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A PARAMETER-BASED METHOD FOR DETERMINING THINNING INTENSITY

A method for quantifying thinning intensity in experimental trials in even aged stands is proposed. The method (ICN) is based on Assmann's theory and assesses thinning intensity in terms of percentage of basal area to be removed. According to the proposed method, maximum stand basal area of an even-aged stand is expressed in terms of its dominant height. The ICN index was used to quantify thinning intensity in an objective and replicable manner in experimental comparisons among different thinning intensities in black pine reforestations in Tuscany (Italy).

Key words: Black pine reforestation; maximum stand basal area; *Pinus nigra*; Italy.

1. Introduction

Determining the intensity of forest thinning through the use of objective indices is important for setting up experimental comparisons between different thinning regimes and for translating the results of the experiments into operational guidelines for forest management.

The literature contains various methods for assessing the intensity of forest thinning (e.g. Becking, 1953; Assmann, 1970), and forest research has long focused on this issue (e.g.: Penistan, 1960; Tustin *et al.*, 1976; Montero *et al.*, 2001; and for Italian forests: Ciancio and Martire, 1971; Ciancio and Nocentini, 1978; Corona *et al.*, 1987, 1995; Corona, 1991).

The method presented here is based on Assmann's theory (1970), which defines variable density thresholds in relation to the *maximum basal area* of the stand. This is the basal area attained, at different ages, by stands

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that have never been thinned and where density is reduced mainly by natural mortality.

To verify its applicability, the method was used for experimental comparisons among different silvicultural interventions in black pine (*Pinus nigra* Arn.) reforestations in Tuscany.

2. METHOD

2.1. Basal area thinning intensity

The following index was developed to quantify basal area thinning intensity expressed in percentage terms:

$$ICN = \alpha * \left(1 - \frac{0.15 * B_{max}}{B}\right) \quad [1]$$

where: B = basal area (in m^2ha^{-1}) of the stand; B_{max} = maximum stand basal area (in m^2ha^{-1}); α = variable parameter in relation to the optimum basal area (*sensu* Assmann) to be identified experimentally.

The formula is based on the following assumptions:

– thinning intensity is highest in stands where the basal area is equal to the maximum basal area (*sensu* ASSMANN, 1970);
– thinning intensity is nil in stands that have just attained canopy closure; according to HUSCH *et al.* (2003), on the average, this condition corresponds to a basal area equal to approximately $0.15*B_{max}$;
– thinning intensity decreases linearly between the maximum basal area and recently achieved canopy closure conditions.

When $B = B_{max}$,

$$ICN_{max} = \alpha * (1 - 0.15)$$

hence

$$\alpha = \frac{ICN_{max}}{0.85} \quad [2]$$

In practice, according to formula [1] with different values of ICN_{max}, we obtain different values of α, for example:

$ICN_{max} = 15\ \%, \alpha = 17.6$
$ICN_{max} = 20\ \%, \alpha = 23.5$
$ICN_{max} = 25\ \%, \alpha = 29.4$
$ICN_{max} = 30\ \%, \alpha = 35.3$

Therefore, this method can be used to quantify thinning intensity in experimental comparison trials. When B_{max} and B are known, we can

compare different parameter-based thinning intensities for different values of α. Thus, once the value α that gives the best results for cultivation purposes has been determined from the experimental results, the same intensity as calculated with *ICN* can be proposed on the operational level for other even-aged stands with the same dendrological composition.

2.2. Estimating the maximum stand basal area

In order to apply *ICN* we must estimate the maximum basal area for the stand. According to Assmann's method, B_{max} is the basal area of "control" stands where no thinning is carried out. This is only possible when long-term experiments are conducted.

According to STERBA'S hypothesis (1987), that has been exploited by SKOVSGAARD and VANCLAY (2007) too, the maximum basal area of an even-aged stand can be expressed in terms of its dominant height (H_{dom}, in m). This can be estimated on the basis of forest inventory data for large areas and the data collected in experimental trials, by drawing a curve where the value of *B* in any given test point is at most equal to the value indicated by the curve itself in relation to the corresponding stand dominant height.

3. EXPERIMENTAL APPLICATION

The ICN formula was tested within the framework of the MOGFUS project which, among other goals, aims at identifying new operational methods for improving reforestation of mainly black pine in Tuscany (www.aisf.it/mogfus/; BARBATI *et al.*, 2008; BIANCHI *et al.*, 2009).

The objective of the MOGFUS project is to evaluate the effectiveness of different types of silvicultural interventions in triggering renaturalization processes. The experiments were conducted in three different black pine stands that differ as to age and previous treatments (BIANCHI *et al.*, 2009):

– Rincine, in the area managed by the Comunità Montana della Montagna Fiorentina (Florence);
– Alpe di Catenaia, in the area managed by the Comunità Montana del Casentino (Arezzo);
– Monte Amiata, in the area managed by the Consorzio Forestale del Monte Amiata (Grosseto).

The experimental protocol called for a comparison of the following treatments:

D – thinning from below;
B – opening of very small gaps;
T – no intervention.

In each location we created three experimental plots of 2500 m^2. The treatments were randomly assigned to the experimental plots. In each plot, each tree with a stem diameter of at least 5 cm at breast height was assigned a number, its diameter measured, and species and position in the plot were recorded.

The ICN index was used for the thinning from below treatment in order to quantify thinning intensity in an objective and replicable manner among the three locations.

Using the data from the Regional Forest Inventory (REGIONE TOSCANA, 1998) and the data acquired during the dendrometric campaigns conducted by the Istituto di Assestamento Forestale of the University of Florence on black pine forests in Tuscany (BERNETTI *et al.*, 1969; HERMANIN and SANI, 1989) and also within the context of the MOGFUS project, we drew the curve of the maximum basal area (Figure 1).

