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Derivation of target stocking for forests of Norway spruce vegetation zone in Slovakia

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ABSTRACT: The present paper deals with derivation of target stocking in forests of Norway spruce vegetation zone. Target stocking in forests with prevailing ecological and social functions is the stocking when the forest fulfils demanded functions in the best way. For forests in the Norway spruce vegetation zone target stocking was derived by original procedures as an optimum stocking in harmonization of demands on the fulfilment of ecological functions (especially erosion control, hydrological and water protection ones), securing static stability and preconditions for the formation and growth of natural regeneration. We investigated the relations between stocking and indicators of static stability (slenderness coefficient and ratio of crown length to tree height), natural regeneration phases, ground and non-wood vegetation coverage and natural regeneration coverage. The most favourable status of these indicators was found out in stocking 0.7 and in the upper forest limit 0.6.

Keywords: Norway spruce vegetation zone; target stocking; static stability; slenderness coefficient

As a rule stocking is defined as an indicator of the growth space utilization by a forest stand. According to Greguš (1976) target stocking is the stocking when the stand fulfils the determined functions in the best way. In commercial forests it is mainly production of wood and simultaneously fulfilment of other functions; in protective forests mainly fulfilment of publicly beneficial (ecological and social) functions (Midriak 1994). Greguš (1989) considered target stocking as an important component of management objectives especially because it informs us, though indirectly, but clearly about the fulfilment of desired functions and about the phase of regeneration. Especially by a change in stocking the manager can influence the development in forests. Derivation of target stocking is therefore a significant prerequisite to ensure professional care of forests, including those in the Norway spruce vegetation zone (*svz*) with the objective of achievement of their maximum functional utility.

Assmann (1961) defined these concepts: optimum stocking with optimum stand basal area in which the forest stand produces maximum volume increment; maximum stocking with maximum stand basal area formed by living trees; critical stocking with critical stand basal area in which the forest stand still produces 95% of its maximum increment. In Slovakia mainly these authors dealt with issues related to target stocking: Halaj (1973, 1985), Faith and Grék (1975, 1979), Korpeľ (1978, 1979, 1980), Šmelko et al. (1992), Korpeľ and Saniga (1993), Kamenský et al. (2002), Fleischer (1999), Moravčík et al. (2002).

MATERIALS AND METHODS

Target stocking in the forests of the *svz* was derived on the basis of an original procedure as optimum stocking with harmonization of the requirements for the fulfilment of ecological functions, securing static stability and the existence of adequate conditions for formation and development of natural regeneration.

To achieve this objective our own empirical material was analyzed whose detailed characteristics are also listed in Moravčík (2007). Research was aimed at the investigation of relations between stocking and indicators of static stability (slenderness coefficient and ratio of crown length to tree height), conditions for the formation and development of natural regeneration, coverage of natural regeneration and coverage of ground and non-wood vegetation in natural and semi-natural stands of the *svz*. The following procedure was used to achieve the objective:

– Obtain and assess the own empirical material from permanent research plots (PRP) with the aim to find out detailed data on both natural and stand conditions of Norway spruce by means of the indicators suitable for expressing the target stocking of structurally differentiated forests.
– In the establishment of PRP use the procedures being usual in research and practice of forest management (Šmelko 1985; Šmelko et al. 1996), i.e. establish circular plots of the area 2–10 ares, at least 25 trees per each plot.
– To derive target stocking it is necessary to find out the state of the following indicators:
  • *Crown length to tree height ratio*; it was calculated as the quotient of the crown length and tree height multiplied by 100.
  • *Slenderness coefficient* as the ratio of the absolute value of tree height to tree diameter; it was calculated as the quotient of tree height and tree diameter $d_{1.3}$ multiplied by 100.
  • *Stocking* as a relative indicator of stand density was determined by a traditional method of Lesoprojekt (1995) as the proportion of considered trees and the sum of considered and missing trees to full stocking.
  • *Canopy* as the percentage of shaded area; it was determined by estimating the percent of shading the area by the stand, whereas all measured trees on PRP were considered.
  • *Ground vegetation* as the percent of coverage of non-wood and shrubby vegetation on PRP; percent of coverage was determined in the groups: grasses, herbs, mosses and lichens, shrubs and semi-shrubs and total coverage.
  • *Young regeneration and thicket* on PRP as the percent of coverage by tree species in respective developmental stages; current year seedlings, natural seeding being high 50 cm, advance growth being high 1 m and thicket within diameter $d_{1.3}$ < 6 cm were distinguished.
  • Conditions for natural regeneration of spruce were evaluated according to Korpeľ (1990), Vacek et al. (2003) in three phases (juvenile, optimal and senile).

