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Content

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RASTER DATABASE OF AGRICULTURAL SOILS OF SLOVAKIA – RBPPS

Rastrová báza poľnohospodárskych pôd Slovenska – RBPPS

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ABSTRACT

This contribution is briefly focused on RBPPS database, its attribute and spatial structure respectively. RBPPS is seen as a spatial extension of Complex Soil Survey – Database (KPP-DB) designed for regional evaluation of agricultural soil cover. The attributes include original analytical properties adopted from KPP-DB, and newly added ones (hydro-physical attributes), which have been estimated by pedo-transfer functions. The paper also deals with some problems related to spatial interpolation via geo-statistical methods, accuracy and extent of soil attributes being calculated for constant and flexible depth intervals by weighted average from KPP database.

Keywords: RBPPS, soil information system, kriging, spatial information, KPP

ABSTRAKT

Príspevok je venovaný Rastrovej báze poľnohospodárskych pôd Slovenska (RBPPS), respektíve jej atribútovému obsahu a priestorovej štruktúre. RBPPS predstavuje priestorovú nadstavbu databázy výberových sond KPP, ktorá slúži na regionálne hodnotenie poľnohospodárskeho pôdneho krytu. Atribútová náplň RBPPS zahrňuje pôvodné analytické vlastnosti pôd prebrané z KPP-DB a novovytvorené informácie o pôdnom kryte (hydrofyzikálne vlastnosti), ktoré boli odhadnuté s použitím pedotransferových pravidiel. V skratke sú preberané aj niektoré problémy súvisiace s priestorovou interpoláciou geoštatistickými metódami, správnosťou a priestorovým rozsahom parametrov, ktoré boli vypočítané pomocou váženého priemeru pre konštantné a flexibilné hĺbkové intervaly pôd z údajov KPP.

Kľúčové slová: RBPPS, informačný systém o pôde, kriging, priestorová informácia, KPP

INTRODUCTION

Raster database of agricultural soils of Slovakia (RBPPS) is a spatial extension of database of the Complex Soil Survey of Agricultural Soils of Slovakia – KPP DB v.1.0 (Skalský, 2002). RBPPS is also a part of Geo-referenced Database of Agricultural Soils of Slovakia (GDPPS) managed by Soil Science and Conservation Research Institute (Skalský, 2005). It implements some analytical properties adopted from selected soil profiles of KPP-DB, which are interpolated via geostatistic methods. The database is a response to actual demands, which are given to modern soil information systems, i.e. to provide attribute-rich information on soil profiles in geo-referenced spatial coverage. Data stored in raster formats are sometimes very suitable for spatial modelling and evaluation of soil-related problems. RBPPS has been already successfully used for evaluation of potential water retention parameters of soil (ORFÁNUS, BALKOVIČ, 2004) and its water-protective function (BALKOVIČ, ORFÁNUS, SKALSKÝ, 2004) in the pilot area of the Záhorská nížina lowland. Soil grid-based information is commonly used in various delineation processes in terms to obtain spatial bodies for modelling landscape properties and events, due to it can be adjusted to be consistent with other information being presented as images (remote sensing data, DEM, land use, grid-based hydrology and relief data etc.). Another substantive reason, why such database has been developed, was that it can be easily implemented in cross-statistical analyses, multi-linear mathematic techniques, cluster analyses and classifications in wide radius of digital soil mapping and evaluation (e.g. BALKOVIČ et al., 2003).

Spatial interpolation methods are commonly used in GIS analyses. They assume regionalised variable being measured in geo-referenced mesh, and generally consist of two main routines: (i) setting the model of spatial autocorrelation and (ii) interpolate values of regionalised variable to unknown points/blocks distributed over the area. The procedure covers complex problem, which is dealt e.g. by WEBSTER and OLIVER (1990).

It is well known that kriging geostatistic methods, which are usually used for spatial interpolation of soil parameters, smooth local observations due to nugget effects and they gives only some generalisation of regionalised variable with respect to map scale. Therefore it is usually better to use field observations (e.g. selected soil profiles) or their statistic-based zone projection to existing coverage (e.g. coverage of KPP mapping units) if possible.

In spite of that, over-mentioned advantages of RBPPS are very attractive when we want to evaluate soil-landscape events, which are consistent with scale of soil information. RBPPS rather represents regional gradients and trends in analysed data then local field values.

This paper tries to introduce RBPPS with brief focus on its structure and involved procedures, which have been used.

DATA AND METHODS

RBPPS is constructed over analytical data of selected soil profiles (KPP DB v.1.0). It directly used profile information on sand, silt and clay content, sorption complex (cation exchange capacity, sum of bases, exchangeable acidity and base saturation), organic carbon, bulk density and exchange soil reaction. Point analytical data, which are specific for genetic soil horizons in KPP DB, were recalculated to constant or flexible depth intervals by weight averaging according to Eq. 1.

Eq. 1. $\overline{x} - \sum_{i=1}^{5} w_i x_i$, where $w_i = \frac{H_i}{\sum_{i=1}^{5} H_i}$

$\overline{x}$ is the average value of soil parameter for evaluated soil depth, w_i is the weight of *i*-th horizon in the depth interval, and x_i is the value of soil parameter *X* in *i*-th horizons (KPP DB defines 5 horizons at maximum), H_i is the thickness of *i*-th horizon in evaluated depth intervals.

Calculated geo-referenced point data for constant depth intervals (0 – 50 cm, 0 – 120 cm, 0 – 30 cm, 30 – 60 cm, > 60 cm) and variable depth intervals (0 – 30 cm defined as topsoil, from 30 cm to half of the subsoil thickness, from half of the subsoil thickness to bottom of subsoil) are stored in MS ACCESS database as an integrated part of RBPPS.

Interpolation, spatial adjustment and raster archive is realised in ESRI ArcGIS software environment using its Geostatistical and Spatial Analyst toolkit.

RESULTS

RBPPS consists of two integrated archives. The first one is seen as a specific derivative of KPP-DB v. 1.0, i.e. it stores geo-referenced data on selected soil profiles, where soil parameters express weighted average values for individual depth intervals of soil. Some of them are adopted from KPP-DB and recalculated only, some of them are newly added by using some pedo-transfer functions as described later. The attribute metadata of such database with brief description are given by Tab 1.

Table 1 *Attributes of RBPPS for constant and flexible depth horizons*

Parameter	Depth interval [cm]	Description	Unit
primary soil parameters (constant intervals)			
SAND	0 – 50, 0 – 120	sand content – category by MSCS 2000	%
SILT	0 – 50, 0 – 120	silt content – category by MSCS 2000	%
CLAY	0 – 50, 0 – 120	clay content – category by MSCS 2000	%
CEC	0 – 30, 30 – 60, 60 – 120	cation exchange capacity	$mval.kg^{-1}$
SOB	0 – 30, 30 – 60, 60 – 120	sum of exchangeable bases	$mval.kg^{-1}$
EA	0 – 30, 30 – 60, 60 – 120	exchangeable acidity	$mval.kg^{-1}$
BS	0 – 30, 30 – 60, 60 – 120	base saturation	%
OC	0 – 30	organic carbon content	%
pH	0 – 30, 30 – 60, 60 – 120	soil reaction in KCl	
secondary soil parameters (constant intervals)			
Theta_r	0 – 50, 0 – 120	residual moisture	cm^3cm^{-3}
Theta_s	0 – 50, 0 – 120	saturated moisture	cm^3cm^{-3}
Alpha	0 – 50, 0 – 120	parameter of van Genuchten equation	cm^{-3}
N	0 – 50, 0 – 120	parameter of van Genuchten equation	
WP	0 – 50, 0 – 120	wilting point at 1 500 kPa	cm^3cm^{-3}
FWC	0 – 50, 0 – 120	field water capacity at 330 kPa	cm^3cm^{-3}
KS	0 – 50, 0 – 120	Saturated hydraulic conductivity	$cm.day^{-1}$
primary soil parameters (flexible intervals)			
SAND	top, H1, H2	sand content – category by MSCS 2000	%
SILT	top, H1, H2	silt content – category by MSCS 2000	%
CLAY	top, H1, H2	clay content – category by MSCS 2000	%
CEC	top, H1, H2	cation exchange capacity	$mval.kg^{-1}$
SOB	top, H1, H2	sum of exchangeable bases	$mval.kg^{-1}$
EA	top, H1, H2	exchangeable acidity	$mval.kg^{-1}$
BS	top, H1, H2	base saturation	%
OC	top, H1, H2	organic carbon content	%
pH	top, H1, H2	soil reaction in KCl	

Parameter	Depth interval [cm]	Description	Unit
secondary soil parameters (flexible intervals)			
BD	top, H1, H2	bulk density	$g.cm^{-3}$
VS	top, H1, H2	volume of stones	vol. %
Theta_r	top, H1, H2	residual moisture	cm^3cm^{-3}
Theta_s	top, H1, H2	saturated moisture	cm^3cm^{-3}
Alpha	top, H1, H2	parameter of van Genuchten equation	cm^{-3}
N	top, H1, H2	parameter of van Genuchten equation	
WP	top, H1, H2	wilting point at 1500 kPa	cm^3cm^{-3}
FWC	top, H1, H2	field water capacity at 330 kPa	cm^3cm^{-3}
KS	top, H1, H2	Saturated hydraulic conductivity	$cm.day^{-1}$

