Forest yield index and its applicability to the assessment of future forest yields

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ABSTRACT: The paper suggests and examines a simplified relative indicator of forest production, with special regard to possibilities of its use in projecting future forests. Forest yield index (I_Y), based on an economic parameter "value of final cutting yield" was proposed, and examined in the model territory of Kysuce in north-western Slovakia. The current values of final cutting yield, dependent on tree species, site index and the length of rotation period served as a basis for the assessment of expected yields. The possibilities and limitations of index applicability in long-term strategic forest management decision-making are discussed, considering the uncertainty of ecological and economic conditions during the long forest production cycle, as well as the complexity of tree species growth and production in the mixed forests, uneven aged forests and forests under climate change.

Keywords: forest growth; wood production; final cutting yield; tree species composition; forest management

The crucial step of each decision-making process is to determine a target. In general, the target should be defined clearly, it should be important, achievable, objectively justified and time-limited (Kolenka 1991). The target of forest management is a forest which can best fulfil the functions required by the society. It is characterized by target tree species composition, target structure, and target wood production, which are interdependent to a large extent. Target tree species composition is the most important feature, and in the practice of forest management based on even aged forests with regulated felling area, a preferred attribute of the target forest. In Slovakia, proposals of recommended target tree species compositions are derived from original tree species compositions of forest typology units according to Zlatník (1959) and Hančinský (1972) that are usually subjectively modified for the category of managed forests by an "adequate" increase in the ratio of so called economic species, such as Norway spruce, Scotch pine and European larch.

The projection of target tree species composition is a strategic long-term decision-making process of key importance for forest management. This process is especially influenced by deficiencies in the information caused by a high level of uncertainty of natural, economic and social conditions during the long forest production cycle. If the information about goals, solution variants and their consequences, and the information about possible states of surrounding conditions as well as about probabilities of their occurrence are missing, uncertain (risky) decision-making takes place.

The key role in projecting future multi-functional forests is to harmonize the requirements for the

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traditionally preferred wood-production function with other forest functions. In order to optimize this process, an inevitable prerequisite is to quantify the wood-production function of future forests. In contrast to the majority of the other forest functions, wood-production function can be relatively simply assessed through quantity (volume of production), value (price of production) or revenue (yield from realization of production), using already existing models. Long-term research of growth processes in Slovakia finished by publishing the third edition of stand growth tables (Halaj, Petráš 1998) and the last edition of assortment yield tables (Petráš et al. 1996) for main tree species. By applying growth and assortment mathematical models, the development of economic evaluation of wood production could be performed (Halaj et al. 1990). The latest economic models that have actually been used to assess the official forest value in Slovakia were elaborated by Tutka et al. (2003).

The paper first presents the methodological principles and the calculation concept of the proposed forest yield index, based on existing growth, assortment and yield models valid in Slovakia. The second part discusses possibilities and limitations of index applicability in forest management, especially in projecting the target tree species composition of future forests, on the basis of results obtained in the model territory of Kysuce region (North-western Slovakia).

MATERIAL AND METHODS

The economic parameter "value of final cutting yield" elaborated and published by Tutka et al. (2003) for the purposes of forest evaluation in Slovakia was used as a parameter for the quantification of wood-production function. This parameter is the main component of the classic Faustman model of periodical land revenue, and it is close to the commercial value of standing timber at the rotation age. In general, it is defined as a difference between all incomes from wood selling and all expenses on cutting activities (1).

$$A_{ijk} = Q_{ijk} (I_{ijk} - E_{ijk}) \quad (1)$$

where:

A_{ijk} – value of cutting yield at age i, for site index j and tree species k (€/ha),

Q_{ijk} – timber volume of all assortments at age i, for site index j and tree species k (m^3/ha),

I_{ijk} – mean commercial value of all assortments at age i, for site index j and tree species k (€/m^3),

E_{ijk} – mean unit expenses on cutting activities at age i, site index j and tree species k (€/m^3).

The volume of timber production of the main tree species (Norway spruce, silver fir, Scotch pine, European larch, European beech, sessile oak) partitioned into assortments at the given age and site index was obtained from assortment yield tables for average conditions in Slovakia (Petráš et al. 1996). For the other considered tree species (sycamore maple, Douglas fir), the volume of timber production was derived from the main tree species or according to foreign tables adjusted for Slovak conditions, as it is described in yield tables for practical forest management published by Lesoprojekt Zvolen in 1992. Timber volume is taken as large sized inside-bark timber at full stocking for the main stand.

