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THE EVALUATION OF ECOLOGICAL FACTORS AFFECTING ENVIRONMENTAL FUNCTIONS OF THE SOILS IN AREA OF TRADITIONAL AGRARIAN STRUCTURES

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Abstract

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Cultural landscape can be seen as a result of hundred years of founding and sensitive cultivation of landscape structures respecting natural conditions. Specific geomorphological, climatic as well as social conditions enabled the conservation of original agrarian landscape structures mainly in the marginal regions of Slovakia. They are created by mosaic structures of extensively used small-scale landscape elements of permanent agricultural and arable land. An example of traditional agrarian way of using is foothill meadow-grazing landscape of the village Liptovská Teplička. By using the traditional extensive maintenance of the agricultural landscape, optimal environmental characteristics of soils were preserved. These were modified to some extent by the way of using and management. The submitted contribution is focused on the following:

- Indication of environmental characteristics of soils
- Quantification of the influence of chosen ecological factors on these environmental functions

Seven research localities representing main types of the traditional landscape maintenance were chosen for needs of the research of soil and environmental conditions in a relation with the way of using the land and management. In given localities, we chose 21 sampling sites for secondary landscape structure (according to the legend of project Corine Land Cover, 2000), geological, soil, physical, biochemical and chemical conditions evaluation.

Environmental functions indication was assessed in the following way: by assigning an amount of organic carbon (C_{ox}) in a standard way (Fiala et al., 1999) for production functions, by assigning a ratio of granular fractions (pipetting method according to Novák) for retention functions. Buffering functions were evaluated potentiometrically by assigning an active soil reaction of pH (H_2O) and exchange reaction of pH (KCl) in a soil. Highest values of C_{ox} in the Ap horizon (7.67–6.62%), as well as pH of the soil environment (pH/KCl 7.26–7.21, pH/H_2O 7.69–7.68) were assigned to anthrosolic and cultisolic rendzinas of extensively used grasslands. On the contrary, the lowest monitored values of organic matter C_{ox} (2.51–2.53%), as well as pH of the soil environment (pH/KCl 4.81–5.21) (pH/H_2O 5.21–6.19) were indicated for soil subtypes anthrosols of the large fields and lithosol of the extensively used grasslands on non-carbonate substrates. Most favourable production and buffering soil properties were preserved in rendzinas on the carbonate substrates and extensively used meadows. Similarly, this type of soil on limestone used in a form of extensive meadows preserved also the most favourable retention functions according to the stated ratio of granularity fractions.

Quantification of the influence of chosen ecological factors on environmental functions was performed using multivariate statistical methods, specifically principal component analysis (PCA). PCA is an indirect gradient analysis using the linear correlation of data, with a biplot as an output. Closeness of points in ordination graph represents their similarity of composition. The CANOCO (Ter Braak, Šmilauer, 2002) software was used to perform the analysis and to create the graph.

Key words: environmental functions of the soils, traditional agrarian structure, ecological factors, landscape management, Liptovska Teplička.

Introduction

Currently in Central and Western Europe one finds relatively few intact or close-to-nature landscapes. The vast majority of area is occupied by cultural landscape in various state of transformation of the original landscape and with varying degree of its preservation or functionality (Podolák et al., 2011). Cultural landscape can be understood as a result of hundreds of years of establishment and sensitive cultivation of landscape structures respecting the natural conditions. In marginal areas and also here in Slovakia, the original or traditional agrarian landscape structures have been retained due to the specific geomorphological, soil, climatic and social conditions.

An example of a traditional agrarian way of using is a foothill meadow-grazing landscape of the village Liptovská Teplička. The value of these preserved agricultural landscape structures results primarily from the low degree of intensification, high landscape and biological diversity, preserved traditional technological farming practices of tillage and management and preservation of the original environmental soil functions (Dobrovodská, Špulerová, 2011). Extensive forms of use and traditional agricultural technologies determined the preservation and revitalization of the original soil functions. Soil in these agro-ecosystems has in several aspects an important role. First, as an irreplaceable component of landscape, it fulfils a (productive) trophic function for crops and plant communities; then as a component with high capacity regulation, detoxification, hygienic and sanitation importance it fulfils the environmental function – protects other components of the environment and natural resources. In traditional agro-ecosystems, it also fulfils the function of a historical medium, where features of natural processes and human activities history are preserved (Fig. 1).