Notice: top: 0 – 30 cm, H1: upper half of subsoil, H2: bottom half of subsoil

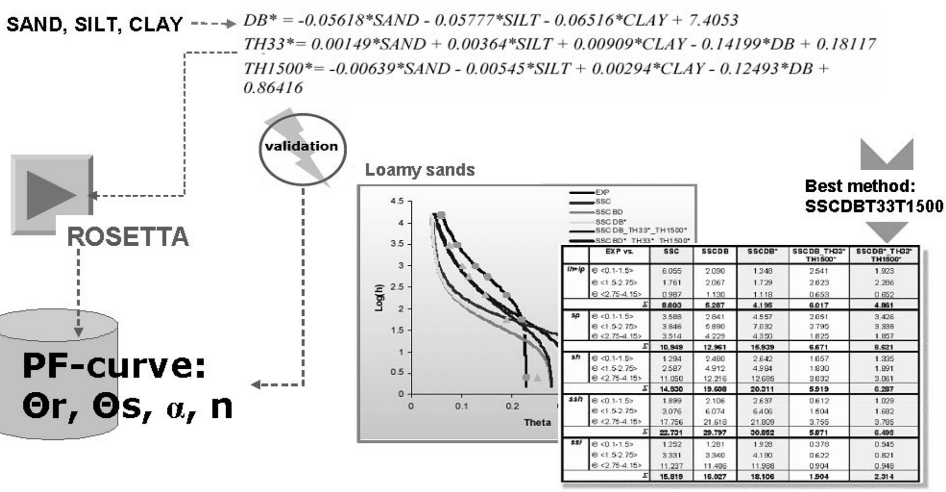
The second archive stores raster layers in harmonised way at ESRI GRID platform. RBPPS is harmonised in S-JTSK_Krovak projection and coordination system with 250 m cell size.

Individual sub-routines, which are needed for creation, maintaining and continual upgrading of RBPPS, include (i) update by qualitatively new information and (ii) spatial interpolation and building the raster layers.

Update by qualitatively new attributes

Attributes of RBPPS, its point as well as raster archive, should be continuously updated by new parameters following new knowledge and published pedo-transfer rules. Recently RBPPS is innovated mostly by hydro-physical parameters, such as water retention and kinetics (notice Tab. 1). Water retention parameters were estimated by procedure published and tested by ORÁNUS and BALKOVIČ (2004) in the Záhorská nížina lowland. It employs Rosseta model (SCHAAP et al., 1997) into infrastructure of processing and validation of KPP-DB data. The process is sketchily presented by Fig. 1.

Figure 1 *Scheme of pedotransfer function designed for estimation of soil hydrophysical parameters from KPP-DB data (Orfánus, Balkovič, 2004)*



Spatial interpolation and building of raster layers

The realisation of the RBPPS assumes the cascade-like process, which is specific for individual regions, and it includes partial and consecutive steps as they are briefly described by following points.

(i) Analysis of stacionarity of semi-variogram

It is well known that several properties of regionalised variable can strongly affect its semi-variogram stationary. We can mention, for example, deterministic trend or drift in spatial realisation of variable or ergodicity in its distribution. The optimal solution occurs when distribution function approximates Gaussian curve. For the case of asymmetry in distribution function, we use Box-Cox transformation to remove it (Johnston et al., 2001) due to such transformation allows unbiased estimation of mean value of spatially dependent variable.

Removing of spatial trend in regionalised variable is another assumption of semi-variogram stacionarity. It can be done by both linear and polynomial detrending functions as an inbuilt routine of ArcGIS Geostatistical Analyst. Despite ordinary kriging assumes deterministic trend to be unknown and constant over the study area, it appeared that it is robust enough to give appropriate results also in areas, where high trend occurs. Ordinary kriging is therefore seen as the universal interpolator, when we assume so-called 'quazy-stacionarity', i.e. when spatial dependence is bounded by range distance.

(ii) Selection of appropriate kriging technique as the result of minimisation of mean square estimation error

Optimal kriging technique (basically ordinary or universal kriging) has been tested in the validation process. Kriging results have tested by validation data, which are random subsets of database of measured soil property. The selection of used technique is based on minimum mean square estimation error (Eq. 2).

Eq. 2. $$\mathrm{MSEE} = \frac{1}{m} \sum_{i=1}^{m} [Z^*(x_i) - Z(x_i)]^2,$$

where $Z(x)$ is measured value of regionalised variable, $Z^*(x)$ is predicted value and m denotes the number of observations in independent validation database.

We have tested ordinary (OK) and universal kriging (UK) for its eligibility to interpolate appropriate sand coverage (50 cm topsoil layer) in the study area of Podunajská rovina plain. The results are summarised by Tab. 2, where the minimum MSEE is estimated by nugget effect of used model and the maximum MSEE is the mean square difference from the average value. Obtained results prove that once spatial autocorrelation is fixed to range distance, ordinary kriging is appropriate predictor even if spatial trend exists and it is not perforce necessary to use universal kriging.

Table 2 *Testing parameters of validation methods of OK and UK in Podunajská rovina plain*

Kriging technique:	OK	UK
N	228	228
MSEE	49.55	50.38
MSEE_MAX	76.96	76.96
MSEE_MIN	40.0	38.0
R^2	0.37	0.35
LIN_REGRESE	Y = 0.32x + 11.95	Y = 0.34x + 11.65

Notice: n – number of observations, R^2 – coefficient of determination, LIN_REGRESSE: equation of linear regression

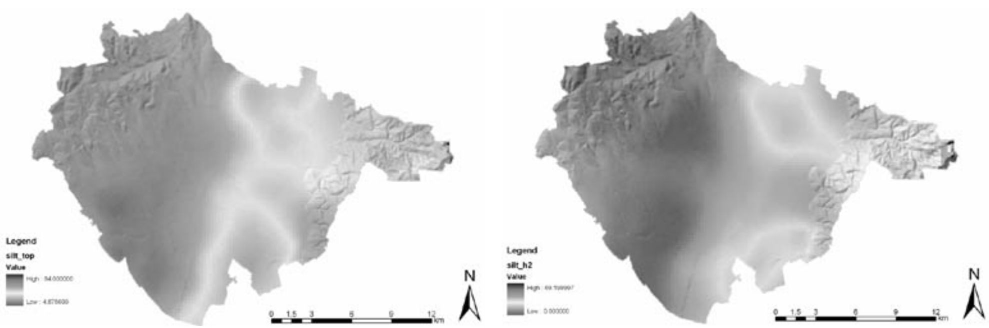
We have also tested point and block techniques of kriging interpolation when raster has been created. Generally block kriging is recommended if regionalised variable shows high nugget effect (ODEH et al. 1990), what is very common in RBPPS data. Punctual and block kriging with different dimensions were tested and it appeared that 10 x 10 block kriging appropriately decrease standard kriging error, because it smoothes local extremes. However, such interpolated coverage does not provide precise local information and it can be used in regional analyses only.

(iii) Building of RBPPS by synthesis of partial kriging results (regional specification)

Several regions have had to be interpolated separately due to different spatial pattern in regionalised variable, originating in different geographic and geologic composition. Partial results have been spatially adjusted to predefined mesh with 250 m cell size by raster algebra tools, so that only pixels belonging to interpolated region were picked up from partial temporary raster. Therefore all outputs are harmonised by simple joining of relevant pixels to template raster.

Fig. 2 shows an example of RBPPS, the subset for Piešťany district respectively, for silt content in the topsoil and bottom subsoil horizon.

Figure 2 *The subset of RBPPS for Piešťany district – silt content in TOP (left) and H2 interval (right)*



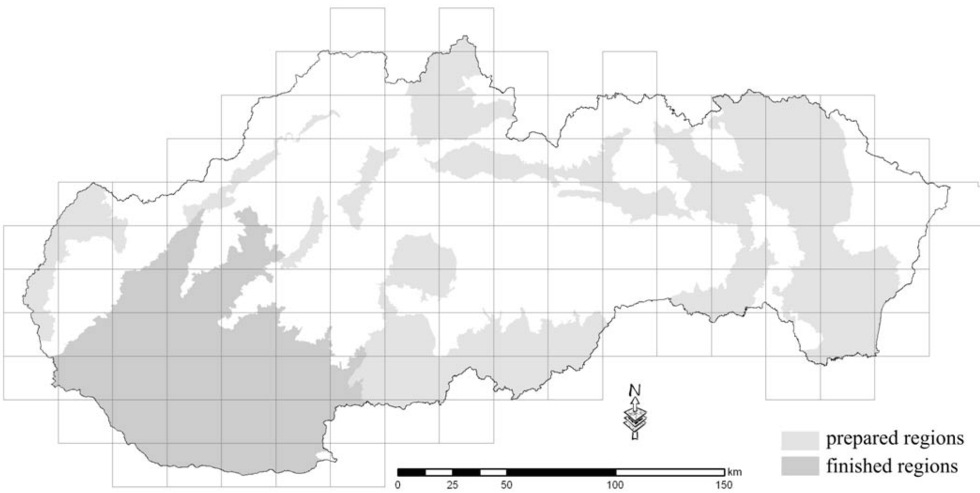
(iv) Refining of RBPPS by using supporting tools and spatial databases of Soil Information System

RBPPS can be potentially refined and upgraded by using additional data from the Soil Information System. Nowadays only the theoretical frame is under construction. The baseline is to analyse mutual relations between regionalised variable and those parameters of soil cover and landscape, which provide more detailed information or sampling density. At the beginning we have assumed to use mainly co-kriging techniques, which can be realised over Digital Elevation Model (DEM) or database of basic soil profiles of KPP.

