

## RELATIONSHIP BETWEEN VERTICAL DIFFERENTIATION INDEX AND THE POSSIBILITY OF WINDTHROWS APPEARANCE

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### REVIEW ARTICLE

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#### Abstract

*The research that was the basis of this work is based on the four types of structures that the stands can have in relation to the ages of the trees that compose it. From field observations and the analysis of the areas affected by windthrows, it was found an increased incidence of this phenomenon in stands with simplified even-aged-type structure. The values of the percentages of the volume that are affected suggest the idea that the stands most stable to windthrows are the uneven aged stands. In the medium and long term, silvotechnical interventions will have to be imagined to lead to the establishment of uneven-aged stands with high stability to the action of disturbing factors. In stands with uneven-aged type structures, the percentages of affected wood are a maximum of 21%, while in even-aged stand structures the values exceed percentages between 60-70%. Increasing the degree of stability of the stands will be achieved by creating complex structures that are much more stable to the action of disturbing factors.*

**Keywords:** vertical differentiation index, stand structure, disturbing factors, percentage of wood affected

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#### INTRODUCTION

The stability of stands in the current conditions of the manifestations of climate changes, the most resistant structures to the actions of disturbing factors as well as the conditions, the means and the ways to manage the forests in order to increase their stability are the most important things for forestry research and practice.

It has been proven in the last decades that the forest structures imagined a century ago will have to be rethought in accordance with the current challenges. Thus, the large-scale promotion of pure and even-aged stands will have to be replaced by mixed stands with vertical differentiation in order to increase the self-protection capacity of these forests and to increase the capacity to fulfill the assigned functions (Pastorella & Paletto, 2013).

The complex structures of the stands determine their high productivity and the fulfillment of ecoprotective functions (Bagnaresi et al, 2015). Also, the increase in the complexity of the structure determines the increase in ecosystem services and the reaction capacity of forests to pollutants and the action of disturbing factors caused by climate changes (Gao et al, 2014; Dănescu et al, 2016). The

diversified structures represented by stands with uneven aged structures proved to be much more stable under the action of disturbing factors (Joelsson et al, 2018).

In recent decades, there have been clearer signs that mention the danger of environmental degradation by decreasing the areas covered by natural forests with uneven aged structures (Duduman G., 2011) and the degradation of their structure mainly composed of spruce but also other forest ecosystems that were traditionally not affected by extreme weather events.

The aim of the work is to show the connection between the values of the vertical differentiation index and the stability of the stands under the action of the winds.

#### MATERIAL AND METHOD

For each stand were measured thirty trees and were determined the approach neighbours in number of three to seven and for them were determined the heights. The analyzed trees were statistically randomly distributed so that any tree in the stand had the chance to be part of the analyzed survey. The neighbours of the trees were chosen based on the smallest distances from the tree who was chosen in the thirty.

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The determination of the vertical differentiation index for each analyzed stand was made using the following relation (Ciubotaru & Păun, 2014, Keren et. Al., 2020):

$$DH_n = 1/N * \sum [1/n \sum (1 - X_{ijmin}/X_{ijmax})]$$

in which:

- $DH_n$  is the vertical differentiation index;
- $N$  - number of trees measured;
- $n$  - the number of trees considered neighbors of the analyzed tree  $i$ ;
- $X_{ijmin}$  - the lowest height in each group of trees analyzed,
- $X_{ijmax}$  - the highest height in each group of trees analyzed.

After determining the vertical differentiation index, an analysis was carried out regarding the correlation between the values of this index and the possibility of the occurrence of disturbing factors caused by wind and respectively the intensity of the occurrence of such phenomena.

## RESULTS AND DISCUSSIONS

The percentage of wood affected by windthrows is between 63-74% in the even-aged stands, it decreases slightly in the relatively even-aged stands, the values being between 45-69%, in the relatively even-aged stands the values are between 19-44% and in the uneven-aged stands the values are relatively low 8-21% in uneven-aged stands (see figure 1).

It is worth noting that in the even-aged stands with simplified structures the maximum percentage of affected wood exceeds on average 70% of the stand volume, sometimes it can be close to 100%, which indicates the volume losses that could have been accumulated in these stands from the moment the appearance of the phenomenon until the stands would have reached the age of exploitability.

