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VARIATION OF THE COEFFICIENT OF EXPANSION IN THE TURKEY OAK STANDS OF OLTENIA PLAIN FROM ROMANIA

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Abstract

The paper presents the results of the investigations carried out in the Turkey oak stands in the Oltenia Plain, whereby a statistically fundamental relation was established between the coefficient of expansion (F) of the stands and its main dendrometric characteristics (diameter - D and height - H), expressed by an equation of the form logF = a0 + a1logD + a2logH, whose coefficients are statistically significant. By demonstrating the joint influence of both dimensional characteristics (D and H) on the coefficient of expansion (F), the influence of the structure of the stands on their production was revealed, thus eliminating the error-generating hypothesis expressed by the identity FD = FH. Finally, for practical purposes, for the area of the study case, tables were developed to determine the coefficient of expansion (F) according to the two characteristics of the tree (D and H). By this way of determining the form factor (F) of the stands, substantial improvements are made to the precision of their volume determination by means of the general formula V = G x H x F.

***Key words**: coefficient of expansion, Turkey oak, Oltenia Plain, Romania.*

INTRODUCTION

The Turkey oak is one of the four European representatives of the section *Cerris* in the subgenus *Quercus*, which also includes *Q. suber* L., *Q. trojana* Webb. and *Q. macrolepis* Kotschy (Tutin et al., 1964; Menitski, 1984; Boratyński et al., 2006; Danielewicz et al., 2014). In optimum conditions this tree attains a height of up to 35-40 m and a breast-height diameter of up to 2 m (Danielewicz et al., 2014). *Quercus cerris* is a sub-Mediterranean species with a geographical range embracing a vast area extending from south-western France through Italy, Switzerland, Austria and the Balkan Peninsula to Asia Minor and Lebanon (Menitski, 1984; Danielewicz et al., 2014; Meusel et al., 1965; Jalas et al., 1976; Browicz, 1953). Its northern limit in central Europe goes across central Slovakia (Danielewicz et al., 2014; Požgaj, et al., 1986; Pagan, 1992) and southern Moravia (Danielewicz et al., 2014; Kaplan, 2012). In the European part of its range, the localities of the Turkey oak extend from the sea level to a height of about 1,500 m a.s.l., in Anatolia usually between 500 and 1,500 m a.s.l., and in the Lebanon mountains, from 1,300 to 2,200 m a.s.l. (Boratyńskiet al., 2006; Danielewicz et al., 2014; Jalas et al., 1976). The climate in the areas where this species occurs ranges between warm temperate (maritime and transitional) and subtropical (from maritime to the continental and highland types) (Danielewicz et al., 2014). Sustainable forest management (SFM) is very important for study the biodiversity of the habitat forests and based on the concept of sustainable development and integrates three equally important pillars: environmental soundness, social justice, and economic viability (Paluš et al., 2018).

1.1. Geobotany characteristics for the analyzed *Quercus cerris* forest

The *Quercus cerris* forests in the studied territory are well structured and from the consistency point of view they are solid stands and very rare they are clearing stands) (Niculescu et al., 2009). The clearing of the forest appears as a result of the anthropic factors and less because of unfavourable stationary conditions (Niculescu et al., 2009). From the ecological point of view, taking into consideration the ecological indicators, it is found out that the *Quercus cerris* forests are xero-mesophyll, moderate-thermophyll and acid-neutrophyll (Niculescu et al., 2009; Borza, 1931; Mucina et al., 2016). From the phytocoenotaxonomical point of view the analyzed the *Quercus cerris* forests are formed of 9 species which are specific to the *Quercetalia pubescentis* et *Quercion petraeae*, 16 species of the *Queretea pubescenti-petraeae*, 4 species for the *Quercion frainetto*, 52 species belong to the *Querco-Fagetea* et *Fagetalia* and the rest are companions. From the floristically physiognomy and composition point of view the analysed *Quercus cerris* forests present at the arborescent stratum together with the dominant and enlightening species the following species: *Acer tataricum, A. campestre, Carpinus betulus, Pyrus pyraster, Malus domestica* etc. (Niculescu et al., 2009). The shrub and subshrub strata are well developed being represented constantly by the following species: *Crataegus monogyna, Prunus spinosa, Cornus sanguinea, C. mas, Euonymus europea, Rosa canina, Ligustrum vulgare* (Niculescu et al., 2009).

1.2. General information of the coefficient of expansion used in the analysed *Quercus cerris* forest

The coefficient of expansion (F) of the stand, defined as the average value of the component tree coefficients, results from the overall relation of the volume (*V = G x H x F)*:

$$F = \frac{V}{G\,x\,H} \qquad (1)$$

where:

V is the real volume of the tree;

G - base area of the stand;

H - average height of the stand.

