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CLIMATIC AND SOIL CHARACTERISTICS OF THE ALTITUDINAL VEGETATION ZONES AND EDAPHIC-TROPHIC UNITS

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Classification of forest ecosystems in Slovakia is based on Zlatnik's geobiocenological school. The reconstruction units are forest geobiocoen types (FGT) and these are arranged into groups of forest geobiocoen types (GFGT) and other super-structured units according to phytosociological and ecological similarities. The classification system is based on consideration that permanent ecological conditions are not changing over a long time and that plant species are a good non-direct indicator of ecological conditions with respect to their specific ecological (soil and climatic) amplitude. Because the herb species composition significantly reflects also the changes in tree species layer the floristic analysis of vegetation along with analysis of ecological properties of sites can be used for typisation geobiocoens. Hence, we also need to know these ecological (climatic, soil and terrain) characteristics. The analysis of basic climatic and soil characteristics of the selected super-structured geobiocenological units (altitudinal vegetation zone (avz), edaphic-trophic non-waterlogged and waterlogged units) showed the high variability of both climatic and soil values.

Key words: *forest geobiocoens, site classification, altitudinal vegetation zone, edaphic-trophic units*

V článku sa prezentujú výsledky analýz klimatických a pôdnych parametrov lesných vegetačných stupňov a edaficko-trofických radov a medziradov a ich vzájomných kombinácií. Analýzy sa vykonali s využitím databázy z Národnej inventarizácie a monitoringu lesov SR. Materiál pre uvedené analýzy tvorila databáza z 1 419 inventarizačných plôch. Na týchto plochách sa starostlivo zisťovali jednotky lesníckej typológie. Taktiež boli odoberané vzorky pôdy, ktoré sa následne chemicky analyzovali v centrálnych laboratóriách NLC. Pre účely sledovania klimatických parametrov sa použili rastrové klimatické vrstvy. Lesné vegetačné stupne a edaficko-trofické rady a medzirady predstavujú najvyššiu hierarchickú úroveň lesníckej typológie na Slovensku, ktoré sú výsledkom dlhoročných výskumov a tvoria základ pre následné modelovanie lesných ekosystémov a v konečnom dôsledku aj pre rámcové plánovanie

a tvorbu manažmentových postupov. Výsledky analýz poukazujú na relatívnu zhodu doterajších poznatkov o lesných vegetačných stupňoch a edaficko-trofických radoch a medziradoch. Napriek uvedenej zhode existuje v rámci skúmaných jednotiek veľmi veľká variabilita ako klimatických, tak aj pôdnych parametrov, čo môže spôsobovať nie celkom jednoznačné vymedzenie uvedených jednotiek.
Kľúčové slová: *lesné geobiocenózy, klasifikácia stanovíšť, lesný vegetačný stupeň, edaficko-trofické jednotky*

1. Introduction

One of the aims of forest geobiocenology is to divide the forest ecosystems into ecologically, phytosociologically and productively more-less homogeneous segments. Specialists from all over the world have been dealing with classifying the sites into units (Zlatník 1959, 1976, Hančinský 1972, 1974, 1983, 1990, Randuška *et al*. 1986, Ellenberg 1974, Bryan 2006, Cajander 1909, 1949, Ray 2001, Bajzak – Roberts 1996, Rowe 1996, Kai – Ying *et al*. 1999, and others). One of the reasons why the people have attempted to create such classifications was to propose similar management measures within the site units. It is to be needed for management decisions making and for assessment of management models as well.

Classification of the forest ecosystems in Slovakia is based on the principles of forest geobiocenology elaborated by professor Zlatník (1959, 1976a), who created mapping reconstruction geobiocenological units of the natural vegetation in 1948. Characteristics of the forest types were elaborated and published by Hančinský (1972). Substantial progress in geobiocoenology represents final publications of Zlatník (1976a, b), in which the primary classification system of forest geobiocoens was supplemented by mezotrophic basic (B/D) and nitrophilous basic (C/D) interorders of geobiocoens. Each altitudinal vegetation zone includes geobiocoens with normally formed soils, limited edaphic-hydric conditions as well as geobiocoens with waterlogged soils (Zlatník 1976a). Geobiocoenological units used in forest practice in SR (Zlatník 1959) are as follows:

- Basic units: forest geobiocoen types – FGT (totally 365);
- Super-structural units:
  - groups of forest geobiocoen types – GFGT (totally 92)
  - edaphic-trophic units (orders, interorders), non-waterlogged – ETUN (totally 6)
  - edaphic-trophic units, waterlogged – ETUW (totally 2)
  - altitudinal vegetation zones – AVZ (totally 8)

Nowadays, Slovak forestry uses the maps of geobiocenological units and the relevant GIS layer based on the maps of forest geobiocoen types (it has been elaborated by National Forest Centre stuff).

Problems and difficulties of current forestry praxis in Slovakia are as follows:
(i) large number of forest geobiocoen types and other classification units, which brings some difficulties with their practical utilisation; (ii) insufficient precise results of reconstructive mapping of strongly changed forest geobiocoenoses;

Table 1. Proportion [% ± St.Err] of altitudinal vegetation zones, edaphic-trophic units of SR and vice versa (ŠEBEŇ, BOŠEĽA 2008)

Altitudinal vegetation zone	Edaphic-trophic orders and interorders																	Total	
	Forest non-waterlogged												Waterlogged units						
	A		A/B		B		B/C		C		D		a		c		0*		
O	0.9	± 0.2	—	—	2.6	± 0.4	0.6	± 0.2	—	—	0.2	± 0.1	0.1	± 0.1	1.8	± 0.4	0.2	6.5	± 0,7
B–O	0.1	± 0.1	—	—	12.4	± 0.9	1.5	± 0.3	0.1	± 0.1	0.2	± 0.1	0.1	± 0.1	0.4	± 0.2	0.5	15.3	± 1,0
O–B	0.6	± 0.2	—	—	22.1	± 1.1	0.9	± 0.2	0.5	± 0.2	0.4	± 0.2	—	—	0.3	± 0.1	0.4	25.3	± 1,2
B	0.7	± 0.2	0.3	± 0.1	15.5	± 1.0	1.4	± 0.3	0.5	± 0.2	1.0	± 0.3	—	—	0.2	± 0.1	0.4	20.2	± 1,1
B–F	2.0	± 0.4	6.8	± 0.7	6.7	± 0.7	2.3	± 0.4	0.3	± 0.1	1.9	± 0.4	0.2	± 0.1	0.1	± 0.1	0.7	21.1	± 1,1
S–B–F	2.0	± 0.4	3.2	± 0.5	1.5	± 0.3	0.8	± 0.2	0.1	± 0.1	0.9	± 0.3	0.1	± 0.1	0.1	± 0.1	0.1	8.7	± 0,8
S	1.6	± 0.3	—	—	—	—	0.2	± 0.1	—	—	0.1	± 0.1	—	—	—	—	—	1.9	± 0,4
DP	1.2	± 0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.2	± 0,3
Total	9.3	± 0.8	10.3	± 0.8	60.8	± 1.3	7.7	± 0.7	1.5	± 0.3	4.7	± 0.6	0.5	± 0.2	2.9	± 0.4	2.3	100	

Note: 0 – non-determined soil nutrient regime type due to less information, A – oligotrophic, A/B – hemioligotrophic, B – mesotrophic, B/C – heminitrophilous, C – nitrophilous and D – calciphile, a – oligotrophic, c – nitrophilous, O – Oak; B–O – Beech–Oak; O–B – Oak–Beech; B – beech; F–B – Beech–Fir; S–B–F – Spruce–Fir–Beech; S – Spruce; DP – Dwarf pine

(iii) different productivity of forest stands with the same tree species composition within segments of the same forest geobiocoen types.