Commercial value of assortments was obtained from actual market timber prices in the years 1997 to 1998. Expenses on cutting activities were calculated according to actual work standards in the range of tree species volume classes, age classes, site indexes and using socio-economic information on forestry in Slovakia during the years 1997–1998. For tree species with no assortment tables (sycamore maple and Douglas fir), the value of timber production was derived from the values of the main tree species using adjustment coefficients defined as the ratio of average timber prices for individual tree species in the period 1993–1998.

For the purpose of this study, the values of the final cutting yield for pure, even aged and fully stocked stands of main tree species, computed for representative site indexes and representative rotation periods published by Tutka et al. (2003) were used. Published values were converted from SKK to EUR according to the fixed exchange rate 30.126. Afterwards, two-dimensional quadratic regression was applied to these values of final cutting yield. A quadratic regression model fitted the data best, with explained variability up to 0.99 for all tree species (see examples in Fig. 1). After the recalculation of absolute yields derived from this regression model ($\tilde{A}_{ijk}$) into average annual yields Y_{ijk}, a continuous matrix (2) of annual unit yields for specific rotation periods (i = 1,2 … n) and site indexes (j = 1,2 … m) was obtained for each tree species (k = 1,2 … o), as a basis for the following calculation.

$$Y_k \in \begin{bmatrix} Y_{ijk} & \dots & & Y_{imk} \\ \dots & \dots & & \\ & & \dots & \\ Y_{njk} & & & Y_{nmk} \end{bmatrix} \quad (2)$$

where:

Y_k – annual unit yield of tree species k (€/ha/year),

Y_{ijk} – the annual unit yield of tree species k reached at the rotation age i in the site with site index j (€/ha/year).

Model: $Z = a + bX + cY + dX^2 + eXY + fY^2$

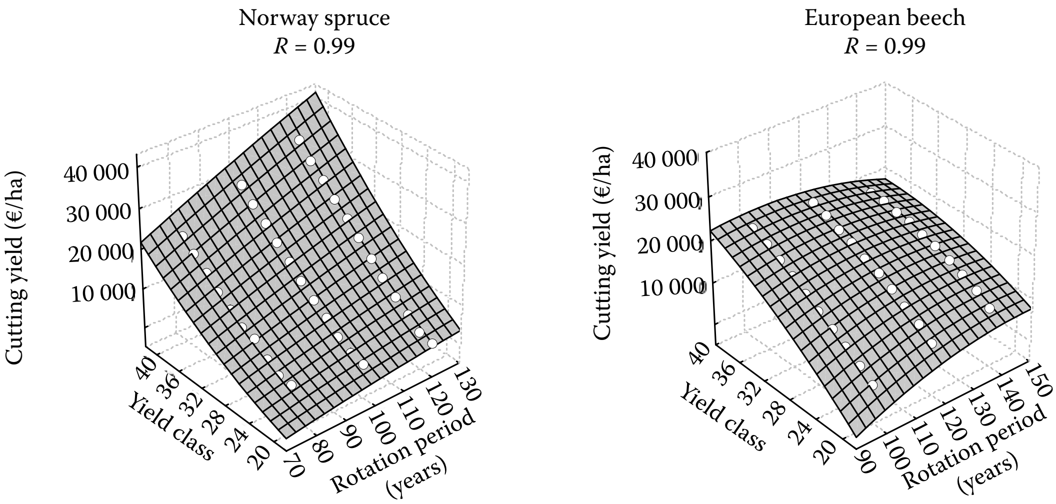

Fig. 1. Published values of absolute cutting yield according to Tutka et al. (2003) (white dots) fitted by two-dimensional quadratic regression (examples for selected tree species)

The maximum value Y_{ijk} represents the highest unit yield of tree species in a given range of rotation periods and site indexes. The value of any element in the yield matrix can be expressed as a proportion of this maximum value. Hence, forest yield index (I_Y) can in general be defined as a relative indicator of the actual forest yield when compared to maximum possible yield in the given spatio-temporal conditions (3).

$$I_Y = \frac{Y_{(\mathrm{act})}}{Y_{(\mathrm{max})}} \qquad (3)$$

where:
I_Y – forest yield index,
$Y_{(\mathrm{act})}$ – actual unit annual yield (€/ha/year),
$Y_{(\mathrm{max})}$ – maximum possible unit annual yield (€/ha/year).