Juvenile (early/premature) phase – it is characterized by the almost closed canopy of stand with a marked microclimate buffering climatic extremes and by low coverage of ground vegetation. In the forests of the *svz* the soil is usually covered by a layer of forest floor, and low herbs and mosses with total coverage 30–40% prevail in the ground vegetation. The parent stand is capable to ensure natural seeding of the plot being regenerated by a sufficient amount of seeds that can germinate but the conditions of the stand environment are not suitable for the growth of natural seeding and formation of advance growth.

Optimal phase – it is characterized by the relatively open canopy, and thus by an increased access lof light, warmth and moisture to the soil surface. Climatic extremes are alleviated by the stand. Thin ground vegetation with prevalence of herbs over grasses occurs on the whole plot. In the forests of the *svz* this phase is frequently characterized also by the whole-area occurrence of mosses (more than 20%). Conditions of the stand environment enable the stages of germination, natural seeding, as well as advance growth on the same plot.

Senile (late) phase – it has the markedly open canopy of parent stand that enables almost a full access of light, warmth and moisture to the soil surface. In the dense ground vegetation grasses and high herbs prevail markedly. Ferns can be dominant in the stands of the *svz* at northern exposures as well. Conditions for the stages of seedling germination and their growth are not favourable any more. Providing there are natural seedlings or advance growth in the stand they can develop successfully.

Basic criteria for the classification of stands according to naturalness classes were based on the categorization of Zlatník (1976) used also in the works of Korpeľ (1989), Greguš (1998), Fleischer (1999) and others as follows:

A – primeval forest (without any anthropic activity),
B – natural forest (appearance like a primary forest without any signs of anthropic activity),
C – semi-natural forest (natural tree species composition, altered spatial structure due to extensive anthropic activity),
D – prevailing semi-natural forest (natural signs prevail over anthropic signs),
E – slightly changed forest (forest with the presence of natural as well as anthropic signs, anthropic ones prevail),

Table 1. Overview of aggregated naturalness classes and their classification according to developmental stages

1 – primeval forests (A)	2 – natural and semi-natural forests (B, C)	3 – man-made forests (D, E)
11 – in the stage of growth	21 – in the stage of growth	34 – tending phase
12 – in the stage of optimum	22 – in the stage of optimum	35 – regeneration phase
13 – in the stage of disintegration	23 – in the stage of disintegration	–

F – markedly changed forest (forests with anthropic signs only but of natural appearance),

G – completely changed forest (forest stand with anthropic signs only, of not natural appearance).

For practical needs of general and detailed planning less detailed classification of forests into aggregated degrees of naturalness was proposed, complemented by Korpeľ's (1989) classification according to basic developmental stages (Table 1).

During research a total of 122 PRP were established in forest regions of Low Tatra Mts. (85 PRP), High Tatra Mts. (18), Poľana (12) and Veľká Fatra (7).

They were established in the group of forest types (GFT) SP – *Sorbeto-Piceetum* and LP hd – *Lariceto-Piceetum* higher degree (8 PRP), AcP hd – *Acereto-Piceetum* higher degree (22), FP hd – *Fageto-Piceetum* higher degree (9) and in CP – *Cembreto-Piceetum* (7).

The classification of PRP according to naturalness classes (NC) including intermediate degrees was as follows: A (1 PRP), A/B (16), B (49), B/C (25), C (20), D (7) and E (4).

The classification of PRP according to altitude was as follows: to 1,350 m (14 PRP), 1,351–1,400 m (212), 1,401–1,450 m (29), 1,451–1,500 m (32), 1,501 to 1,550 m (19) and above 1,551 m (7).