The difficulties in determination of the geobiocenological units are connected especially with the occurance of the various qualitative, quantitative, topical, choric and dynamic manifestations of chtonophytical taxa (KUKLA 1993b). All ecological characteristics of forest geobiocoen types can be determined only indirectly at the present, by means of the floristic analysis of vegetation though it is required to confront the obtained result with characteristics of the abiotic environment. The complete analysis of ecological factors influencing a nature of ecosystems has not been performed yet (KUKLA 1993a).

Geobiocenological units on the forest geobiocoenose type's level should reflect ecological as well as production conditions, and assumes that the tree species composition and structure of stands have not been changed. However, all forest geobiocoenoses have already been more or less changed. The site conditions are not only interdependent but there are also dependent in part upon the status of forest stand, which is itself a major site-forming factor. Because of these interactions, the simple regression technique of estimating site quality from an evaluation of a few important site factors, as it is in practical forest ecology, can only be approximate (Barnes *et al*. 1998).

Productivity, or actual site quality, may be measured directly only for a few forests where accurate long-term records of forest stand development and growth have been maintained. However, it can be estimated only indirectly by one or more of the alternatives, as follows (Barnes *et al*. 1998):

- Forest vegetation – tree height (site index method), ground vegetation (indicator species and ecological groups of species), overstorey and ground-cover vegetation in combination;
- Physical environment factors – climate, physiography, and soil survey and soil-site methods;
- Multiple-factor and multiple-scale approaches (using some or all of the above factors, disturbance regime, and forest land-use history.

1.1. Definition of the altitudinal vegetation zone and the edaphic-trophic units

Altitudinal vegetation zones (AVZ): reflects a sequence of differences in vegetation depending on differences in macro-climate of elevation and exposition (Buček, Lacina 1999, Zlatník 1976a). They are defined by means of indicator species and named on the basis of combination of dominant climax tree species (Zlatník 1976a) as follows: 1 – oak; 2 – beech-oak; 3 – oak-beech; 4 – beech; 5 – fir-beech; 6 – spruce-beech-fir; 7 – spruce; 8 – dwarf pine.

Edaphic-trophic units (ETU) of forest geobiocoens: ETU are defined with respect to representation of ecological groups of plant species reflecting the content of soil nutrients (Zlatník 1976a) and limit values of active soil reaction (Kukla 1993a). They were created mainly on the basis of floristic analysis of vegetation due to insufficient knowledge on soil nutrient regime of forest ecosystems (Kukla 2004). Zlatník (1959) distinguished following ETU:
A – oligotrophic, A/B – hemioligotrophic, B – mesotrophic, B/C – heminitrophilous, C – nitrophilous and D – calciphile orders and interorders in the case of non-waterlogged forest geobiocoens and: a – acidic (oligotrophic) and c – eutrophic (nitrophilous) sets in the case of waterlogged forest geobiocoens.

Proportions of altitudinal vegetation zones, edaphic-trophic units along with corresponding standard errors are presented in the Table 1 (Šebeň, Bošeľa 2008). The results were taken over from the National forest inventory of Slovak forests (NFIM SR 2005–2006).

2. Material and methods

2.1. Inventory plots

The data collected on inventory plots (IP) during the National Forest Inventory in 2005 and 2006 (Šmelko *et al*. 2006) were used. IP were established in regular grid of 4×4 km on the whole territory of Slovakia. The area of particular IP was of 500 m^2 (if the different growth stages, site conditions or parts with different tree species composition were recognized the IP was divided into two or more smaller parts to be more homogeneous).

The number of inventory plots is 1419. Some IP were divided into subplots due to soil or stands differences, so the total number of plots and subplots is as much as 1439. In some subplots, edaphic--trophic unit (or forest geobiocoen type) was not recognized due to uncompleted determination of soil and phytocoenological properties (it could happen in forests growing on non-forest land, which have not been geobiocoenologically mapped, yet). The number of subplots, in which the edaphic-trophic unit was determined, is as much as 1430.

2.2. Soil parameters

The samples from 0–10 cm topsoil mineral layers as well as from 10–20 cm layers were taken for determination of values of some chemical parameters such as pH_{H2O}, total nitrogen (N_t), and total and organic carbon (C_t, C_{org}). The samples taken from 0–10 cm topsoil layer were considered to be analyzed in this study. The slope inclination and altitude of each IP were detected as well. pH-values were found electrometrically in the suspension of soil to water in 1 : 2.5 ratio, N_t and C_t were quantified using the NCS-FLASH 1112 analyzer (weight percentage of dry matter), and C_{org} by calculation:

$$C_{org} = C_t - Ekv.CaCO_3 \,.\, 0{,}12$$

The amount of Ekv. $CaCO_3$ were found using a volumetric method (weight percentage of dry matter). All of chemical analyses were performed in Central Forestry Laboratory at National Forest Centre in Zvolen.

2.3. Climatic parameters

The raster models of climatic parameters were used to analyze the climatic characteristic within super-structured geobiocenological units (AVZ, ETU). Primary data were gathered at meteorological stations distributed over the entire Slovakia. The number of meteorological stations used for prediction of temperature characteristics was as much as 170 and for prediction of precipitation it was 552. As many of climate parameters exhibit strong correlation with orography, the elevation above sea level of Slovakia (digital elevation model with 30 meters resolution), was used as predictor (auxiliary) variable. Descriptive statistics of July precipitation totals and July average air temperature for the period of 1951–1980 (Hlásny 2007) are given in the Table 2. The climatic parameters analyzed in this study were such as mean annual precipitation (mm), sum of precipitation from April to September, mean temperature in the period May–August, number of days with temperature over 5°C, long time average of temperature, and mean temperature in the period April–September. To avoid climatic changes during last decades, the data gathered during the period of 1951–1980 representing a normal climate.

Variogram was constructed by plotting the mean squared differences of values separated by a range of distances against separation distance. Produced chart is fitted by a function, in order to produce a variogram model, which is a key component of any kriging system.