The coefficient of expansion (F) of a stand according to the relation (1) can be obtained only if the volume of the tree is determined and known. This is often unknown, and F is determined precisely in order to measure the stand.

In our country, at the equian stands are used the usual coefficients of expansion, the value of which can be determined expediently using the production tables (Giurgiu, 1972; Giurgiu et al., 2004; Giurgiu & Drăghiciu, 2004)according to species, production class, age and average height.

Taking into account the mathematical-auxological model which formed the basis of the general production tables, the coefficient of expansion varies only with the average height (H) of the stands, based on the identity $F_{(D)} = F_{(H)}$, where $F_{(D)}$ is the joint coefficient obtained from the production tables according to the average diameter (D) of the base surface of the stand, and $F_{(H)}$is the coefficient of expansion of the stand, extracted from the production tables according to the average height H of the stand.

This method of determining the coefficient of expansion, without taking into account the influence of the stand structure on their production, is a simplifying and error-generating method (Leahu, 1994). Knowing that the structure bearer is the diameter, it is absolutely necessary that both the height (H) and the diameter (D) be taken into account when determining the coefficient of expansion.

In 2004, Leahushows that with *the aging of the stand, the coefficient of expansion decreases,* and according to Giurgiu (1979), *at the same height of the trees, the coefficient of expansion decreases as their diameter increases and vice versa*. This means that there are recorded the differences between the average coefficient of expansion of the real stand (F_r) and the normal stand (F_n) given in the production tables.

MATERIALS AND METHODS

2.1. Study area

The research was carried out in the pure Turkey oak stands of the Oltenia Plain from Romania, which occupy an area of 6451.2 ha (Cojoacă, 2010). The choice of the stands for the study of the variation of the coefficient of expansion was used deliberately. The research material consists of 16 sample areas of 2000 m^2 installed on the entire area of the Oltenia Plain of Romania (Amaradia Forestry District, Caracal Forestry District, Craiova Forestry District, Perisor Forestry District, Segarcea Forestry District and Vanju Mare Forestry District).

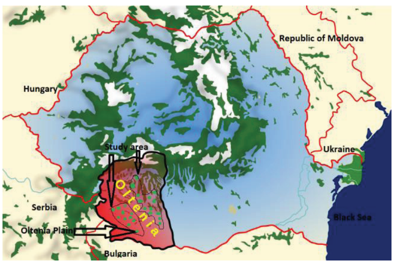

Figure 1. Map of Romania with the study area
(Source:https://www.google.ro/search?q=harta+campia+olteniei&tbm - modified)

2.2. Field data and Methods

The sample surfaces were placed in landscape planner or practically pure units, of full-consistency, with ages ranging from 30 to 105 years old.

As a result, the distribution of the sampling areas would ensure the study of the stands in the various conditions: stationary, age, productivity, etc.

At the setup of the sample surfaces, account was taken of the weight of the Turkey oak, the structure by age classes, production classes and the consistency of the stands, as well as by the stationary and typological considerations, following the consultation of numerous parcel descriptions in forestry arrangements.

The sample markets, within the studied stands were placed according to representativeness criteria and their number was determined using known formulas from mathematical statistics (Giurgiu, 1972; Giurgiu et al., 2004).

Within each trial area, fieldwork consisted of:

- inventories of diameter category of 2 by 2 cm ranges by measuring the diameter at 1.30 m of the soil of all the trees in its range;
- the measurement of heights for all the trees of the surface;

The calculation of the tree volume in the sample areas was performed using the bifactorial regression equation (Niculescuet al., 2009; Pagan, 1992):

$$\log v = a_0 + a_1 \log d + a_2 \log^2 d + a_3 \log h + a_4 \log^2 h \quad (2)$$

where:

v represents the unitary volume of the trees by categories of diameters d, in m^3;

d - the base diameter of the tree in cm;

h -the tree's height;

a_0, a_1, a_2, a_3, a_4 - regression coefficients, established by species.

RESULTS AND DISCUSSIONS

Based on the field data and using the relation (1) we calculated the coefficients of expansions for each studied stand (Table 1).

Further on, starting from the research material made available, consisting of the 16 sample areas located in the Turkey oak stand in the Oltenia Plain, we studied the variation of the coefficient of expansion (F) in relation to the average height (H) as well as the average diameter (D).

