Terrain properties of selected forest sites in the Jizerské hory Mts., Czech Republic

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ABSTRACT: Differentiation of forest technologies according to ecosystem properties is a necessary step to achieve sustainable forestry. A forest typological system is considered to be the basic unit of ecosystem differentiation in the Czech Republic. Terrain characteristics, potential water erosion and applicable harvest technology were examined for 44 forest sites in a landscape segment of the Jizerské hory Mts. Forest site was found homogeneous in terms of terrain and technological properties. Edaphic category and groups of forest types as higher classification units and management sets as units of alternative classification showed lower homogeneity insufficient for operational planning.

Keywords: forest typology; terrain classification; harvest technology; erosion

Entering the 21st century, forest management in Europe has to undergo changes aimed at sustainability of the use of limited natural resources. Differentiation of forestry technologies throughout the production process according to natural conditions of forest stands is a necessary step in such an attempt. The most obvious conflict between forestry technologies and forest ecosystems occurs in the harvest phase of forest management. Removal of tree cover, movement of timber and heavy machinery through forest stands influence all other parts of the forest ecosystem. Harvest and skidding technologies (harvest and skidding of timber are often understood as one step and they are both referred to in the following text as harvest operations) selected regardless of ecosystem properties can result in serious damage that may involve high production loss.

Direct costs and possibilities of machinery traffic through the forest stand have been widely used for selection of harvest technology. Terrain properties such as slope inclination and terrain obstacles, grouped into terrain classifications (e.g. ŠTAUD 1973; LESPROJEKT 1980), have been taken into account as the most important factors determining applicable harvest technologies. Technological type groups terrain types of the same applicable skidding technology. SIMANOV et al. (1993) included erosion threat in the terrain and technological classification for the first time but the definition of the site under erosion threat was unclear in the paper.

In forestry practice in the Czech Republic, model forestry technologies including harvest technology are recommended at the level of units called "management sets". Management set groups together a wide range of ecosystems with relatively similar production and site characteristics. Although the model technology is generally applicable, it may not be the most relevant for all ecosystems within the management set due to internal variation of ecosystem properties. This variation was a reason to search for more detailed ecosystem classification enabling sensible differentiation of forestry technologies. We have chosen the forest typology system that is considered to be the basic unit of forest ecosystem differentiation in the Czech Republic. It is based on Cajander's (CAJANDER 1926) theory of forest types and it is related to ecological site classifications elsewhere (KLINKA et al. 1984; PYATT 1995). Forest sites are commonly used as a base for silvicultural decisions (PLÍVA 2000; PRŮŠA 2001). See VIEWEGH (1997) for a description of Czech typological system. As defined by ZLATNÍK (1976) and later interpreted by RANDUŠKA (1982), the forest site "is an aggregate of natural geobiocoenosis and of all geobiocenoses originating from it, from the viewpoint of development, and partly geobiocenoses (geobiocenoids) changed to a certain extent, including developmental stages". This forest site represents all ecosystems of analogical biotic and abiotic properties such as climate, soil, parent rock, relief type and potential natural vegetation. That means it possesses the information necessary for the planning of complex forestry technology from forest regeneration through silvicultural treatments to harvest and

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skidding operations aimed at the use of the nature potential without excessive damage to the ecosystem.

Basic site characteristics were described for some forest sites in the past (MODRÝ 2000). Potential soil water erosion can be used to estimate the erosion threat (MÍCHAL 1973). It is determined by the factors that are not influenced by forest management (climate, soil properties, geomorphology). It is important to keep in mind that although these factors are considered to be constant, they may change over a long period. MÍCHAL (1973) calculated potential soil water erosion for 198 forest sites according to the method of STEHLÍK (1970) based on soil structure, parent rock, slope inclination and climatic factors and later compared the values with those obtained by field measurements in Ukraine. He did not found any significant differences between the calculated and field values. The majority (93%) of examined forest sites had a narrow span of calculated potential erosion showing that forest site is a homogeneous unit in the sense of soil erodibility. VOLOŠČUK (1978) calculated potential soil water erosion for selected forest sites in Slovakia using the equation of STEHLÍK (1970) based on descriptions of typological units published by HANČINSKÝ (1972).

A study of MODRÝ (2000), examining the relationship between forest sites and terrain types according to SIMANOV et al. (1993) in Křtiny Training Forest Enterprise, showed the homogeneity of forest site in the sense of terrain and technological types. Higher variations of technological types were found for edaphic categories that were not found to be homogeneous enough to enable the operational planning of harvest technology.

This paper was aimed at describing the basic site and technological characteristics (terrain type, technological type and potential soil erosion) of forest sites in a landscape segment in the Jizerské hory Mountains. It was hypothesized that the forest site possesses higher homogeneity of site characteristics than the edaphic category and management set and is more suitable for determining model harvest technologies.

METHODS

The study was conducted in the Jizerské hory Mts. in Northern Bohemia within forest districts Harcov and Dětřichov. An area of 1,605 ha with altitude span of about 500 m including several relief forms from flatlands in the valley of the Smědá river (approx. 350 m a.s.l.), through steep rocky northern slopes of Poledník ridge to moderate slopes and flatlands in the upper part of the mountain top of Olivetská Mt. (886 m a.s.l.) was selected. Forest stands in the area include a semi-natural beech forest on the steep slopes described in detail by VACEK et al. (1996) and Norway spruce monocultures of the upper and lower flatlands. Location of the study site is shown in Fig. 1.