Ordinary kriging and external drift kriging as perhaps the best recognized of kriging methods (Hlásny 2007) was used to model climatic parameters (in order to predict values at unknown locations). Some

Table 2. Descriptive statistics of temperature, precipitation and elevation data used for the modelling of raster of climatic characteristics of SR (Hlásny 2007)

Temperature	**n**	**Mean**	**SD**	**Skewness**	**Range**	**Min**	**Max**
(°C)	170	17.2	2.3	-1.29	13.8	6.9	20.7

Precipitation	**n**	**Mean**	**SD**	**Skewness**	**Range**	**Min**	**Max**
(mm / month)	552	92	31.2	2.4	231	50	281

more information on the methodology of modeling climatic parameters in the ISATIS environment presented Hlásny (2007).

Subsequently, the GIS layers of raster models of particular climatic parameters were overlapped with layer of inventory plots to gain these values for each plot. Basic statistics such as average, standard error were computed for altitudinal vegetation zones and their combinations with edaphic-trophic units.

2.4. Statistical processing

Basic statistics, such as average, standard deviation and standard error of climatic and soil parameters for each altitudinal vegetation zones, edaphic-trophic unit as well as its combinations are presented in the paper. Furthermore, median, 25–75 percentile and dispersion (non-outlier min-max, outlier and extreme values) of climatic and soil parameters within each geobiocoenological unit are given as well.

3. Results

Values of basic statistics of climatic parameters for altitudinal vegetation zones (AVZ) are presented in the Table 3. The number of IP, which was used for calculation of basic statistics ranges from 15 to 354. Standard error ranges from 0.2% to 3.6%. It can be stated that the number of IP is sufficient and represents the altitudinal vegetation zone as for the selected climatic parameters. Trend of both precipitation and temperature along altitudinal vegetation zones is almost linear. While the mean precipitation increases the mean temperature drops.

Average annual precipitation for whole Slovakia is as much as 879 mm and average temperature in the period from April to September reaches 12.3°C. Such values of the precipitation and temperature are reached in the 4th Beech altitudinal vegetation zone.

Table 3. Basic statistics of climatic parameters within altitudinal vegetation zones of SR

Altitudinal vegetation zones	n	Mean annual precipitation [mm]			Precipitation from April to September [mm]			Mean temperature in per. May – August [°C]			Number of days with temperature over 5°C		
		Av.	SD	SE	Av.	SD	SE	Av.	SD	SE	Av.	SD	SE
O	65	652	45	6	373	27	3	17.0	0.5	0.1	235	5	0.6
B–O	208	722	64	4	412	34	2	16.0	0.8	0.1	223	8	0.5
O–B	354	805	84	4	465	41	2	15.1	0.8	0.0	214	9	0.5
B	285	894	107	6	514	43	3	13.9	0.8	0.0	202	9	0.5
B–F	297	978	138	8	565	56	3	12.7	0.8	0.0	188	9	0.5
S–F–B	130	1121	146	13	635	69	6	11.2	0.7	0.1	172	8	0.7
S	25	1335	159	32	710	81	16	9.8	0.6	0.1	154	7	1.5
K	15	1406	197	51	763	101	26	8.3	0.8	0.2	137	8	2.0
a, c	60	694	134	17	409	86	11	16.0	2.0	0.3	224	21	2.7
Total	1439	879	186	5	504	95	3	14.1	2.0	0.1	203	21	1.0

Note: Av. – average, SD – standard deviation, SE – standard error, the explanation of other abbreviations as in the Table 1.

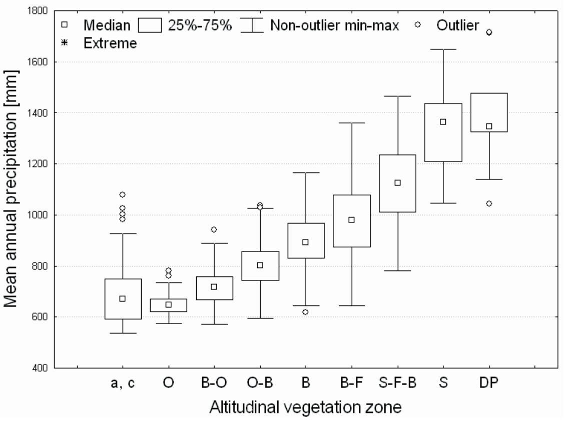

Figure 1. Mean annual precipitation within the altitudinal vegetation zones of SR

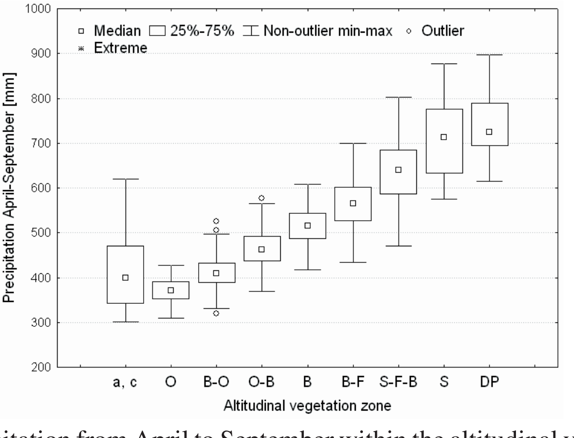

Figure 2. Sum of precipitation from April to September within the altitudinal vegetation zones of SR

In the Figure 1, the amounts of mean annual precipitation along forest vegetation zones are showed. Boxes mean 25th and 75th percentiles of the distribution. The 25th percentile of a variable means that 25% of the measured values fall below that value. Similarly, the 75th percentile means that 75% of measured values fall below that value and is calculated accordingly. Whiskers mean the ranges of values of the variable from non-outlier minimum to non-outlier maximum. Variability of the mean annual precipitation (Fig. 1) and sum of precipitation from April to September (Fig. 2) ranges from 13% in the Oak vegetation zone to 28% in the Fir-Beech vegetation zone and the ranges of values in adjacent altitudinal vegetation zones are overlapping each other. When considering a standard error of the variable values, the significant differences in precipitation between the altitudinal vegetation zones can be found.

Table 4. Basic statistic of climatic parameters within altitudinal vegetation zones of SR

Altitudinal vegetation zones	n	Temperature – long time average [°C]			Mean temperature in per. April – September [°C]			Elevation [m a. s. l.]		
		Av.	SD	SE	Av.	SD	SE	Av.	SD	SE
O	65	8.6	0.5	0.1	15.2	0.5	0.1	217	62	8
B–O	208	7.7	0.7	0.0	14.2	0.7	0.0	356	109	8
O–B	354	6.9	0.7	0.0	13.3	0.8	0.0	456	122	6
B	285	6.0	0.7	0.0	12.1	0.8	0.0	618	126	7
B–F	297	4.9	0.7	0.0	10.9	0.8	0.0	817	135	8
S–F–B	130	3.7	0.7	0.1	9.4	0.7	0.1	1061	123	11
S	25	2.5	0.5	0.1	8.0	0.7	0.1	1335	82	16
K	15	1.3	0.5	0.1	6.6	0.7	0.2	1629	105	27
a, c	60	7.7	1.7	0.2	14.2	2.0	0.3	317	247	32
Total	1439	6.1	1.7	0.05	12.3	1.9	0.1	614	299	8

Note: explanation of abbreviations as in the Table 1 and Table 3.