DISCUSSION

Building of RBPPS is the spatial upgrade of KPP-DB, where soil profile properties are interpolated by geo-statistical methods to predefined raster with 250 m cell resolution. Such process is crucially dependent on spatial density of selected soil profiles. First of all it determines the total extent of RBPPS (notice Fig. 3), but it also influences the accuracy and scale of interpolated layer. Generally, semi-variance models show high nugget effects in all observed variables, what can be clearly assigned to variance at shorter distances. Then it is gathered by sample pattern. Therefore, RBPPS covers rather spatial trend than field-size effects in observed soil parameter and therefore it can be used for regional analyses as direct source of soil inputs, or for various delineation processes in landscape ecology.

Figure 3 *Possible extent of RBPPS*



It has appeared that usually ordinary kriging is the appropriate tool for geo-statistical interpolation of parameters. However, it should respect geomorphologic as well as geologic oneness of individual regions, where soil variables are distributed by different forces over the regions. Several types of anisotropy and non-stationary in spatial distributions have been observed during constructing of RBPPS.

In regional way RBPPS doubtlessly provides effective database for various evaluation and co-evaluation of soil cover. However, one should keep in mind that it is biased for field scales due to local values are significantly smoothed and it has no ambition to replace KPP-DB information for such field scale research.

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MITIGATION OF SOIL DEGRADATION PROCESSES IN THE SLOVAK REPUBLIC WITHIN FRAMEWORK OF UN CONVENTION TO COMBAT DESERTIFICATION

Zmierňovanie procesov degradácie pôdy v Slovenskej republike v rámci Dohovoru OSN o boji proti dezertifikácii

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ABSTRACT

Annex V to the Convention represents programme for countries of the Middle and East Europe, and besides drought mitigation creates frame for soil preservation against degradation processes. Knowledge on status, consequences and driving forces represents the start-point for definition of efficient measures that in integral form in context of UN CCD defines National Action Programme. Submitted paper focuses attention on problems with the soil degradation regarding particular soil use in agriculture, forestry, urban and industrial areas.

The significance of soil threats in agricultural sector decreases in the order as: decrease of soil organic matter content > water erosion > subsurface compaction > acidification > wind erosion > pollution > salinization. Till now soil sealing mostly from agricultural sector has had tolerable extent but the present trend in development of foreign and national investment does not respect present legislation and new areas of agricultural soil without respect to their unique quality. Soils in the forestry sector are mostly affected by acidification and pollution. Soils in the urban or industrial areas are significantly affected by pollution and compaction.

Soil degradation negatively influences the provision of soil environmental functions, biomass production inclusive. Improper use and following soil degradation is immediately connected with deterioration of other environmental issues (decrease of biodiversity, air and water pollution). Polluted urban soils immediately affect health status of citizens.

Immediate reason of the soil degradation in agriculture is the insufficient application of the good agricultural practice principles and giving permanent precedence to production function over remaining ecological ones that is reflection of value criterion of the society. Forest cover and consecutively soils are affected by emissions and immissions from local sources or trans-boundary transfer. Status of urban soils is reflection to economic human activities considered as stability factor forf employment and economic prosperity of individuals, groups and country. Sealing of the next agricultural soil for infrastructure building instead of brown fields restoration is also reflection of the value priorities of the society. Only a man has creative thinking that influences surrounding reality.

From measures on mitigation of the soil degradation that are part of the upcoming National Action Programme to Convention is necessary to list:

- creation and performance of information tools for strategic decision support
- creation of new strategic documents, actualisation of existing and development of new national legislation relevant to the Convention
- proposal and realisation of technical measures to mitigate soil degradation processes
- continual creation of a new knowledge through integrated research
- increase of environmental awareness of soil users and broader population
- support of regional cooperation and provision of professional aid to affected countries.

Keywords: soil degradation, driving forces, state, impacts, national action programme, UN CCD

ABSTRAKT

Príloha V Dohovoru OSN o boji proti dezertifikácii vytvára pre krajiny strednej a východnej Európy podmienky tak pre zmierňovanie sucha, ako aj rámec pre ochranu pôdy pred degradačnými procesmi. Poznatky o stave, dôsledkoch a príčinách degradácie pôdy sú východiskom pre tvorbu účinných opatrení, ktoré v ucelenej podobe v zmysle Dohovoru definuje Národný akčný program.

Príspevok analyzuje stav degradácie pôdy v podmienkach Slovenska s prihliadnutím na osobitosti využívania v oblasti poľnohospodárstva, lesníctva a urbánnych a priemyselných oblastí.

Významnosť degradačných procesov v sektore poľnohospodárstva klesá v poradí: pokles obsahu pôdnej organickej hmoty > vodná erózia > zhutnenie pôdy > acidifikácia > veterná erózia > znečisťovanie > zasoľovanie. Zábery najmä poľnohospodárskej pôdy boli doteraz v únosnom rozsahu avšak nastúpený trend rozvoja zahraničných a domácich investícií na Slovensku nerešpektuje súčasnú legislatívu a dochádza k záberu nových plôch poľnohospodárskych pôd, bez ohľadu na ich unikátnu kvalitu. Pôdy v lesnom sektore sú najviac ovplyvnené acidifikáciou a znečisťovaním. Pôdy v urbánnych a priemyselných oblastiach sú výrazne postihované znečisťovaním a zhutňovaním.

Degradácia pôdy negatívne ovplyvňuje zabezpečovanie tak produkčnej, ako aj ostatných ekologických funkcií pôdy. Nevhodné využívanie a následná degradácia pôdy sa následne spája s poškodzovaním ostatných zložiek prostredia (znižovanie biodiverzity, znečisťovanie ovzdušia a vodných zdrojov). Kontaminácia pôdy v urbánnych oblastiach priamo ovplyvňuje zdravotný stav obyvateľstva.

Bezprostrednou príčinou degradácie pôdy v poľnohospodárstve je nedostatočné uplatňovanie zásad správnej poľnohospodárskej praxe a trvalé nadraďovanie významu produkčnej funkcie pôdy nad ostatné ekologické, čo je odrazom súčasných hodnotových kritérií spoločnosti. Lesné porasty a následne pôdy sú ovplyvnené emisiami a imisiami z lokálnych zdrojov a diaľkového prenosu. Stav urbánnych pôd je odrazom hospodárskych aktivít človeka, ktoré sú považované za stabilizačný faktor z pohľadu zamestnanosti a ekonomickej prosperity jednotlivcov, skupín a štátu. Zábery ďalšej poľnohospodárskej pôdy na výstavbu infraštruktúry namiesto využívania opustených priemyselných a hospodárskych plôch je taktiež odrazom hodnotových priorít spoločnosti. Len človek disponuje tvorivým myslením, ktoré ovplyvňuje okolitú realitu.

Z opatrení na zmiernenie procesov degradácie pôdy, tvoriacich súčasť pripravovaného akčného programu k Dohovoru treba spomenúť nasledovné:

- tvorba a prevádzka informačných nástrojov pre podporu strategického rozhodovania
- tvorba strategických dokumentov a aktualizácia resp. tvorba novej legislatívy
- návrh a realizácia technických opatrení
- kontinuálna tvorba nových poznatkov prostredníctvom integrovaného výskumu
- pravidelné vzdelávanie užívateľov pôdy a zvyšovanie širšej spoločnosti v oblasti ochrany pôdy a ostatných zložiek prostredia
- podpora regionálnej spolupráce a pomoci postihnutým krajinám.