In the recommendation of the Council of Europe num.8 from the year 1992 (Blum, 1990), individual functions of soils are defined as ecological functions and functions which are related to human activities – technical, industrial and socio-economic functions.

Juráni, 2005 collectively called all functions of soil systems environmental functions, but for the purposes of clarity he divides them into productive and non-productive functions. Productive (trophic) function of soils represents the ability of soils to provide vegetation as well as soil biota with necessary nutrients. Non-productive functions are related to environmental protection, landscaping and revitalization of species diversity, which is an important stabilizing factor for the landscape.

Fig. 1. Surroundings of Liptovská Teplička with traditionally used narrow strip shelves (Photo: J. Hreško).

Our contribution includes an evaluation of the following environmental functions of soils.

- ***Trophic (productive) function of soils*** – is defined (Džatko, 1981) as a measurable level of the main attribute of each soil unit to accept, transform, store and deliver the required amount of water, nutrients and energy for growth and production of plants. Value of production capacity of soils is a function of interaction between abiotic and biotic components of the landscape ecosystem, where substantially the anthropogenic factor also enters in the form of land use and management (Krnáčová, Bedrna, 1994).
- ***Retention (accumulation) function*** – the ability of soil to accumulate rainwater or rising groundwater. Accumulation function of soils in relation to soil water retention has a significantly physical nature, i.e. is a function of the ratio of soil fractions.
- ***Buffering function of soil*** – lies in their ability to reduce the effect of chemical substances and temperature. Emissions of chemical nature, e.g. acidification components, are buffered by base cations present in the soil (Demo et al., 1998). Soil also reduces the impact of atmospheric temperature, which is of great importance in soil overheating. The size of the buffering capacity of soils is affected by grain size ratios, soil organic matter content and significantly also chemistry of the geological subsoil as well as the type of vegetation cover.

The overall aim of the research was focused on the following:

- Indication of selected environmental (trophic, accumulation (retention) and buffering) properties of soils
- Quantification of the impact of selected ecological factors on the environmental functions

Material and methods of the research

Research locality

According to the natural urban catchment regions of Slovakia (Miklós, Hrnčiarová, 2002), the area of Liptovská Teplička belongs to the Spiš region, Poprad micro-region. The area is a part of the Low Tatras National Park (LTNP) and its protection zone.

Administratively, it falls in the Prešov region, Poprad district. It is located in the area of river basin of the Black Váh. The area is designated by the cadastral boundary and takes the intravillan of the town and extravillan with adjacent areas of meadows, pastures, arable land and forests. The total surface area is 9 869 ha, 81% of which are parcels of the forest land fund (FLF), 17.26% agricultural land fund (ALL), of which 16.57% is permanent grasslands (PG), almost 1% is a built-up area and 0.55% water surfaces.

Methodology of the research

There were selected 3–4 sampling sites (21 in total) within the selected research localities, where the following attributes of landscape and soil-substrate conditions were set.

- Analysis of the current land-use from the year 2010, which was interpreted with help of the Basic Maps of the Slovak Republic at a scale 1:10 000 (from years 1992–1993) and ortophotos at a scale 1:5 000 from years 2002–2003 (Ortofotomapa© Geodis Slovakia, s. r. o, 2003; Letecké snímkovanie a digitálna ortofotomapa © Eurosense, s. r. o, 2003). These were verified by the reconnaissance field research in the year 2010. When evaluating the secondary landscape structure, we used the legend created for the Corine Land Cover project from the year 2000 (Feranec, Oťaheľ, 2001, 2008; Petrovič et al. 2009),
- Analysis of geological conditions according to the Regional Geological Map of the Low Tatras (Biely et al. 1992, Biely et al, 1999) at a scale 1:50 000
- Analysis and classification of the soil type, subtype and class directly in the field according to the Morphogenetic Classification Soil System of Slovakia (VÚPOP, 2000; Čurlík, Šurina, 1998).
- For laboratory determination of the granular composition of soils, a pipetting method according to Novak was used. Active soil reaction (pH/H_2O) was determined potentiometrically in aqueous suspension (soil to water ratio 1:2.5) and an exchange soil reaction (pH/KCl) was determined in a leachate of 1M solution of KCl also potentiometrically (ratio of soil to KCl solution 1:2.5). The overall content of organic carbon (C_{ox}) was determined using a standard procedure (Fiala et al., 1999).

