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THE INFLUENCE OF STRUCTURAL CHARACTERISTICS ON THE STABILITY OF STANDS AFFECTED BY WINDFALLS AND WINDBREAKS

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Abstract

The stability of stands can be quantified according to their structural, qualitative and synthetic characteristics. The indicators that can be determined according to the main dendrometric characteristics are represented by the thickness index, the density indices, the slenderness index and the Hart-Beking spacing index.

In order to determine the structural and synthesis indices, the field data were recorded on sample plot. by statistical-mathematical inventory.

The values of the indices, which were determined following the processing of field data, emphasized the fact that the analyzed and studied stands have a relatively low thickness and density as well as a corresponding spacing. What is more, the stability to the action of the dominant wind, evaluated by means of slenderness index, is high.

The effects of the extreme weather events that occurred on September 2017 can be explained in correlation with soil thickness and with the presence of the rock relatively to the soil surface. These aspects predisposed the stands to ecosystem instability, being at the same time predisposing factors to a series of ecosystem imbalances.

In conclusion, the stability of stands affected by windfalls and windbreaks is influenced by a complex of factors that are directly correlated with vegetation, environmental conditions and the complex of silvicultural interventions, necessary to be achieved at the right time.

Key words*:* stand stability indices, affected stands, thickness indices, density indices, spacing indices, slenderness indices.

INTRODUCTION

The effects of extreme meteorological phenomena, namely windfalls and windbreaks, on compact surfaces, caused to deciduous stands within the management unit VII Văratec, Sudrigiu Forest District, County Forest Administration Bihor, since 17 09 2017, have affected a considerable area, seriously disrupting the production process (Crainic, 2017).

For the edification and analysis of the factors that favored and triggered the windfalls and windbreaks, in the stands within the management unit VII Văratec, it is necessary to analyze and study the structural, qualitative and synthetic characteristics of these stands. Inthis context, a relevant silvicultural analysis and diagnosis must be carried out,

determining the extent to which the characteristics of the affected stands have contributed to the onset and to the realization of these major natural disasters, respectively (Crainic, 2017).

The elements that are necessary to determine the characteristics of the affected stands, to perform the analysis and silvotechnical diagnosis, are represented by: the composition of the stands, the width index, the density indices, the slenderness index and the Hart-Beking spacing factor. The determination of these elements will be performed following the processing of the data recorded on the occasion of the statistical-mathematical inventories, in the experimental devices, located in the affected stands.

The thickness of the stand can be evaluated as a ratio between the number of existing trees per unit area and the optimal number of trees, established with the production tables for a stand with the same structural and qualitative characteristics.

Thickness by number of trees (from Nicolescu, 1995, Crainic, 2020):

$$I_N = \frac{N_{field}}{N_{table}} \quad (1)$$

where,

I_N - thickness index by number of trees;

N_{field} - number of trees in the field, per hectare:

N_{table} - number of trees in the production tables, per hectare, for a stand with the same structural and qualitative characteristics.

Stand density

Density on the basal area (from Nicolescu, 1995, Crainic, 2020):

$$I_G = \frac{G_{field}}{G_{table}} \quad (2)$$

where,

I_G - thickness index on the basal area;

G_{field} - basal area per hectare, from the field;

G_{table} - basal area from the production tables, per hectare, for a stand with the same structural and qualitative characteristics.

Density by volume (from Nicolescu,1995, Crainic, 2020):

$$I_V = \frac{V_{field}}{V_{table}} \quad (3)$$

where,

I_V - density volume by volume;

V_{field} - volume per hectare, from the field;

V_{table}-the volume in the production tables, per hectare, for a stand with the same structural and qualitative characteristics;

Hart-Beking spacing factor

The spacing factor of the stand expresses the degree of spacing of the trees in the stand, as a ratio between the theoretical distance between the trees and the dominant height, respectively (from Florescu, Nicolescu, 1998). This index will be calculated in two variants, in the situation where the trees in the stand are arranged in the corners of a square of side a and respectively in the corners and center of a hexagon of side a, respectively in chinconz.