RESULTS AND DISCUSSION

Analysis of the present stocking of forests of Norway spruce vegetation zone

Actual stocking on PRP was analyzed in the forests of the *svz* in relation to the degrees of naturalness classes, development stages, altitude and GFT. Average stocking on PRP (Fig. 1) established in primeval forests reached the value 0.61, in natural and semi-natural forests 0.62 and in artificial forests 0.76. The lowest values of stocking were found in the decline stage (0.52 in NC 1 and 0.45 in NC 2). In the growth stage these values are 0.55 in NC 1 and 0.65 in NC 2. In the stage of optimum the values 0.69 and 0.72 were found. In average data on stocking there were not any statistically significant differences between stocking in the upper and lower altitudinal zone.

Forests of the *svz* are permanently naturally open and thin by their appearance, towards the timberline the stands are thinner. Along the timberline they have a character of thin park forests. The assessment of stocking by the procedure being used and traditional in lower vegetation zones indicates that in extreme site conditions of *svz* the density of stands is lower. The covered necessary production area of one equally mature tree (in the same height of the stand) is higher than in lower vegetation zones (Halaj 1973). This is a result of the natural growth process not influenced by man. Trees in extreme conditions need a relatively greater growth area.

Using the traditional way of stocking determination as the ratio of considered trees and the sum of considered trees and trees missing to the full stocking we estimate its value to be lower than 1.0 though it is frequently only the result of natural growth processes not influenced by man or injurious agents and its higher value under the given conditions (with regular spacing of trees) is not possible. In this case reduced clearing is unproductive clearing. Its reforestation is impossible. It is a part of the natural growth process and natural stocking of stands below the timberline also according to Assmann (1961).

By the used procedure in *svz* we estimate stocking lower than 1.0 but we understand it as full natural stocking under given conditions.