Environmental performance indication

We evaluated the production (trophic) soil functions using the organic matter content (C_{ox}) as an indicator, next the buffering soil functions were evaluated according to the parameter of the soil reaction of pH (H_2O) and pH (KCl) and accumulation (retention) characteristics with respect to soil water retention indicated according to the ratio of specified granularity fractions.

Quantification of the impact of selected ecological factors on environmental functions

The objective of the analysis was a quantification of the impact of some ecological factors (impact of geological substrate, management, land use method etc.) on properties of environmental functions. We used a principal component analysis (PCA) for this purpose. It is an indirect linear gradient analysis, whose objective is finding the highest variability data axes. In the output ordination graph we can interpret the proximity of two points (coordinates of individual samples) as their similarity in composition. The analysis and the output graph were created with CANOCO software (Ter Braak, Šmilauer, 2002).

Quantification of the input variables (indicators)

When using input variables while using any statistical software, it is required to use quantitative interval scale variables as input variables. Failure to keep this strict condition may strongly deform the results of analysis. In case of an inevitable use of qualitative indicators, there is a possibility of their requalification to nominal scale variables (quasi quantitative type) which may be used for the analysis. Distinction of variable scale type (Krnáčová, Krnáč, 1999):

- Nominal variables (quasi-quantitative variables),
- Ordinal variables (qualitative variables),
- Interval variables (quantitative variables).

Input data table structure

Data structure in an input table is closely related to quantification, as it allows:

- to quantify information which cannot be quantified directly,
- to quantify ordinal data which cannot be directly used for ecosystem models analysis,
- to modify measured data into standard shapes (multidimensional matrices) suitable for synthesis of various character data sets (data sets describing characteristics of the physical environment, method of land use and other character data).

The most widely used data structure is the following:

$$X(n,N)=\begin{bmatrix} x_{11}, & x_{12}\cdots\cdots\cdots & x_{1n} \\ x_{21}, & x_{22}\cdots\cdots\cdots & x_{2n} \\ & & \\ x_{N1}, & x_{N2}\cdots\cdots\cdots & x_{Nn} \end{bmatrix}$$

set of *n* variables which are element indicators

N-component sample set

Results and discussion

Diversity of soil-substrate complexes in a wider cadastral area

Knowledge of soil properties on a broader cadastral level provides detailed knowledge about spatial variability of soil cover as a component of the environment. On the carbonate rocks – there are developed moderately to strongly skeletal rendzinas with dark (mollic) humic A-horizon, loamy, humus and moderately deep, which, however, are due to the altitude and rising humidity a subject to leaching of carbonates from the soil profile and change themselves into cambisolic rendzinas and rendzinous cambisols, relatively less productive soils. Typical for steep slopes and sharp backs is modal rendzina, characterized by shallow soil profile which is strongly skeletal and low in productivity. Their presence is bound to the southern part of the model area, the vast complex of dolomitic limestones, respectively Ramsau dolomites of the middle and upper trias in the area of localities Grúň, Skorkovec, Opálené, Kolibisko and Panská Hoľa.

Mineral-rich, non-carbonate substrates such as basalts, andesites and marly shale determine the presence of sandy-loamy to loamy, moderately humus and moderately deep to deep cambisols with low to medium content of skelet, located in the northern part of the area. It is a complex of cultisolic cambisols and modal cambisols, small parts of which are used as terraced fields in the vicinity of the intravillan of Liptovská Teplička.

Mineral-poorer rocks such as light-grey conglomerates, colourful sandstones, siltstone and shales determine the formation of modal cambisols with more acidic soil environment and therefore moderate to low productive soils. On the substrate basis of basalts, andesites and volcaniclastics in the northern part of the area developed andosolic cambisols; locally at steep slopes developed strongly skeletal cambisolic rankers, low productive soils. In the depression parts of the relief including broad backs platforms developed, due to the water stagnation in soil profile, stagnosolic cambisols.

