AES BIOFLUX

Advances in Environmental Sciences -
International Journal of the Bioflux Society

Influence of some soil characteristics on the productivity of stands in Dragomirna plateau, Suceava county, Romania

Alexei Savin, Daniel Avăcăriţei, Cătălin-Constantin Roibu, and Bogdan M. Negrea

"Stefan cel Mare" University, Suceava, Romania, EU.
Corresponding author: Alexei Savin, alexeisavin@gmail.com

Abstract. The interdependence between ecological factors of the forest site rock-soil has a large variability in the case of Dragomirna plateau (because of the geology of the area) and occurs in various situations of site quality. As an consequence of this diversity, some of the soil properties represent a larger influence on the biometrical characteristics of the stands, implicitly on their productivity. Starting on the premise that not all the tree species present on the area have the same edaphic ecological exigences and the fact that the common beech, the main species in the analized tree stands is in a suboptimal climate (Stănescu 1979), was considered to be useful to determine wich of the soil conditions studied, influence more the productivity of the main species from the Dragomirna plateau.
Key words: site, soil conditions, Dragomirna plateau, stands, significant.

Rezumat. Tandemul factorilor ecologici ai staţiunii rocă-sol, cu o variabilitate mai ridicată la nivelul Podişului Dragomirnei (datorită geologiei zonei), dă naştere la numeroase situaţii staţionale de bonităţi diferite. Ca efect al acestei diversităţi, o serie de proprietăţi ale solului prezintă o influenţa mai mare asupra caracteristicilor biometrice ale arboretelor şi implicit asupra productivităţii acestora. Pornind de la premiza faptului că nu toate speciile prezintă aceleaşi exigenţe ecologice de ordin edafic, şi de la faptul că fagul, specie principală în arboretele analizate, se află în suboptim climatic după Stănescu (1979), s-a considerat a fi util de stabilit care dintre condiţiile de sol studiate influienţează mai mult productivitatea principalelor specii de pe cuprinsul Podişului Dragomirnei.
Cuvinte cheie: staţiune, condiţii de sol, Podişul Dragomirnei, arborete, semnificativ.

Introduction. More studies were carried out on the international level on the subject of the influence of soil characteristics to the productivity of the tree stands. These were largely debated in the literature. In France, USA, and other countries quantification of the site fertility is based on dendrometric data recordings of some representative tree populations of the main forest species. Parameters as values of average annual growth, dominant height and others, gathered in synthetic productions tables, and comparative graphical representations define the site potential, depending of the "behavior" of a particular forest species in a certain area (Becker 1992). The quantification of the site potential coincides with the assessment of productivity of the main forest species. Productivity of one species in a particullary site can be quantified by measuring the mean increment of volume at a particullary age, or by volumetrical maximal growth. However, these growth values are difficult to estimate if are not used standardized production tables adapted for each forest species in particular (mainly in France). In this respect, it is routinely used an expedient method for assessing the productivity using the dominant height wich one tree population can reach an certain reference age, height referred to as "fertility index".

For a wide range of treatment methods in uniform system tree stands dominant height growth merely depends on the stationary conditions (environments). In this case the fertility index overlaps with the notion of timber production. The relation between the two indexes (fertility index and the maximum average growth) it is a linear. Rating of forest sites in terms of productive potential based on the fertility index it is identhical with the one obtained by measuring the real productivity values expressed by average annual increases (Becker et al 1980).

The purpose of this study was to find out which of the soil characteristics influence more on the productivity of the tree stands and of the main forest species in particular. The main objectives of the study were:

- the analysis of correlative links between the main five soil characteristics studied and the average productivity of stands;
- the analysis of multiple influence (bifactorial) of the soil characteristics on the productivity;
- analysis of correlations between soil characteristics and the average site class of the main component species in the studied stands;
- the study of the influence of soil characteristics on the quality of the stands expressed as percentage of total standing timber wood.