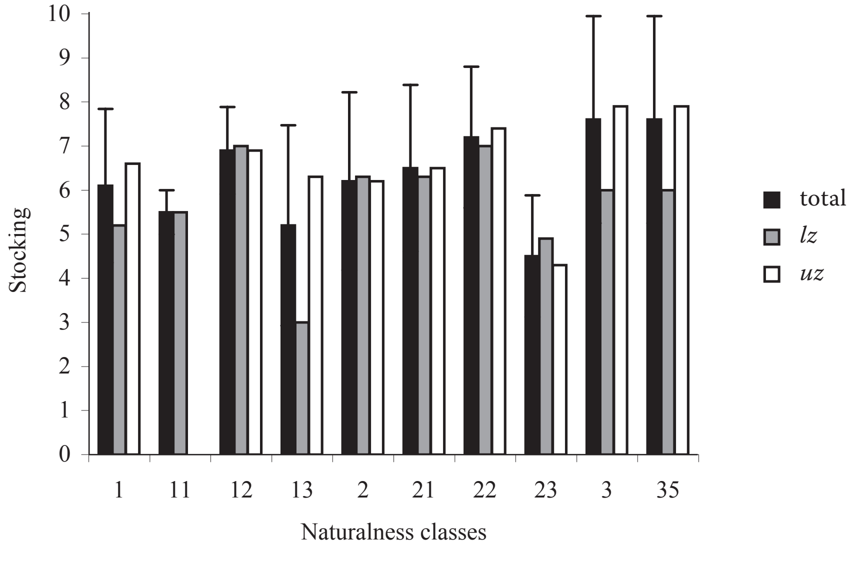

Fig. 1. Stocking according to the naturalness classes and altitudinal zone

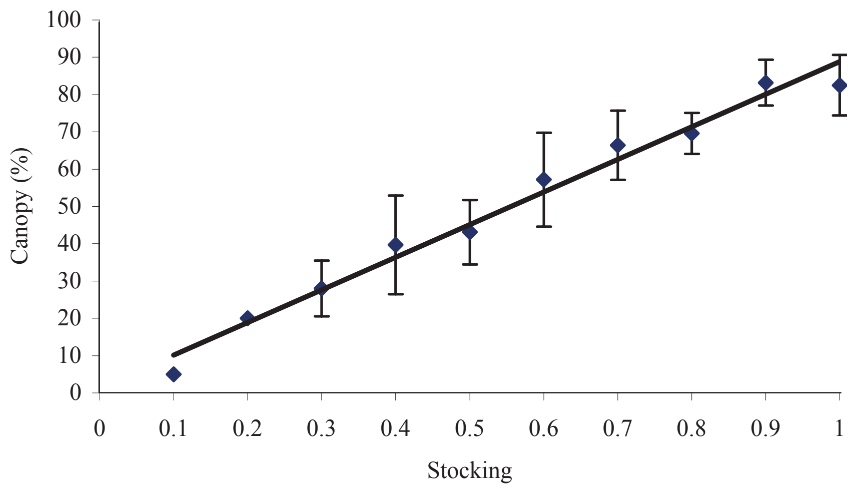

Fig. 2. A relation between estimated canopy (%) and stocking

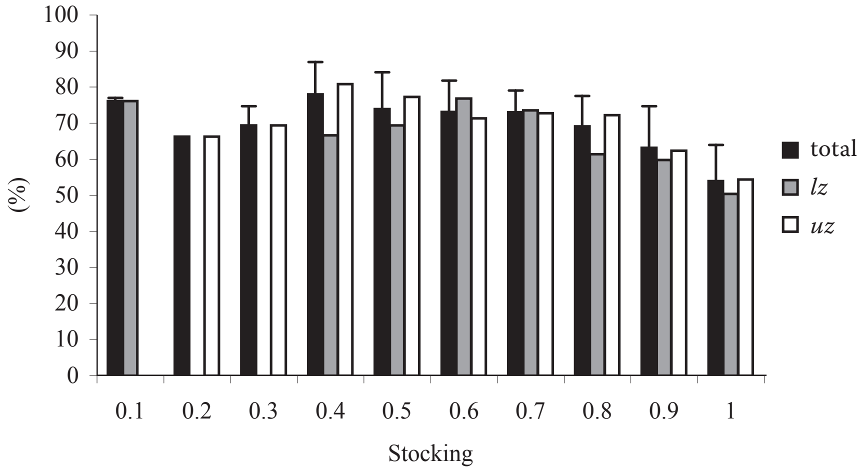

Fig. 3. A relation between the ratio of crown length to tree height (%) and stocking

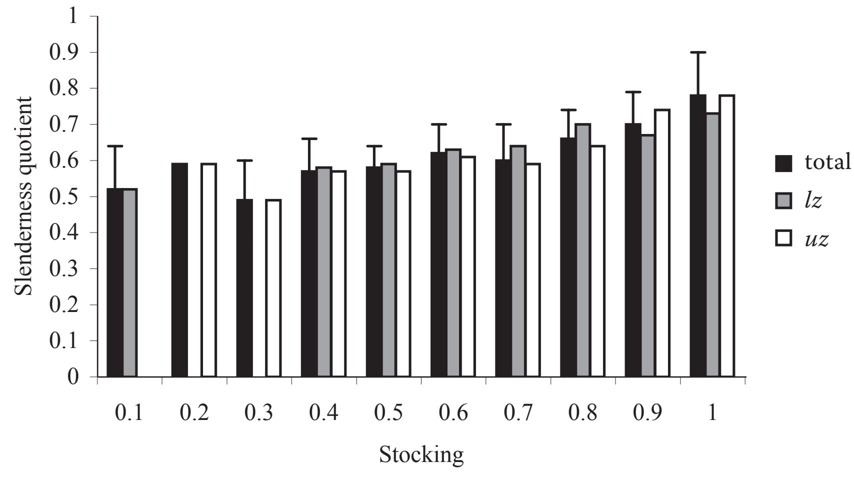

Fig. 4. A relation between slenderness coefficient and stocking

Derivation of target stocking

Optimal stocking in the forests of *svz* was derived so as it would correspond in the best possible way to requirements for the fulfilment of ecological functions (soil protection, hydrological function), securing static stability and the existence of conditions for the formation and development of natural regeneration.

It follows from the analysis of the relation between the ratio of crown length to tree height and stocking that with lower stocking the ratio is increasing, up to stocking about 0.7. Further drop of stocking is not reflected significantly in the increase in the ratio (Fig. 2).