They occur mainly in the northern part area of localities Doštianka, Soľanka, Pod Zálomom. Bottoms of valleys are created by fluvial loamy-sandy and gravelly-sandy sediments, where a relatively narrow range of gley fluvisols, from more skeletal sandy-loamy and low production soils to deep, loamy less skeletal gley fluvisols, also low production as a result of prevailing reducing conditions in the soil environment. In vast areas in the confluence of Ždiarsky brook and Black Váh as well as alongside mentioned streams (Rovienky, Záteplica, Na Váhu) developed typical gley soils. These are soils with gley reduction G-horizont within 50 cm under the surface, in the profile, as a result of high groundwater level, prevail strong reduction conditions. These are soils with low productivity.

At the anthropogenic forms of relief with graded terraces, where rocks were removed by human, developed mostly productive cultisolic rendzinas, rarely cultisolic cambisols. Prevailing in the Nový Diel locality on the substrate of light-grey conglomerates, multicoloured sandstones, siltstones and shales are cultisolic cambisols, less skeletal, moderately productive. The occurrence of terraced fields with developed cultisolic cambisols is further bound with deluvium from clayey and marly shale, less skeletal soils with deeper soil profile in the areas with local names Podvora a Pod Kikulou. There is an extensive occurrence of cultisolic rendzinas at deluviums of Ramsais dolomites and limestones in the southern part of intravillan in the Skorkovec locality. In the close proximity of the intravillan from the northern part, on the substrate of radiolarian limestones are also classified cultisolic rendzinas, and at their deluvias developed cambisolic rendzinas. Figure 2 shows partial abiocomplexes which characterize geomorphological, climatic and soil characteristics processed for the whole cadastral area of Liptovská Teplička.

Selection of research localities

Seven research localities representing basic types of traditional farming landscapes in Liptovská Teplička (Fig. 3) were chosen for the needs of research of soil-ecological conditions in relation to the way of land use and management.

Indication of environmental features

We were evaluating the chosen production, accumulation (retention) and buffering functions according to the set selected soil-substrate parameters, management and land-use patterns in the research localities (LT1–LT7) as follows. As a part of the research, anthropogenic forms of relief (AFR) were also classified. Environmental functions of anthropogenic soils within the forms of anthropogenic relief are not being assessed.

Fig. 2. Partial abiocomplexes.

Fig. 3. Location of research areas within the model area of Liptovská Teplička.

LT1 – extensively used permanent grasslands (PG) mainly used as pastures, with loamy-rocky terraces (2.3537 ha), **LT2** – extensively used mosaic of arable land and PG mainly used as meadows, with loamy-rocky mounds, re-cultivated meadow and re-cultivated arable land (4.1688 ha), **LT3** – extensively used PG with rocky earthed mounds and extensively used PG (meadow) without balks (3.636 ha), **LT4** – extensively used PG alternately mowed or grazed with rocky mounds on the siliceous substrate (3.4507 ha), **LT5** – extensively used mosaic of arable land and PG with loamy terraces (7.122 ha), **LT6** – extensively used mosaic of arable land and PG with loamy-rocky mounds, re-cultivated meadow (3.6838 ha), **LT7** – extensively used PG used mainly as meadows with loamy-rocky terraces (3.1492 ha) (Dobrovodská, Špulerová et al., 2011).

Extensively used pasture with the occurrence of loamy-rocky terraces (LT1)

Cultisols are dominating on the substrate of silicate conglomerates, sandstones and shales with medium skeleton content, which also corresponds with the laboratory set values of pH (H_2O) 5.95 and pH (KCl) 5.02. The measured pH of the soil environment indicates soils with weak buffering system – soils moderately resistant to acidification. The higher proportion of organic carbon C_{ox} 3.71–3.26% is conditioned by the supply of organic substances from excrements of occasionally grazing cattle. The C_{ox} content of the extensively used pastures characterizes these soils as moderately to highly productive. The soil is loamy-sandy with medium skeleton content, what may be interpreted as soils with moderately strong storage capacity regarding the soil water retention. On loamy-rocky terraces a modal ranker was classified with higher content of skeleton, and with slightly acidic soil reaction.