In Table 4, the basic statistics of some climatic parameters such as long time average of temperature, the mean temperature from April to September and elevation above sea level are given. In the case of first two climatic parameters the total average temperature from April to September is met in the 4th Beech vegetation zone. Decrease of temperature towards higher altitudinal vegetation zones is almost linear.

The variability of mean temperature from April to September (Fig. 3) ranges from 7% in Oak vegetation zone to 22% in the Dwarf pine vegetation zone. Variability of

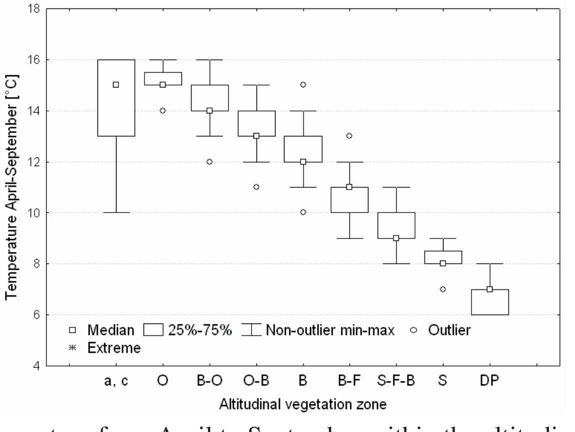

Figure 3. Mean temperature from April to September within the altitudinal vegetation zones of SR

Table 5. Basic statistics of soil properties within edaphic-trophic units of SR

Edaphic-trophic units	**n**	**Surface humus thickness [cm]**			**Skeleton [%]**			**pH_{H2O}**		
		Av.	**SD**	**SE**	**Av.**	**SD**	**SE**	**Av.**	**SD**	**SE**
Oligotrophic	131	4.3	2.9	0.3	29.8	24.0	2.1	4.3	0.6	0.1
Hemioligotrophic	149	3.6	2.0	0.2	32.9	20.2	1.7	4.8	1.1	0.1
Mesotrophic	880	2.6	1.4	0.0	22.9	20.5	0.7	5.2	0.8	0.0
Heminitrophilous	115	2.7	1.6	0.1	28.5	23.0	2.1	5.4	1.0	0.1
Nitrophilous	23	2.6	1.1	0.2	68.7	20.0	4.2	6.0	1.0	0.2
Calcalophile	73	3.5	1.8	0.2	45.0	18.8	2.2	6.9	0.8	0.1
Olig. – waterlogged	7	6.6	8.2	3.1	3.6	7.5	2.8	4.2	0.3	0.1
Nitr. – waterlogged	52	1.5	1.4	0.2	4.9	10.3	1.4	6.3	1.3	0.2
Total	1430	2.9	1.9	0.05	26.2	22.4	0.6	5.3	1.0	0.0

the number of days with temperature over 5°C (Fig. 4) ranges from 4% to 11% and standard error values range from 0.2% in the 3rd Oak–Beech vegetation zone to 1.5% in the 8th Dwarf pine vegetation zone (it is caused mainly due to less number of IP). Significant differences among the altitudinal vegetation zones as for the above-mentioned climatic parameters can be found.

Average surface humus thickness found for whole Slovakia is as much as 2.9 cm (Table 5). In the case of edaphic-trophic units the surface humus thickness ranges from 1.5 cm ± 0.2 in the waterlogged nitrophilous set of geobiocoens to 6.6 cm ± 3.1 in waterlogged oligotrophic set of geobiocoens. Within the nitrophilous and mesotrophic orders of non-waterlogged geobiocoens the surface humus thickness reaches

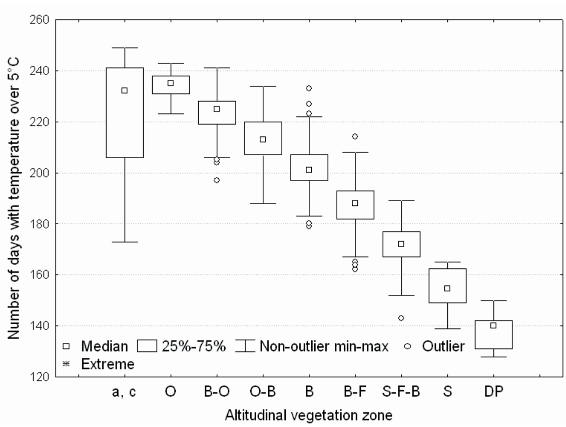

Figure 4. Number of days with temperature over 5°C within the altitudinal vegetation zones of SR

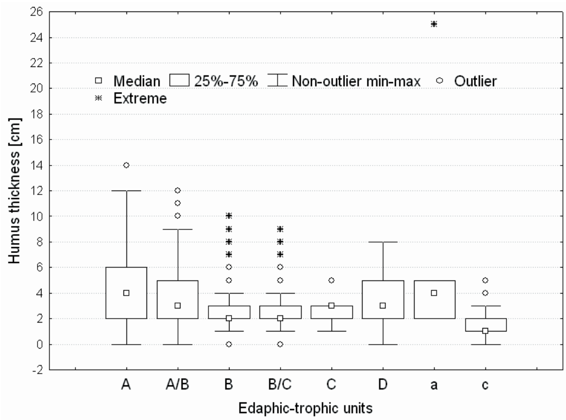

Figure 5. Surface humus thickness in the edaphic-trophic units of SR

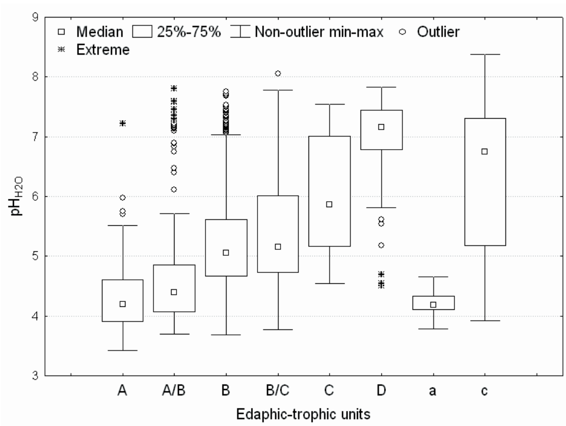

Figure 6. Soil acidity in soils of the edaphic-trophic units of SR

the minimum of 2.6 cm ±0.2, and the maximum (4.3 cm ± 0.3) in oligotrophic order of geobiocoens (A). The soils of waterlogged forest geobiocoens contain the lowest proportion of skeleton (3.6% ± 2.8 and 4.9% ± 1.4). The highest percentage of skeleton was found in soils of non-waterlogged nitrophilous order of forest geobiocoens (68.7% ± 4.2). Variability of skeleton percentage within soils of edaphic-trophic units of forest geobiocoens is very high and the percentage from 0% to 60% was found almost in the soils of each edaphic-trophic unit. The average pH_{H_2O} values in soils of SR range from 4.2 ± 0.1 to 6.9 ± 0.1 (Table 5).

