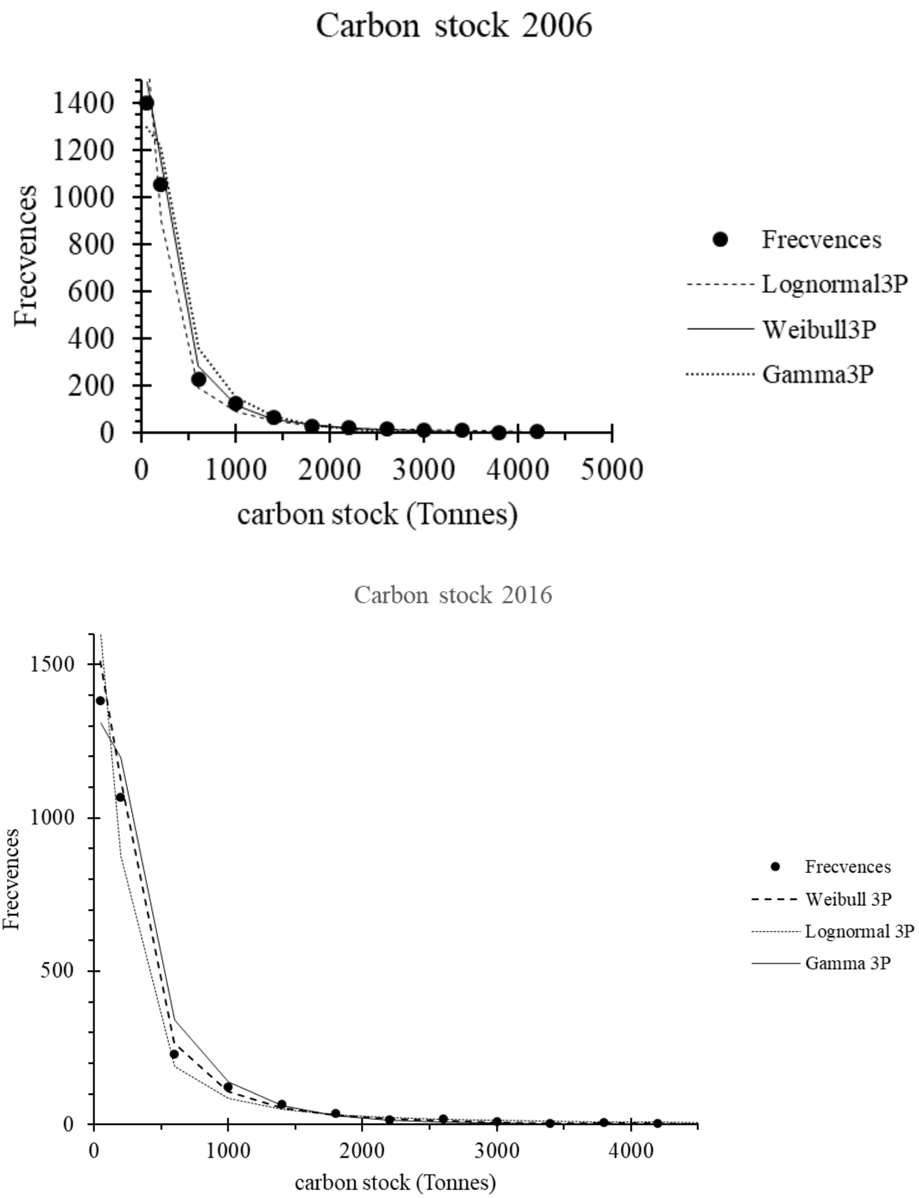

Figure 2: Fitting experimental carbon stock distribution using Gamma 3P, Lognormal 3P and Weibull 3P functions.

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.