It follows from the analysis of the relation between slenderness coefficient and stocking that with lower stocking the value of slenderness coefficient is lower as well. It drops to the value about 0.7. Further drop

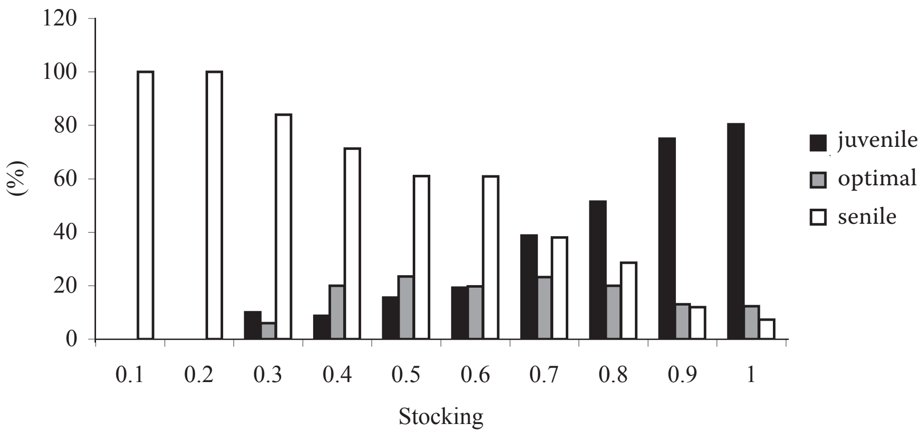

Fig. 5. A relation between natural regeneration phases (%) and stocking

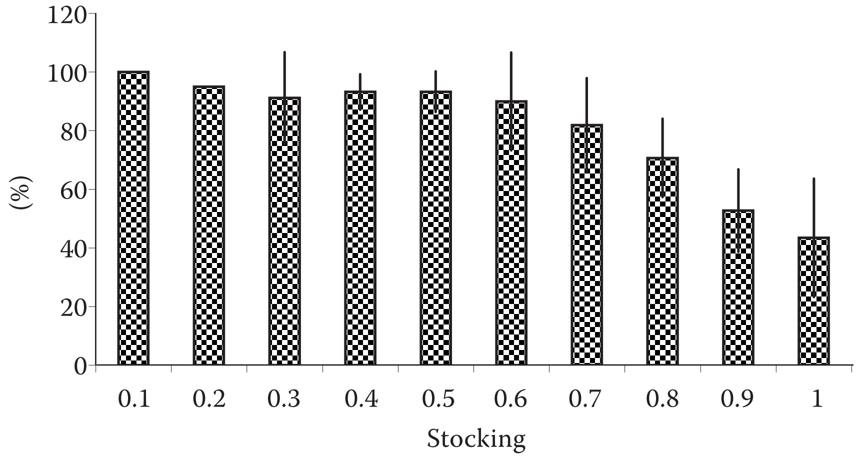

Fig. 6. A relation between ground and non-wood vegetation coverage (%) and stocking

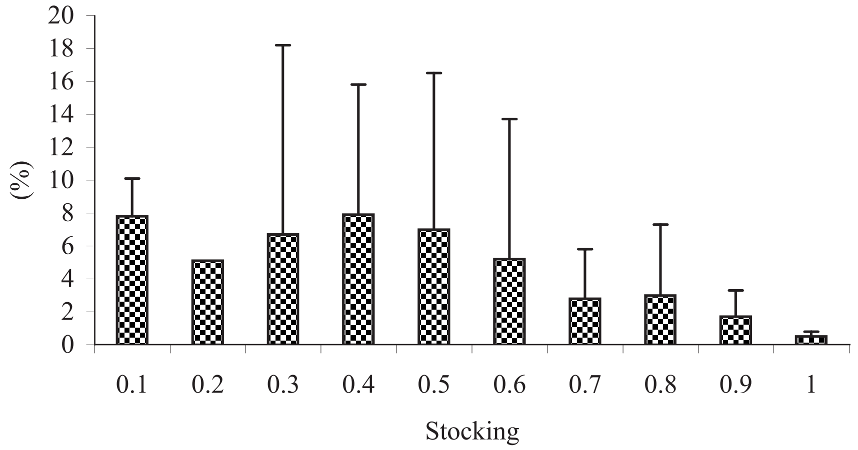

Fig. 7. A relation between the coverage of natural regeneration (%) and stocking

of stocking is not reflected significantly in the drop of the slenderness coefficient (Fig. 3).