The lowest pH value occurs in the oligotrophic waterlogged set of forest geobiocoens and the highest one was found in the non-waterlogged calciphile order of forest geobiocoens. The pH values vary within the each edaphic-trophic unit (Fig. 6). The

Table 6. Basic statistics of soil N and C within edaphic-trophic units of SR

Edaphic-trophic units n	n	Total nitrogen [weight % of DM]			Organic carbon [weight % of DM]			Slope inclination [%]		
		Av.	SD	SE	Av.	SD	SE	Av.	SD	SE
Oligotrophic	131	0.44	0.29	0.03	7.3	4.6	0.4	33	24	2
Hemioligotrophic	149	0.50	0.28	0.02	7.9	4.6	0.4	39	19	2
Mesotrophic	880	0.35	0.24	0.01	4.9	3.6	0.1	30	17	1
Heminitrophilous	115	0.52	0.30	0.03	6.6	4.1	0.4	35	20	2
Nitrophilous	23	1.05	0.79	0.16	13.2	9.1	1.9	52	24	5
Calcalophilous	73	0.82	0.44	0.05	12.4	7.6	0.9	54	19	2
Olig. – waterlogged	7	0.53	0.44	0.17	8.9	7.1	2.7	2	4	1
Nitr. – waterlogged	52	0.36	0.37	0.05	4.4	4.6	0.6	7	13	2
Total	1430	0.4	0.3	0.01	6.1	4.8	0.1	32	20	1

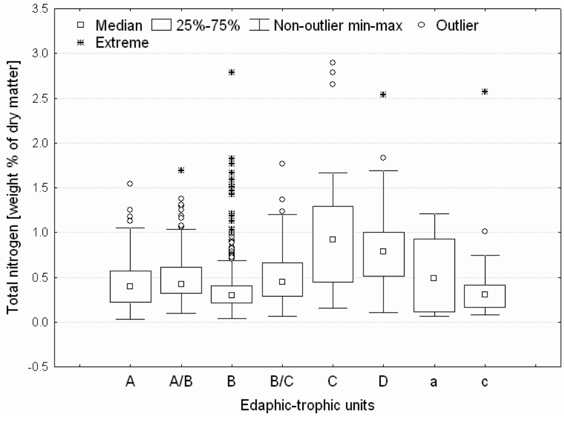

Figure 7. Content of the total nitrogen in soils of the edaphic-trophic units of SR

smallest variability was found in the, A, A/B, B, D and a edaphic-trophic units. The soils of B/C interorder were formed from silicate and carbonate rocks and that is why the range of pH values is rather wide.

The highest average content of the total nitrogen as well as the organic carbon is in the non-waterlogged nitrophilous order of forest geobiocoens, but variability of the values is very high (Table 6, Fig. 7 and 8). It should be noticed that the very high extreme values occur. These facts could be pointed at the uncertain or wrong determination of the forest geobiocoen type. Comparable results were found concerning the organic carbon content.

The highest value of organic carbon to nitrogen ratio is in oligotrophic non-waterlogged (A) and waterlogged (a) orders (Figure 9). The median is between 16 and

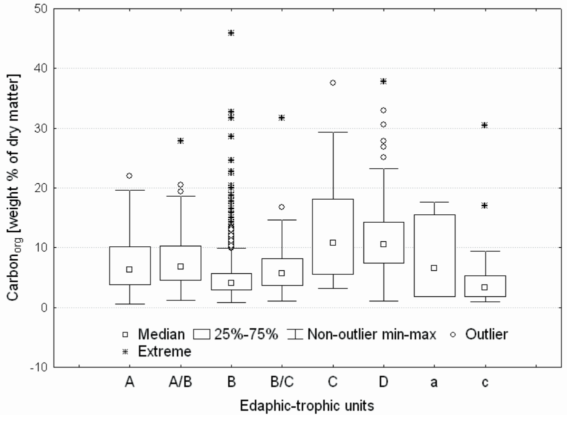

Figure 8. Content of organic carbon is soils of the edaphic-trophic units of SR

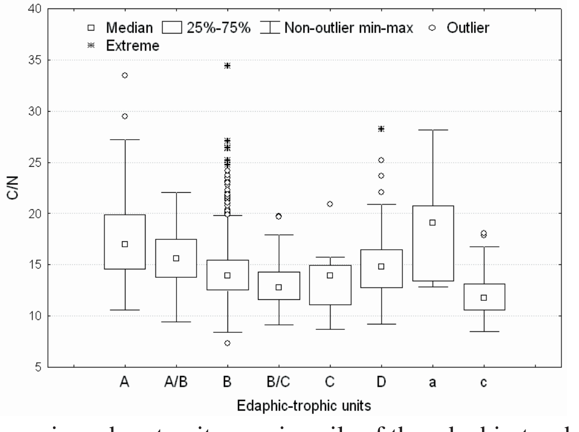

Figure 9. Ratio of organic carbon to nitrogen in soils of the edaphic-trophic units of SR

20. The maximum values of C/N ratio were reached in the soils of B (34) and A (33) edaphic-trophic orders.

Concerning the content of the soil skeleton the highest one was found in the C and D order of forest geobiocoens (Table 7, Fig. 10), which corresponds with data of Zlatník (1976a). However, the very high contents (up to 80 – 95%) of the soil skeleton were found also in the some segments of other edaphic-trophic units, what could point out the wrong classification of these geobiocoenoses.