Fieldwork was carried out during August 2001 within 10 days following a period of stable, mostly dry weather. All characteristics were measured on plots 2 × 2 m in size regularly located over the area in a 100 × 100 m

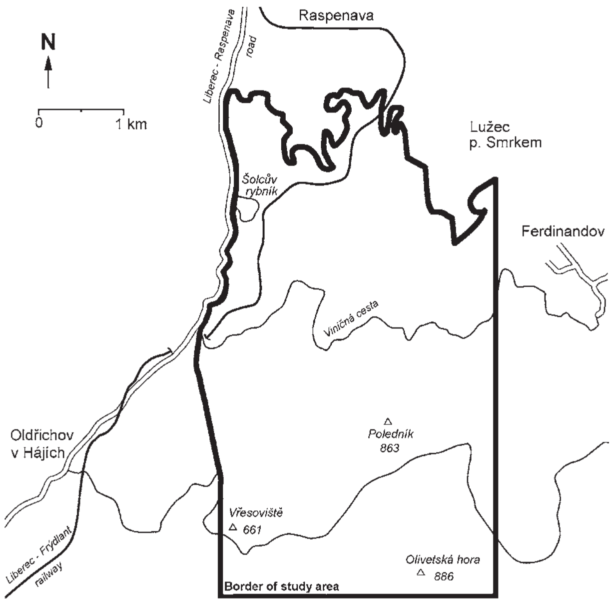

Fig. 1. Location of the study site

grid, giving the total of 1,431 measured plots. Plots were marked in the forest map (scale 1:10,000). Slope inclination was measured over a 10m distance perpendicularly to the contours with simple clinometer in degrees. The current soil situation and other characteristics such as deep wheel tracks, footprints, stagnating water, etc. were used to estimate the bearing capacity that was classified into 3 grades: "bearable", "conditionally bearable" and "non-bearable". Rocks, boulders and terrain unevenness were recorded as obstacles when higher than 0.3 m and closer than 5 m apart. In that case they were divided into grades "0.3–0.5 m high" and "higher than 0.5 m". The above-mentioned characteristics were used to assign the terrain type to each plot according to the classification by SIMANOV et al. (1993) (Table 1). Forest site was obtained from the map of forest sites (scale 1:10,000, Institute for Forest Management [IFM] 1999) for each measured plot. Technological type was derived from the terrain type for each plot according to SIMANOV et al. (1993). Technological type "U" refers to the terrains where industrial tractors are applicable for skidding, type "S" refers to the terrains suitable for skidders. Technological type "F" requires the use of industrial tractors with improved stability factors and equipped with low-pressure tires (e.g. Zetor – Horal). Horse skidding and technologies grouped to technological types "F" and "L" are applicable in technological type "E", which is associated with increased soil erosion threat. Since the erosion threat was not clearly defined in SIMANOV et al. (1993), technological type "E" was assigned to study plots with calculated potential soil erosion higher than 6 mm/year (MÍCHAL 1973). Sites classified as technological type "L" require the use of skyline transport devices because the movement of ground-based machinery is not possible (SIMANOV et al. 1993). Technological type "E" was divided into subtypes "E_f" (tractor skidding applicable on dry or frozen surface) and "E_l", where only

Table 1. Characteristics of recorded terrain types. Number of recorded plots shows the number of observations with site characteristics corresponding to each terrain type. Classification of terrain and technological types follows SIMANOV et al. (1993)

Terrain type	Number of recorded plots	Relative frequency (%)	Slope inclination (°)	Obstacles	Bearing capacity	Technological type
11	45	3.1	0–6	< 0.3	bearable	U
12	225	15.6	0–6	0.3–0.5	bearable	S
13	94	6.6	0–6	< 0.5	conditionally	F
15	33	2.3	0–6	< 0.5	non-bearable	L
16	18	1.3	0–6	> 0.5	bearable	L
21	6	0.4	7–11	< 0.3	bearable	U
22	227	15.9	7–11	0.3–0.5	bearable	S
23	18	1.3	7–11	< 0.5	conditionally	E
25	5	0.3	7–11	< 0.5	non-bearable	E
26	34	2.4	7–11	> 0.5	bearable	L
31	3	0.2	12–18	< 0.3	bearable	F
32	94	6.6	12–18	0.3–0.5	bearable	S
33	4	0.3	12–18	< 0.5	conditionally	F
36	39	2.7	12–18	< 0.5	bearable	L
39	125	8.7	12–18	various	various	E
49	297	20.8	19–27	various	various	E
59	150	10.5	28–35	various	various	E
69	14	1.0	≥ 36	various	various	E

skyline transport techniques are applicable owing to steep slopes (over 27°) or terrain obstacles higher than 0.5 m.

Management set (MS) was assigned to each plot according to IFM (1999). Soil protection function of MS was taken over from IFM (1999).