Material and Method. In terms of geomorphological, the studied area is part of Dragomirna plateau, as a sub-unit of Suceava plateau. Stationary the studied site belongs to sessile oak bioclimatic zone. There were studied 16 sample plots of a rectangular shape with the surface of 500 m^2 (20 x 25 m), situated in different stationary conditions. In order to eliminate the influences of another stational, geomorphological and climatical factors, the sample plots were put in a small area, not exceeding 50 km^2, average altitude ranging between 380 and 420 m. In the sample plots were made 16 main soil profiles, and a series of pedological analyzes were conducted: mechanical composition, degree of base saturation (V%), pH, humus content (H%).

In the sample plots were conducted a series of dedrometric measurements in order to characterize the stands. The measures were: diameter and height of each tree from the sample plot, prune height, grade, Kraft grade, crown diameter and in order to see the tridimensional profile – Cartesian coordinates (x and y). In order to calculate the volumes and relative production grades was determined a series of dendrometric parameters as: average diameter calculated using basal area (*dg*), the average height of the average diameter as the base area (hg), diameter as the central base area (*dgm*) and the average height of the central diameter as the base area (hgm).

In the research methodology were included modern statistical methods used in forestry research as correlation analysis, regression analysis, variance and specific methods, specific analysis of the structure stands.

Statistical analysis was performed using computer applications such as "STATISTICA", Stat Soft 2004, Microsoft Office Excel, S.V.S. (StandVisualizationSystem). Soil analysis have been conducted in the "O.J.S.P.A" - Suceava pedological laboratory by standardized methods.

Results and Discussion

Analysis of the influence of soil related factors on average relative production class. When establishing the stational favorability, a trusty indicator of stational potential is the production class value, an expresion of the stand’s average height (hg), calculated using basal area at a certain age (Giurgiu & Draghiciu 2004).

In determining the relative production class for each species, the “*production tables*” (height curves) method has been used. The production class was determined in relation to average height values for each species, calculated using basal area.

In some European countries the dominant average height value (*hdom)* is used (Becker & Le Goff 1988). The motivation for using the value of the dominant average height is given by the fact that conducting stand interventions, e.g. thinning, have little effect on it (Giurgiu & Draghiciu 2004).

In reference to the soil proprieties, the following characteristics have been taken into consideration:

-average value of soil acidity determined for all analyzed horizons of the soil profile (pH avr);

- percentage of humus content exclusively from Ao or Aom horizon (H%);
- average value for each horizon of the base saturation percentage (V%);

-percentage of clay content from the finest (texture) horizon Bt or Bv (A% from B);
-textural differentiantion index, representing clay percentage from B-horizon to clay percentage from A or E-horizon, ratio (Idt).

Table 1

Average relative production class values in relation to different soil characteristics

S.P.	Ride	Clp Avr.	Timber (%)	pH avr.	H (%)	V avr. (%)	A (%) from B	Idt
1	1 A	2.56	59.8	5.46	2.17	51.8	26.71	1.25
2	2 A	2.50	51.9	5.45	1.84	52.0	27.14	1.34
3	5 A	2.43	59.8	6.13	3.49	73.5	24.31	1.24
4	11 A	2.37	56.8	6.80	4.56	90.3	22.42	1.21
5	19 D	3.02	51.2	4.64	1.41	43.2	35.16	1.92
6	22 B	2.10	62.2	6.80	1.94	79.6	25.44	1.32
7	23 D	3.29	59.8	5.25	1.19	45.2	34.8	2.13
8	25 B	2.18	46.4	5.10	1.67	44.1	26.12	1.45
9	32 A	3.30	48.3	4.58	1.42	36.9	32.22	1.85
10	37	2.07	49.6	5.76	2.03	49.8	26.94	1.30
11	47 A	1.64	44.4	5.73	2.79	52.2	23.26	1.36
12	50 B	3.80	37.5	4.64	1.18	36.2	32.28	1.87
13	51 B	2.38	51.3	6.64	3.05	80.8	20.12	1.08
15	64 A	2.45	55.5	6.71	2.21	84.9	21.6	1.06
16	72 A	2.60	57.2	5.34	1.88	47.3	29.45	1.43

Correlation coefficients "*r*" have been calculated, for each of the five characteristics, using regression analysis.