KĽÚČOVÉ SLOVÁ: degradácia pôdy, príčiny degradácie, stav degradácie, následky degradácie, národný akčný program, Dohovor OSN o boji proti dezertifikácii

INTRODUCTION

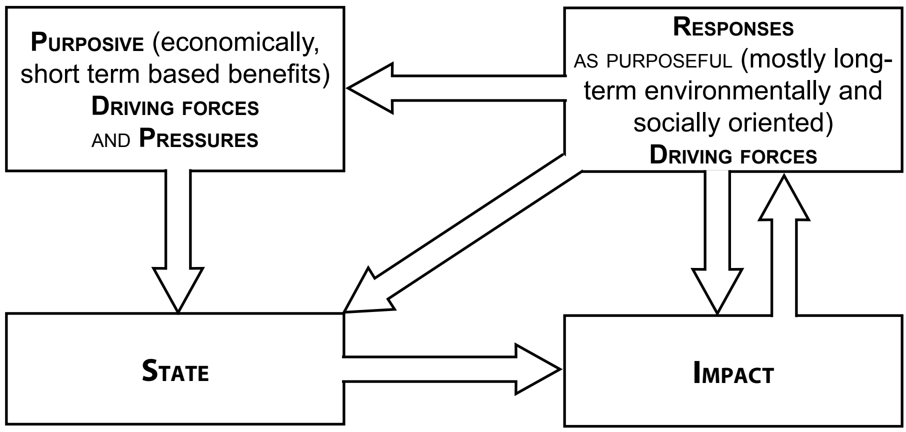
Intensity and extent of the degradation and destruction of environmental components was manifested in the 20th century by global Earth problems. The international community began to pay attention to seek solutions and these efforts culminated at the World summit of the UN on Environment and Development (Earth Summit) in 1992 in Rio de Janeiro. As a result of negotiations, world wide activities were initiated and global (Rio) conventions were endorsed, the ones as United Nations Convention to Combat Desertification – UN CCD (ANONYM, 1994). The Slovak Republic joined the Convention in 2001. Annex V to Convention represents programme for countries of Middle and East Europe and besides drought mitigation creates frame for solution of current problems with soil degradation.

Knowledge on status of the degradation processes as well as insight of driving forces behind them represent the start-point for definition of efficient measures that can mitigate the environmental and broader societal consequences. To realise defined measures, it is necessary to create sufficient capacities based on previous inventory. Slovak Republic had opportunity to obtain and solve UNDP/GEF project "National capacity self-assessment related to environmental management of global conventions" UN CCD inclusive. Submitted paper focuses attention to problems of soil degradation.

MATERIAL AND METHODS

The paper summarises existing status of soil degradation in Slovak Republic published in many sources (e.g. BIELEK, 1999; BUJNOVSKÝ et al., 2004; FULAJTÁR, JANSKÝ, 2001; KOBZA et al., 2002; LINKEŠ et al., 1997; SOBOCKÁ, 2001; SOBOCKÁ, 2004). The reasons and consequences of the soil degradation were examined with help of modified Driving Forces and Pressures-State-Impact-Response analysis or DPSIR (European Commission, 1999) as illustrated in Fig. 1. The responses consist of definition of main types of the activities considered as frame for National Action Programme to Convention preparation that should promote preservation of soil and affected natural resources against the degradation.

Figure 1 *Modified DPSIR scheme*



RESULTS AND DISCUSSION

State in the soil degradation

The significance of soil threats summarises the Table 1. In agricultural sector the relevancy of soil threats decreases in the order: decrease of soil organic matter > water erosion > subsurface compaction > acidification > wind erosion > pollution > salinization. Till now soil sealing mostly from agricultural sector had tolerable extent but the present trend in development of foreign and national investment does not respect present legislation and new areas of agricultural soil without respect to their unique quality. This soil threat dramatically affects the soil quality. As evidence of non-sustainable soil use and degradation can serve the brown-fields from previous industrial and agricultural activities. Usually, the soil degradation in the forestry sector (acidification, pollution) is induced secondary, through emissions and immissions from local industry and trans-boundary transfer. Main soil threats in the urban areas are soil pollution and compaction.

Impact

Soil degradation negatively influences provision of soil environmental functions, biomass production inclusive. Soil degradation in agricultural sector contributes to the reduction of potential incomes of farmers. Deterioration of other environmental constituents caused by soil degradation is difficult to quantify because of indirect manifestation. For example, soil erosion and decrease of SOM increases soil susceptibility to compaction, or decrease of water retention capacity, as well as occurrence of drought or floods. Another example serves decrease of SOM through gaseous carbon loses that supports greenhouse effect and climate change affecting all population on the Earth. Soil degradation in the forest sector is rather perceived as secondary effect. Emissions and immissions of local or trans-boundary origin primarily cause health status of forests. Soil afforestation is considered as efficient measure to mitigate the soil and land degradation with positive impact on decrease of GHG loses into atmosphere.

Degraded and polluted soil immediately affects life quality in urban and industrial areas with direct impact on health status of citizens.

Table 1 *Overview of soil degradation in Slovak Republic*

Soil threat	Status	Significance
Agricultural sector		
Erosion (water)	56 % area potentially threatened (based on sloppiness)	very significant
Erosion (wind)	6.5 % area potentially threatened	less significant
Decrease of SOM	more than 59 % area affected through soil cultivation and deficient OM input	very significant
Compaction	27 % area affected by subsurface compaction	very significant
Landslides	negligible extent	non significant
Contamination	below 1.5 % area reaching/exceeding of acceptable limits	less significant
Acidification	17.5 %	significant
Salinization	0.2 % area occupied by saline soils (Solonchaks and Solonetz)	non significant
Sealing	tolerable extent (around 3 ha daily) but increasing trend	less significant
Forestry sector		
Erosion (water)	minor extent, mostly on sloppy areas after timber extraction or disasters	less significant
Erosion (wind)	negligible extent	non significant
Decrease of SOM	minor extent, areas under forest rather maintain or accumulate SOM	non significant
Compaction	negligible extent	non significant
Landslides	minor extent – on deforested steep slopes or forest/infrastructure interface	less significant
Contamination	around 7 % area directly influenced by local sources of immissions	significant
Acidification	55 % area has soil pH_w below 5.0 due to emission deposition	very significant
Salinization	negligible extent around routes	non significant
Sealing	negligible extent, recently forest area increases on account of agriculture	non significant
Urban and industrial area		
Erosion (water)	negligible extent	non significant
Erosion (wind)	negligible extent	non significant
Decrease of SOM	minor extent	non significant
Compaction	practically all area is affected in different extent	very significant
Landslides	minor extent mostly on forest/infrastructure interface in hilly areas	less significant
Contamination	most relevant to cities with high traffic and industrial influence	very significant
Acidification	minor extent	less significant
Salinization	areas around roads chemically treated in winter period	significant
Sealing	urban areas gradually increases due to sealing of next mostly agricultural soil	not relevant

Driving forces and Pressures

The degree of soil degradation is influenced by concrete soil use and suitability of individual measures. Evolution of the climatic conditions in the last period and accessory disasters are fully ascribed to the nature despite of the long-term man participation. This impact might be classified rather as pressure than driving force.

Soil degradation in the agricultural sector results from non-respecting the principles of good agricultural practice relevant to soil, fertiliser and crop management. Until now, soil was considered as tool of production that serves for satisfying of increased farmer needs. The farmers, especially in the most productive areas, still prefer activities oriented on crop/animal production that are together with area payment subsidy from the EU funds dominant source of farm incomes. Consistent application of SAPS requirements (Simplified Area Payments Scheme), as well as subsidy from agri-environmental programme to care on soil and land can in the future positively influence soil quality formation.

Usually the change of land ownership from state or collective to private one does not always guarantee the improvement of management as in agriculture so in forestry. Land mining and degradation is also matter of affinity of a man to the soil formed through many generations.

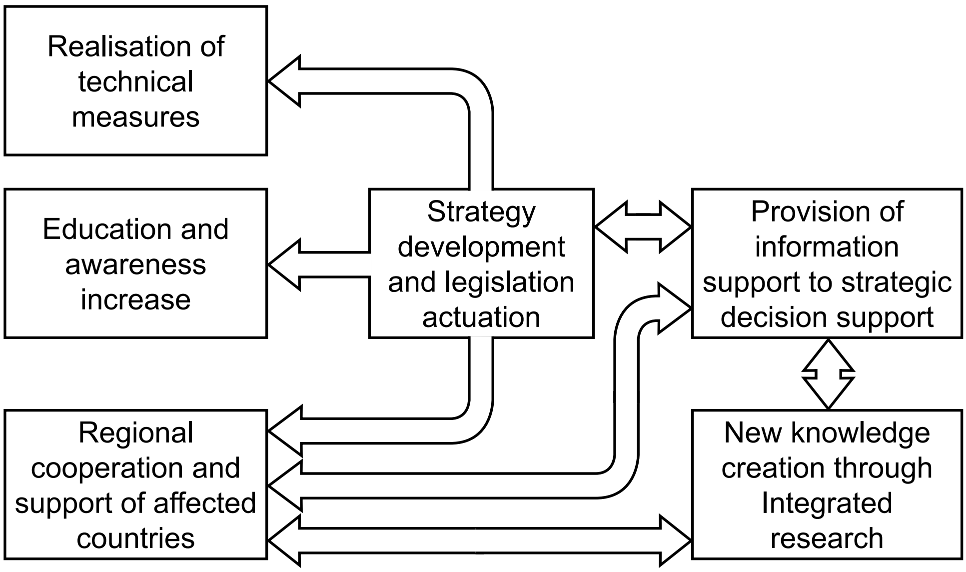
Broad spectrum of human activities linked with urban and industry sector is generally considered as a stability factor of employment and economic prosperity of a given country. Numerous activities have direct impact on quality of soil and other environmental constituents. They disturb ecological stability of territory. While for building of a new infrastructure is necessary new area usually coming from agriculture, restoration of brown fields is considered as less attractive or economically unacceptable as by (mostly foreign) investors so by government bodies that consider national economy development as the primary objective. Soil in the private sector is usually considered as property that serves exclusively for owner purposes. The above-mentioned issues are a mirror of the society values and priorities.