Following the methods described in § 2.2, the equation which best interprets the variations in B_{max} in relation to H_{dom} is:

$$B_{max} = 110 * (1 - e^{-0.056 * H_{dom}}) \quad [3]$$

According to the proposed method, once we have determined H_{dom} in a given black pine stand, we can calculate B_{max} using formula [3] and compare it with the real basal area (B) of the stand. By inserting B_{max} and B in [1] we can determine the *ICN* for different values of α. Or, if we know the intensity of the thinning, we can obtain α in order to be able to compare with values of α obtained by thinnings conducted under similar conditions.

In the MOGFUS experiments, B_{max} was estimated for the three areas according to the method shown in Table 1. The relationship between B and B_{max} was strongly correlated with the management history of the stands. In the Rincine areas, where the stands had never been thinned, the ratio between B and B_{max} varies between 0.99 and 0.97; in the Monte Amiata pine forest where the reforested area had already been thinned once, the ratio between B and B_{max} varies between 0.83 and 0.69, while in the Alpe di Catenaia, where the stand had been thinned twice, the ratio ranges from 0.64 to 0.52.

For the experiment we selected a value of 25 for α which corresponds to a theoretical thinning when B=B_{max} equal to 21% of the stand basal area. Thinning intensity was calculated for each location using the mean dominant height of the plots assigned to the treatments *T* and *D*. From [1] we calculated a thinning intensity in terms of percentage of the basal area to remove, and this varied from 19% to 21% in the different stands (Tab. 2). As set out in the experimental protocol, the trees were chosen according to thinning from below criterion.

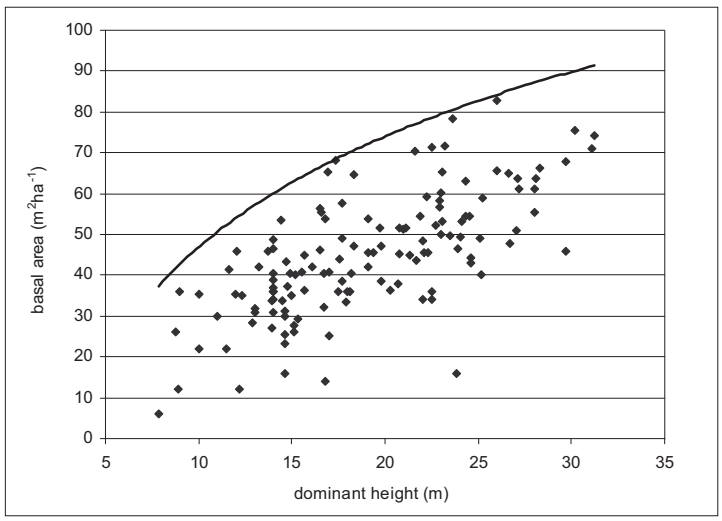

Figure 1 – Scatterplot of *B* vs. H_{dom} in black pine stands in Tuscany. The graph shows the curve of equation 3.

Table 1 – Experimental areas in black pine stands in Tuscany. Dendrometric data prior to thinning (B_{max} calculated by equation 3).

	Age years	Number of trees (N ha^{-1})	Mean diameter (cm)	Stem volume (m^{3}ha^{-1})	H_{dom} (m)	B_{max} (m^{2}ha^{-1})	B/B_{max}
			Rincine				
D thinning from below	35	1360	25.2	530	17.4	68.48	0.99
T control	35	1712	22.1	494	16.9	67.31	0.97
			Alpe di Catenaia				
D thinning from below	39	1216	22.2	402	19.8	73.70	0.64
T control	39	1160	20.5	318	19.8	73.70	0.52
			Monte Amiata				
D thinning from below	50	1128	25.0	413	16.6	66.58	0.83
T control	50	960	24.8	344	16.5	66.34	0.69

4. Discussion and conclusion

The objective of this method is to identify a procedure that permits an objective comparison of different grades of thinning from below on the basis of dendrometric parameters such as dominant height and basal area. These parameters are easily measured in the forest and are considered significant indicators of structural and productivity characteristics of an even-aged stand (Rollison, 1985). Vanclay and Sands (2009) also suggest that in many cases

Table 2 – Thinning intensity according to the ICN method (with α = 25) in the MOGFUS study plots assigned to the treatment D.

	B* (m^2ha^{-1})	H_{dom}* (m)	ICN (%)	Basal area to be removed (m^2ha^{-1})
Rincine	66.78	17.1	21	14.02
Alpe di Catenaia	42.81	19.8	19	8.13
Monte Amiata	50.85	16.6	20	10.17

* average of T and D plots

the concept of maximum stand basal area may be a practical and parsimonious explanation of mortality in even-aged forest plantations.

Assman's theory was formulated to identify the optimum cultivation density of forests for productive purposes. In this sense the optimum basal area is the basal area that produces the greatest positive increment differential with respect to non-thinned forests. However, since basal area is correlated with the degree of canopy cover (HUSCH *et al*., 2003), the index proposed here can also be useful for parameter-based cultivation treatments with different aims such as ascertaining the effects of thinning on triggering renaturalization processes.

The critical point of the method is the quantification of the relationship $B_{max}= f(H_{dom})$, especially with regard to the availability of adequate inventory and experimental data. But, since the aim of the *ICN* method is primarily to provide a parameter-based procedure for the experimental comparison of different thinning intensities, we believe that the method can indeed be useful. The experiments currently in progress may be able to provide information about the *ICN's* ability to shed light on possible differences in the stands' reactions to different thinning intensities as well as on the method's real utility on the operational level.

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