$$s_{\%} = \frac{a}{h_{dom}} \times 100 ; \quad (4)$$

$$a_4 = \sqrt{\frac{10000}{N}} ; \quad (5)$$

$$a_6 = \sqrt{\frac{10000}{N\left(\frac{\sqrt{3}}{2}\right)}} ; \quad (6)$$

$$h_{dom} = \bar{h} + 0.15 \cdot \bar{h} \quad (7)$$

$$h_{dom} = 1.15 \times \bar{h} ; \quad (8)$$

where:

$S_{\%}$ - spacing index;

a - average distance between trees in m;

N- number of trees per hectare;

h_{dom} - dominant height;

$\bar{h}$ - medium height.

10000 –number of m^2in a hectare.

$\frac{\sqrt{3}}{2}$ - factor indicating the distribution in chinconz.

a_4 - the theoretical average distance between the trees when they are arranged in a square device;

a_6-the value of the theoretical average distance between the trees when they are arranged in chinconz;

As a result, we will have the following expressions for spacing indices:

$$s_{4\%} = \frac{a_4}{h_{dom}} \times 100 \quad (9)$$

$$s_{6\%} = \frac{a_6}{h_{dom}} \times 100 \quad (10)$$

The spacing factor of the stand, usually used for young and mature stands, pure and equine, can be considered a sensitive indicator of its thickness and stability.

Depending on the value of the spacing factor, the stands can be classified as follows (from Florescu, Nicolescu, 1998, according to Riou-Niver 1984, Bary-Lenger s.a.,1988):

-$S_{\%}$>20% - stands with normal thicknesses;

-$S_{\%}$ =15-20% - relatively thick stands;

-$S_{\%}$ =10-15% - thick, unstable stands;

-S% <10% - excessively thick stands.

The slenderness index

The slenderness index (z) is expressed by the ratio between the average height and the average diameter of the trees (from Florescu, Nicolescu, 1996, Crainic, 2020).

In excessively thick stands, the trees have high heights and small diameters, as a result the slenderness index can register values higher than 100. Consequently, these stands are more vulnerable to damage caused by wind, snow and frost (from Florescu, Nicolescu, 1996, Crainic, 2020).

For the main tree species in the national forest fund, in conditions of optimal ecosystem stability of the stands, the slenderness indices are necessary to have values between 60% - 90% (from Florescu, Nicolescu, 1996; Crainic, 2020).

$$z_{\%} = \frac{\bar{h}}{\bar{d}} \times 100 \quad (11)$$

where:

$\bar{h}$ - medium height;

$\bar{d}$ - medium diameter.

MATERIAL AND METHOD

The case study was carried out in the 104A and 65B compartments (ua), in the management unit VII Văratec,Sudrigiu Forest District, within the County Forest Administration Bihor, during 2017 - 2020. The stands in the analyzed and studied plots, which were affected by windfalls and windbreakscaused by extreme weather phenomena on 17 09 2017.

For the realization of the case study, an appropriate bibliographic documentation was made, using in this context treatises and specialized works and scientific articles.

In the field, observations were made on the itinerary and in stationary, statistical-mathematical inventories and digital recording of field images.

The statistical-mathematical inventories were made on circular sample plots with an area of 1000 m^2 (Giurgiu, Decei, Armășescu, 1972).

The following data were recorded in the field: species, base diameter, package diameter, diameter of the two-way perpendicular root, height of the two-way root, tree height, quality class, condition of the tree.

Photo.1- Location of the case study
(https://www.google.com/maps/place/Sudrigiu/@46.8444641)

Photo. 2 presents the location of the case study for the stand in u.a. 65B.