Extensively used mosaic of arable land and permanent grasslands (PG) with loamy-rocky mounds (LT2)

The occurrence of cultisols and cultisolic cambisols is predominant on the substrate of the weathered eluvial clay and marly shale. The set pH/H_2O within the interval 6.19–7.47 indicates soils with neutral soil reaction, which may be interpreted as soils with moderately strong to high buffering system. The organic matter content in the intensively used arable lands and meadows is relatively low, which is indicated by the measured value of C_{ox} within the range 2.51–2.53%. The low value of organic substances is associated also with acidic silicate rock substrate and intensive land use. Soils are loamy; skeleton content is low, indicating soils with good to high accumulation capability to bind soil water.

Extensively used meadow with rocky-loamy mounds and meadow without AFR (LT3)

The prevailing soil subtype is cambisolic rendzina on the substrate of rocky limestone deluviums. The way of use is an extensively occasionally grazed meadow. Soil reaction is neutral to alkaline, conditioned by the presence of carbonates in the soil, pH /H_2O is within the range 7.13–7.69 and pH/KCl within the interval 6.46–7.26. The soils have a high buffering system, interpreting soils as highly resistant to acidification. Organic substances content, indicated by value of C_{ox} is high, within the interval 7.67–6.62%. High proportion of organic matter is conditioned by grass biomass residues and natural organic fertilizers, as well as the carbonate substrate. The soils are moderately to highly productive, a limiting factor is thickness of the soil profile. The soil is loamy. Locally, at the rocky and loamy mounds (AFR), carbonate and lithosolic anthrosols are present on the substrate of rocky mound. Measured pH (H_2O) value is 7.52 and pH (KCl) value is 7.11, which are neutral to slightly alkaline soils, conditioned by carbonate rocks. The C_{ox} value is 5.45%, thus indicating higher value of organic substances affected by the presence of carbonates in the soil and grass biomass residues.

Extensively used permanent grasslands (PG) with rocky mounds on siliceous substrate (LT4)

In this locality a cultisolic ranker is classified on a substrate of loamy-rocky silicate deluvium on siliceous sandstones and shales. Value of pH (H_2O) is 6.02 and pH (KCl) value is 4.94, which are slightly acidic to acidic soils. These may be interpreted as soils with weak buffering system. The C_{ox} value is 4.9%, which is quite a high number considering the siliceous substrate. However, occasionally grazed meadows are enriched with natural organic fertilizers, which affect the higher values of organic carbon. There are three rocky mounds (AFR) with classified silicate anthrosol on a substrate of Permian rocks. They are acidic soils. The value C_{ox} is 5.61%. Relatively high value of organic matter can be justified by form of use, i.e. occasional mowing and grazing of PG. The soil is loamy-sandy.

Mosaic of arable land on permanent grasslands (PG) with loamy-rocky terraces (LT5)

A cultisol on an eluvium substrate of limestones shale is present. It is a carbonatic substrate and also the measured values of pH (H_2O) 7.73 and pH (KCl) 7.26 are corresponding, in the category of alkaline soils with strong buffering system. The C_{ox} value 4.77% is relatively high due to fertilization with natural organic fertilizers. Skeleton content is moderate. The soil is loamy-sandy, with medium to lower accumulative capability. On the loamy terraces a soil subtype – modal cultisols – was classified on a substrate of deluvial-colluvial-loamy rocky sediments of shale. The value of pH (H_2O) is 7.74 and pH (KCl) is 7.18, thus the soil is alkaline with moderately strong to high buffering system. The C_{ox} value is between 3.11% and 3.8% and correlates with the use of the locality as a slope of loamy terrace that is not being mowed (AFR). The skeleton content is generally high. The soil is loamy-sandy.

Mosaic of arable land and permanent grasslands (PG) with loamy-rocky mounds (LT6)

In the evaluated locality occurs cultisolic rendzina on a substrate of deluvium from carbonates. The measured value of pH (H_2O) is 7.47 and of pH (KCl) is 7.08, indicating neutral to slightly alkaline soils with strong buffering system. The C_{ox} value is 4.5%, a relatively high value associated with the presence of carbonates in the soil profile. Occasionally is in the locality present carbonate ranker on carbonate deluviums. The soil reaction is neutral to slightly alkaline due to the carbonate substrate. On the rocky and loamy mounds (AFR) carbonate anthrosol was classified with alkaline soil reaction. The organic matter content is also relatively high (C_{ox} 5.47). The soil is loamy to loamy-sandy.