The equation of Wischmeier adapted by ZDRAŽIL (1965) for agricultural soils in the interpretation of MÍCHAL (1973) was used to calculate potential soil erosion (Ep) (1).

$$Ep = C \, . \, G \, . \, I \, . \, S \, . \, R \qquad \text{(mm/year)} \qquad (1)$$

where: C – coefficient of climate,
G – coefficient of parent rock,
I – coefficient of slope,

Table 2. Coefficients used for calculation of potential water erosion for edaphic categories. Detailed description of soil characteristics of edaphic categories can be found in IFM (1999), VIEWEGH (1997) and PRŮŠA (2001)

Edaphic category	Climate (C)	Parent rock (G)	Soil texture	(S)	Reduction factor	(R)
A (acerose)	0.63	1.0	sandy loam	1.4	stony	1.4
G (watterloged)	0.63	1.0	sandy loam	1.4	gleyic	0.4
K (acid)	0.63	1.0	sandy loam	1.4	stony	1.4
L (floodplain)	0.63	1.0	sandy loam	1.4	semi-gleyic	0.7
M (poor)	0.63	1.0	sandy loam	1.4	gravelly	1.2
N (stony)	0.63	1.0	sandy loam	1.4	stony	1.4
O (gleyed)	0.63	1.0	sandy loam	1.4	semi-gleyic	0.7
R (peaty)	0.63	1.0	peat	2.0	peat	1.2
S (fresh)	0.63	1.0	mesotrophic sandy loam	1.2	gravelly	1.2
T (watterloged)	0.63	1.0	sandy loam	1.4	semi-gleyic	0.7
U (valley)	0.63	1.0	sandy loam	1.4	stony	1.4
Y (skeletal)	0.63	1.0	exposed boulder fields	2.5	gravelly	1.2
Z (stunted)	0.63	1.0	exposed rocks	2.5	gravelly	1.2

Table 3. Frequency and characteristics of erosion threat classes

Erosion threat class	Span of potential erosion (mm/year)	Relative frequency (%)	Estimated area (ha)	Span of slopes estimated from equation (3) (°C)
I. No threat	0–2	30.4	487.92	0–7
II. Low threat	3–6	28.6	459.03	8–14
III. Increased threat	7–16	21.9	351.50	15–25
IV. High threat	> 16	19.1	306.56	> 26

S – coefficient of soil type,
R – reduction factor for soil structure.

ZDRAŽIL's (1965) coefficient of climate was used, its value 0.63 representing the whole area of the Czech Republic. This value was also used by MÍCHAL (1973) and VOLOŠČUK (1978). The coefficient of parent rock was set to 1.0 (tabled in MÍCHAL 1973 for granite). The values of soil type coefficient and soil structure reduction (Table 2) were taken from MÍCHAL (1973) based on descriptions of edaphic categories (IFM 1999). Coefficients of slopes up to 30° were taken from STEHLÍK (1970, cited in MÍCHAL 1973). Since Stehlík's classification was designed for agricultural land, he did not take into account slopes steeper than 30°. Those data were extrapolated from a regression equation fitting his values (2).

$$I = 0.036 \cdot s^{1.7747} \qquad (2)$$

where: s – slope inclination in degrees.

Forest sites were divided into erosion threat classes depending on the value of potential erosion (Table 3). Potential erosion up to 2 mm per year indicates sites that are not threatened by water erosion while sites with potential erosion value higher than 16 mm per year have to be treated as seriously threatened and soil protection has to be the primary goal for forest management. Potential water erosion of soil between 3 and 6 mm per year indicates sites where the forest soil protection function should be taken into account, sites of potential erosion 7 to 16 mm per year should be treated in respect of the soil protection necessity (MÍCHAL 1973).

All statistical data analyses were carried out using SYSTAT 10.0 program. Differences in slope inclination ranges and potential erosion ranges between the forest sites were tested by ANOVA (significance criterion $P \leq 0.05$). No transformation was applied to data before processing.

RESULTS

FOREST SITE COMPOSITION

Forty-four forest sites belonging to 13 edaphic categories were encountered in the studied area. Edaphic categories K (acid), S (fresh), N (stony) and Y (skeletal) dominate the area, forest sites 3S8, 5K3, 5Y1 and 6S1 were the most frequent, covering an area of more than 100 ha each. Nine and ten forest sites represented edaphic categories K and N, respectively, while 1 to 3 forest sites represented other edaphic categories in the area (Tables 4 and 5).

Table 4. Terrain characteristics of edaphic categories. Values in parenthesis show the percentage of dominant terrain type and technological type in the total number of forest sites