Table 7 shows some soil properties within the edaphic-trophic units in the framework of altitudinal vegetation zones and edaphic-trophic units of forest geobiocoens. The thickest surface humus layer occurs in soils of the oligotrophic order of forest geobiocoens within the 7th spruce altitudinal vegetation zone. It can be stated that the

Table 7. Basic statistics of soil properties within edaphic-trophic units in particular altitudinal vegetation zones of SR

Geobiocoenological units non-water-logged	n	Surface humus thickness [cm]			Skeleton percentage [%]			pH H_2O		
O (A)	14	2.6	2.4	0.6	0	0	0	4.9	0.5	0.1
O (B)	37	2.1	1.5	0.2	4	8	1	5.3	0.9	0.2
O (B/C)	9	1.4	0.5	0.2	2	5	2	5.4	0.5	0.2
O (D)	4	2.3	1.0	0.5	46	19	9	6.6	1.4	0.7
B–O (A)	3	2.0	1.0	0.6	45	43	25	4.7	0.3	0.2
B–O (B)	178	2.0	1.2	0.1	19	21	2	5.3	0.7	0.1
B–O (B/C)	22	2.0	1.1	0.2	19	24	5	5.7	1.1	0.2
B–O (C)	2	2.5	0.7	0.5	73	11	8	5.9		
B–O (D)	3	3.3	2.5	1.5	55	23	13	6.7	0.7	0.4
O–B (A)	8	3.1	2.3	0.8	49	23	8	4.5	0.5	0.2
O–B (B)	319	2.8	1.4	0.1	21	19	1	5.3	0.8	0.0
O–B (B/C)	13	2.2	1.0	0.3	30	24	7	5.7	0.9	0.3
O–B (C)	8	2.5	1.3	0.5	75	21	7	6.2	1.1	0.4
O–B (D)	6	2.8	1.9	0.8	42	23	9	7.5	0.2	0.1
B (A)	10	4.1	2.4	0.8	49	22	7	4.2	0.5	0.2
B (A/B)	4	2.3	1.5	0.8	46	11	6	4.5	0.2	0.1
B (B)	225	2.9	1.4	0.1	29	20	1	5.3	0.9	0.1
B (B/C)	21	3.1	1.7	0.4	33	19	4	5.3	1.0	0.2
B (C)	8	2.5	0.8	0.3	64	14	5	6.2	1.1	0.4
B (D)	16	3.3	1.7	0.4	49	15	4	6.8	0.8	0.2
B–F (A)	33	4.8	3.0	0.5	31	26	4	4.3	0.7	0.1
B–F (A/B)	95	3.8	2.1	0.2	36	21	2	4.7	1.1	0.1
B–F (B)	99	2.8	1.3	0.1	28	21	2	5.0	0.9	0.1
B–F (B/C)	32	3.5	1.8	0.3	41	22	4	5.1	0.9	0.2
B–F (C)	5	2.8	1.5	0.7	64	30	14	5.5	0.5	0.2
B–F (D)	30	3.7	1.9	0.3	41	20	4	6.8	0.8	0.1
S–B–F (A)	29	4.3	3.1	0.6	24	16	3	4.1	0.4	0.1
S–B–F (A/B)	50	3.4	1.9	0.3	26	17	2	4.8	1.1	0.2
S–B–F (B)	22	2.8	1.4	0.3	29	17	4	5.1	1.0	0.2
S–B–F (B/C)	15	2.5	1.5	0.4	28	17	4	5.6	1.3	0.3
S–B–F (D)	14	3.9	2.0	0.5	48	18	5	7.3	0.4	0.1
S (A)	21	5.3	3.0	0.6	33	17	4	4.0	0.5	0.1
S (B/C)	3	2.3	1.5	0.9	18	10	6	5.2	1.0	0.6
DP (A)	13	4.2	2.2	0.6	37	25	7	4.6	0.6	0.2
Waterlogged a	7	6.6	8.2	3.1	4	7	3	4.2	0.3	0.1
Waterlogged c	52	1.5	1.4	0.2	5	10	1	6.3	1.2	0.2
Total	1430	2.9	1.9	0.0	26	22	1	5.3	1.0	0.0

Note: AVZ – altitudinal vegetation zone, ETU – edaphic-trophic units; explanation of other abbreviations as in Table 1.

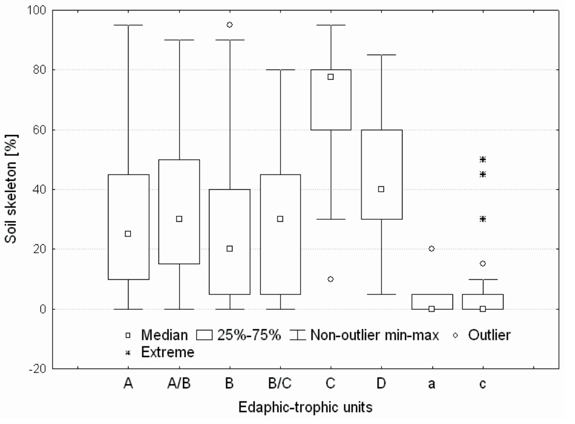

Figure 10. Content of soil skeleton in soils of the edaphic-trophic units of SR

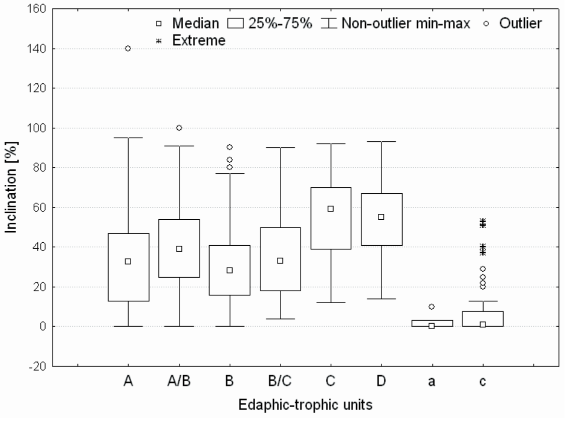

Figure 11. Slope inclination within the edaphic-trophic units of SR

surface humus layer is thickest in the oligotrophic and calciphile orders within each altitudinal vegetation zone. Concerning the soil skeleton the highest percentage was found mainly in C and D orders of forest geobiocoens within each altitudinal vegetation zone as according to Zlatník (1976a) and Križová (1995). pH values range from 4.0 (± 0.5) in oligotrophic order within the Spruce vegetation zone up to 7.5 (± 0.2) in the calciphile one within the Oak-Beech vegetation zone.

The basic statistics of other soil parameters are presented in Table 8. Content of total nitrogen was found to be highest in soils of C order of forest geobiocoens within 3rd altitudinal vegetation zone, and lowest one in A order within 1st altitudinal vegetation zone. Content of total nitrogen increased with the increasing of organic carbon contents.