For the analytical expression of the relationship between the coefficient of expansion (F) of the stands and their main dendrometric characteristics (D and H), the following regression equation was chosen:

$$\log F = a_0 + a_1 \log D + a_2 \log H \ \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where:

F represents the co-coefficient of expansion;

D- the average diameter of the stalk, in cm;

H - the average height of the stand, in m; a_0, a_1, a_2-regression coefficients.

Using the facilities of the SPSS statistics program (Statistical Package for the Social Sciences), the coefficients a_0, a_1, $a_2$of the multiple regression equation were determined.

From the analysis of the general statistics of the regression equation (Table 2), one can see how the multiple coefficient of correlation (*R*), the coefficient of determination (*R Square*) and the adjusted value of the coefficient of determination (*Adjusted R Square*) have very high values (close to 1), which means we have chosen the model correctly.

Thus, taking into account that the value of coefficient of determination (R^2) is 0.919, it results that 91.9% of the dependent variable (the coefficient of expansion F) is explained by the variation of the variables included in the model (D and H).

So the chosen linear regression model explains the dependence of the variables.

Also, the standard error (Standard error) was calculated, which is equal to 0.00447 meaning very close to zero, which means that the observed points are on the straight line of regression.

Testing of the chosen model was performed by the variance analysis method (ANOVA test) (Table 3).

It has thus been verified whether the model is relevant, meaning if the regression equation parameters differ significantly from 0.

As the unilateral critical probability (Sig.) is less than 0.05% (the assumed risk threshold or the fixed significance threshold) means that the model is statistically relevant (rejecting the hypothesis of the lack of significance of the independent variables).

Table 1. Base area, volume and coefficient of expansion in experimental areas (Cojoacă, 2010)

Test market symbol	Age, years	Production class	The average diameter of the base area, d_g	The average height, h_g	The base area, G		Volume, V		Coefficient of expansion F
					m^2/survey	m^2/ha	m^3/survey	m^3/ha	
Se_1	45	III	18.1	16.6	5.50	27.50	46,524	232,620	0.510
Se_4	40	III	17.9	15.9	6.89	34.45	54,460	272,300	0.497
Se_5	35	III	12.6	12.8	5.11	25.55	33,867	169,335	0.518
Se_7	30	III	13.4	12.7	4.78	23.90	30,979	154,895	0.510
Se_9	50	III	19.7	17.6	5.92	29.60	51,615	258,075	0.495
Se_{10}	50	III	19.7	18.2	5.97	29.85	53,522	267,610	0.493
Se_{11}	35	III	16.4	15.1	4.80	24.00	36,620	183,100	0.505
Se_{13}	55	III	22.6	18.7	6.26	31.30	57,425	287,125	0491
Se_{15}	105	III	33.5	23.6	7.39	36.95	81,624	408,120	0.468
Se_{17}	65	III	24.7	20.5	6.37	31.85	62,283	311,415	0.477
Se_{19}	55	III	21.1	16.8	5.67	28.35	46,234	231,170	0.485
Se_{20}	95	III	28.4	22.2	6.65	33.25	69,097	345,485	0.468
Se_{25}	75	III	27.0	21.3	733	36.65	73,880	369,400	0.473
Se_{26}	55	II	26.6	22.0	6.03	30.15	64,150	320,750	0.484
Se_{27}	70	II	30.8	24.8	729	36.45	86,231	431,155	0.477
Se_{28}	55	II	28.7	21.2	6.54	32.70	64,661	323,305	0.466

Table 2. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.959[a]	0.919	0.907	0.00447	0.919	73.932	2	13	0.000
a. Predictors: (Constant), logH, logD									
b. Dependent Variable: logF									

Table 3. ANOVA[a]Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.003	2	.001	73.932	.000[b]
	Residual	.000	13	.000		
	Total	.003	15			
a. Dependent Variable: logF						
b. Predictors: (Constant), logH, logD						

Estimated values for model coefficients, as well as the statistics needed to verify common assumptions about coefficients, are shown in Table 4. It can be seen (Table 4) that the significance level (*Sig.*) for both the constant and the independent variables (log D and log H) is less than 0.05 and the confidence intervals do not contain 0, where it follows that all the coefficients are statistically significant and the model is relevant.

This means that the size of the coefficients of expansions (F) in the studied area depend on both the diameter D and the height H of the stands. Thus, the estimated model is as follows:

$$\log F = -0.217 - 0.215\log D + 0.153\log H \quad (4)$$

By tabling the (4) relation which expresses the relation between the coefficient of expansion (F) and the diameter (D) and the height (H) for the Turkey oak stands in the Oltenia Plain it was possible to obtain the coefficient of was possible to obtain the coefficient of expansion of the stand depending on diameter and height (Table 5). The graph in Figure 2 and 3 suggests the variation of the coefficient of expansion in relation to both the diameter and the height. It can be noticed that at the same average diameter of the stand, the average coefficients of expansion increase as the height increases, while maintaining the constant height, the average values of the coefficient of expansion decrease with the increase of the average diameter of the stand.