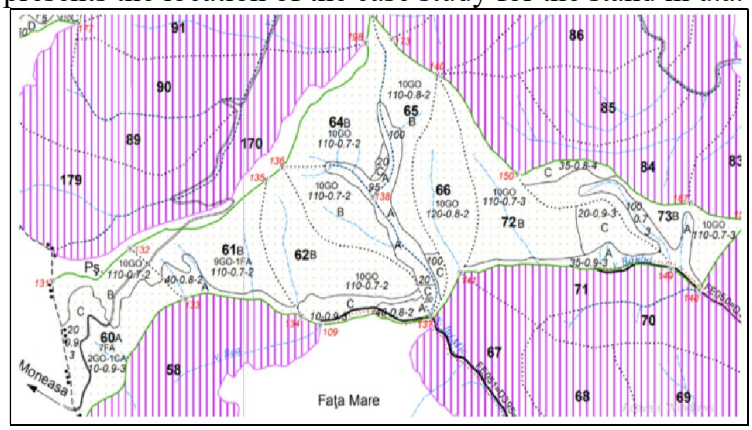

Photo. 2 - Location of the stand in the u.a. 65B (from the general map of U.P. VII Văratec)

Table 1 shows the description of the forest site and respectively, the tree stand in the u.a.104A.

The elements that formed the basis of the statistical-mathematical inventory are the following: u.a. - 65B, $S_{u.a.}$ = 15.0 ha, C.L.P. = II, T = 116

years, K = 0.8, $s_{\%}$ = 30, probability of coverage p = 90%, tolerance t = 10%, shape - circular, Sp = 1000 m2, R_{Sp} = 17.85 m.

Table 1

Description of the stand and site in the u.a. 65B (from amenajamentul U.P. VII Văratec)

DESCRIEREA STATIUNII SI ARBORETULUI	ELM ARB	P R P	M RE GE	VAR STA ANI	DM CM	HM M	C L P	A MES TEC	EL AG AJ	PROVE NIENTA	VI TA LI	DENS CONS	VOLUM MC/ HA	VOLUM MC/ UA	CRES MC/ HA
65 B 15.00 HA GF: 1 - 5I1 5M SUP: K TS: 5153 TP: 5111 SOL: 2201 Versant mijlociu ondulat EXPOZITIE: SV INC: 25 G ALTITUDINE: 500 - 690 M LITIERA: continua-normala TIP FLORA: Asarum-Stellaria Natural fundamental prod. sup. relativ-echien COMP.ACTUALA: 10 GO COMP.TEL: 10GO SORT: FA Gros si mijl.,cherestea VARSTA EXPL.: GOS Gros si mijlociu,cherestea SEM.UTIL: SUBARBORET: DATE COMPL.: Alte date complement. POL: ERZ: LUCRARI EXEC.: 2012-T.produse accidentale 2013-T.igiena LUCRARI PROP.: T.IGIENA	GO	10	IN	110	42	28	2		.6	RN	N	0.80	449	6735	4.4
	TOTAL			110			2					0.8	449	6735	4.4

As a result, according to the ***Tabelele pentru inventarierea statistică a arboretelor*** - 1972 edition, a number of 21 (experimental) sample plots of 1000 m^2 of circular shape was established, the distance between the centers of the sample plots measuring 85 m.

Photo. 3 shows the location of the case study for the stand in u.a. 104A.

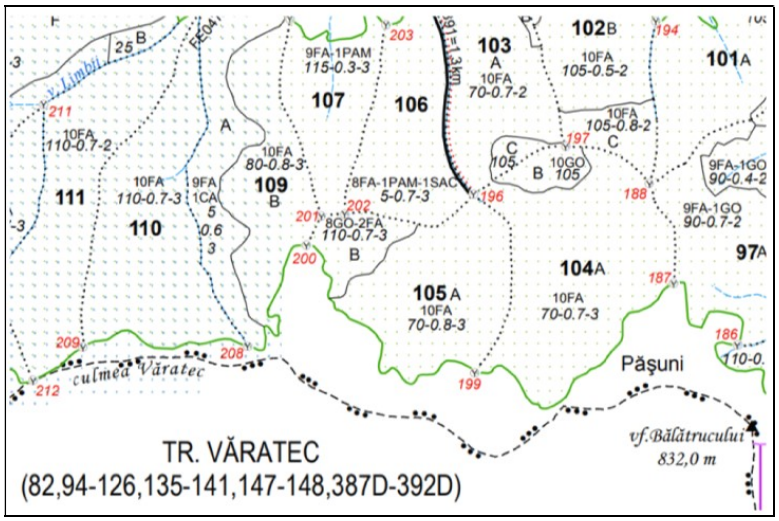

Photo. 3 - Location of the stand in the u.a.104A (from the general map of U.P. VII Văratec)

Table 2 shows the description of the forest site and respectively, the tree stand in the u.a.104A.