Edaphic category	Number of forest sites	Relative frequency (%)	Slope inclination (°) mean ± S.E.	Ep (mm/year) mean ± S.E.	Dominant terrain type	Dominant technological type
A	2	2.6	19.3 ± 1.3	9.7 ± 1.0	49 (33.3)	L + El (77.8 + 11.1)
G	3	3.7	6.0 ± 0.9	0.7 ± 0.3	13 (66.7)	F + Ef (66.7 + 8.7)
K	9	27.5	10.7 ± 0.3	4.2 ± 0.2	12 (28.3)	S (64.9)
L	1	0.1	5.0 ± 5.0	0.9 ± 0.9	13/23	F + Ef (50 + 50)
M	1	2.3	20.0 ± 1.9	9.5 ± 1.4	49 (30)	L + El (33.3 + 43.3)
N	10	13.4	19.7 ± 0.4	9.7 ± 0.3	49 (43.6)	L + El (12.8 + 70.1)
O	4	4.8	4.5 ± 0.8	0.8 ± 0.2	13 (72.3)	F + Ef (72.3 + 4.3)
R	3	1.5	4.9 ± 0.3	1.8 ± 0.2	15 (63.9)	L + El (63.9 + 13.9)
S	4	23.0	7.6 ± 0.2	2.0 ± 0.1	12 (34.9)	S (80.9)
T	1	1.7	1.8 ± 0.3	0.2 ± 0.04	13 (100)	F (100)
U	1	0.3	8.2 ± 2.6	3.1 ± 1.3	13/23	F/L (50/50)
Y	2	14.7	25.6 ± 0.4	22.2 ± 0.5	49 (52.9)	El (98.5)
Z	3	4.4	25.2 ± 0.9	22.5 ± 1.3	49 (45.7)	L + El (8.6. + 90.1)

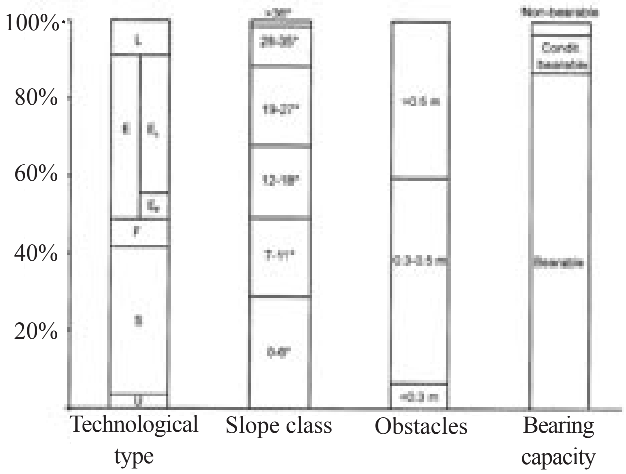

Fig. 2. Frequencies of basic terrain characteristics

TERRAIN PROPERTIES

During the survey, 18 terrain types (according to SIMANOV et al. 1993) were found (Table 1). The most frequent terrain type was 49 followed by 22 and 12 (20.8, 15.9 and 15.7 %, respectively). The structure of individual site characteristics is shown in Fig. 2. The majority of observed plots had bearable soils (89.2%) while unbearable soils accounted for 2.6% of the observations only. Obstacles were higher than 0.3 m almost in all cases, in more than 40% they were higher than 0.5 m preventing the movement of ground-based machinery. Slope inclination classes were relatively equally distributed with the exception of the steepest slopes over 71% that were of minor importance (1.0%).

Technological type "E" (threatened by erosion) was the most frequent followed by type "S" (42.6% and 38.2% of study plots, respectively). Technological types "U", "F" and "L" were less frequent (3.5%, 6.9% and 8.7%, respectively). Subdivision of type "E" into "E_f" and "E_l" and addition of subtypes "E_f" to "F" and "E_l" to "L" changes the composition of technological types. Technological type "L" becomes the most important accounting for 45.3 % of cases (Fig. 2).

POTENTIAL WATER EROSION

The potential water erosion (*Ep*) ranged from less than 1 mm to 46.0 mm/year. The mean value for all measured plots was 8.0 mm/year. Mean square of the regression between *Ep* and slope inclination (R^2 = 0.94) was higher than that of regression between *Ep* and soil type coefficient (R^2 = 0.57) showing the major influence of slope inclination on potential water erosion. Taking into account all studied plots, the potential water erosion could be predicted from slope inclination by using regression equation (3).

$$Ep = 0.080 \, . \, s^{1.6364} \qquad \text{(mm/year)} \qquad (3)$$

where: s – slope inclination in degrees (R^2 = 0.94, $P < 0.001$).

Based on potential soil erosion calculated by equation (1) 19% of the total studied area (approx. 307 ha) is estimated to be under high erosion threat with soil protection being the primary task for forest management. On 22% of the area (approx. 352 ha), the soil protection and production functions should be balanced, on 29% (approx. 459 ha) of the area the forest management should take into account the potential erosion risk with production being the primary task and about 30% of the area (488 ha) was found not to be under erosion threat (Table 3). Only 48 out of 1,431 measured plots showed differences in the erosion threat class calculated by equations (1) and (3).

RELATIONS BETWEEN FOREST SITE, TERRAIN TYPE AND POTENTIAL SOIL EROSION

Significant differences (ANOVA, $P \leq 0.05$) were found between the mean slope inclinations of forest sites as well as between the mean slope inclinations of different edaphic categories. Mean potential erosion was also significantly different at particular forest sites and in edaphic categories. Within the edaphic category, the mean slope inclination differed significantly at forest sites of edaphic categories K, N, R, S, Y and Z suggesting that the edaphic category includes forest sites of different terrain properties. Potential erosion follows the patterns found in slope inclination.

The main terrain characteristics including slope inclination, potential erosion, dominant terrain type and dominant technological type are overviewed in Table 4 for edaphic categories and in Table 5 for forest sites. Based on the mean potential erosion, 15 forest sites belonged to erosion threat class I (no threat), 13 belonged to class II, 11 to class III and 5 forest sites belonged to class IV with high erosion threat. Six edaphic categories (G, L, O, R, S and T) belonged to class I, categories K and U to class II, categories A, M and N to class III and categories Y and Z to class IV.