Extensively used meadows with loamy-rocky terraces (LT7)

On the extensively mowed meadows was classified cultisolic rendzina on limestone deluviums. The value of pH (H_2O) is 7.52 and pH (KCl) value is 7.21, indicating alkaline soils with strong buffering system. The C_{ox} value is 5.89%, a relatively high value resulting from the presence of carbonates in the soil and management, what can be interpreted as soils with medium to high productivity function. On the terraces was diagnosed carbonate cultisol with alkaline soil reaction and relatively high organic matter content, indicated by the C_{ox} value 5.6%.

Quantification of the impact of selected ecological factors on the environmental functions

Selection of input indicators and method of their quantification

We chose multivariable statistical methods to evaluate the diversity of geological substrate, soil subtypes and way of use.

To detect and quantify the highest variability of obtained parameters we used indirect linear gradient analysis performed using CANOCO software. To create the input data table, we used the data from laboratory set soil parameters, results of field landscape research and soil-substrate conditions while keeping the condition of using quantitative and semi-quantitative data type. Tables 1 and 2 include input data table and table with measured values and data.

Interpretation of the results

Impact of ecological factors on buffering functions

Significant bonds between a variable 'geological substrate' and variables 'soil environment pH' were confirmed, namely $R = 0.617$, $P < 0.05$ to the variable pH (H_2O) and $R = 0.634$, $P < 0.05$ to the variable pH (KCl). Negative correlation bonds were shown by the variable 'IV. Grain size category' (content of sandy fraction in %) $R = -0.542$, $P < 0.05$ in a relation to the variables 'pH (H_2O)' and ($R = 0.514$, $P < 0.05$) in relation to the variable 'pH (KCl)'. The size of soil buffering capacity is affected by grain size conditions, soil organic matter content and significantly by the geological bedrock chemistry. On carbonate rocks – dolomites and limestones – with mineral-rich representation of base cations with positive granularity, developed soil subtypes with high buffering system resistant to acidification. On the contrary, low pH values of the soil environment conditioned the occurrence of mineral poor rocks with higher representation of sand fraction, like light-grey conglomerates, colourful sandstones and siltstones.

Impact of ecological factors on production functions

Between the variable 'soil subtype' and the variable 'organic matter content C_{ox}' was observed a positive correlation ($R = 0.555$, $P < 0.05$). The main soil-forming process of dominantly occurring soil subtypes in the evaluated area is accumulation of organic substances, which is determined by the high content of base cations from mineral-rich rock substrates as well as favourable grain size conditions. The foregoing implicates that main factors affecting production functions are mineral-rich rocks, occurrence of base cations and presence of favourable granularity fraction ratios, determining the soil subtype. These facts are also confirmed by similar studies about quantification of links between some abiotic parameters and way of

T a b l e 1. Input data table.

Number of the localities	Sampling sites- Land use	pH/H_2O (-)	pH/KCl (-)	Cox (%)	Soil separate [%]					Soil subtype	Geology
					Physic. clay	I. cat	II. cat	III. cat	IV. cat		
					< 0.002 mm	< 0.01 mm	< 0.01–0.05 mm	0.05–0.1 mm	0.1–2 mm		
1	1-FAR--Z-K	6.02	5.22	3.26	0.81	16.67	41.98	13.31	28.04	1-Skeletic Leptosols	1-conglomerates, sandstones, shales
2	4-EP	5.95	5.02	4.71	1.12	19.97	34.85	13.09	32.09	2-Ari-anthropic regosols	1-conglomerates, sandstones, shales
3	1-FAR--Z-K	7.47	7.07	5.26	0.43	24.27	48.46	15.36	11.91	1-Skeletic leptosols	2-delúvium, weathered clayey and marly shale, chert limestone and Ramsau dolomite
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
21	5-EL	7.52	7.21	5.89	0.25	11.45	44.26	21.59	22.70	6-Rendzic leptosols	5-Ramsau dolomite

T a b l e 2. Table with measured values and data.