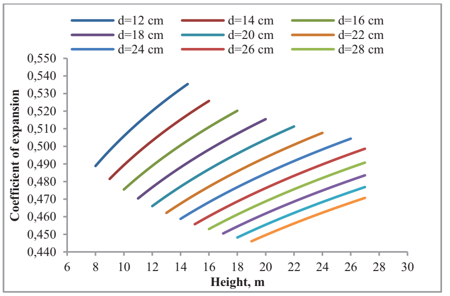

Figure 2. The variation of the coefficient of expansion in relation to both the height

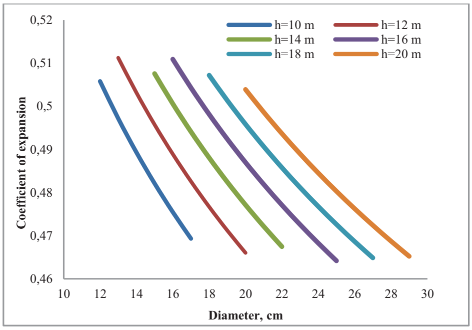

Figure 3. The variation of the coefficient of expansion in relation to both the diameter

Table 4. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
1	(Constant)	-.217	.027		-8.023	.000	-.276	-.159			
	logD	-.215	.049	-1.851	-4.356	.001	-.321	-.108	-.943	-.770	-.343
	logH	.153	.070	.924	2.174	.049	.001	.305	-.895	.516	.171
a. Dependent Variable: logF											

Table 5. The average coefficients of expansion (F) of the Turkey oak in the Oltenia Plain
logF = -0.217 - 0.215logD + 0.153logH

Average heights, H - m	Average diameters, D - cm										
	12	14	16	18	20	22	24	26	28	30	32	34
8	0.489	-	-	-	-	-	-	-	-	-	-	-
8.5	0.493	-	-	-	-	-	-	-	-	-	-	-
9	0.498	0.481	-	-	-	-	-	-	-	-	-	-
9.5	0.502	0.485	-	-	-	-	-	-	-	-	-	-
10	0.506	0.489	0.475	-	-	-	-	-	-	-	-	-
10.5	0.510	0.493	0.479	-	-	-	-	-	-	-	-	-
11	0.513	0.496	0.482	0.470	-	-	-	-	-	-	-	-
11.5	0.517	0.500	0.486	0.474	-	-	-	-	-	-	-	-
12	0.520	0.503	0.489	0.477	0.466	-	-	-	-	-	-	-
12.5	0.523	0.506	0.492	0.480	0.469	-	-	-	-	-	-	-
13	0.527	0.509	0.495	0.483	0.472	0.462	-	-	-	-	-	-
13.5	0.530	0.512	0.498	0.485	0.474	0.465	-	-	-	-	-	-
14	0.533	0.515	0.501	0.488	0.477	0.467	0.459	-	-	-	-	-
14.5	0.535	0.518	0.503	0.491	0.480	0.470	0.461	-	-	-	-	-
15	-	0.521	0.506	0.493	0.482	0.472	0.464	0.456	-	-	-	-
15.5	-	0.523	0.508	0.496	0.485	0.475	0.466	0.458	-	-	-	-
16	-	0.526	0.511	0.498	0.487	0.477	0.468	0.460	0.453	-	-	-
16.5	-	-	0.513	0.500	0.489	0.479	0.470	0.462	0.455	-	-	-
17	-	-	0.516	0.503	0.492	0.482	0.473	0.465	0.457	0.450	-	-
17.5	-	-	0.518	0.505	0.494	0.484	0.475	0.467	0.459	0.452	-	-
18	-	-	0.520	0.507	0.496	0.486	0.477	0.469	0.461	0.454	0.448	-
18.5	-	-	-	0.509	0.498	0.488	0.479	0.471	0.463	0.456	0.450	-
19.0	-	-	-	0.511	0.500	0.490	0.481	0.473	0.465	0.458	0.452	0.446
19.5	-	-	-	0.513	0.502	0.492	0.483	0.474	0.467	0.460	0.454	0.448
20	-	-	-	0.515	0.504	0.494	0.485	0.476	0.469	0.462	0.455	0.450
20.5	-	-	-	-	0.506	0.496	0.486	0.478	0.470	0.464	0.457	0.451
21	-	-	-	-	0.508	0.497	0.488	0.480	0.472	0.465	0.459	0.453
21.5	-	-	-	-	0.509	0.499	0.490	0.482	0.474	0.467	0.461	0.455
22	-	-	-	-	0.511	0.501	0.492	0.483	0.476	0.469	0.462	0.456
22.5	-	-	-	-	-	0.503	0.493	0.485	0.477	0.470	0.464	0.458
23	-	-	-	-	-	0.504	0.495	0.487	0.479	0.472	0.465	0.459
23.5	-	-	-	-	-	0.506	0.497	0.488	0.480	0.473	0.467	0.461
24	-	-	-	-	-	0.508	0.498	0.490	0.482	0.475	0.468	0.462
24.5	-	-	-	-	-	-	0.500	0.491	0.484	0.476	0.470	0.464
25	-	-	-	-	-	-	0.501	0.493	0.485	0.478	0.471	0.465
25.5	-	-	-	-	-	-	0.503	0.494	0.486	0.479	0.473	0.467
26	-	-	-	-	-	-	0.504	0.496	0.488	0.481	0.474	0.468
26.5	-	-	-	-	-	-	-	0.497	0.489	0.482	0.475	0.469
27	-	-	-	-	-	-	-	0.499	0.491	0.484	0.477	0.471