Seven out of the 28 recorded groups of forest sites included more than one forest site. Forest sites within the groups of forest sites 5K, 5N, 5Z, 6N, 6K and 6S differed from each other in slope inclination and potential erosion (ANOVA, $P \leq 0.05$). Only one group of forest sites grouped together forest sites with different dominant technological types (Table 5).

The homogeneity of site characteristics within the forest site and edaphic category is apparent from the dominance of certain terrain and technological type. One terrain type covered 50–70% of measured plots at 13 forest sites and > 70% in 10 out of 44 forest sites. Higher homogeneity was found in the technological type where a dominant technological type covered 50–70% of plots at 8 forest sites and over 70% at 34 forest sites. Edaphic categories show similar trends with one terrain type covering 50–70% of the area in 3 cases and > 70% of the area also in 3 cases. One technological type covered 50–70% of the area in 1 edaphic category and > 70% in 12 edaphic categories.

Table 5. Terrain characteristics of observed forest sites. Codes of forest sites are used according to IFM (1999). Management set (MS) shows MS corresponding to the forest site according to IFM (1999). Values in parenthesis show the percentage of dominant terrain type and technological type at forest site

Forest site	Relative frequency (%)	Slope inclination (°) mean ± S. E.	Ep (mm/year) mean ± S. E.	Dominant TT	Dominant TeT	MS
1G2	0.5	3.3 ± 0.4	0.3 ± 0.04	15 (71.5)	L (85.7)	29
1T1	0.9	1.8 ± 0.3	0.2 ± 0.04	13 (100)	F (100)	29
3K1	1.5	10.4 ± 1.1	4.0 ± 0.6	22 (19.0)	S (42.9)	43
3L1	0.1	5.0 ± 5.0	0.9 ± 0.9	13 (50.0)	F + Ef (50 + 50)	29
3N2	0.1	15	6.1	39 (100)	El (100)	41
3O6	2.0	3.7 ± 1.2	0.8 ± 0.4	13 (69.0)	F (69.0)	47
3S8	4.5	4.1 ± 0.4	0.9 ± 0.1	11 (65.6)	U (71.88)	43
5A3	2.4	19.4 ± 1.4	9.8 ± 1.0	49 (34.3)	L + El (20.0 + 68.5)	51
5K1	3.9	16.6 ± 0.7	7.4 ± 0.4	49 (33.9)	Ef (50.0)	53
5K3	4.3	14.2 ± 0.8	6.1 ± 0.5	39 (29.0)	S (38.7)	53
5M1	2.1	20.0 ± 1.9	9.4 ± 1.4	49 (30.0)	L + El (33.3 + 43.3)	43
5N1	1.3	19.6 ± 1.4	9.6 ± 1.0	49 (42.1)	El (78.9)	51
5N2	2.0	17.0 ± 1.1	7.7 ± 0.7	49 (48.3)	L + El (13.8 + 48.3)	51
5N3	2.8	23.3 ± 0.9	12.5 ± 0.7	49 (52.5)	El (77.5)	51
5N5	4.1	19.6 ± 0.9	9.7 ± 0.6	49 (37.3)	L + El (11.9 + 64.4)	51
5O1	0.2	9.3 ± 1.8	1.7 ± 0.4	– (–)	S (66.7)	57
5S6	0.4	11.5 ± 3.1	3.6 ± 1.3	16 (33.3)	L + El (50.0 + 16.7)	55
5U1	0.4	8.2 ± 2.6	3.1 ± 1.3	13 (33.6)	L + El (33.3 + 16.7)	51
5Y1	12.2	26.1 ± 0.4	22.8 ± 0.6	49 (51.4)	El (98.3)	01
5Z3	1.9	23.6 ± 1.5	20.2 ± 2.1	49 (51.9)	L + El (14.8 + 83.2)	01
5Z9	2.2	28.0 ± 1.4	26.4 ± 2.4	59 (43.8)	El (96.9)	01
6A3	0.1	15	6.1	39 (100)	El (100)	51
6K1	1.3	9.8 ± 1.3	3.7 ± 0.6	12 (44.4)	S (66.7)	53
6K3	3.5	9.1 ± 0.5	3.3 ± 0.2	22 (37.5)	S (68.8)	53
6K4	6.5	6.6 ± 0.3	2.2 ± 0.1	12 (54.8)	S (100)	53
6K5	1.4	8.4 ± 0.5	2.9 ± 0.2	22 (65.0)	S (100)	53
6K6	0.3	11.4 ± 1.5	4.4 ± 0.8	22 (60.0)	S (80.0)	53
6K7	3.1	9.9 ± 0.9	3.9 ± 0.5	14 (33.3)	S (81.8)	53
6N1	1.0	21.6 ± 1.2	10.8 ± 1.0	49 (60.0)	L + El (6.7 + 93.3)	51
6N2	0.3	21.0 ± 1.7	10.2 ± 1.2	49 (80.0)	El (100)	51
6N3	0.9	16.4 ± 1.6	7.3 ± 1.1	39 (30.8)	L + El (30.8 + .61.5)	51
6N4	0.9	14.7 ± 0.8	6.0 ± 0.4	39 (46.2)	L + El (46.2 + 53.8)	51
6N5	1.3	20.9 ± 1.1	10.3 ± 0.9	49 (58.8)	L + El (5.9 + 88.2)	51
6O1	0.6	4.8 ± 0.8	0.7 ± 0.1	13 (87.5)	F (87.5)	57
6R1	1.4	5.8 ± 0.4	2.2 ± 0.2	15 (45.0)	L + El (45.0 + 25.0)	79
6S1	12.9	7.6 ± 0.2	1.9 ± 0.1	12 (48.7)	S (100)	55
6S4	6.0	10.1 ± 0.5	2.8 ± 0.2	22 (43.0)	S (86.0)	55
6Y1	2.0	22.6 ± 1.0	18.1 ± 1.4	49 (62.1)	El (100)	01
6Z9	1.5	23.0 ± 1.8	19.6 ± 2.1	49 (45.5)	L + El (13.6 + 86.4)	01
7G3	2.4	5.8 ± 0.4	1.0 ± 0.5	13 (67.6)	F (67.6)	79
7O1	0.5	5.1 ± 0.3	0.8 ± 0.1	13 (100)	F (100)	77
7R1	0.5	3.3 ± 0.5	1.1 ± 0.2	15 (83.3)	L (83.3)	79
7R2	0.7	4.2 ± 0.4	1.5 ± 0.2	19 (90)	L (90.0)	79
8G3	1.1	4.5 ± 0.4	0.4 ± 0.03	13 (87.5)	F (87.5)	79