The matrices of unit yields differ between tree species due to the differences in growth, production value, and cutting expenses. Nevertheless, if both growth dynamics of individual tree species expressed by site index and the rotation age $i = x$ are known for a predefined planning unit, using forest yield index (4) it is possible to calculate the relative potential yield.

$$I_Y = \frac{\dfrac{\sum_{k=1}^{o} Y_{xjk} \cdot p_k}{\sum_{k=1}^{o} p_k}}{Y_{(\mathrm{max})}} \qquad (4)$$

where:
I_Y – forest yield index,
Y_{xjk} – unit yield of tree species k at rotation age x, site index j in the planning unit (€/ha/year),
p_k – proportion of tree species k in stand mixture (%),
$Y_{x\,(\mathrm{max})}$ – maximum possible unit yield for the planning unit (€/ha/year).

The proposed method of relative yield evaluation was experimentally applied in the model territory of Kysuce in the north-western part of Slovakia. The territory of interest represents 55,000 ha of forested area in the West Beskidians Mts., and is actually affected by the mass dieback of prevailing secondary unnatural spruce forests due to biotic pests, mainly bark beetles (*Scolytidae*) and honey fungus (*Armillaria* sp.). Reforestation of large cleared areas after sanitary cuttings and solution of optimization of future forests projecting are highly urgent issues in this region.

As a spatial planning unit, ecologically homogeneous site units called management groups of forest types (MGFT), in Slovakia commonly used for the differentiation of forest management, were designated. For the most frequent selected MGFTs, mean absolute site index (as meters of height at the age of 100 years) was computed for each tree species using forestry enumeration data from the years 1999–2000. Only even-aged, single layered stands older than 20 years were included in the computations. Missing values were estimated from tree species growth relations in other MGFTs.

As a temporal framework, rotation age based on combined rotation maturity according to Halaj et al. (1990) was designed. Combined rotation maturity represents the age of the synergic culminating effect (culminating mean increment) of technical, economic and value benefits of a forest stand, and depends on tree species, site index and stand density. The published values of combined rotation maturity according to tree species, modal (most common in Slovakia) stand densities and model site indexes with 4 meters step were interpolated by polynomial regression. For each projected stand mixture, the weighted mean of combined rotation maturity ($i = x$) was calculated, while proposed species ratios were used as weights.

Finally, an attempt to evaluate the accuracy of calculated yield indexes was performed, which is dependent on the accuracy of the used basic models and on some presumptions that were suggested in the cases when no objective information is available. For growth tables, standard error 10% is declared, while for assortments tables its value ranges between 20 and 35% depending on the tree species (sessile oak 20%, Norway spruce and European larch 25%, Scotch pine 30%, silver fir and European beech 35%). For the yield model derived from prices and costs in 1997–1998, the accuracy 10% was presumed. Uncertainties of future conditions in the year 2075, i.e. the changes in yield proportions due to fluctuations of prices and costs, as well as the expected shift of production conditions due to climate change, were evaluated by including additive errors equal to 10% for yield proportions and 30% for climate change. Standard errors were first calculated for unit yields of individual tree species, and then for unit yields of mixtures, and finally for yield indexes according to the rules of error transmission summarized by Šmelko et al. (2003).

RESULTS AND DISCUSSION

The annual unit yields of all tree species logically rise with the increasing site index and related amount of produced wood (Fig. 1). Similarly, with the prolonged rotation period in the range from 80 to 160 years unit yields increase for most tree species analogously to spruce (Fig. 1). Beech is the only exception, because at older age its stems are usually attacked by fungi and create false heart-