It is time to gradually change fear that survives and is determined by continually accelerating process of goods acquisition or soil benefits. Human activities should be in harmony with life principles as: functionality, adaptability and sustainability. The most important is the first one because it is necessary to evaluate whether the concrete activities (in policy, practice etc.) are functional from the view of reaching the concrete goals that should lead to environmental and social improvement or not. Only a man has creative thinking affecting surrounding reality. Whatever positive change in soil use and management is, it consists in change in people`s thinking as of policy makers, as well as soil users. Measures on mitigation of the soil degradation must be systemic, usually top-down directed, but their success depends on general acceptance by all engaged.

Responses

As follows from the Fig. 1, responses can be directed on each part of the cycle. Deep understanding of the process can help to create realistic goals and efficient use of available capacities. The closer the state to root of the problem, the more efficient and less demanding are the measures. This also explains the difference between preventive and regulative measures. Mutually dependent activities of the National Action Plan to Convention should be prevention oriented as well as on mitigation of the existing status. Their cross connection is illustrated in Fig. 2.

Figure 2 *Mutual inter dependence of the assumed activities for prevention or mitigation of the soil degradation as a part of the National Action Programme to UN CCD*



Creation and operation of information tools for strategic decision support

Definition, the extent, and intensity of soil degradation processes is the first precondition for planning the necessary actions and measures based on objective information. To solve this problem it is necessary to continue in provision of permanent monitoring of the agricultural and forest soil properties development (provided in Slovakia since 1992) taking into account recent EU demands. Not negligible is also need to develop special information system on urban and industrial areas.

Creation of new strategic documents, actualisation of existing ones and development of a new national legislation relevant to the Convention

The decisive international strategic documents relevant to soil and environment protection find application in the creation of the national cross cutting and sector strategic documents. From many of them let mention the National strategy of sustainable development (2001), Concept of soil preservation and use (2000), as well as Rural Development Plan of Slovak Republic (2004). For the realisation of positively oriented goals and measures, these documents are missing adequate and efficient legislative support.

The most developed national legislation relevant to the soil protection against degradation is observed in the agricultural sector represented by the act No. 220/2004 on soil protection as well as act No. 188/2003 that prevents soil pollution from application of sludge and river basin sediments. Activities in the forest sector are treated by the act No. 61/1977 on forests and act No. 100/1977 on forest management. The soil protection is considered as a secondary effect of forest management, as afforested land is considered the primary measure for soil protection. Until now, soil protection in the urban areas has not been treated by a special legislation document.

Next legislation documents, more oriented to the land use and preservation, deal with territorial planning, environmental impact assessment, integrated prevention and control of pollution and preservation of nature and land.

PROPOSAL AND REALISATION OF TECHNICAL MEASURES TO MITIGATE SOIL DEGRADATION PROCESSES

System of measures having regulatory and preventive character will aim to the improvement of soil use and management through consistent application of the principles of good or best practice as in the agriculture so in the forestry.

CONTINUAL CREATION OF NEW KNOWLEDGE

For creation of new knowledge, there is necessary to prepare proposal of new cross-cutting national research program relevant to land desertification and soil degradation and provide it's financing from state budget. Integrated solution of this problem assumes to improve cooperation among individual institutions.

INCREASE OF ENVIRONMENTAL AWARENESS OF SOIL USERS AND BROADER POPULATION

Spontaneous or non-regulated economy changes in society, having positive environmental effect, usually negatively influence living standard of population in countryside. As example can serve decrease of production intensity in the agriculture in the previous period. This process had positive effect on decrease of soil erosion and loading of soil by chemicals (fertilisers, pesticides). However, simultaneously it has contributed to worsening in economic conditions of the agricultural subjects and population on countryside.

The primary reason and accelerator of the changes in soil and environment is the human being and permanent need to satisfy his increasing demands. Quality of thinking and subsequently of life is decisive factor of the next progress. In line with mentioned the importance of soil users and public awareness on reasons and consequences of soil degradation and its broad societal context increases. It is necessary to develop sufficient capacities for periodical education of soil users in the agriculture and forestry. Positively is evaluated the elaboration of codes of good agricultural practice for the protection of soils and affected environmental sources in the agriculture (BIELEK, 1996; BUJNOVSKÝ, 2000; ANONYM, 2001). Improvement and enforcement of professional institutions cooperation with media can create a good basis for gradual improvement of the state in the soil and environment protection.

SUPPORT OF REGIONAL COOPERATION AND PROVISION OF PROFESSIONAL AID TO AFFECTED COUNTRIES

This area of activities represents the way of help to other affected countries to mitigate the soil degradation.

CONCLUSIONS

Until now, society has insufficiently evaluated the cross-social environmental benefits that soil in agricultural and forest area provides. The outstaying confronting relationship between legislative, technological and ecological state authority on one side and excessive market neo-liberalism at pressing of economic interests of groups or individuals satisfactorily on the other side does not solve the existing cross-social problems connected with environmental status and living standard of population. From the long-term view, it is necessary to change the strategy "who from whose" on the strategy of cooperation for benefit to all. Life is movement. That, who prevents or corrects the negative that is moving towards.

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INVESTIGATION OF SOIL COMPACTION WITHIN A SELECTED FIELD BY MEASUREMENT OF PENETROMETRIC SOIL RESISTANCE

Prieskum pôdnej kompakcie na vybranom hone ornej pôdy metódou penetrometrie

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ABSTRACT

The paper presents results of an investigation of soil compaction within a selected field with aim to (1) confirm soil degradation by compaction and (2) to obtain information about area of compacted soils. Based on potential soil compaction (Halas et al., 2003) defined from main soil units, penetrometric measurements at arable field were carried out in a grid 75 x 75 m. The values of pressure were consequently corrected according to actual soil moisture. Space distribution of soil penetration resistance is presented in the maps. The results and above-limit values of soil compaction confirmed that degradation process of soil compaction is actually present. The high space variability of soil compaction was detected.

Keywords: soil compaction, resistance to penetration

ABSTRAKT

Príspevok je venovaný problematike prieskumu kompakcie (utlačenia) pôdy na vybranom hone, s cieľom overenia a preukázania prítomnosti degradačného procesu pedokompakcie vrátane získania informácie o jeho plošnom výskyte. Na základe zisteného potenciálneho utlačenia pôdy vymedzeného na báze hlavných pôdnych jednotiek (HPJ), boli na vybranom hone ornej pôdy realizované penetračné merania odporu pôdy. Merania sme uskutočnili v jednotlivých vrcholoch (bodoch) štvorcovej siete s pomerom strán 75 x 75 m. Namerané hodnoty tlaku boli následne korigované podľa momentálnej vlhkosti pôdy na štandardnú vlhkosť 19 %. Priestorové vyhodnotenie penetračného odporu pôdy po korekcii je prezentované na obrázkoch. Z dosiahnutých výsledkov vyplynulo, že degradačný proces pedokompakcie je na hone reálne prítomný, a to aj v nadlimitných hodnotách, pričom sa preukázala jeho značná priestorová variabilita.

Kľúčové slová: kompakcia pôdy, penetrometrické merania

INTRODUCTION

Soil is non-renewable multifunctional natural source and basic part of the environment. It is common wealth of all people and heritage of coming generations. While its utilization, soil is often exposed to various degradation processes. Everyone who owns or uses the soil has obligation to make agrotechnical measures with aim to protect the soil, to preserve its quality and functions and to take care of its protection against damage and degradation (MP SR, 2004).

Soil compaction is the most expressive sign of degradation processes in soils (HOUŠKOVÁ, 1998). According to BEDRNA (2002), it is defined as the rate of potential soil disability to resist the pressure. Soil compaction affects not only the productivity, but it has also ecological consequences. Process of soil compaction is very complex, variable and goes off gradually. It is closely connected with changes of other physical and technological soil properties, as well as with changes of soil chemistry and biology. At inappropriately cultivated soils, critical increase of the above-limit compaction leads to violation of balance between productive and reproductive aspects of soil processes and to general threat of positive development of soil fertility. Soil compaction is closely connected to conditions and factors of the environment – climate, weather, soil utilisation and system of tillage, used cultivation technologies and techniques (ZRUBEC, 1997).

The aim of this article is to confirm presence and intensity of the degradation process of soil compaction by measurement of soil penetration resistance. At the same time another goal is to gain information about the area of compacted soils.