Table 8. Basic statistics of soil properties within edaphic-trophic units in particular altitudinal vegetation zones of SR

Geobiocoenological units non-water-logged	n	Total nitrogen			Organic carbon			Slope inclination [%]		
		[weight % of dry matter]								
	1430	0.42	0.32	0.01	6.1	4.8	0.1	32	20	1
O (A)	14	0.06	0.02	0.01	1.2	0.4	0.1	4	4	1
O (B)	37	0.22	0.16	0.03	3.0	1.8	0.3	10	10	2
O (B/C)	9	0.31	0.11	0.04	4.0	1.7	0.6	12	6	2
O (D)	4	0.24	0.08	0.04	3.4	0.8	0.4	61	24	12
B–O (A)	3	0.16	0.09	0.05	3.0	1.6	0.9	47	19	11
B–O (B)	178	0.27	0.16	0.01	3.7	1.9	0.1	21	13	1
B–O (B/C)	22	0.33	0.17	0.04	4.0	2.1	0.5	27	22	5
B–O (C)	2	0.97	0.21	0.15	9.3	0.7	0.5	22	1	1
B–O (D)	3	0.56	0.23	0.13	7.2	3.1	1.8	30	15	8
O–B (A)	8	0.45	0.27	0.10	7.2	4.7	1.7	48	19	7
O–B (B)	319	0.29	0.15	0.01	4.1	2.0	0.1	30	16	1
O–B (B/C)	13	0.60	0.28	0.08	7.5	3.4	1.0	25	12	3
O–B (C)	8	1.22	1.08	0.38	15.2	12.7	4.5	56	22	8
O–B (D)	6	0.49	0.34	0.14	7.1	4.3	1.7	52	8	3
B (A)	10	0.31	0.12	0.04	5.3	1.8	0.6	32	18	6
B (A/B)	4	0.34	0.29	0.14	5.6	4.5	2.3	33	25	13
B (B)	225	0.42	0.30	0.02	6.2	4.9	0.3	34	17	1
B (B/C)	21	0.45	0.26	0.06	5.8	2.7	0.6	35	15	3
B (C)	8	1.14	0.75	0.27	14.9	7.9	2.8	53	22	8
B (D)	16	0.72	0.41	0.10	11.5	7.3	1.8	43	15	4
B–F (A)	33	0.33	0.14	0.02	5.7	2.7	0.5	28	19	3
B–F (A/B)	95	0.47	0.29	0.03	7.4	4.6	0.5	39	18	2
B–F (B)	99	0.46	0.23	0.02	6.5	3.6	0.4	41	17	2
B–F (B/C)	32	0.63	0.29	0.05	8.0	3.5	0.6	43	17	3
B–F (C)	5	0.65	0.33	0.15	8.6	4.3	1.9	58	29	13
B–F (D)	30	0.99	0.49	0.09	14.8	8.2	1.5	57	20	4
S–F–B (A)	29	0.50	0.22	0.04	8.7	4.0	0.8	32	20	4
S–F–B (A/B)	50	0.57	0.26	0.04	9.0	4.5	0.6	41	19	3
S–F–B (B)	22	0.72	0.42	0.09	10.1	7.0	1.5	38	18	4
S–F–B (B/C)	15	0.69	0.41	0.11	9.3	6.9	1.8	51	18	5
S–F–B (D)	14	0.92	0.24	0.06	14.4	6.1	1.6	65	16	4
S (A)	21	0.73	0.28	0.06	12.0	4.4	1.0	51	23	5
S (B/C)	3	0.58	0.28	0.16	7.1	3.6	2.1	44	12	7
K (A)	13	0.65	0.34	0.09	9.8	4.2	1.2	41	36	10
Waterlogged a	7	0.53	0.44	0.17	8.9	7.1	2.7	2	4	1
Waterlogged c	52	0.36	0.37	0.05	4.4	4.6	0.6	7	13	2

Note: explanation of abbreviations as in Table 1 and Table 7.

Table 9. Comparison of the values of climatic parameters published by ZLATNÍK (1976a) and results of forest inventory (NFIM SR, 2005–2006)

Altitudinal vegetation zones	Elevation [m a. s. l.]			Average year temperature [°C]			Total precipitation [mm]		
	ZLATNÍK (1976a)	NFIM SR		ZLATNÍK (1976a)	NFIM SR			NFIM SR	
		25%	75%		25%	75%		25%	75%
O	<300	180	250	>8.5	8	9	600>	620	670
B–O	200–500	270	420	6–8.5	7	8	600–700	670	760
O–B	300–700	370	540	5.5–7.5	6	7	700–800	750	860
B	400–800	520	710	5–7	6*		800–900	830	970
F–B	500–1000	720	910	4.5–6.5	4	5	900–1050	870	1080
S–B–F	900–1300	990	1150	3.5–5	3	4	1000–1300	1010	1240
S	1250–1550	1280	1420	2–4	2	3	1100–1600	1210	1440
DP	1500<	1570	1670	<2.5	1	2	1500<	1320	1470

*Note: explanation of abbreviations as in Table 1; * values in 25 and 75 percentile are very closed to 6 (min–max is 4 and 8 °C).*

4. Discussion

Some information on climatic and soil conditions in altitudinal vegetation zones and edaphic-trophic units of forest geobiocoens have been published by ZLATNÍK (1976a), KUKLA (1993b), KRIŽOVÁ (1995), ŠKVARENINA *et al*. (2002, 2004) and others. On the other side, the results of National Forest Inventory, based on data collected from sample plots covering an entire forest area in Slovakia with its statistical design may be used for comparison, how these two sources of information are different from each other. The climatic parameters in the inventory plots were derived from raster layer (HLÁSNY 2007) by overlapping both NIML shape layer and raster of climatic parameters. The results from NFIM SR are presented in percentile intervals to omit outliers and extreme values. There are some differences, but it can be concluded that compared values correspond to each other (Table 9).

The pH-value is an integral indicator of physical-chemical properties (DARBIN 1989) and biological condition of soils (ŠÁLY 1982). The ecological breadth of the non-waterlogged edaphic-trophic units of forest geobiocoens is determined by the limited values of the actual soil reaction found out in 0–5 cm mineral soil layers by KUKLA (1993a). By means of these limits may be anticipated changes in soil reaction caused by activity of natural or anthropogenic factors in the individual segments of geobiocenoses (KUKLA 1993a). Among the many soil properties, the soil reaction is one of the most important (LONDO 2002). Soil pH provides a good indication of the chemical status of the soil and can be used in part to evaluate potential plant growth. LONDO (2002) presented a table of an availability of the soil nutrients for plants at the particular pH level. For example Aluminium is good available for plants when the pH_{H_2O} values in soils range from 4.0 to 4.5. If the pH_{H_2O} value is of 5.0 the availability of Al is only moderate, and higher pH_{H2O} values causes unavailability of the Aluminium for plants. On the other hand, Calcium and Magnesium ions are best available for plants, when the pH_{H2O} values range from 5.5 to 10.0.