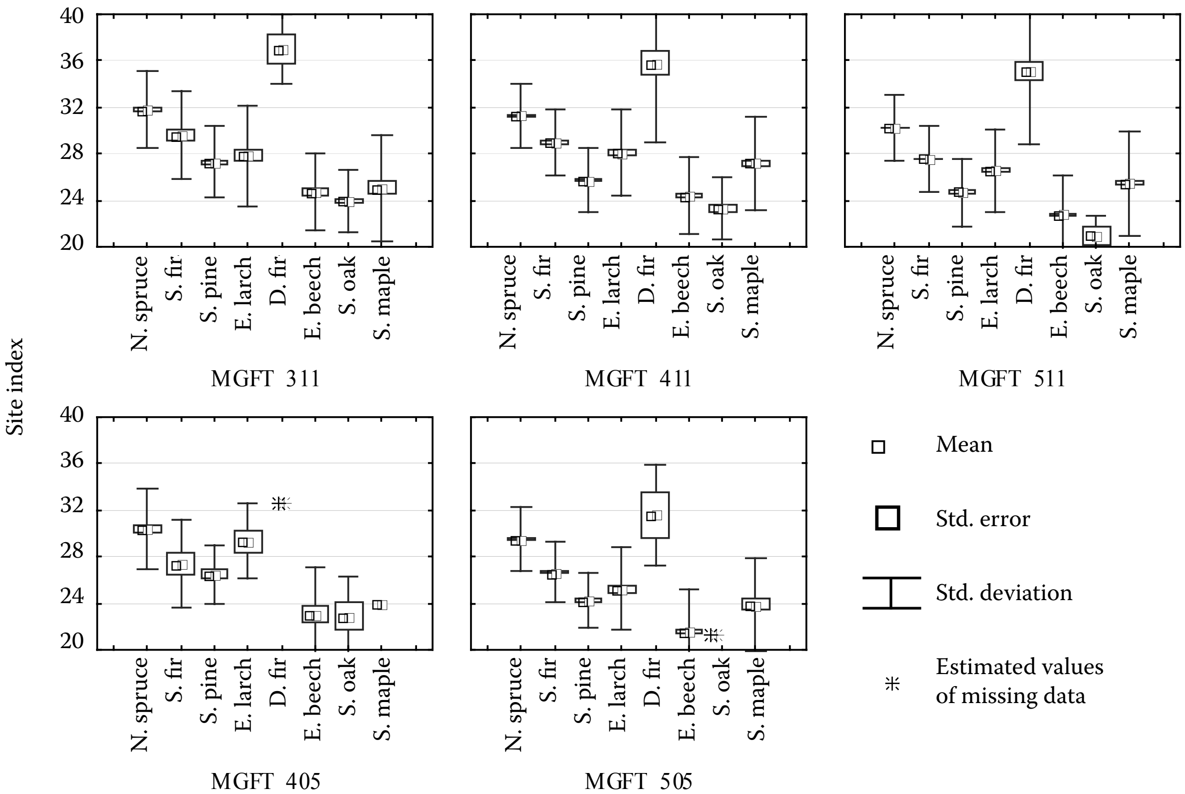

Fig. 2. Average site index of selected tree species in conditions of the most frequent (411, 505, 511) and the nearest lower (311, 405) management groups of forest types (MGFT) in the studied territory

MGFT: 311 – eutrophic oak-beech forests, 405 – oligotrophic beech forests, 411 – eutrophic beech forests, 505 – oligotrophic silver fir-beech forests, 511 – eutrophic silver fir-beech forests wood, which reduces the average price of assortments.

The values of site indexes of individual tree species showed in general a considerably large variability. Mean values vary in all examined MGFTs similarly (Fig. 2). In the given conditions, Douglas fir, Norway spruce, silver fir and European larch are tree species with maximum height growth rate, and among broadleaves it is sycamore maple. However, due to the large sample data set, differences between tree species within main MGFTs (411, 505, 511) are mostly significant, but some differences between MGFTs are insignificant on a 95% significance level, though the trend of the site index decrease with increasing altitude is apparent.

The observed variability of site indexes within site units is in accordance with knowledge summarized by Šmelko et al. (1992). On the basis of findings from Central European conditions it is stated that site units are able to express tree growth only in the range of 2–3 site index classes. For example, a 7-m variation range of top heights was observed on the plots on identical site units in Germany (Franz in Šmelko et al. 1992).

The results of our study show that in the territory of interest Douglas fir, Norway spruce, silver fir, European larch, and among broadleaved species sessile oak are the tree species with the highest unit yields (Fig. 3). The lowest yield was obtained for Scotch pine and European beech, which questions the ranking of Scotch pine among economic tree species, at least in the examined territory. The low accuracy of determination of the mean unit yield of some tree species is caused by their low presence in the sample data (Table 1).