Table 2

Coefficients of the correlation between average production class (CLP) and soil related factors

Coefficients	*clp = f (pH, H, V, A, Idt)*	*clp= f (pH)*	*clp= f (H)*	*clp= f (V)*	*clp= f (A)*	*clp= f (Idt)*
Correlation coefficients "*r*"	0.854*	-0.617*	-0.525*	-0.478	0.746**	0.752**
Coefficient determined R^2	0.730	0.381	0.275	0.229	0.557	0.565
Significance of correlation coefficient (p)	0.0197	0.0143	0.0447	0.0712	0.0014	0.0012

Correlation coefficients analysis (Table 2 and Figs 1-3) shows that in the case of average pH values and the humus content in the superior horizon, the connection to average relative production class is moderate and significant.

For the clay content percentage from B-horizon, and also the textural differentiation index the correlation is strong and distinctly significant. Relatively close values of the correlation coefficients for the two characteristics (r=0.746** for A % and r=0.752** for *Tdi*) can be explained by the strength of the statistical connection between Idt and the clay content in the B-horizon (r=0.938; Table 3).

Table 3

Coefficient of correlation matrix, between main soil characteristics and relative production class

Values R	clp avg.	pH avg.	H (%)	V avg. (%)	A (%) to B	Idt
clp avg.	1.000					
pH avg.	-0.617	1.000				
H (%)	-0.525	0.718	1.000			
V avg. (%)	-0.479	0.960	0.764	1.000		
A (%) to B	0.746	-0.837	-0.749	-0.790	1.000	
Idt	0.752	-0.784	-0.674	-0.731	0.937	1.000

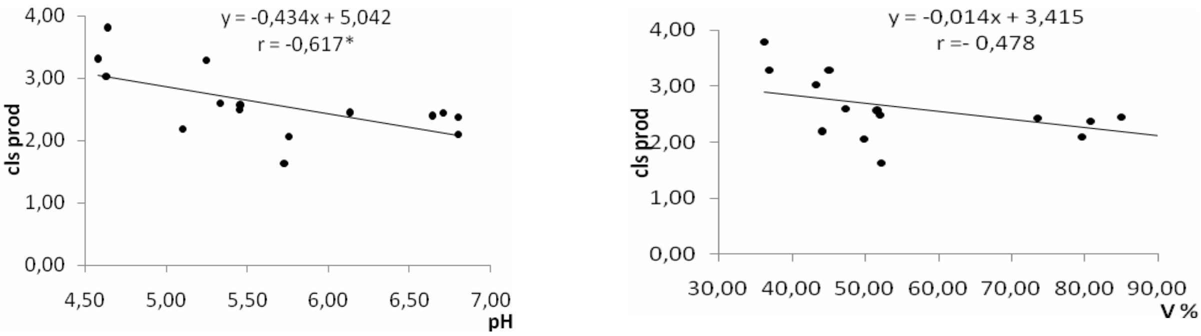

Figure 1. Dependence between relative production class values and pH, V (%) respectively.