In the Table 10 are presented the limited pH_{H2O} values found by Kukla (1993a) in 0–5 cm mineral layers of soils for non-waterlogged edaphic-trophic units of forest geobiocoens and those ones found during the NFIM SR (2005–2006). It can be

Table 10. Comparison of homeostatic pH values in the 0–5 cm topsoil layer of the edaphic--trophic units (Kukla 1993a) and results of forest inventory (NFIM SR 2005–2006)

SNRT	**Kukla (1993a)**		**NFIM SR**	
	min	**max**	**25%**	**75%**
Oligotrophic	<3.9	3.9	3.9	4.6
Hemioligotrophic	3.9	4.9	4.1	4.9
Mesotrophic	4.9	6.0	4.7	5.6
Heminitrophilous	6.0	7.2	4.7	6.0
Nitrophilous	6.0	7.2	5.2	7.0
Calcalophilous	7.2	8.6	6.8	7.5
Olig. – waterlogged			4.1	4.3
Nitr. – waterlogged			5.2	7.3

Table 11. The differentiation of the edaphic-trophic units of forest geobiocoens by means of limit pH_{H2O} values of topsoil (Kukla 1993a)

Edaphic-trophic order/interorder	**Code**	**pH_{H2O} in 0–5cm/ >5cm layer**
Normal	A	<3.9
Mesooligotrophic	B/A	<3.9/<4.9
Oligomesotrophic	A/B	3.9–4.9
Oligocalcitrophic	A/D	3.9–4.9/< 8,6
Normal	B	4.9–6.0
Nitromesotrophic	C/B	4.9–6.0/< 7.2
Mesocalcitrophic	B/D	5.5–6.0/< 8,6
Mesohalotrophic	B/E	5.5–6.0/>8,6
Mesonitrotrophic	B/C	6.0–7.2
Nitrocalcitrophic	C/D	6.0–7.2//< 8,6
Normal	C	6.0–7.2
Nitrohalotrophic	C/E	6.0–7.2/> 8.6
Calcitrophic	D	7.2–8.6
Calcihalotrophic	D/E	7.2–8.6/> 8.6
Halocalcitrophic	E/D	> 8.6
Halotrophic	E	salt ctust

Table 12. Ratio of the carbon to nitrogen in the edaphic-trophic units according to AMBROS (1993)

C/N	AMBROS (1993)		NIML SR (2005–2006)	
	min	**max**	**25%**	**75%**
A	30	<	15	20
A/B	24	30	14	17
B	18	24	12.5	15.5
B/D	15	18	–	–
B/C	12	15	11.5	14.5
C	10	12	11	15
C/D – D	<	10	13*	16*

** Determined only for calciphile order of forest geobiocenose.*

concluded that these pH_{H_2O} values are comparable with exception of values found by the NFIM SR in segment of heminitrophilous interorder of forest geobiocoens. In the case of B/C and partially also C order of forest geobiocoens the pH_{H_2O} values differ substantially because values found by NFIM SR are in the range of mesotrophic order of forest geobiocoens. That could be pointas at impact of acid atmospheric pollutants as at wrong classification of geobiocoenoses.

The auxiliary discriminating criterion is content of the soil skeleton. The skeleton contents higher than 70% are typical for the C order, and from 40% to 70% for the B/C interorder of forest geobiocoens. In calciphile order D calcareous vegetation dominate. It may happen that the plant roots reach the calcareous soil layer although the top soil layer does not have a mildly alkaline reaction. In such cases, the geobiocoenoses belong into mesotrophic-basic interorder of forest geobiocoens B/D.

C/N-ratio is a general index used for evaluation of the cycling of nutrients with low values indicating good nutrient status (LEXER *et al*. 2000). Along with other soil characteristics it is common parameter in ecological studies (ENGLISH *et al*. 1991). C/N values found by NFIM SR for A, A/B, B and B/C edaphic-trophic units of forest geobiocoens were lower in comparison with data published by AMBROS (1993). On the contrary, the C/N values found for calciphile D order of forest geobiocoenswere were higher. Finally, values found in the nitrophilous C order of forest geobiocoens are very similar each other.

5. Conclusion

The forest typology (geobiocoenology) is of high importance in Slovakia and in foreign countries as well. At present, the requirements for sustainable forest management (sustaining or increasing of the forest cover in the country, getting better of a management quality, protection of the forest ecosystems and individual biotopes, and others) and differentiated approaches in the silvicultural and harvesting techniques have being increased.

Differentiated approach means the application of tailor-made management measures reflecting character of particular site types (i.e. potential productivity), current tree species composition of managed stands (whether natural or altered) and ecological conditions on regional or local level. Outputs of forest ecosystem mapping, as well as site-based knowledge and related regulations, can (or should) be crucial in this effort.

Current classification of forest geobiocoenoses in Slovakia is focused on the reconstruction of the potential vegetation, which, as believed, should reflect ecological conditions of forest sites (soil and climate conditions, physiographic properties, and others) and should allow monitor their changes. However, despite the wording of forest site type definition (forest geobiocoens), the Slovak classification is based mainly on a description of potential natural vegetation, but particular geobiocoen definitions usually do not contain clear rules how field worker should cope with current state of each particular site and forest stand on it, with man-induced changes to soil properties or tree species composition and productivity.

The results of forest inventory (NFIM SR) mostly correspond with various known information (Zlatník 1976a, b, Kukla 1993a, b, 2002, 2004, Ambros 1993). Moreover, method of forest inventory provide very good base for evaluation of the objective information at regional or even in whole-area level with the known precision of results.

The aim of the paper was to show the variability of some soil and climatic characteristics within the altitudinal vegetation zones and edaphic-trophic orders or interorders of forest geobiocoens. Concerning often occurring high variability of the values of mentioned parameters one can imagine the difficulties connected with determination of various geobiocoenological units. This point out that most of climatic, soil and other ecological characteristics are continuous, e.g. without clear boundaries between them.

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Resumé

Klasifikácia lesných ekosystémov (lesných geobiocénov) je založená na Zlatníkovej geobiocenologickej škole. Rekonštrukčnými jednotkami sú lesné typy, ktoré sú usporiadané do skupín lesných typov a ďalších nadstavbových jednotiek na základe fytosociologických a ekologických podobností. Klasifikačný systém je založený na úvahe, že permanentné ekologické podmienky sa nemenia počas dlhej doby.

Rastlinné druhy sa považujú za veľmi vhodné nepriame indikátory ekologických podmienok pri zohľadnení ich špecifickej ekologickej amplitúdy. Na druhej strane, bylinné druhy odrážajú taktiež zmeny v stromovej vrstve, a preto pri klasifikácii geobiocénov sa zohľadňujú tak rastlinné indikátory ako aj ekologické vlastnosti stanovíšť.

Hlavným cieľom článku je poskytnúť základné klimatické a pôdne charakteristiky lesných geobiocenóz vyskytujúcich sa v rámci nadstavbových geobiocenologických jednotiek. Tými sú lesné vegetačné stupne a edaficko-trofické rady a medzirady (nezamokrené a zamokrené). Ďalším cieľom príspevku je poukázať na veľkú variabilitu týchto charakteristík v rámci uvedených geobiocenologických jednotiek. Výsledky prevzaté z Národnej inventarizácie lesov SR korešpondujú s doteraz publikovanými informáciami (Zlatník 1976a, b, Kukla 1993a,b, 2002, 2004, Ambros 1993), a navyše poskytujú aj rámec presnosti pre konkrétne ekologické charakteristiky.