A hard, though an inevitable task when projecting future forests is to assess the impact of climate change on the growth of tree species. Climate change, being in progress, can be one of the reasons for the observed general increase in tree growth rate in Europe, documented for example by Spiecker et al. (1996). A significant increase in radial increment of Norway spruce in Austria in the period of 1961 to 1990, during which the length of growing season increased by 11 days associated with the increase in mean annual temperature by 0.72°C, was demonstrated by Hasenauer et al. (1999). On the basis of forest management plans and systematic measurements on pilot research plots in the Czech Republic in the period of 1965–1994, different course and increasing kurtosis of mean height growth curves of Norway spruce and Scotch pine was documented, which signifies an increasing height growth trend of both species (Sequens et al. 2004). In northern Slovakia, a regional study of Norway spruce radial growth in conditions of climatic change predicted

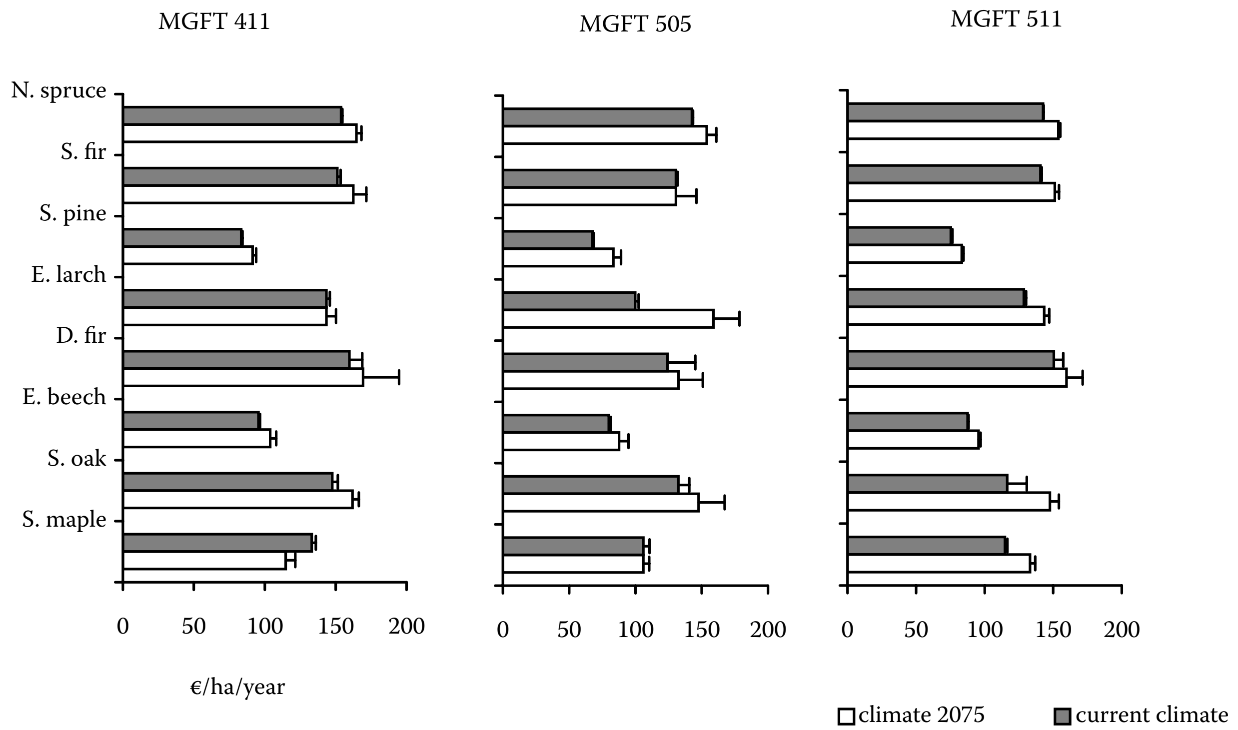

Fig. 3. Annual unit yields of selected tree species in the model territory of Kysuce at the age of its fixed optimal harvesting with presumed standard error at a 68% significance level

MGFT: 411 – eutrophic beech forests, 505 – oligotrophic silver fir-beech forests, 511 – eutrophic silver fir-beech forests

Table 1. The structure of supporting data (number of stands N) used for real unit yield calculation according to planning units and tree species obtained from forest management plans in the model territory of Kysuce (variant of climatic conditions (A – current climate, B – climate in 2075))

	Planning unit (MGFT)					
	411		505		511	
	A	B	A	B	A	B
Norway spruce	2,157	398	3,039	82	7,244	2,157
Silver fir	575	76	1,184	17	2,869	575
Scotch pine	846	270	470	44	460	846
European larch	280	82	122	12	434	280
Douglas fir	44	6	5	–	67	44
European beech	1,036	142	368	36	2,170	1,036
Sessile oak	83	205	–	9	4	83
Sycamore maple	299	70	72	1	589	299

by CCCM 2000 model on the level of monthly values of air temperature and precipitation in the year 2090 was performed. According to the obtained results, 14.6% of trees will react to climatic changes negatively, the reaction of 34.1% of trees is supposed not to change, and 51.3% of trees will have a positive reaction to climatic changes, all values valid at a 95% significance level (Ďurský et al. 2006).