Table 2

Description of the stand and site in the u.a. 104A (from amenajamentul U.P. VII Văratec)

DESCRIEREA STATIUNII SI ARBORETULUI	ELM ARB	P R P	M RE GE	VAR STA ANI	DM CM	HM M	C L P	A MES TEC	EL AG AJ	PROVE NIENTA	VI TA LI	DENS CONS	VOLUM MC/ HA	VOLUM MC/ UA	CRES MC/ HA
104 A 35.58 HA GF: 1 - 5M SUP: A TS: 5242 TP: 4212 SOL: 3101 Versant mijlociu ondulat EXPOZITIE: NV INC: 25 G ALTITUDINE: 640 - 840 M LITIERA: continua-subtire TIP FLORA: Asperula-Asarum Natural fundamental prod. mij. relativ-plurien COMP.ACTUALA: 10 FA COMP.TEL: 10FA SORT: FA Gros si mijl.,cherestea VARSTA EXPL.: 110 ani GOS Gros si mijlociu,cherestea SEM.UTIL: SUBARBORET: DATE COMPL.: Roca la suprafata/0,1S Alte date complement. POL: ERZ: LUCRARI EXEC.: 2012-Rarituri 2013-T.produse accidentale LUCRARI PROP.: T.IGIENA	FA	4	IN	105	40	29	3	M	.6	RN	N	0.28	157	5586	1.8
	FA	6	IN	70	26	23	3		.6	RN	N	0.42	161	5728	4.0
	TOTAL			70			3					0.7	318	11314	5.8

The elements that formed the basis of the statistical-mathematical inventory are the following: u.a. - 104A, $S_{u.a.}$ = 35.58 ha, C.L.P. = II, T = 105/70 years, K = 0.8, $s_{\%}$ = 41%, probability of coverage p = 90%, tolerance t = 10%, shape - circular, Sp = 1000 m^2, R_{Sp} = 17.85 m.

As a result, a number of 38 (experimental) sample plots of 1000 m2, of circular shape, was established, the distance between the centers of the sample plots measuring 95 m.

RESULTS AND DISCUSSION

The results obtained from the processing of data recorded on the occasion of statistical-mathematical inventories - respectively the number of trees, the basal area and the volume per hectare, are presented synthetically, by species, for each stand, below.

The following values were obtained for the stand in u.a. 65B:

N_{Go} = 119 pieces./ha;

N_{Fa} = 15 pieces/ha;

G_{Go} = 14.076 m^2/ha;

G_{Fa} = 0.920 m^2/ha;

V_{Go} = 190.271 m^3/ha;

V_{Fa} = 10.430 m^3/ha.

Next, the analysis and silvicultural diagnosis for the stand in the u.a. 65B.

The composition of the stand in u.a 65B

The composition of the stand in u.a 65B will be determined according to the number of trees per hectare, the basal area per hectare and the volume per hectare, respectively.

The composition of the stand by number of trees

$N_{stand} = N_{Go} + N_{Fa}$ = 119 + 15 = 134 pieces./ha.

In conclusion, the composition by number of trees in u.a 65B is:

9Go1Fa - the stand being practically pure.

The composition of the stand on the basal surface

$G_{stand} = G_{Go} + G_{Fa}$ = 14.076 + 0.920 = 14.996 m^2/ha.

In conclusion, the composition on the basal surface of u.a 65B is:

9Go1Fa - the stand being practically pure.

Composition by volume

$V_{stand} = V_{Go} + V_{Fa}$ = 190.271 + 10.430 = 200.701 m^3/ha.

In conclusion the volume composition in u.a 65B is:

9Go1Fa - the stand being practically pure.