It should also be noted that in the uneven-aged stands the maximum percentage of affected wood does not exceed 20-21% of the total stand volume. This affected volume largely supports the ecosystem process of continuous regeneration, which supports the perpetuation of structurally diversified stands over time. In these situations, specific structural models capable of increasing the resistance of the stands to destabilizing factors can be imagined in specific areas in relation to the disturbing factors.

The values of the percentages of the volume that are affected suggest the idea that

the stands most stable to windthrows are the relatively uneven aged-stands and uneven aged-stands. In the medium and long term, silvotechnical interventions will have to be imagined to lead to the establishment of uneven-age stands with high stability to the action of disturbing factors.

The vertical differentiation index provides information on the stability of stands and their sustainability over time and also shows us the degree of complexity of the structures, when this index is close to the value one, we have strong stands in front of disturbing factors, while the index is closer to the value zero, the stands are extremely vulnerable.

The possibility of the occurrence of disturbing phenomena is favored by the stands conditions, the structure of the stands, the silvotechnical interventions applied over time, which most often lead to the simplification of the structure of the stands, which makes them extremely vulnerable.

In order to be able to reduce the unfavorable effects of climate change, stands with simplified structures should gradually be replaced by mixed stands with complex structures diversified horizontally and vertically. The management plans will have to be designed in such a way as to achieve the regeneration of stands over longer periods of time in order to obtain uneven-aged stands mixed with at least three to four stand elements.

The silvotechnical interventions proposed in the technical norms will have to take into account the current realities related to climate change and find effective solutions in terms of increasing the stability of the stands under the action of disturbing factors.

In this point we suggest extensive research to establish for various forest formations the ways forward in terms of the intensity of the interventions and finding effective ways to increase the stability of the stands. However, the ability of the stands to exercise their protective functions where the situations require them will also have to be monitored so that the protective side can be realized in the first place.

Table 1

**The structural differentiation of stands in relation to the vertical differentiation index and the percentage of affected wood**

Types of structure	Vertical differentiation index		Percentage of wood affected	
	Minim value	Maxim value	Minim value (%)	Maxim value (%)
Even aged stand forest	0,04	0,19	63	74
Relativ even aged stand forest	0,34	0,45	45	69
Relativ uneven aged forest	0,56	0,68	19	44
Uneven aged stand forest	0,76	0,87	8	21

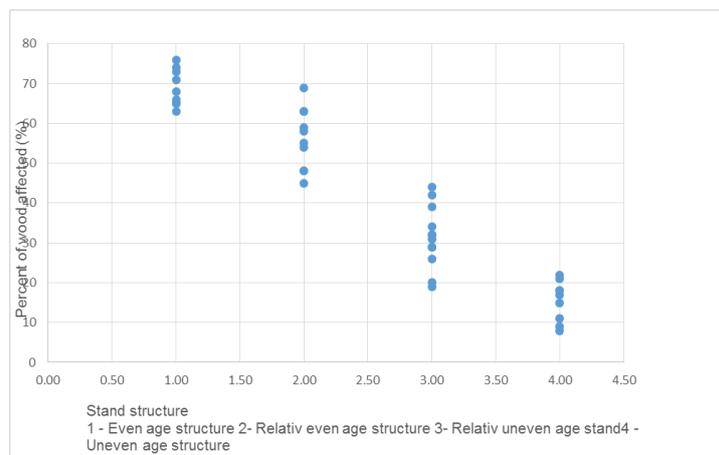


Figure 1 The percentage of wood affected in relation to the type of structure

**CONCLUSIONS**

In the future it will be necessary extensive research on forest formations will be carried out in order to find the best ways to manage the stands so as to reduce the negative effects of climate change.

Variability of the vertical differentiation index in stands of all types of structures supports the idea that silvotechnical interventions influence the values of this index, which makes us argue that in cultivated forest the stability of stands can be directly influenced by the intensity and quality of silvotechnical interventions.

In the even-aged stands, there is a fairly high incidence of windthrows due mainly to simplified structures that are extremely vulnerable to the action of disturbing factors. What should be specified is the fact that these stands with a simplified structure have recently become vulnerable to wind and snow fall.

Increasing the degree of stability of the stands will be achieved by creating complex structures that are much more stable to the action of disturbing factors.

In the future, the transition from monocultures to mixed stands capable of performing multiple functions of great stability to the action of disturbing factors will also be encouraged.

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