Number of the localities	Sampling sites-	pH/H_2O	pH/KCl	Cox (%)	Physic. clay	I. cat %	II. cat %	III. cat %	IV. cat %	Soil sub-type	Geology
	Land use	(-)	(-)		< 0.002 mm	< 0.01 mm	< 0.01–0.05 mm	0.05–0.1 mm	0.1–2 mm		
	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{110}	X_{111}
X_{11}	1	6.02	5.22	3.26	0.81	16.67	4.98	13.31	28.04	1	1
X_{21}	4	5.95	5.02	4.71	1.12	19.97	34.85	13.09	32.09	2	1
X_{31}	1	7.47	7.07	5.26	0.43	24.27	48.46	15.36	11.91	1	2
↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
X_{211}	5	7.52	7.21	5.89	0.25	11.45	44.26	21.59	2.70	6	5

FAR-Z-K – forms of anthropogenic relief (FAR) -loamy-rocky terraces, pH/H_2O – active soil reaction, pH/KCl – exchange soil reaction, C_{ox} – content of organic carbon, EL – extensively used meadows, EP – extensively used pastures, I. cat. – content of colloidal in fraction in %, II. cat.- content of dust fraction in %, III. cat. – content sandy-dust fraction in %, IV.cat. – content of sandy fraction in %.

T a b l e 3. Table of Pearson correlation coefficients.

	land use	*pH(H2O)*	*pH(KCl)*	*Cox(%)*	*Phys.clay*	*I.cat.*	*II.cat.*	*III.cat.*	*IV.cat*	*soil type*	*geology*
land use	1	0.029151	0.025266	-0.16919	0.365474	0.407263	-0.0085	-0.1698	-0.28259	0.283127	-0.0477
pH(H2O)	0.029151	1	0.978071	0.353243	0.360338	0.272389	0.413531	0.055282	-0.54284	0.274252	0.617334
pH(KCl)	0.025266	0.978071	1	0.382174	0.315178	0.198483	0.43905	0.100921	-0.51418	0.247651	0.634385
Cox(%)	-0.16919	0.353243	0.382174	1	-0.07402	-0.40026	-0.02299	0.121217	0.319398	0.555588	0.143844
Phys.clay	0.365474	0.360338	0.315178	-0.07402	1	0.837447	-0.1702	-0.59231	-0.36853	0.18011	0.278278
I.cat.	0.407263	0.272389	0.198483	-0.40026	0.837447	1	-0.04704	-0.67905	-0.55593	-0.12385	0.178264
II.cat.	-0.0085	0.413531	0.43905	-0.02299	-0.1702	-0.04704	1	0.269199	-0.74023	0.03115	0.338717
III.cat.	-0.1698	0.055282	0.100921	0.121217	-0.59231	-0.67905	0.269199	1	-0.0269	0.222309	0.088367
IV.cat	-0.28259	-0.54284	-0.51418	0.319398	-0.36853	-0.55593	-0.74023	-0.0269	1	-0.01147	-0.42413
soil type	0.283127	0.274252	0.247651	0.555588	0.18011	-0.12385	0.03115	0.222309	-0.01147	1	0.184143
geology	-0.0477	0.617334	0.634385	0.143844	0.278278	0.178264	0.338717	0.088367	-0.42413	0.184143	1

Identification of significance of correlation links

Significant (primary) correlation links between variables are those values of Pearson correlation coefficients which fall in the **interval 0.6–1.0.**

Secondary correlation links are those values of Pearson correlation coefficients which fall in the **interval 0.3–0.59.**

Correlation links at the border of significance are those values of Pearson correlation coefficients which fall in the **interval 0.29–0.0** (Krnáčová, Krnáč, 1996).