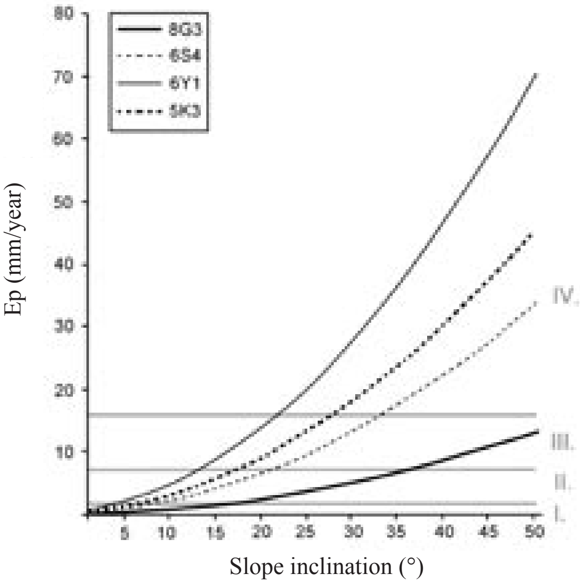

Fig. 3. Relation between slope inclination and potential water erosion for selected forest sites. Dashed lines and letters show erosion threat classes

Although slope inclination is the major factor influencing potential soil erosion, the soil characteristics play a role in differences between edaphic categories and forest sites. Fig. 3 shows the relation between potential soil erosion and slope inclination for four forest sites representing different soil conditions. Since the soil characteristics are incorporated on the level of edaphic category and they partly overlap in the edaphic categories in the study area, the curve of forest site 6Y1 approximately represents the curves of forest sites of edaphic categories Y and Z, curve of forest site 5K3 represents those of edaphic categories A, K, M and N, curve of forest site 6S4 those of edaphic category S and curve of forest site 8G3 those of edaphic category G. The curves of forest sites of edaphic category R are similar to the curve of 5K3, those of edaphic category M to 6S4 and those of edaphic categories L, T and O are intermediates between 6S4 and 8G3.

MANAGEMENT SET (MS) AND TERRAIN PROPERTIES

Eleven management sets (Table 6) were recorded within studied area. Sets 53, 55 and 01 were the most frequent, each of them covering an area over 300 ha. There is a close relationship between the soil protection function described in IFM (1999) and the span of mean potential erosion. MS 01 (protection forests) corresponds to erosion threat class IV; forests with increased soil protection function correspond to erosion threat class III (Table 6). The variability of dominant technological types of forest sites corresponding to each MS is related to the variability of natural conditions within MS and shows the negligible potential use of MS for predicting model technology. Five MS are related to forest sites with the same dominant technological type but only 2 of them correspond to more than 1 forest site (MS 01 and MS 51). The majority of MS correspond to forest sites with various dominant technological types; MS 43 corresponds to forest sites with 3 different dominant technological types (Table 6).