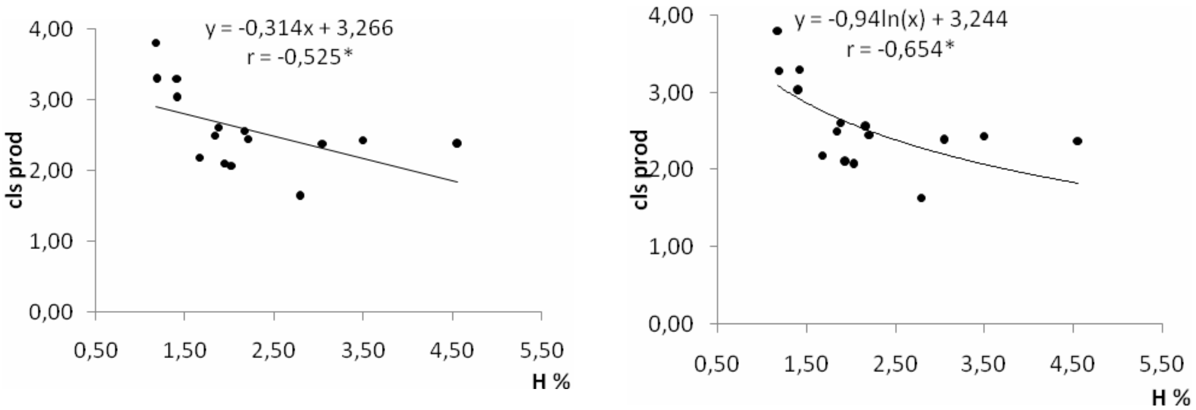

Figure 2. Dependence between average relative production class values and H (%) by a linear and a logarithmic regression.

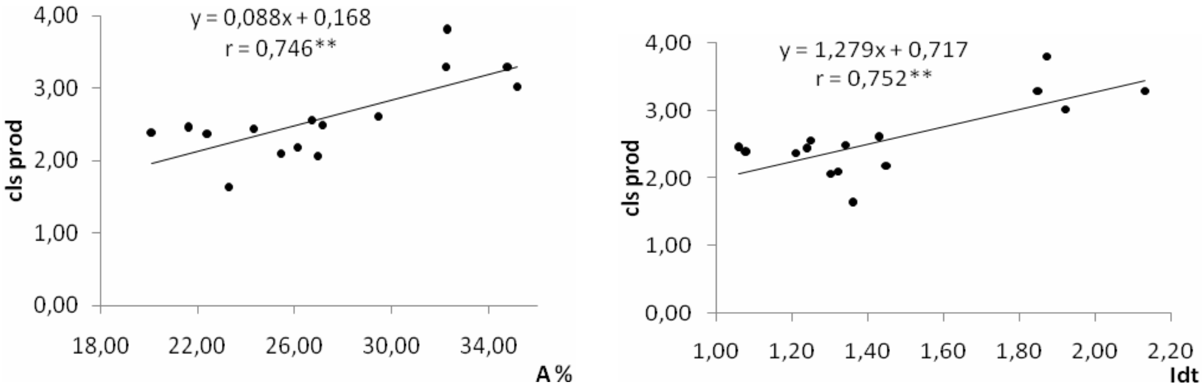

Figure 3. Dependence between average relative production class values and A (%), Idt, repectively.

Analysis of the multiple influence on productivity of soil properties. Using "Statistica" software an analysis has been conducted on components of the soil related factors (Figure 4). Average production class value is close to Idt and A (%) values, while the other components are distinctly grouped. This fact called for a multiple influence analysis, dependent on the degree of "closeness" between components (soil properties).