Škvarenina and Tomlain (2003) analyzed the present and predicted climatic water balance (CWB) in the vegetation period (III–IX) for all altitudinal vegetation zones in Slovakia according to CCCM climate model for the year 2075. CWB is understood as the difference between the amount of precipitation and the potential evapotranspiration, and it is suggested to be the most suitable synthetic climatic parameter associated with tree growth. The predicted values of CWB for the year 2075 in 4th and 5th vegetation zones, which prevail in the territory of our interest, are equal to the conditions of localities situated 1.5–2 vegetation zones lower in the reference period 1951–1980. If the climate change follows almost linear trends, which have occurred since the second half of the 20th century, the minimum change in CWB equal to the shift of 1 vegetation zone upwards should be taken into consideration from the present to the year 2075. Hence, in this study in order to obtain an idea of the production of new forest generation in the conditions of expected climate change, absolute site index values from the nearest lower vegetation belt of the same site ranking (eutrophic, oligotrophic) were taken for each tree species to assess its estimative yield in future. The results show a general increasing trend of unit yields of almost all tree species, even if insignificant in some cases (Fig. 3).

All so far presented findings are relevant only for pure, even-aged and full stocked forest stands, which is related to the essence of basic models used as a source for the yield index computation. There arises a question whether and to what extent it is possible to apply these findings for the yield assessment of mixed stands, which is crucial for index applicability in forest management of mixed forests. Šmelko et al. (1992) summarized that a great number of possible combinations of various tree species was the main reason why the knowledge of the production of mixed stands was insufficient and why it was not proved to satisfaction if tree species grew better in mixed stands or in pure stands. Recent findings show that the volume of production of mixed stands equals approximately the average production of all tree species in the mixture. For example, Wenk et al. (in Šmelko 1992) demonstrated good accordance of real development and production of Norway spruce, European larch, Eastern white pine, Scotch pine and silver birch in mixed stand in comparison with their development according to models derived for pure stands, regardless of interactions between tree species. Neutral interaction between European beech and Norway spruce growing in mixed stands in several sites was observed by Pretzsch (in Knoke, Wurm 2006). The same author detected better growth elasticity of mixed spruce-beech stands. It is apparent that in pure stands maximum growth can be obtained only at specific stand density, whereas in mixed stands growth is almost unchanged over a range of low, medium and high stand density (Pretzsch 2003). High elasticity, ecological stability and ability to keep high production have been observed on the basis of 40-year research on various mixed stands in the Czech Republic. The mixture of

European beech, Douglas fir and European larch was proclaimed as especially highly productive (Kantor et al. 2002). Piotto (2008) made a study based on the meta-analysis of worldwide relevant and statistically well-founded published findings of the growth of 46 tree species in pure and mixed stands. It was found that height growth rates of mixed plantations did not differ from pure stands. Diameter growth rate was higher in mixed plantations, with moderate but statistically significant size effect.

Density and vertical structure of forest stands and their relations to tree species growth are other issues that are not regarded in the stand growth models used as a basis of the proposed yield index. To solve the problem of the changing growth space of trees, single-tree growth simulators are suitable which in addition to increment models also contain competition models, mortality models and thinning models, and thus they are able to simulate real growth rates of the trees. One of the most advanced simulators in Europe is SILVA (Pretzsch et al. 2002), from which tree growth simulator SIBYLA was derived for Slovak conditions (Fabrika 2003). Nevertheless, the growth models in tree growth simulators do not account for the interactions between species. When simulating the mixture of more tree species, identical growth of tree species is assumed as in the pure stand.

Considering the above-mentioned and with respect to some lack of knowledge of this topic, there is no reason to reject several assumptions which are necessary for the relative yield assessment of mixed stands by the method proposed in this study. Those assumptions are:

(1) growth processes of individual tree species in mixed even-aged stands and in pure even-aged stands of the same species are similar, i.e. between tree species interactions are neutral;
(2) this statement holds generally, even in conditions of various stand densities of even-aged forests, i.e. relative light increment of all considered tree species is similar.

These assumptions allow us to calculate the mean site indexes of tree species for the planning unit using data from both pure and mixed stands, as well as to suppose constant ratios of production between tree species in real conditions of naturally or artificially decreased stand density in mixed forests.