Thickness and density of the stand

Table 3

Theoretical values for beech tree stand elements, from u.a. 65B (extract from the *Biometria arborilor și arboretelor din România, Ediția 1972*, table 18.8, p. 673 and table 18.6, p. 661)

1	**Go: T = 110 years, C.L.P. II**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	404	38.2	549	9
2	**Fa: T = 110 years, C.L.P. II**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	401	40.6	625	1
3	**Medium values**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	404	38.44	557	9 + 1

Thickness by number of trees

$$I_N = \frac{N_{field}}{N_{table}} = \frac{134}{404} = 0.33 \cong 0.3$$

Stand density

$$I_G = \frac{G_{field}}{G_{table}} = \frac{14.996}{38.44} = 0.39 \cong 0.4$$

Density by volume

$$I_V = \frac{V_{field}}{V_{table}} = \frac{200.701}{557} = 0.36 \cong 0.4$$

For the u.a. 65B the values of the spacing indices are shown below.

$$a_4 = \sqrt{\frac{10000}{N}} = \sqrt{\frac{10000}{134}} = \sqrt{74.627} \cong 8.6\ m$$

$$a_6 = \sqrt{\frac{10000}{N\left(\frac{\sqrt{3}}{2}\right)}} = \sqrt{\frac{10000}{134\left(\frac{\sqrt{3}}{2}\right)}} = \sqrt{\frac{10000}{116.004}} = \sqrt{86.204} \cong 9.3\ m$$

$$h_{dom} = 1.15 \times \bar{h} = 1.15 \times 26.25 \cong 30.2\ m$$

$$s_{4\%} = \frac{a_4}{h_{dom}} \times 100 = \frac{8.6}{30.2} \times 100 = 28.5\ \%$$

$$s_{6\%} = \frac{a_6}{h_{dom}} \times 100 = \frac{9.3}{30.25} \times 100 = 30.7\ \%$$

As a result, the values of the Hart-Beking spacing indices, we ascertain that the stand in 65B has a very good spacing.

The slenderness index

$$z_{\%} = \frac{\bar{h}}{\bar{d}} \times 100 = \frac{26.25}{41} \times 100 = 64\ \%$$

The value of 64% of the slenderness index indicates that the stand in the u.a. 65B has a high stability to the action of some destabilizing climatic factors (wind, snow, frost, etc.).

In photo. 4, uprooted trees, from the oak species, are presented in the stand from u.a. 65B.

Photo. 4 Oak trees, uprooted in the stand from u.a.65B (G. C. Crainic, 01 08 2019)

Photo.5 Uprooted trees in the u.a. 104A stand (G. C. Crainic, 01 08 2019)

From the analysis of the image in photo 4 and the reality in the field, it can be seen that the roots of the uprooted oak have grown and developed horizontally, being traceable - atypical for this species, due to relatively low soil thickness .

There is also the presence of rock fragments, which were displaced by the roots (and soil) of uprooted trees.

The stand in u.a. 104A

The following values were obtained for the stand in u.a. 104A:

N_{Go}= 6 pieces/ha;

N_{Fa} = 175 pieces/ha;

G_{Go} = 0,418 m^2/ha;

G_{Fa} = 17,893 m^2/ha;

V_{Go} = 5.345 m^3/ha;

V_{Fa} = 221.090 m^3/ha.

Next, the analysis and silvicultural diagnosis for the stand in u.a. 104A.

The composition of the stand in u.a. 104A

The composition of the stand in u.a. 104A will be determined according to the number of trees per hectare, the basal area per hectare and respectively, the volume per hectare.

The composition of the stand by number of trees

$N_{stand}= N_{Go}+ N_{Fa}= 6 +175 = 181$ pieces/ha.

In conclusion, the composition by number of trees in 104A is: **10Fa**, disseminated oak, the stand being pure.

The composition of the stand on the basal surface

$G_{stand}= G_{Go}+ G_{Fa} = 0,418 + 17,893 = 18,311$ m^2/ha.

In conclusion, the composition on the basal surface of u.a 104A is: **10Fa**, the stand being pure and the oak species is disseminated.