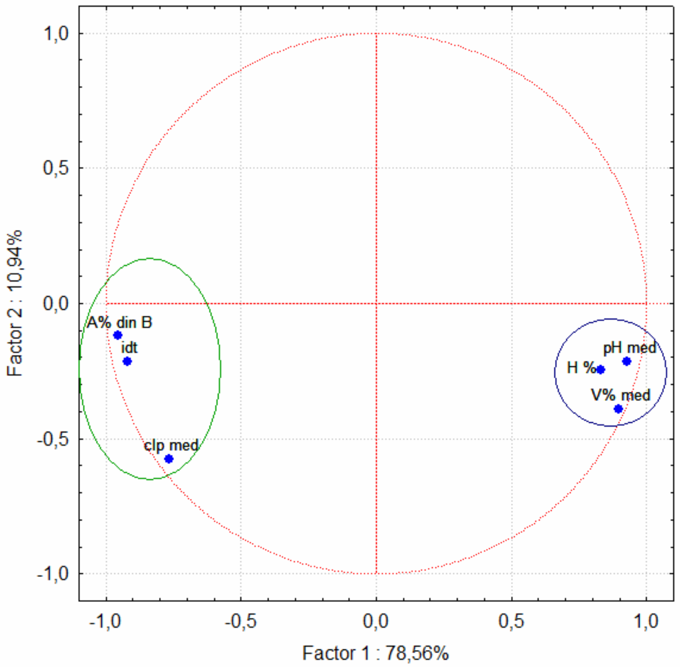

Figure 4. Analysis based on main components of soil characteristics in relation to average production class.

In the case of bifactorial regressions also, a higher influence on stand productivity of clay content in B-horizon and Idt in comparison with V (%), has been identified in (Table 4). Correlation coefficient value of 0.761, between the production class (CLP) and Idt indicates a positive, strong and distinctly significant connection.

Table 4

Correlation coefficients between average production class and 2 soil related factors

Coefficients	clp = f (pH, H)	clp = f (pH, V)	clp = f (V, H)	clp = f (A, Idt)
Correlation coefficients "*r*"	-0.628*	-0.742**	-0.538	0.761**
Coefficient determinated R^2	0.394	0.550	0.290	0.579
Significance of correlation coefficient (p)	0.0494	0.0083	0.1285	0.0055

• shaded values are significant for a probability of p =0.05.

Analysis of the influence of soil related factors on relative production class for each species. In order to conduct an regression analysis between relative production class for each species and the soil characteristics mentioned above, it has been necessary to convert soil related factor values into distinct categories, in relation with known descriptions from scientific literature (Table 5). Main values of correlation coefficients, "r" and "χ^2" test for evergreen oak (*Q. petraea* Lieb.) and hornbeam (*Carpenus betulus* L.) are presented in Table 5.

Table 5

Explanation of the values of the edaphic factors as categories and classes

Sample Plot	Ride	Relative tree class				pH avg.	H (%)	V avg. (%)	A (%)	Idt
		Be	Ses	Oak	Hrn					
1	1 A		II	III	III	moderate	weak	oligomezobasic	clay	moderate
2	2 A		III	II	IV	moderate	weak	oligomezobasic	clay	moderate
3	5 A	III	II	II	III	weak	moderate	mezobasic	clay	moderate
4	11 A		II	III	III	weak	moderate	eubasic	clay	weak
5	19 D	III			III	strong	very weak	oligomezobasic	loamy clay	strong
6	22 B	II	II		III	weak	weak	eubasic	clay	moderate
7	23 D	III	III	III	IV	moderate	very weak	oligomezobasic	loamy clay	very strong
8	25 B		III	II		strong	weak	oligomezobasic	clay	strong
9	32 A		III	III	IV	strong	very weak	oligomezobasic	loamy clay	strong
10	37	II	I	I	III	moderate	weak	oligomezobasic	clay	moderate
11	47 A		I	I	III	moderate	weak	oligomezobasic	clay	moderate
12	50 B	IV	III		IV	strong	very weak	oligomezobasic	loamy clay	strong
13	51 B	II	II		IV	weak	weak	eubasic	sandy clay	weak
15	64 A	III	II		III	weak	weak	eubasic	clay	weak
16	72 A	II	II	III	IV	moderate	weak	oligomezobasic	clay	strong
Definitions						acidity	humiferous		class	diferentiate

Due to a weak presence of oak and beech in the analyzed stand, relative production class values aren't representative, this having a direct impact on the determined correlation's significance. Results for beech show a dependence type connection between relative production class and humus content in A-horizon (r =0.806**; p=0.00867) - strong and distinctly significant. For oak, the correlation between production class and Idt (r=0.625*; p=0.04387) is moderate and significant.