DISCUSSION

This study was conducted on a landscape segment of approximately rectangular shape 3 × 5 km. Minor deviations from the rectangle were caused by accepting important boundaries (forest district, major communications, agricultural land). The area was selected to represent a wide range of environmental conditions while the balance of different conditions (relief, soil properties) was given minor importance only. Thus the relative frequency of some

Table 6. Terrain and technological properties of management sets (MS). Soil protection function was taken from IFM (1999). The column "Dominant technological types" shows the dominant technological types of related forest sites. Values in parenthesis show the number of forest sites with corresponding dominant technological type

MS	Relative frequency (%)	Soil protection function	Ep mean ± S.E. (mm/year)	Number of forest sites	Dominant technological types
01	19.9	major importance	22.3 ± 0.5	5	L (5)
29	1.5	normal	0.3 ± 0.1	3	L, F (1, 2)
41	0.1	increased	6.1	1	L (1)
43	8.0	normal	3.7 ± 0.5	3	S, U, L (1, 1, 1)
47	2.0	normal	0.8 ± 0.4	1	F (1)
51	17.6	increased	9.6 ± 0.3	12	L (12)
53	24.2	normal	4.3 ± 0.2	8	S, F (7,1)
55	19.4	normal	2.2 ± 0.1	3	S, L (2, 1)
57	0.8	normal	1.0 ± 0.2	2	S, F (1, 1)
77	0.5	normal	0.8 ± 0.1	1	F (1)
79	6.0	normal	1.2 ± 0.2	5	L, F (3, 2)

terrain characteristics need not necessarily represent those of a greater region. The high variability of natural conditions is reflected in high variations of edaphic categories and forest sites.

Terrain properties correspond with the diversified mountain landscape. The distribution of plots in slope inclination classes is similar to that in the Drahanská hills (MODRÝ 2000) showing that the altitude does not play the main role. A clear difference is in the frequency of terrain obstacles of all sizes. Slower weathering of granite compared with limestone can result in a high amount of rocks in the whole area causing dominance of terrain with obstacles 0.3–0.5 m high in contrast to Vranov forest district where the terrain without obstacles or with obstacles smaller than 0.3 m high prevails. The high frequency of terrain obstacles is reflected in the distribution of terrain types that is shifted from dominant types 11, 21 and 31 in Vranov to 12, 22 and 32 in the Jizerské hory Mts. Although the structure of technological types cannot be compared directly since minor changes were made in technological classification used by MODRÝ (2000), the tradeoff between skidder and industrial tractor technologies is clear owing to different frequency of terrain obstacles. The proportion of technological type "L" terrains is the highest in both areas.

Although the proportion of the terrain of technological types "L" and "E_l" is high (45%), it need not necessarily imply such a high volume of skyline-logged timber. Small fragments situated within the skidder or tractor terrain form a part of the "L" and "E_l" terrain. Timber from these fragments can often be transported from the surroundings using winch and cable.

The observed range of potential water erosion corresponds with data published by MÍCHAL (1973) and VOLOŠČUK (1978). VOLOŠČUK (1978) reported the extreme value (67.6 mm/year) for dwarf pine stands on limestone outcrops, MÍCHAL (1973) 41.0 mm/year for sub-alpine pine forests. In both cases the maximum values of potential water erosion refer to steep rocky slopes in mountain areas with sparse vegetation. The most vulnerable sites in the Jizerské hory Mts. (extreme calculated value 46.0 mm/year) belong to edaphic categories Y and Z followed by categories A, M and N. The compound effect of steep slopes and relatively unfavorable soil conditions causes the high erosion threat. These results correspond with the basic forest functions prescribed in IFM (1999). Special-purpose forests (MS 01) that are maintained for soil protection correspond to all forest sites of erosion threat class IV. Forests with increased soil protection function (MS 41 and MS 51) correspond to forest sites belonging to erosion threat class III. Forest sites of erosion threat classes II and I are all listed as production forests without special soil protection function (IFM 1999). Forest site 5M1 listed as a production forest without increased soil protection function (MS 43) in IFM (1999) was found to be under erosion threat class III. Although the value of potential erosion (9.4 mm/year) is near the lower limit of the class, prescription of increased soil protection function (e.g. MS 41) should be considered for this forest site.

The span of technological properties of forest sites was fairly narrow. The properties of groups of forest sites are slightly less homogeneous, but in most cases they group together forest sites of the same dominant technological type. In order to decrease the number of classification units, groups of forest sites can be used for the planning of forest management as documented also by recent publications (PLÍVA 2000; PRŮŠA 2001).

In most cases the management set is related to forest sites with various dominant technological types. These results correspond to PRŮŠA (2001) suggesting that forest sites give more information necessary for describing the model technology than an ecologically wider management set.

The relation between edaphic category and terrain properties is stronger than that between management set and terrain properties. Differences can be explained by different construction of these units. Edaphic categories group forest sites with the same or similar site properties regardless of the altitudinal zonation. Management sets take into account both the altitudinal zonation and site properties and in order to keep the number of differentiated units reasonably low, those include a wider range of natural conditions.

In general the span of potential water erosion as well as the span of technological properties of single forest site and group of forest sites were found to be satisfactorily narrow for operational planning of harvest operations. Edaphic categories and management sets can be used for rough orientation, but their properties are not homogeneous enough to provide the basis for operational management decisions.

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Terénní vlastnosti vybraných lesních typů v Jizerských horách

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ABSTRAKT: Diferenciace lesnických technologií podle charakteristik ekosystému je základním krokem nezbytným k dosažení trvale udržitelného lesnictví. Lesnický typologický systém obsahuje základní jednotky diferenciace lesních ekosystémů v ČR. Terénní charakteristiky, potenciální vodní eroze půdy a použitelné těžební technologie byly zjišťovány pro 44 lesních typů ve vybrané části Jizerských hor. Lesní typ byl shledán homogenním z hlediska terénních a technologických vlastností. Nadstavbové klasifikační jednotky (edafické kategorie a skupiny lesních typů) a hospodářské soubory vykázaly menší homogennost, nedostatečnou pro provozní plánování. Lesnická typologie může sloužit jako základ optimalizace lesnických technologií.