The research carried out in the Turkey oak stands in the Oltenia Plain on the variation of the coefficient of expansion led to the following results:

- based on the experimental material available, a link between the coefficient of expansion (F) of the stands and its main dendrometric characteristics (D and H) was established by means of the multiple linear regression, expressed by the following equation: logF = -0.217 - 0.215 logD + 0.153logH, whose coefficients are statistically significant;
- the determination coefficient $R^2 = 0.919$ shows that approximately 92% of the variation of the coefficient of expansion F is explained by the variation of the diameter D and the height H of the stand;
- with the help of the ANOVA test (Table 3) it was demonstrated that the model adopted was statistically relevant (the hypothesis of the lack

of significance of the independent variables was rejected - Sig. <0.05%);
- by demonstrating the joint influence of both dimensional characteristics (D and H) on the coefficient of expansion (F), the influence of the structure of the stands on their production was revealed, thus eliminating the error-generating hypothesis expressed by the identity $F_D = F_H$;
- given the fact that in establishing the coefficient of expansion (F) of the stand its is taken into account its variability in relation to both the height (H) and the diameter (D), it is possible to make substantial improvements to the determination of the volume of the stands by means of the general formula V = G x H x F. Thus, assuming that the surface would be determined by integral inventories and the height by exact procedures, it is assured a precision as high as in the average tree of the stand method, provided these tables be applied only to the stand category for which they were developed (Leahu, 1994);
- for practical purposes, by tabulation of the relation (4), for the area under study and for the types of stands where the research was carried out, it was possible to prepare provisional tables for determining the coefficient of expansion according to the two features of the stand (D and H) (Table 5). Knowing that variation in the coefficient of expansion of a stand differs from the composition, consistency, age, and production class of the stand (Giurgiu, 1979) for extending the application of these tables to other stand species is necessary complex biometric research.

The research carried out on small spaces, which established the common influence of the diameter D and the average height H on the average coefficient of expansion F of the stand, are in accordance with the recommendations of the specialty literature. Thus, Giurgiu et al. (1979) and Leahu (1994) recommends "the continuation and deepening of the research regarding the auxological dynamics of the stands in relation to the age, structure and household interventions in order to adapt the mathematical-auxological models and the production tables to the regional particularities of the forest ecosystems, passing from general to regional ones on ecological bases."

CONCLUSIONS

By demonstrating the joint influence of both dimensional characteristics (D and H) on the coefficient of expansion (F), the influence of the structure of the stands on their production was revealed, thus eliminating the error-generating hypothesis expressed by the identity $F_D = F_H$.

In conclusion, for practical purposes, for the area of the study case, tables were developed to determine the coefficient of expansion (F) according to the two characteristics of the tree (D and H).

By this way of determining the form factor (F) of the stands, substantial improvements are made to the precision of their volume determination. We can be noticed, after this analysis in the research area in the pure Turkey oak stands of the Oltenia Plain, that at the same average diameter of the stand, the average coefficients of expansion increase as the height increases, while maintaining the constant height, the average values of the coefficient of expansion decrease with the increase of the average diameter of the stand. The research carried out on small spaces, which established the common influence of the diameter D and the average height H on the average coefficient of expansion F of the stand, are in accordance with the recommendations of the specialty literature.

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