Table 6

Correlation coefficient values for evergreen oak (*Q. petraea Lieb.*)

Soil characteristics	pH med	H (%)	V med (%)	A (%)	Idt
Pearson Test (χ^2)	12.267	8.311	7.778	7.520	9.733
Significance (p)	0.0155	0.0426	0.1001	0.1108	0.0136
Correlation coefficient R (Spearman)	0.450	0.578*	-0.300	0.456	0.628*
Significance (p)	0.1066	0.0477	0.2981	0.1011	0.0162

• shaded values are significant for a probability of p =0.05.

The same two characteristics (Idt and H%) are significant from a influential point of view, on evergreen oak's production class, the correlation being moderate and significant. Graphic representations (Figure 5) show a close connection between production class III and the distribution of experimental plots with high Idt, while low Idt corresponds to a superior production class (I or II).

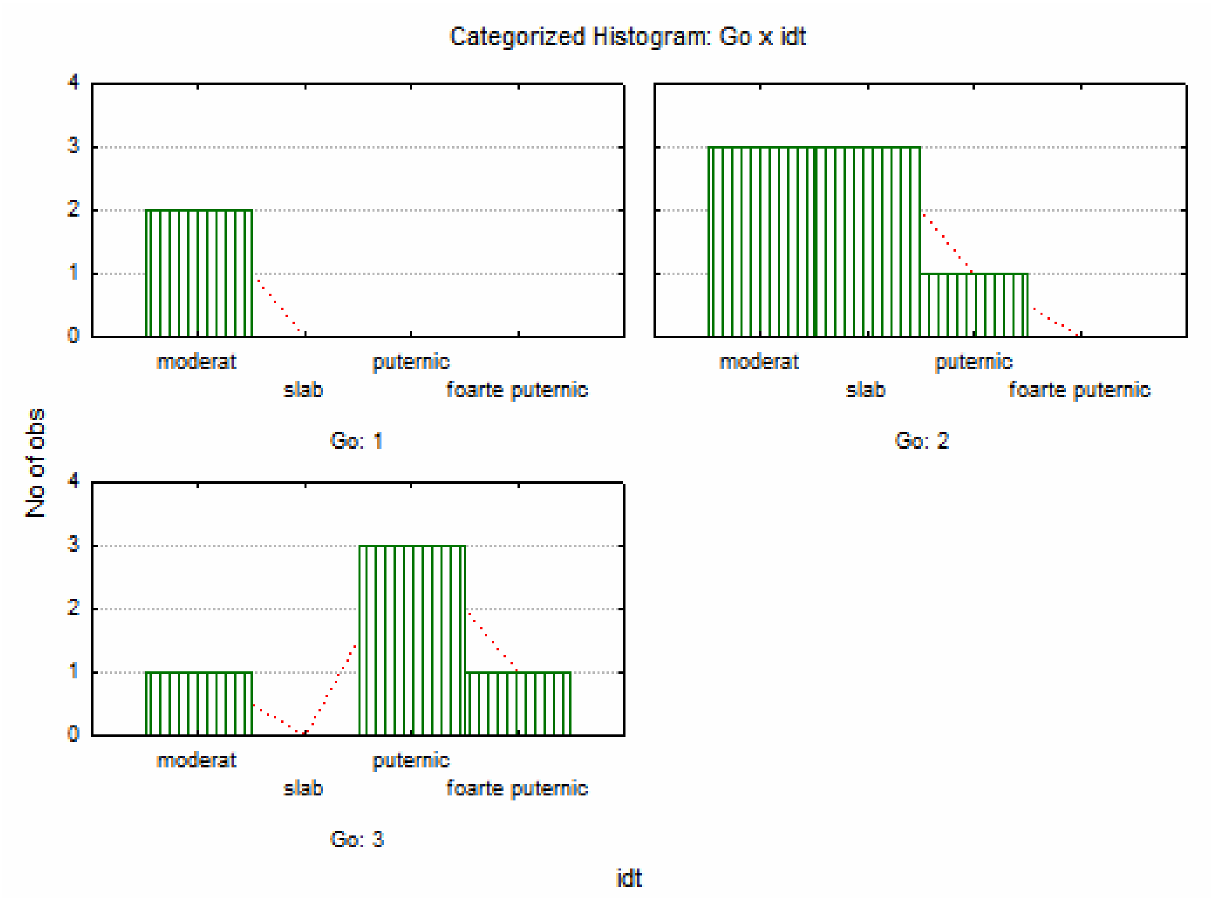

Figure 5. Repartition of evergreen oak plots in relation to production class and Idt.