MATERIALS AND METHODS

As a first step, potential soil compaction was delimited on the basis of main soil units (HALAS et al., 2003). Afterwards, we carried out penetrometic measurements within the selected field of arable land. Depths of the compacted layers, degree of soil compaction and acreage of compacted soil were determined using the penetrometer – an instrument for measuring the resistance of the soil against penetration of a steel cone of penetrometric probe (LHOTSKY, 2000).

The investigated field is located in region Bardejov, in cadastre Kobyly. It lies in altitude 380 – 400 m and belongs to moderately warm climatic zone, climatic district M 3 (moderately warm, wet, hilly). Average annual temperature is between 6 and 7.5°C and average annual precipitation is 650 – 700 mm (MŽP SR, 2002). The acreage of the field is 8 ha; the slope of the field is 3 – 7°, exposition south, west and east. Dystric Planosol is the main soil type on this field. Soil is deep (more than 0.6 m), loamy in topsoil and also in subsoil, without soil skeleton.

On investigated field, in accordance with the recommended method (ZRUBEC, 1997), we chose a grid 75 x 75 m to measure the penetration resistance. In the nodes of the grid, profiles of penetration resistance were recorded in 22nd and 23rd April 2004 (5 repetitions per node). At the time of the measurement, soil was without vegetation cover. From each investigated profile, samples for gravimetric determination of actual soil moisture were taken from depths 0.10, 0.25 and 0.45 m. Concerning availability of the penetrometric instruments, we used penetrometric probe STS Šumperk – diameter of the measuring cone 11.28 mm, surface of cross-section 100 mm^2, the terminal angle 30°; maximal measurable soil resistance 6 MPa (BAJLA, 1998). Altogether, penetrometric profiles of 15 sites (75 measurements) were measured and recorded in MPa on penetrograms. Afterwards, for each node, average value of 5 measurements was calculated. These values were corrected to soil moisture of 19 %. We had used critical value of 3.8 MPa for penetrometric resistance of loamy soil, according to SIMON, LHOTSKY et al. (1989).

Interpolation method kriging was used for area interpretation of soil penetration resistance for layers of thickness 0.05 m, up to 0.6 m. In each map, we used the same colour scale of penetration resistance.

RESULTS AND DISCUSSION

The results are presented in graphic part of the paper (Figures 1 to 6). They record the degree of soil compaction in individual depth as well as the area extent of soil compaction.

Figure 1 *Maps of penetrometrics soil resistance in depth 0.05 m (up) and 0.1 m (down) in grid density 75 x 75 m*

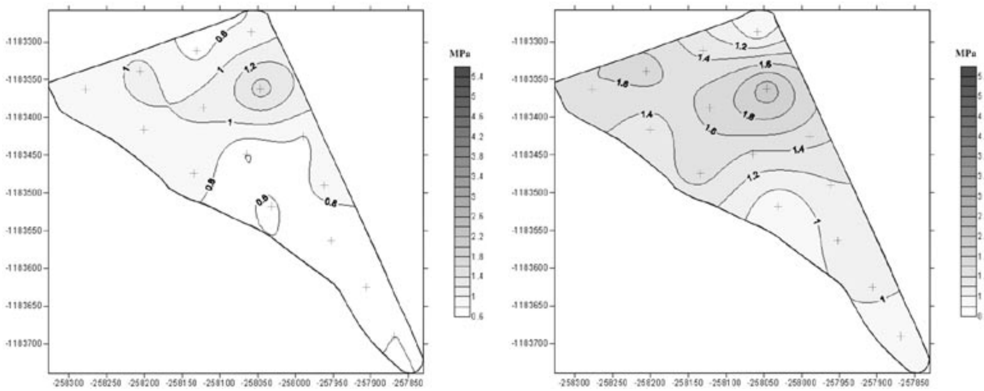


Figure 2 *Maps of penetrometrics soil resistance in depth 0.15 m (up) and 0.2 m (down) in grid density 75 x 75 m*

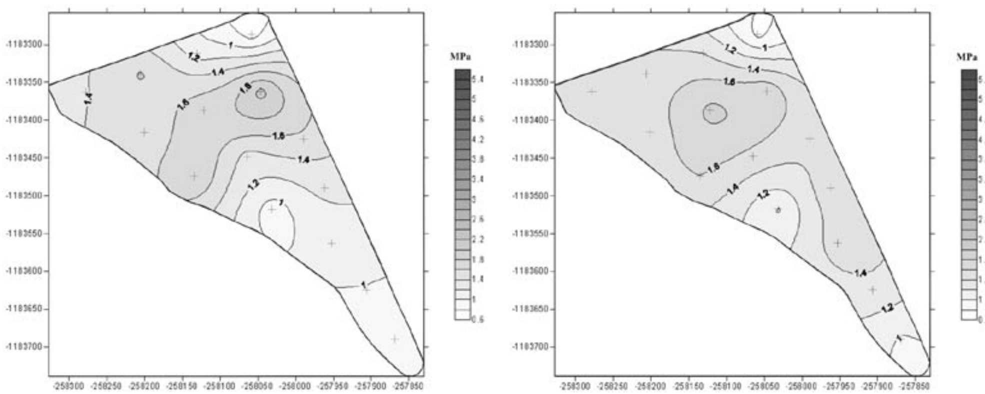


Table 1 *Average values of measured penetration resistance (average for whole data-set)*

depth of penetration (m)	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6
resistance of soil (MPa)	0.90	1.39	1.39	1.47	1.78	2.84	3.35	3.61	3.73	3.75	3.87	4.00

Figure 3 *Maps of penetrometrics soil resistance in depth 0.25 m (up) and 0.3 m (down) in grid density 75 x 75 m*

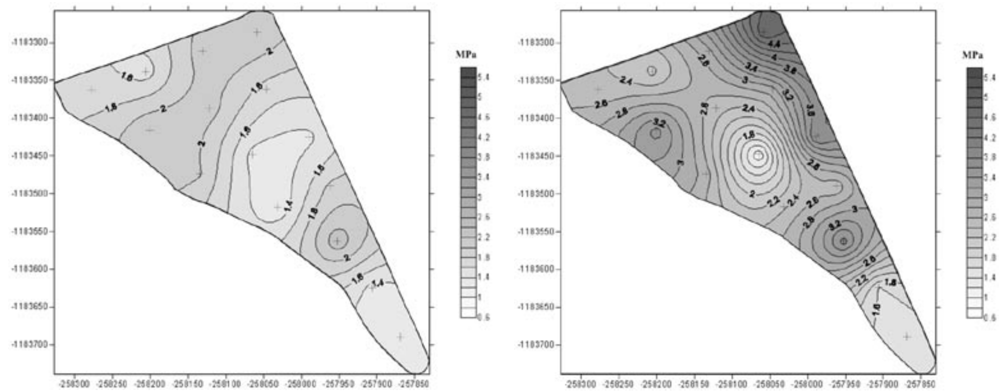


Figure 4 *Maps of penetrometrics soil resistance in depth 0.35 m (up) and 0.4 m (down) in grid density 75 x 75 m*

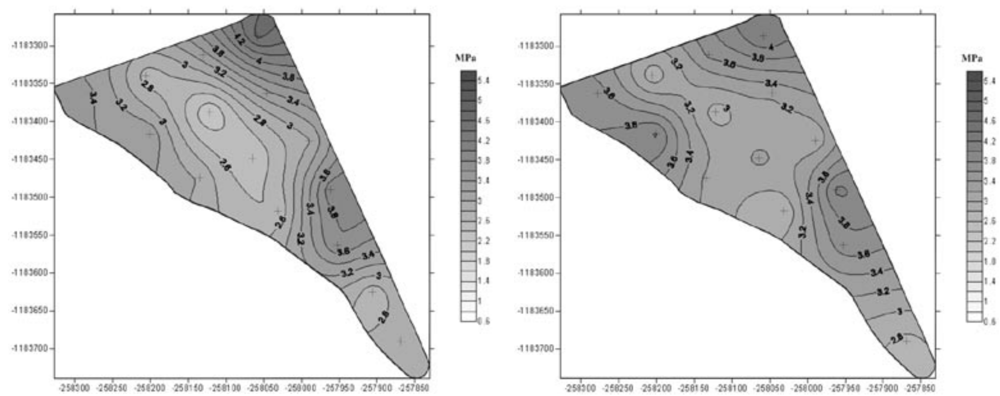


Figure 5 *Maps of penetrometrics soil resistance in depth 0.45 m (up) and 0.5 m (down) in grid density 75 x 75 m*