Composition by volume

$V_{stand}= V_{Go}+ V_{Fa}= 5.348 + 221.090 = 226.435$ m^3/ha.

In this case, the volume composition of the stand in u.a 104A is: **10Fa**, and the oak species is disseminated, the stand being pure.

Thickness and density of the stand

Table 4

Theoretical values for beech tree stand elements, from u.a. 104A
(excerpt from *Biometria arborilor și arboretelor din România, Ediția 1972*, table 18.6, p. 662)

1	**Fa: T = 70 years, C.L.P. III**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	845	32.4	358	6
2	**Fa: T = 105 years, C.L.P. III**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	523	36.5	480	4
3	**Medium values**			
	N(pieces/ha)	**G(m^2/ha)**	**V(m^3/ha)**	**%**
	716	34.04	406.80	10

Density by number of stands

$$I_N = \frac{N_{field}}{N_{table}} = \frac{181}{716} = 0.25 \cong 0.3$$

Tree Stand

Density on the basal surface

$$I_G = \frac{G_{field}}{G_{table}} = \frac{18.311}{34.040} = 0.54 \cong 0.5$$

Density per volume

$$I_V = \frac{V_{field}}{V_{table}} = \frac{\frac{226.435\ \mathrm{m}^3}{ha}}{\frac{406.800\mathrm{m}^3}{ha}} = 0.55 \cong 0.6$$

Hart-Beking spacing index

For the stand located in u.a. 104 the values of the spacing indices are presented below.

$$a_4 = \sqrt{\frac{10000}{N}} = \sqrt{\frac{10000}{181}} = \sqrt{55.249} \cong 7.4\ m$$

$$a_6 = \sqrt{\frac{10000}{N\left(\frac{\sqrt{3}}{2}\right)}} = \sqrt{\frac{10000}{181\left(\frac{\sqrt{3}}{2}\right)}} = \sqrt{\frac{10000}{156.750}} = \sqrt{63.796} \cong 8\ m$$

$$h_{dom} = 1.15 \times \bar{h} = 1.15 \times 26.5 \cong 30.5\ m$$

$$s_{4\%} = \frac{a_4}{h_{dom}} \times 100 = \frac{7.4}{30.5} \times 100 = 24.3\ \%$$

$$s_{6\%} = \frac{a_6}{h_{dom}} \times 100 = \frac{8}{30.5} \times 100 = 26.2\ \%$$

Given the values of the HartBeking spacing indices, we find that the 104A stand has a very good spacing.

From the analysis of the image in the photo.5 and of the objective reality in the field, it is found that the roots of the uprooted beech specimen, grew and developed horizontally, becoming tracing - atypical for this species, this aspect due -a relatively low soil thickness.

There is also the presence of a considerable volume of rock fragments, which was displaced by the root of the uprooted tree.

The slenderness index

$$z_{\%} = \frac{\bar{h}}{\bar{d}} \times 100 = \frac{26.5}{40} \times 100 = 66.25\% \cong 66\ \%$$

The value of 66% of the slenderness index indicates that the stand in the u.a. 104A has a high stability to the action of destabilizing climatic factors (wind, snow, stove, etc.)

CONCLUSIONS

From the analysis of the results obtained from the processing of field data, and from the analysis and silvotechnical diagnosis, it can be concluded that the structural and synthesis indicators of the stands have values that build an ecosystem stability, consolidated even.Indicii de desime şi densitate a arboretelor studiate au valori subunitare, ca urmare stabilitatea acestora este bună.

The values of the Hart-Beking spacing factor in the studied stands are over 24%, as a result, they have an optimal spacing.

Also, the values of the slenderness indices that are included in the range 60 - 70%, indicate stands with high stability to the destabilizing action of some climatic factors - dominant winds in particular

An important factor that considerably influenced the stability of the studied stands, is represented by a relatively low physiological-active thickness of the soil (determined by the presence of rock on the surface) - aspect that limited the development of the tree rooting system in the studied stands.

As a result, these particularities of the soil and the lithological substrate favored and predisposed to windfalls the stands that presented an atypical rooting system, for the oak and beech species.

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