Only two factors have a significant influence on hornbeam's relative production class: clay content in B-horizon and Idt (Table 7). As for the case of evergreen oak it's important to point out the inflluence of Idt on productivity.

Table 7

Correlation coefficient values for hornbeam (*Carpinus betulus L.*)

Soil characteristics	pH avg.	H (%)	V avg. (%)	A (%)	Idt
Test χ^2 (Pearson)	1.886	3.281	1.863	4.586	4.813
Significance (p)	0.3894	0.1939	0.3939	0.1010	0.1861
Corelation coeficient R (Spearman)	0.019	0.242	-0.318	0.572	0.569
Significance (p)	0.9481	0.4055	0.2683	0.0326	0.0339

- shaded values are significant for a probability of p =0.05.

The influence of soil related factors on the percentage of grade timber. Forestry researchers agree that the production of grade timber is largely influenced by stand interventions (e.g. thinnings). It's also stated that stational conditions (mostly soil related) have a strong influence on wood quality in a stand. Based on these statements, it became important to underline the influence of soil related factors on wood grade inside the analyzed plots. Average stand grade, as a notion, has still a narrow acceptance, and that is why we calculated the total volume of standing timber, divided into dimensional sortiments and determined the percentage of grade wood for each stand and plot, respectively. Using regression analysis for grade wood percentage, correlation coefficients have been calculated (Table 8).

Table 8

Coefficients of the correlation between grade wood percentage and soil related factors

Coefficients	% luc = f (pH, H, V, A, Idt)	% luc= f (pH)	% luc= f (H)	% luc= f (V)	% luc= f (A)	% luc= f (Idt)
Correlation coefficients "*r*"	0.803	0.514*	0.287	0.518*	-0.162	-0.271
Coefficient determinated R^2	0.644	0.265	0.083	0.269	0.026	0.073
Significance of correlation coefficient (p)	0.0591	0.0497	0.2992	0.0478	0.5648	0.3291

• shaded values are significant for a probability of p =0.05.

It can be seen that only two factors (pH and V%) influence grade wood percentage, the correlation being moderate and significant (r=0.514* and r=0.518*). Correlation with other factors is weak and insignificant.

Discussions. A lot of papers from forestry scientific literature approach the soil influence on stand productivity topic. An american research team documented a variation in total wood biomass from 5.4 Mg (tone)/year/ha, in low productivity stations, to 9.2 Mg (tone)/year/ha in high productivity stations. A strong connection between the levels of basic cations and NO_3, NH_4, degree of nitrification, was registred (Baribault et al 2010). The same authors concluded that from all elements, calcium (an indicator of soil basic character and V %) has the strongest correlation with the above-ground woody biomass production (r^2= 0.72). It has been established as optimum, a calcium level of 0.45 cmol/kg. The same strong correlation with wood biomass production is found also for Mg (r^2 = 0.70), a strong connection existing between Ca and Mg.

Non-wood biomass production is correlated with N (r^2 = 0.61) and NO3 (r^2 = 0.51) levels.The correlation between wood biomass production and calcium from the soil was only r^2= 0.42, and r^2 = 0.36 for nitrification degree. A significant correlation between soil texture and stand productivity hasn't been established (Baribault et al 2010).

The influence of calcium content on productivity in deciduous forests from the N-Eastern parts of USA has been studied by Bigelow & Canham (2007), Gradowski & Thomas (2008), Park et al (2008). Low calcium content has a negative influence on growth and immunity to disease, especially in the case of acide soils. Individual tree growth depends on calcium levels, which influence also the fine root system. Adding calcium to the soil can boost seedling growth, and canopy size of mature trees (Gradowski & Thomas 2008).