Accepting the predefined assumptions, the assessment of relative yield in the model territory of Kysuce was performed according to the present growth relations in 1999–2000 and economic relations in 1997–1998, as well as for presumed growth in the future climate in 2075. Yield indexes were calculated for four example types of mixed forests (Table 2). The first example type represents a natural forest with the original tree species composition calculated for planning units (MGFT) as a weighted mean of natural compositions of entering lower typological units – forest site types defined by Vološčuk (2001). The second type represents a close-to-nature forest with little divergence from the natural forest in favour of economically interesting autochthonous tree species, with approximation to natural composition by more than 50%. The third simulation type offers a semi-natural alternative reflecting enhanced economic demands on the target forest. Semi-naturalness is guaranteed by a minimum ratio of native broadleaved tree species set to 40% in the 4th and 30% in the 5th vegetation belt. Douglas fir is accepted as a suitable introduced tree species. The last example type is a forest with maximum yield.

The results show that in the studied sites natural forests produce about 0.57–0.79 of the maximum possible cutting yield expressed by forest yield index. Logically, if the ratio of tree species with higher unit yield increases, the yield index of stand mixture is also increasing. Interpretation and practical applicability of the obtained results are limited due to their accuracy, which is acceptable in our experiment only in MGFT 505 in actual conditions (Table 2, column 12), where the relative standard error of yield index determination fluctuates around 5% at a 95% significance level. Markedly lower accuracy of yield index in other MGFTs is caused by large standard error of Douglas fir unit yield determination due to the low occurrence of this tree species in the studied territory and thereby also in the analyzed data set (Table 1). Douglas fir has been found to be the reference tree species reaching maximum cutting yield in the conditions of eutrophic MGFTs, and through stepping-in final indexes calculation unfavourably attempts accuracy of results. In MGFT 505, where acceptable accuracy was achieved, Norway spruce reaches maximum yield.

Presumed uncertainty of future conditions in the year 2075 decreases the accuracy of determined yield indexes (Table 2, column 13). The results indicate that the future forest yield can be assessed either with lower accuracy or at a lower significance level. The accuracy of predicted values can be enhanced by increasing the precision of climate models as they significantly contribute to the uncertainty of future conditions. In this study the additive error of the estimated change of climate conditions was presumed to be 30%, which reflects our tolerance of a wide range of possible temperature increase from 1 to 4°C with the mean around 2–2.5°C at a 95% significance level in comparison with the reference period. This range

Table 2. Examples of relative yield assessment in assumed conditions of even-aged, fully stocked forest stands, for the main types of target forests and most frequent MGFTs in the model territory of Kysuce, North-western Slovakia

MGFT	Type of target forest	Tree species proportion									Forest yield index (I_Y) with std. error at 95% significance level	
		Norway spruce	Silver fir	Scotch pine	European larch	Douglas fir	European beech	Sessile oak	Sycamore maple	Other broadleaved	actual conditions	estimated conditions in 2075
411	Natural forest	–	0.20	–	–	–	0.69	–	0.11	–	0.65 ± 0.08	0.65 ± 0.20
	Close-to-nature forest	0.20	0.10	–	0.10	–	0.40	0.10	0.10	–	0.73 ± 0.08	0.72 ± 0.22
	Semi-natural yield oriented forest	0.20	–	–	–	0.40	0.10	0.20	0.10	–	0.81 ± 0.10	0.81 ± 0.27
	Forest with maximum unit yield	–	–	–	–	1.00	–	–	–	–	1.00 ± 0.16	1.00 ± 0.42
505	Natural forest	0.11	0.46	–	–	–	0.38	–	0.02	0.03	0.74 ± 0.03	0.70 ± 0.21
	Close-to-nature forest	0.30	0.20	–	0.10	–	0.30	–	0.10	–	0.78 ± 0.03	0.79 ± 0.22
	Semi-natural yield oriented forest	0.50	–	–	0.20	–	0.20	0.10	–	–	0.85 ± 0.04	0.87 ± 0.24
	Forest with maximum unit yield	1.00	–	–	(1.00)	–	–	–	–	–	1.00 ± 0.05	(1.00 ± 0.37)
511	Natural forest	–	0.49	–	–	–	0.43	–	0.08	–	0.72 ± 0.07	0.75 ± 0.11
	Close-to-nature forest	0.20	0.20	–	0.10	–	0.30	–	0.20	–	0.74 ± 0.07	0.77 ± 0.12
	Semi-natural yield oriented forest	0.40	–	–	–	0.30	0.10	0.10	0.10	–	0.82 ± 0.08	0.84 ± 0.13
	Forest with maximum unit yield	–	–	–	–	1.00	–	–	–	–	1.00 ± 0.13	1.00 ± 0.21

MGFT: 411 – eutrophic beech forests, 505 – oligotrophic silver fir-beech forests, 511 – eutrophic silver fir-beech forests covers most of the actual climate change scenarios developed for Central Europe.