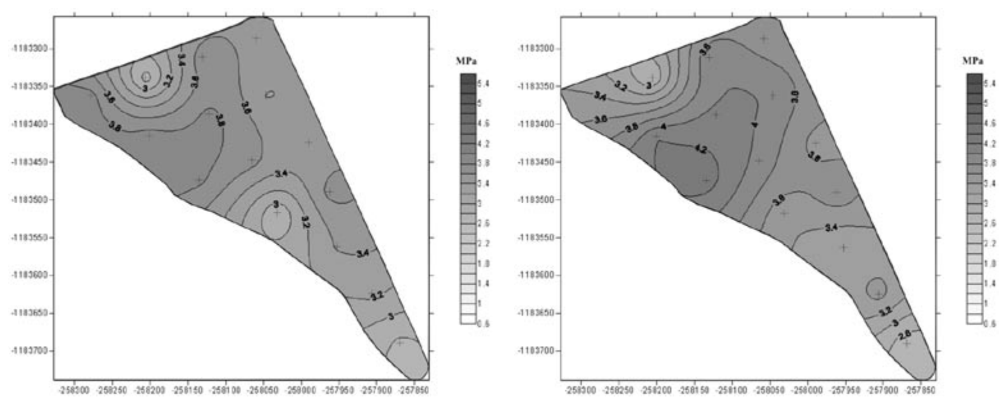


Figure 6 *Maps of penetrometrics soil resistance in depth 0.55 m (up) and 0.6 m (down) in grid density 75 x 75 m*

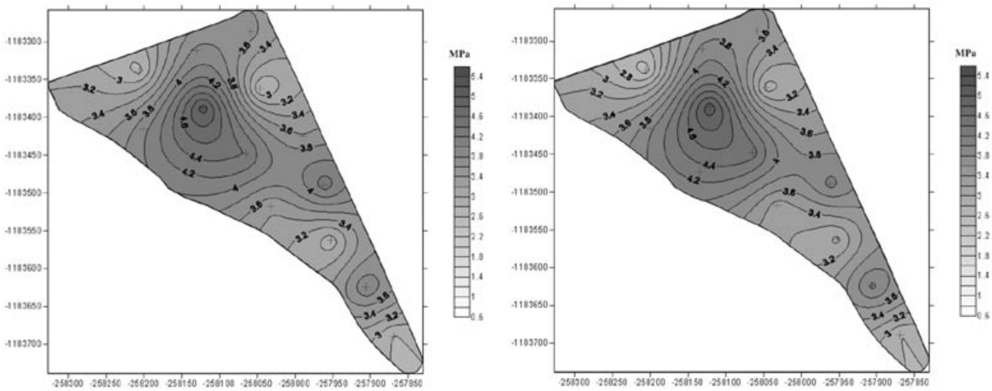
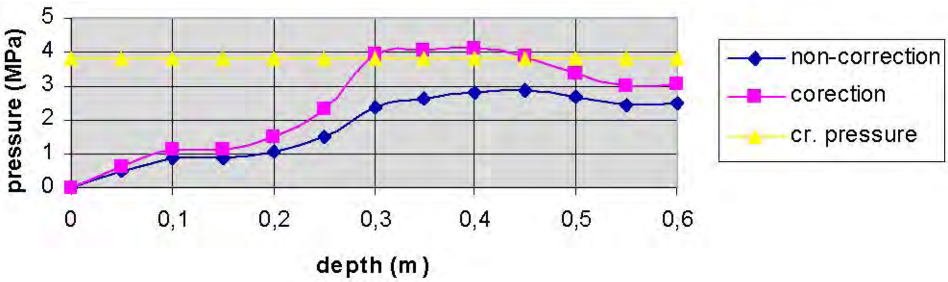
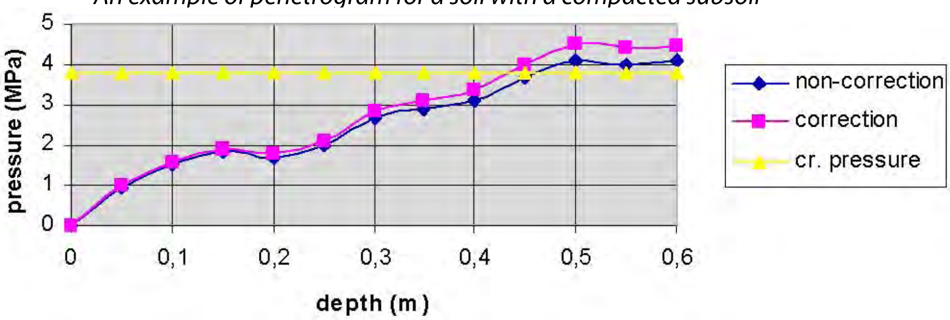


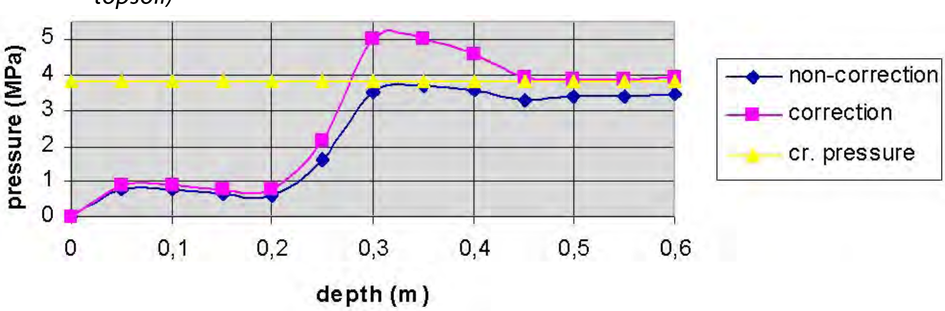
Figure 7 *An example of penetrogram for a soil with a compaction induced by tillage*



An example of penetrogram for a soil with a compacted subsoil



An example of penetrogram for a soil with a compaction of whole profile (except topsoil)



From the Table 1 and penetrograms (Fig. 7) is evident, that depth of the conventional technology is about 0.25 m. Within this topsoil horizon, we recorded values up to 1.78 MPa. Well-marked is „the edge" (transition) in depth 0.25 – 0.3 m, within which the biggest increase of soil penetration resistance was recorded (1.78 – 2.84 MPa). For the first time, the value of critical pressure (3.8 MPa) was exceeded in this transition horizon. In depth 0.3 m is a relatively well-marked spot of above-limit compaction in right top corner of Fig 4 (node 1). It is a place of access of agricultural machines from public road. This expressive compaction was detected up to the depth of 0.45 m. The compaction of the furrow bottom, caused by yearly tillage to the same depth, was detected practically in the whole investigated field. Interesting phenomenon was also observed in the central part of the field, where soil compaction is the most visible from depth of 0.4 to 0.6 m. This can be connected with erosion, soil texture and active processes of illimerisation.

CONCLUSIONS

On the basis of our measurements, the presence of process of soil compaction was proven within the investigated field. The degree of soil compaction, the depth of individual compacted layers and the area of soil compaction were determined. At the same time, the high spatial variability of soil compaction was detected.

The paper is a part of wider-orientated project, within which research of endangerment of soil by degradation processes is carried out. The aim of the project is to propose complex measures for amelioration of arable land.

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SOIL MAPPING IN MIDDLE SCALE (1:50 000), SEVERAL BASIC PRINCIPLES OF SOIL PARAMETERS AS REGIONALIZED VARIABLE IN 2DIMENSION

MAPOVANIE PÔD V STREDNÝCH MIERKACH (1:50 000), NIEKTORÉ ZÁKONITOSTI PÔDNYCH PARAMETROV AKO PRIESTOROVO ZÁVISLEJ PREMENNEJ V 2 DIMENZIÁCH

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ABSTRACT

The paper deals with soil mapping in middle scale (with regard on scale 1:50 000). The basic principles of soil sampling, area size, number of observations, accuracy and sampling scheme is researched. Theory of regionalized variable in two dimensions is applied in investigation of spatial variability of different soil parameter. The result of paper is determination of middle size area for representation in format A4 and A0, optimalization of sample size for mapping in scale 1:50 000. There are established limits of geostatical methods for extreme case of random variable and its distribution in two dimensions.

Keywords: sample pattern, soil mapping, geostatistics, regionalized variable, dimension

ABSTRAKT

Príspevok sa zaoberá problematikou mapovania pôd v stredných mierkach (s upriamením sa na mierku 1:50 000), pričom sleduje zákonitosti pôdneho vzorkovania so zreteľom na veľkosť územia, počet pozorovaní (vzoriek), presnosť a schému vzorkovania. Pri sledovaní priestorovej variability definovaného pôdneho parametra sa v príspevku vychádza z teórie priestorovo závislej náhodnej premennej a jej realizácie v 2D. Výsledkom príspevku je stanovenie strednej veľkosti sledovaného územia pre zobrazenie vo formáte A4 a A0, optimalizácia počtu pozorovaní pre mapovanie v mierke 1:50 000. Stanovuje limity použitia geoštatistických metód pre niektoré rozdelenia náhodnej premennej spolu s priestorovou distribúciou.