Klíčová slova: lesnická typologie; terénní klasifikace; těžební technologie; eroze

Se vstupem do 21. století musí lesní hospodářství v Evropě projít změnami směřujícími k zajištění trvale udržitelného využívání lesních ekosystémů. Nezbytným krokem ke snížení dopadu lesnických činností na stabilitu a produkční schopnost ekosystémů je důsledná diferenciace lesnických technologií podle vlastností ekosystému. K nejzávažnějším zásahům do ekosystému dochází při těžebních operacích. K odnětí části či celého korunového patra přibývají vlivy způsobené pohybem těženého dříví a těžební mechanizace porostem, především narušení soudržnosti půdního povrchu a poškození vegetačního krytu včetně případné přirozené obnovy. V úvahu přichází i chemická kontaminace půd, která je však nepříliš častá a ve většině případů má pouze lokální význam.

Lesnický typologický systém (ÚHÚL 1983) do detailu rozlišuje lesní ekosystémy v České republice. Typologický systém zahrnuje biotické a abiotické charakteristiky stanoviště, a měl by tedy obsahovat i informace o charakteristikách rozhodujících o použitelné a vhodné těžební a přibližovací technologii – reliéfu terénu, sklonu svahu, výskytu terénních překážek, únosnosti půdního povrchu a celkové odolnosti ekosystému proti narušením způsobeným pohybem těženého dříví a mechanizace. Práce zaměřené na studium vazby těchto technologických vlastností na systém lesnické typologie jsou řídké (MÍCHAL 1973; VOLOŠČUK 1978).

Cílem práce bylo posoudit homogennost jednotek lesnické typologie z pohledu technologických vlastností stanoviště, a tím ověřit vhodnost lesnické typologie pro návrh těžebních technologií.

Ve vybraném segmentu Jizerských hor (1 605 ha) byl v pravidelné síti 100 × 100 m na plochách 2 × 2 m sledován sklon svahu, výskyt terénních překážek a odhadována únosnost terénu. Pro každou plochu byl určen lesní typ podle mapy lesních typů. Na základě uvedených charakteristik byl stanoven terénní a technologický typ (podle SI-

MANOVA et al. 1993) a podle metodiky užité MÍCHALEM (1973) vypočítána potenciální vodní eroze půdy, která byla použita jako reprezentant citlivosti ekosystému k narušení půdního povrchu. Pro každý lesní typ a edafickou kategorii byla vyhodnocena frekvence jednotlivých terénních a technologických typů a rozpětí potenciální vodní eroze půdy. Pro porovnání byly tyto vlastnosti vyhodnoceny i pro hospodářské soubory, které jsou běžně používány k návrhu těžebních technologií.

Ve sledované oblasti bylo zaznamenáno 44 lesních typů ve 13 edafických kategoriích. Nejrozšířenějšími byly typy 3S8, 5K3, 5Y1 a 6S1, kategorie K, S, N a Y. V naprosté většině případů byla registrována únosná půda (89 %), překážky byly ve většině případů vyšší než 0,3 m, ve 40 % případů vyšší než 0,5 m. Frekvence sklonových tříd byla vyrovnaná, pouze nejvyšší třída (71 % +) byla méně zastoupená (obr. 2). Celkem bylo zaznamenáno 18 terénních typů (tab. 1). Celkové rozpětí potenciální vodní eroze půdy bylo 1–46 mm/rok s průměrem 8 mm/rok. Hlavním faktorem ovlivňujícím potenciální vodní erozi půdy je sklon svahu; půdní vlastnosti mají menší význam.

Mezi lesními typy i mezi edafickými kategoriemi byly shledány statisticky významné rozdíly (ANOVA, $P \leq 0{,}05$) v hodnotách sklonu svahu a potenciální vodní eroze půdy. Jeden terénní typ zabíral 50–70 % plochy lesního typu u 13 lesních typů a více než 70 % plochy u 10 ze 44 lesních typů. Větší homogennost byla zjištěna u technologických typů, kde jeden technologický typ zabíral 50–70 % plochy lesního typu v osmi případech a více než 70 % plochy dokonce ve 34 případech.

V oblasti bylo zaznamenáno 11 hospodářských souborů, z nichž nejrozšířenějšími byly soubory 01, 53 a 55. Byl nalezen úzký vztah mezi hospodářským souborem a potenciální vodní erozí půdy. V rámci hospodářského souboru byla shledána vyšší variabilita technologických typů. Pouze dva hospodářské soubory odpovídající více než jednomu lesnímu typu mají stejný dominantní technologický typ pro všechny lesní typy. U ostatních nelze z hospodářského souboru jednoznačně určit, jaký technologický typ je dominantní pro všechny odpovídající lesní typy (tab. 6).

Technologické vlastnosti lesních typů a skupin lesních typů byly shledány dostatečně homogenními k plánování těžebních technologií. Edafické kategorie a hospodářské soubory zahrnují širší rozpětí technologických vlastností a mohou sloužit pouze k hrubší orientaci.

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