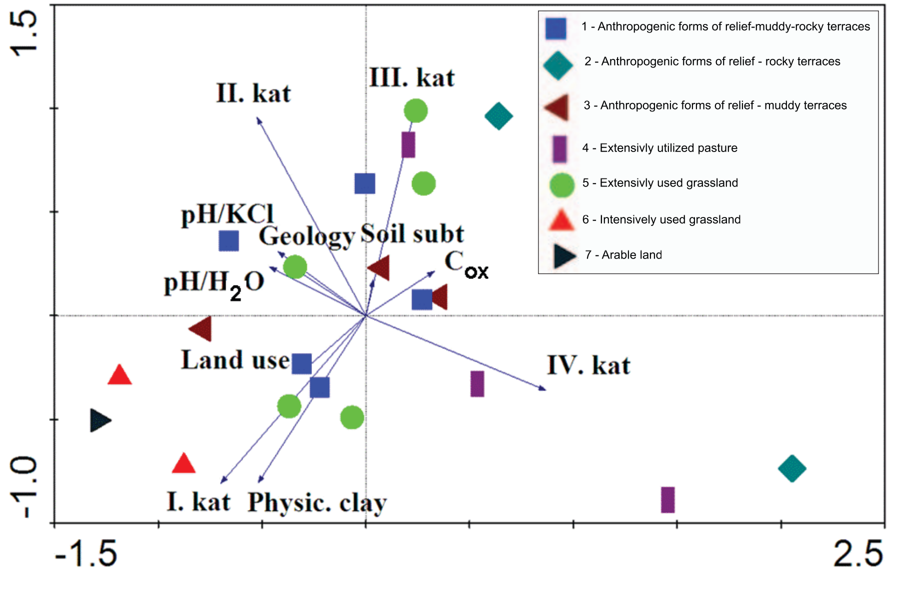

Fig. 4. Ordination graph characterizing bonds of the main components in relation to variables according to PCA.

land use (Krnáčová, Krnáč, 1996, 1999). Due to its low variability – permanent grasslands are dominant – the impact of the way of land use and management was not confirmed in our analyses.

Impact of ecological factors on retention (accumulation) functions

The variable 'IV. Grain size category' (sandy fraction content in %) is in negative correlation with I. (clay particles content in %) and 'II. Grain size category' (dust sandy fraction content v %) ($R = -0.555$, $P < 0.05$ $R = -0.740$, $P < 0.05$). Retention (accumulation) soil function has a significantly physical nature in relation to soil water retention, i.e. it is a function of soil granular fractions ratio. Granular composition of soil primarily affects physical, hydro-physical and chemical properties of soils. Higher proportion of sandy fraction content significantly lowers retention function of soils. Due to its small active surface, sand has low sorption capacity and overall negative effect on hydro-physical soil properties. On the contrary, soils with higher clay particles content (loamy-clayey, clayey-loamy) have very positive effect in physical, hydro-physical and chemical properties of soils.
The ordination graph (Fig. 4) characterizing links between the main components (factors) and the analysed variables is confirmed by the foregoing facts.

Conclusion

Based on the research of selected representative landscape features of traditional agrarian landscape, we can say that the most favourable production and buffering soil functions have been preserved in rendzinas on carbonate substrates of extensively used meadows. Similarly, this type of soils used as extensive meadows have also maintained the most favourable retention functions according to the proportion of granularity of fractions. This is confirmed by the laboratory stated values of C_{ox} in the Ap horizont (7.67–6.62%), as well as the pH value of soil environment (pH/KCl 7.26–7.21, pH/H_2O 7.69–7.68). Relatively lower values of soil organic matter C_{ox} (2.51–2.53%) as well as the pH value of soil environment (pH/KCl 4.81–5.21) (pH/H_2O 5.21–6.19) indicated less favourable production functions of cultisoils of big fields and very low values of buffering and retention functions of soils, set for lithosoil of extensively used pastures on siliceous substrates.

Multivariate analysis of the main components of PCA confirmed the assumption that the size of the buffering capacity of soils is significantly influenced by chemistry of the geological bedrock. Production functions of soils greatly determine the soil subtype, which is confirmed by a significant correlation between the factor (soil subtype) and the variable (C_{ox} – organic matter content). PCA analysis further confirmed that hydro-physical properties of soils and hence also value of retention function of soils is primarily (significantly) determined by a proportional representation of granularity fractions.

Soil is increasingly becoming an endangered natural resource, knowledge of which is vital for sustainable development of human society. Research of traditional agrarian landscape of Liptovská Teplička in the foothill region is a good example of creating the preconditions of sustainable state of high landscape and biological diversity as well as the production state of agriculture in expanding its non-productive functions.

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