It follows from the analysis of the relation between the conditions for natural regeneration and stocking that the most suitable combination of all three phases of preconditions for natural regeneration (juvenile, optimal, senile) is with stocking 0.7 (Fig. 4). At this value there are the most suitable conditions for the formation and development (advance) of natural regeneration as well as adequate coverage of ground and non-wood vegetation (Figs. 5 and 6).

The optimum values of stocking with regard to the state of evaluated indicators are for stocking 0.7 or 0.7+. It follows from this finding that on average target stocking is about 0.7 for the forests of *svz*. It can differ slightly in dependence on the altitudinal zone or GFT. More significant differentiation can occur in dependence on the developmental stage but the objective of the care of forests of *svz* is to prevent the occurrence of the developmental stage "decline" on large areas. It is a desirable permanent (continuous) effect of this indicator of stand structure on forest functions.

Table 2. Target stocking according to the groups of forest types and altitudinal zone

Group of forest types	Target stocking	
	lower zone	upper zone
SP	0.7	0.7. at timberline 0.6
LP hd	0.7	0.7. at timberline 0.6
AcP hd	0.7	0.7. at timberline 0.6
FP hd	0.7	0.7. at timberline 0.6
CP	individuals and trees in clusters and shrubs on rocks and cliffs	

SP – *Sorbeto-Piceetum*, LP hd – *Lariceto-Piceetum* higher degree, AcP hd – *Acereto-Piceetum* higher degree, FP hd – *Fageto-Piceetum* higher degree, CP – *Cembreto-Piceetum*

We can consider the given stocking rounded to 0.7 as Assman's natural stocking of the stands of *svz* below the timberline being evaluated by a practical manager with a traditional attitude. The values of stocking lower than 0.7 but within 0.7 determine the area share to complement or regenerate the stand. This can be considered if it is a continuous plot of circular not very elongated shape of minimal area (300 m^2, e.g. 17 × 18 m, 20 × 15 m, etc.), which is an obvious stand gap after missing trees. Similarly Fleischer (1999) stated that he found more permanent natural regeneration already on the area of minimally 300 m^2. In this sense also Korpeľ and Saniga (1993) considered the area 200–300 m^2 as sufficient even for larch as well. Kamenský et al. (2002) reported that in the stands with stocking about 0.7 without herbaceous cover, herbs and mosses occur only occasionally are the best conditions for the formation of natural regeneration. Korpeľ (1979) concluded that at the altitudes above 1,300 m it is important that individuals of spruce have a high ratio of crown length to tree height with open canopy. According to the conducted research he gives the stocking about 0.7 as desirable at the timberline and on extreme and stony soils as well as at lower sites. The proposed target stocking according to GFT and altitudinal zone following from the results of the presented research is listed in Table 2. In given stocking the stands of *svz* are capable to fulfil determined ecological and social functions in the best way.

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Odvodenie cieľového zakmenenia lesov smrekového vegetačného stupňa na Slovensku

ABSTRAKT: Príspevok sa zaoberá odvodením cieľového zakmenenia lesov smrekového vegetačného stupňa (*vs*). Cieľové zakmenenie v lesoch s prevládajúcimi ekologickými a sociálnymi funkciami je zakmenenie, pri ktorom lesy najlepšie plnia požadované funkcie. V lesoch smrekového *vs* sa odvodilo na základe pôvodného postupu ako optimálne zakmenenie pri zosúladení požiadaviek na plnenie ekologických funkcií (najmä pôdoochranných, vodoochrannej a vodohospodárskej), zabezpečenie statickej stability a podmienok pre vznik a odrastanie prirodzenej obnovy. Preto sa s využitím vlastného empirického materiálu skúmala závislosť medzi zakmenením a ukazovateľmi statickej stability (štíhlostný kvocient a korunovosť), fázami prirodzenej obnovy, pokryvnosťou prízemnej a nedrevnej vegetácie a pokryvnosťou prirodzenej obnovy. Optimálny stav týchto ukazovateľov sa zistil pri zakmenení 0,7 a pri hornej hranici lesa 0,6.

Kľúčové slová: smrekový vegetačný stupeň; cieľové zakmenenie; statická stabilita; štíhlostný kvocient

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