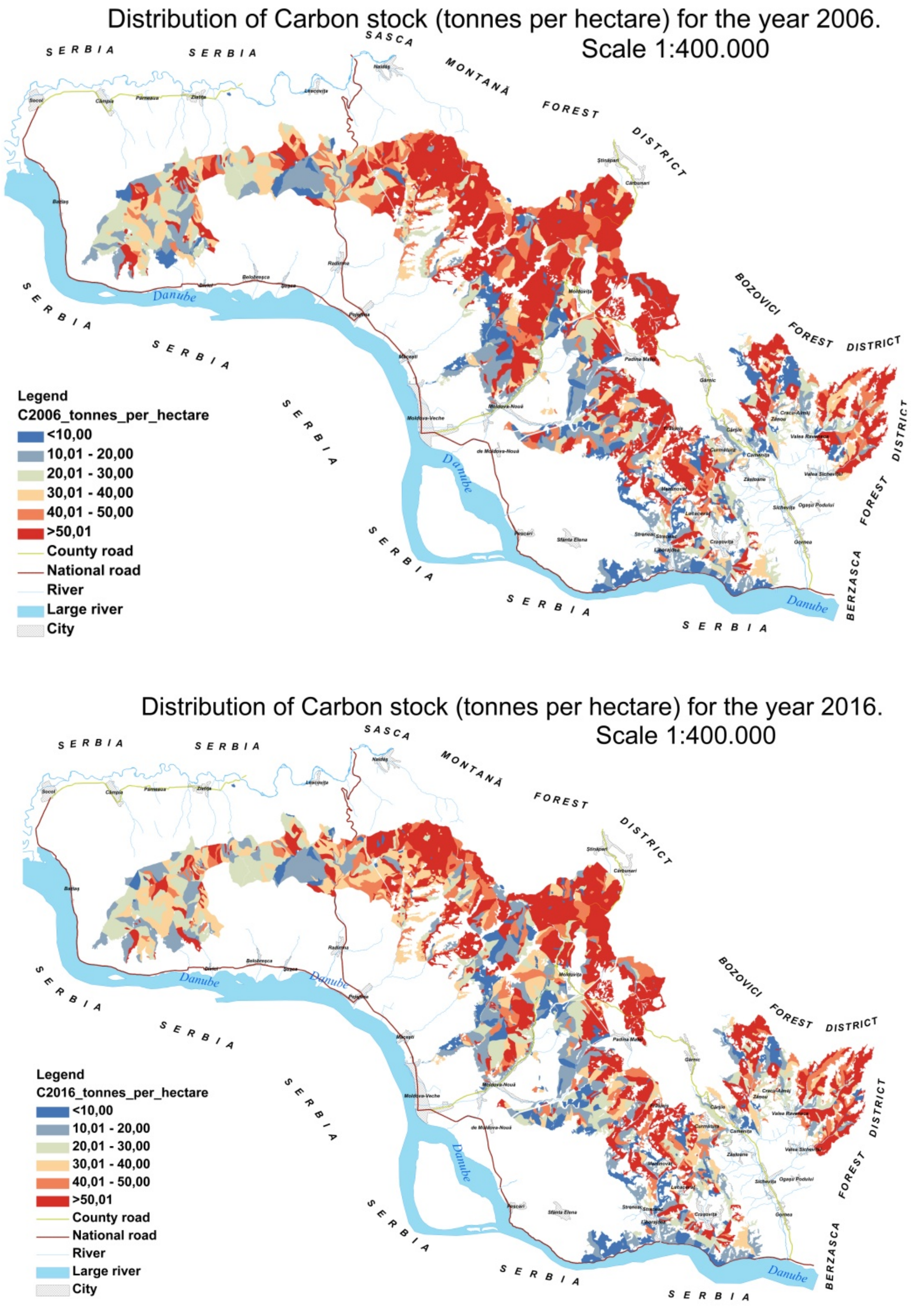

Figure 3: Distribution of carbon stock from year 2006 to year 2016 in Moldova Noua Forest District

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 (m^3)**	**Above-ground biomass (Tonnes)**	**CO_2 stock (Tonnes)**
2006	2376182	1814297	852720
2016	2234466	1706545	802076

The previous table shows that the volume has decreased by 141.716 m^3, 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 m^3 were exploited, the current volume increment of about 4,8 $m^3 \cdot year^{-1} \cdot ha^{-1}$ 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 χ^2 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.

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