STABILITY OF PURE EVEN-AGED CONIFER STANDS IN PORTUGAL

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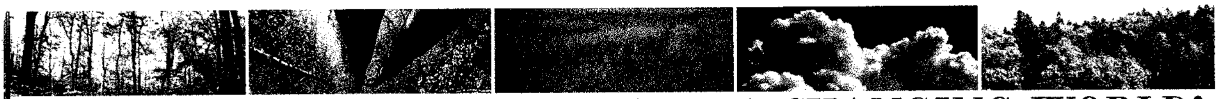
The slenderness coefficient of a tree is defined as the ratio of total height (h) to diameter at 1.3 m above ground (d). For the stand level, the slenderness coefficient is calculated using the quadratic mean diameter and the height of the mean tree as (hg/dg). There is well known that a straight relationship exist between the slenderness coefficient of the stands and the risk of stem breakage or tree fall due to abiotic factors such as the wind or snow. When ignoring or neglecting the aspects related to the stands stability, risks of wood production losses caused by storms can be high. Storms of 1982 and 1999 with wind speeds above 100 Km h^{-1} have particularly damaged extensive forest areas (mainly conifer stands) in the Central European Plain. As the result of learning from these occurrences, the combined effect of hg/dg coefficient and dominant height was found to be a useful and practical criterion for the diagnosis of the stability situation (wind-firmness) of pure even-aged stands of conifer species. Three stability levels have been considered which could be presented in a simple diagram: optimum, moderate and instable. A stand that is let to grow naturally, without intervention, quickly attains the instability level, being more vulnerable to winds of great strength. In Portugal there have been no meaningful episodes of windthrow in conifer stands where the maritime pine (*Pinus pinaster* Ait.) is the most representative species. Future climate scenarios forecast an increase in the growth potential in some forest sites. Higher dominant heights may increase the risk of tree damage caused by violent storms. In this study, an evaluation of the stability status of Portuguese pure even-aged stands of maritime pine and other conifer species is made, based on data from the national forest inventory (NFI) and using stability diagrams. The analysis is undertaken by territorial units of level II (NUT II) with the support of GIS software. Characteristics of the stands that lay in each stability level are compared and discussed.



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Stability of Pure Even-aged Conifer Stands in Portugal

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1. INTRODUCTION

Nivert (2001) presented the main factors affecting stand stability dividing them into biological and physical factors. Physical factors are mainly related to the wind components (direction, speed, and duration), the topography and the site properties (soil depth, structure and drainage). Biological factors include the species characteristics (root anchorage, crown architecture, stem form and strength as well as the mechanical properties of the wood), tree dimensions (height, diameter, crown ratio and slenderness coefficient), tree vigour and health, and tree aggregation (stand density).

The slenderness coefficient of a tree is defined as the ratio of total height (h) to diameter at 1.3 m above ground (d). At the stand level, the slenderness coefficient is calculated using the quadratic mean diameter (dg) and the height of the mean tree (hg). A straight relationship exist between the slenderness coefficient of the stands and the risk of stem breakage or tree fall due to abiotic factors such as the wind or snow. Becquey and Nivert (1987) proposed three stability zones (stable, moderately stable and unstable) in pure even-aged stands of conifer species based in the combined effect of hg/dg coefficient and dominant height (hdom). The authors presented a stability diagram for monitoring the stability status (wind-firmness) of conifer stands. Nivert (2001) presented new stability diagrams based on the dominant height and the quadratic mean diameter.

In Portugal there have been no meaningful episodes of windthrow in conifer stands among which the maritime pine (*Pinus pinaster* Ait.) is the most representative species. However, future climate scenarios predict an increase in the growth potential in some forest sites. Higher dominant heights may increase the risk of tree damage caused by violent storms. A diagnostic of the present situation on stability of Portuguese pure even-aged stands of conifer species is made in this study, using the diagrams proposed by Becquey and Nivert (1987) and Nivert (2001) and based on data from the last national forest inventory (NFI).

2. METHODS

Plots from pure even-aged stands were obtained from the NFI (2005) database. An initial exploratory data analysis was made in order to identify possible anomalies in the data. A total of 616 plots were used in this study, 587 being of maritime pine. In the NFI, only dominant trees and sample trees by diameter class are measured for total height. To obtain the height of the mean tree (hg), height-diameter equations were fitted to the available individual tree data, using also variables from the stand, namely hdom, basal area (G), number of trees per hectare (N) and dominant diameter (ddom). The slenderness coefficient was then computed with the estimated values of hg (hg/dg) and also as hmed/dg, where hmed is the mean value of the measured heights in the plot. Plots were located in the stability diagrams of Becquey and Nivert (1987) and Nivert (2001) by territorial units of level II (NUT II) and classified as stable (1), moderately stable (2) and unstable (3). Using GIS software (ESRI Inc., 2009), unstable plots were identified in the NUT II territorial map. Plots in the three stability zones were compared in relation to dendrometrical, physiographical, silvicultural and other variables as fire occurrence, grazing and tree vigour. A stepwise discriminant function analysis was done in order to evaluate the discriminant power of the studied variables concerning the considered groups (stability zones).

3. RESULTS

Figures 1 and 2 present the plot location in the stability diagrams. In Figure 3, the plots classified as unstable are identified in the NUT II map. Figures 4 and 5 present the distribution of the stand dendrometrical variables by stability zones. Figure 6 shows the structure matrix with the loadings, resulting from the discriminant analysis. The two extracted linear discriminant functions, are plotted in Figure 7.