Another element of uncertainty is associated with changes in yield proportions between tree species due to fluctuations of prices and costs, and was represented by additive error of 10% for the purpose of this study. Its value can also be reduced by the development of relevant economic and marketing prognoses. PETRÁŠ et al. (2002) analyzed the development of raw timber prices for the main tree species in Slovakia during the period 1988–2001. Their results showed that during the period 1990–1993 the price level increased significantly, following the principal change in the economic system in former Czechoslovakia. After this increase, price development and especially price relations between tree species and timber assortments have become relatively stable and adapted to free market conditions.

The proposed yield index is methodologically linked to conservative fixed harvest policy, when harvesting is simulated at fixed time points (end of rotation periods) regardless of the timber price. Some authors suggest flexible harvest policy to avoid risks resulting from uncertain price fluctuations. This approach is based on reservation prices that indicate when current revenue would be equal to the expected revenues from delayed harvests. Hence, harvesting is desirable only if the actual price exceeds the reservation price (KNOKE, WÜRM 2006).

CONCLUSIONS

The proposed forest yield index should serve as a simple indicator of relative forest yield, using accessible forest enumeration and forest valuation data. It is based on a comparison of the real observed yield of tree species with maximum possible yield achievable in predefined planning units, i.e. it expresses the current relative utilization of wood-production function of the forests. Methodologically, the index is based upon mathematical models of forest growth (stand growth tables), proportions of timber assortments (stand assortment tables), and forest revenue (final cutting yield) derived for even-aged and fully stocked stands of main tree species. Therefore, the index is mainly applicable to even-aged pure stands. The index can be applied to real even-aged mixed forest stands only if the assumption is accepted that between tree species growth interactions are neutral and relative light increment of tree species is similar. For the assessment of future forest growth, as an important issue for the planning of target tree species composition, a simplified method considering the change in climate water balance in forest altitudinal zones was suggested, using the actual growth rates of tree species situated in lower sites for the estimation of their future growth on the basis of ecological analogy. Both, the change in climate conditions and the shift in the relation of prices and costs have been regarded as factors increasing the uncertainty of future yield assessment.

Generally, a relatively low accuracy of computed yield indexes was determined due to the limited accuracy of used models as well as additional errors resulting from the uncertainty of future conditions. Low accuracy of assortment tables and high regarded uncertainty of tree growth in changing climate are the main sources of the final error. In addition, the low presence of some tree species in the source data set negatively influenced the accuracy of the results. Theoretically, the standard error of yield index determination about 10% for present conditions and 15% for estimated conditions in 2075 is achievable at a 95% significance level and with the sample size of 50–100 stands for each tree species and each planning unit. Hence, the proposed index is more suitable for the assessment of current utilization of the wood-production potential of forests. The assessment of future forest generation yield with comparable accuracy is possible only at a lower 70% significance level. More precise results could be obtained by a large-scale analysis, for example on the national level.

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Index výnosu lesa a jeho využitelnost k odhadování výnosovosti budoucích lesů

ABSTRAKT: Práce se zabývá návrhem a odzkoušením zjednodušeného relativního indikátoru produkce lesa se speciálním důrazem na možnosti jeho využití při projekci budoucích lesů. Byl navržen index výnosu lesa (I_Y), založený na ekonomickém parametru hodnota výnosu mýtní těžby, který byl následně odzkoušen na modelovém území Kysuce na severozápadním Slovensku. Jako východisko pro odhad očekávaných výnosů se použily aktuální výnosy mýtní těžby, závisející od druhu dřeviny, absolutní bonity a doby obmýtí. Diskutovány jsou možnosti a omezení využitelnosti indexu ve strategickém dlouhodobém rozhodování hospodařské úpravy lesů, vyplývající z neurčitosti vývoje ekologických a ekonomických podmínek během dlouhého produkčního cyklu lesa, a také ze složitosti problematiky růstu a produkce dřevin ve smíšených porostech, v nestejnověkých porostech a v podmínkách klimatických změn.

Klíčová slova: růst lesa; produkce dřeva; výnos mýtní těžby; cílové zastoupení dřevin; hospodařská úprava lesů

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