Low calcium levels cause low above-ground wood biomass production, calcium being in the same time affected by levigation, due to acid rain. In phloem, calcium is immobilized: the Ca consumption is bigger than that of other mobile elements from phloem like K, Mg, P or N (Brown et al 1999).

Conclusions. Soil related factors have an important influence on stand productivity and wood quality, a fact undelined by the following conclusions:

-soil related stational factors have a strong influence on stand productivity in forests situated in the Dragomirna Plateau - a strong and significant correlation (r=0.854*);

-of all the soil characteristics taken into consideration, clay content in B-horizon (A% from B) and Idt are strongly and distinctly significant correlated with average relative production class, and so a key role in determining stand productivity;

- influence analysis of the five factors taken into consideration, for each species shows that in the case of evergreen oak and hornbeam soil characteristics are strongly and significantly correlated with the relative production class;

-of all the soil related stational factors, Idt has a key influence on relative production class of each species, at lest in the case of evergreen oak, hornbean and common oak;

-the role of soil characteristics in determining standing tree quality, represented by grade wood percentage, has proved to be secundary, moderate and significant correlations being established for average pH and V%, in each horizon.

References

Baribault T., Kobe R., Rothstein D., 2010 Soil calcium, nitrogen, and water are correlated with aboveground net primary production in northern hardwood forests. Forest Ecology and Management **260**:723-733.

Becker M., 1992 [Two competition indices for comparing the height and the diameter growth of trees characterized by various and unknown slivicultural histories]. Annals of Forest Science **49**:25-37. [In French]

Becker M., Le Goff N., 1988 [Site diagnosis and production potential]. Revue Forestiere Française, Vol 40. [In French]

Becker M., Le Tacon F., Timbal J., 1980 [The limestone plateau of Lorraine. Types of sites and forest potential]. École nationale du Génie rural, des Eaux et des Forêts, Nancy. [In French]

Bigelow S. W., Canham C. D., 2007 Nutrient limitation of juvenile trees in a northern hardwood forest: calcium and nitrate are preeminent. For Ecol Manage **243**:310–319.

Brown P. H., Bellaloui N., Hu H. N., Dandekar A., 1999 Transgenically enhanced sorbitol synthesis facilitates phloem boron transport and increases tolerance of tobacco to boron deficiency. Plant Physiol **119**:17–20.

Gradowski T., Thomas S. C., 2008 Responses of *Acer saccharum* canopy trees and saplings to P, K and lime additions under high N deposition. Tree Physiol **28**:173–185.

Giurgiu V., Drăghiciu D., 2004 [Mathematical and auxological models-stand production tables]. "Ceres" publishing house, Bucharest, 607 p. [In Romanian]

Park B. B., Yanai R. D., Fahey T. J., Bailey S. W., Siccama T. G., Shanley, J. B., Cleavitt N. L., 2008 Fine root dynamics and forest production across a calcium gradient in northern hardwood and conifer ecosystems. Ecosystems **11**:325–341.

Stănescu V., 1979 [Dendrology]. "Didactică si Pedagogica" publishing house, Bucharest, 470 p. [In Romanian]

Received: 15 February 2011. Accepted: 18 February 2011. Published online: 18 November 2011.

Authors:
Alexei Savin, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU. E-mail: alexeisavin@gmail.com;
Daniel Avăcăriței, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU;
Cătălin-Constantin Roibu, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU;
Bogdan-Mihai Negrea, Faculty of Forestry, University "Stefan cel Mare" Suceava, University Street no. 13, 720229, Suceava, Romania, EU.

How to cite this article:
Savin A., Avăcăriţei D., Roibu C.-C., Negrea B. M., 2011 Influence of some soil characteristics on the productivity of stands in Dragomirna plateau, Suceava county, Romania. AES Bioflux **3**(3):259-267.