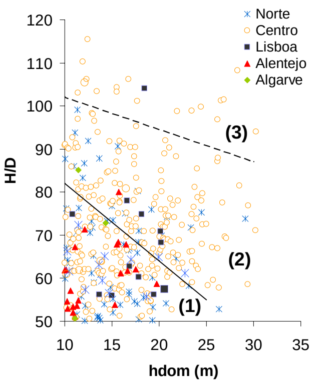

Figure 1. Location of the sample plots in the stability diagram from Becquey and Nivert (1987) by NUT II: 1=stable; 2=moderately stable; 3=unstable

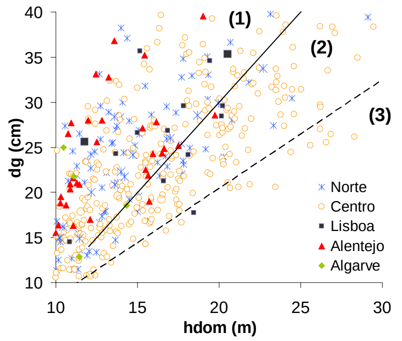

Figure 2. Location of the sample plots in the stability diagram from Nivert (2001) by NUT II: 1=stable; 2=moderately stable; 3=unstable

Figure 3. Location of unstable plots in the NUT II map

	Function	
	1	2
H/D	.722	.474
SI	.338	.069
N	.213	-.089
hdom	.527	-.601
dg	.083	-.520

Figure 6. Structure matrix with the loadings. Function 1 is more related with H/D coefficient and hdom. Function 2 contrasts H/D and SI with hdom, dg and N. Site Index (SI) is more related with Function 1.

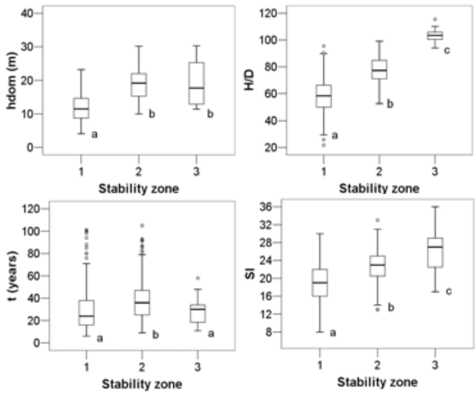

Figure 4. Distribution of stand variables by stability zone (i): 1=stable; 2=moderately stable; 3=unstable. Different letters represent significant differences using a Kruskal-Wallis test and multiple comparison of mean ranks.

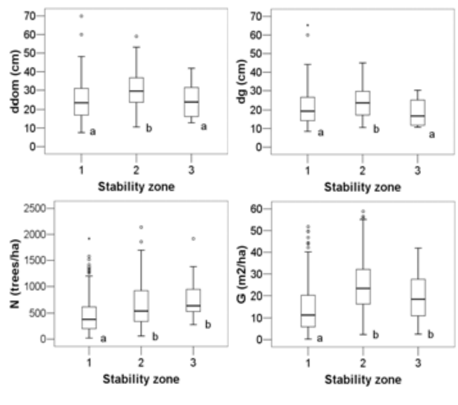

Figure 5. Distribution of stand variables by stability zone (ii): 1=stable; 2=moderately stable; 3=unstable. Different letters represent significant differences using a Kruskal-Wallis test and multiple comparison of mean ranks.

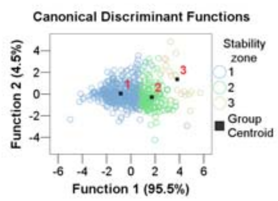

Figure 7. Linear discriminant functions. Groups are: 1=stable; 2=moderately stable; 3=unstable.

4. DISCUSSION

The classification of the plots by stability zone using the diagrams in Figures 1 and 2 were more similar when the stability diagram of Becqey and Nivert (1987) (Fig. 1) was constructed with hmed than with the hg predicted values from the height-diameter equations. Only 19 plots (3%) were located in the unstable zone (3). The median age of these plots which is around 30 years is not significantly different from the median age of plots in the stable zone (1) (Fig. 4). The same occurs for dominant diameter and quadratic mean diameter (Fig. 5). However, plots in zone (3) present significantly higher dominant height than in zone (1) (Fig. 4). This explains the great difference in the values of H/D coefficient between these two stability zones. Plots in the unstable zone (Figs. 1 and 2) represent, on average, stands originating from seedling or natural regeneration with medium to high vigour, related with high site index values. These plots are located in the Centre of Portugal (NUT II - Centro, see Fig. 3), and almost all presented no sign of silvicultural intervention. They are mainly found under the elevation of 600 m and facing north. Thinning early is advisable in high productive sites so that the fast growth in hdom can be compensated by diameter growth and thus, promote robustness of individual trees (Nivert, 2001; Wilson and Baker (2001). Maintaining H/D values under 75 should keep stands in a moderately stable situation.

Sites exposed to prevailing wind and with high slopes are more susceptible to potential damages. The three variables with higher discriminant power between stability zones were, by decreasing order, H/D, hdom and SI. The variables N and dg were also significant. Changes in stand density (N, G) affect average tree dimension (dg). Classification functions using the discriminant variables correctly classified 96.4% of plots by the groups.

5. CONCLUSIONS

- Pure even-aged conifer stands in Portugal, in which the maritime pine is the most representative species, are generally stable based on the diagnostic through the stability diagrams. The mean value of the heights measured in the IFN plots proved to be a good substitute for the height of the mean tree.
- Plots in unstable zone which were only 3% of the total analysed plots, were located in the NUT II Centro.
- Silvicultural operations in high productive sites must be done in proper time to avoid a fast increase of the H/D coefficient and thus the risk of moving to the unstable zone (H/D<75). This could be achieved by applying early moderate-to-heavy thinning and (or) promote low initial stand densities.

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