Kľúčové slová: schéma vzorkovania, pôdne mapovanie, geoštatistika, priestorovo závislá premenná, dimenzionalita

INTRODUCTION

The shape of investigated region changes with the parameter of area and perimeter. In 2D can get feature shape close to ring, square or rectangle. Compactness $C = 4*\prod*A/P^2$

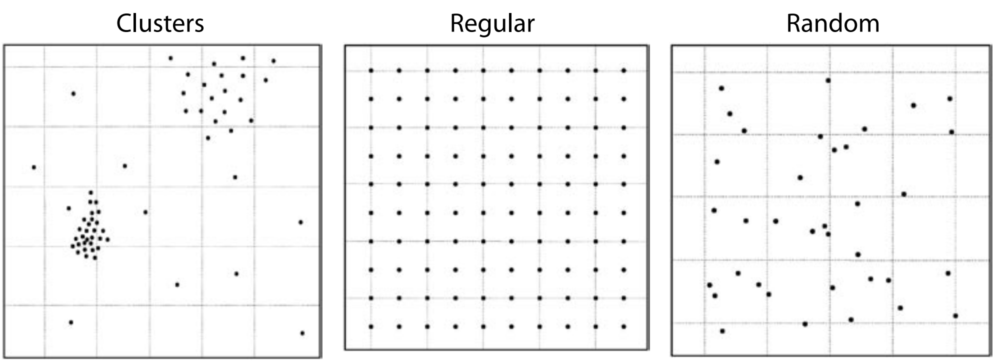
(where A is area and P is parameter of investigate shape) is one of the criterion how to express this shape (Tab. 1).

Table 1 *Values of compactness for several basic shapes*

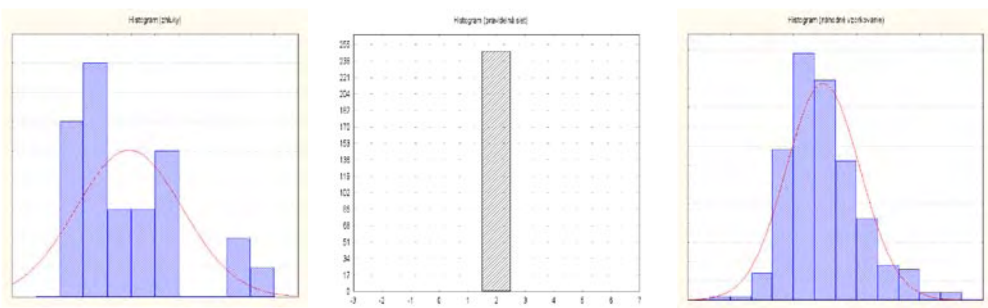
ring	square	rectange 1	rectangle 2 (b = 2a)	rectangle 3 (b = 4a)
1.00	0.79	0.76	0.70	0.50

The investigation of soil variation in space is based on terrain survey. This research requires good knowledge on soils and their distribution in landscape. The result of soil space variation is map, which represents much understanding graphic issue of space distribution in two dimensions. To obtain such a result, soil samples (represented by point features) distribution is needed. Basic sample pattern (sampling design) in plane and average distance of neighbourhood samples are realized in picture Fig.1:

Figure 1 *Basic sample pattern in plane (2D) and average distance of neighbourhood samples*



– cluster, regular and random sample pattern in 2 dimensions



– the histogram of average distance of neighbourhood samples

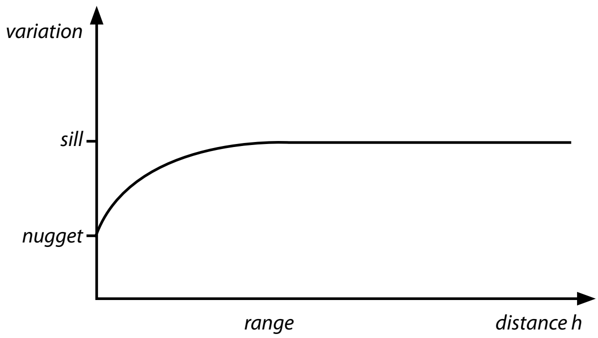
The sample distribution (sampling design) and number range of random variable are two basic criteria in understanding spatial variance of regionalized variable. Character of soil variable as random variable may bee continued (normal, lognormal, etc.) or discrete (binominal, regular, etc.) regarding to origin of observed parameter (Tab. 2).

Table 2 *Values and range of soil parameters*

Character of parameter	Absolute (measured)	Relative (measured)	Transformed (measured)	Descriptive (estimated)
Num. character	continued	continued	continued	discrete
Range of parameter	0 – num.	0 – 100 %	0 – 14	number of classes
Example of soil parameter	Content of Cox, N, P, Hg, etc.	% content of sand, silt, etc.	pH	Soil moisture, consistence, etc.

The basic concept of theory of random variable represents the semivariogram (Fig. 2), which is characterized by following parameters (Burrough P. A., McDonnell R. A., 1998, Pannatier, Y., 1996): monotonic increasing from lowest semivariance (nugget) to highest semivariance (sill) within this range of graduating. Semivarience $[\hat{y}(h) - \frac{1}{2n}\sum_{i=1}^{n}\{z(xi) - z(xi+h)\}^2]$ represent the condition, where differences between sites are merely a function of the distance between them. The realization of this conditions yields in 2dimensions to arealization characterized by concentric isolines. These isolines express the gradient between low and high value of observing variable.

Figure 2 *Semivariogram – central concept of geostatistical methods and his characteristics*



MATERIAL AND METHODS

Four cases of soil mapping (region Trnavska pahorkatina, Chvojnicka pahorkatina, region Lučenec Rimavská Sobota and region Zahorie) were analysed and compared to basic 2D topological features to obtain middle size (area in km^2 for scale 1:50 000) of territory in format A4, A0. Shape and length of study areas were calculated after the digitizing as well as the XY position of point samples. Regular sample pattern and binominal distribution of variable were projected to demonstrate the limitation of theory of regularized variable in two dimensions.

RESULTS AND DISCUSION

There are several basic shapes in two dimensions that can express both area and perimeter of investigated feature (Tab. 3). Every simple feature in 2D approximate these shapes, just like the investigate regions (Tab. 4):

Table 3 *Example of study regions and their shape attributes*

	area (km²)	perimeter (km)	compactness
region_Trnava	1 696.66	217.52	0.45
region_Chvojnica	719.09	130.05	0.53
region_Zahorie	1 097.20	221.40	0.28
region_Lucenec Rimava	1 255.64	226.35	0.31

Middle size of investigated area mapped in format ISO A0 refer to 1 250 km² (half the ISO A0 format) but in praxis has to bee smaller due to naturally elongated shape. All three regions (Trnava, Zahorie and Lucenec – Rimava) are out of border in ISO A0 due to this reason. Soil sample distribution (sample design) refers to random (regular) sample pattern, with average distance of neighbourhood samples 1, 4 km and number of samples 1/2 – 3 km². Position accuracy of samples refer to 186 m (average position error) in free scale 1:50 000 mapping (HUTÁR, V., 2001). All mentioned characteristics are represent in following table:

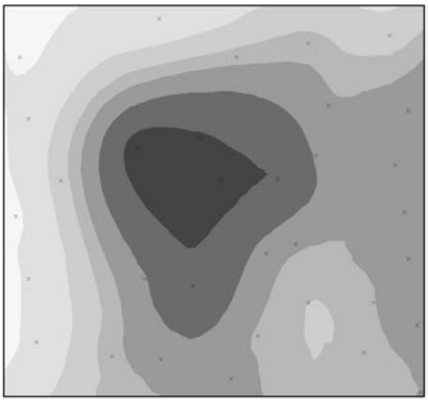
Table 4 *Basic characteristics of soil sampling in middle scale 1:50 000*

Map classify-cation regarding to technical content	Target map scale	Average mapping error in target map scale	Number of samples N/km²	Middle size of territory in format A4	Middle size of territory in format A0	Average distance of neigh-bourhood samples
semidetail	1 : 50 000	186 m	1/2 – 3 km²	78 km²	1 250 km²	1.4 km

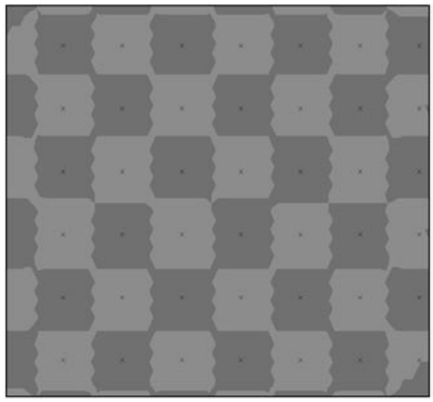
Theory of regionalized variable assumes condition of normal (lognormal) distribution of investigated parameter. To search for spatial dependence of investigated parameter in study area, random sample distribution is provided. Spatial dependence of investigated parameter leads to semivariogram creation, which serves for value estimation in unsampled location. All interpolation methods (determistic and stochastic) use weighed averaging of neighbourhood samples to estimate value in unsampled location. The weighing parameters are derived from mathematical function regarding selected method (IDW, spline, kriging etc.) Regular sample design of binominal variable with scatter distribution demonstrates the situation, when variable shows no spatial dependence. There are no values of range and sill in semivariogram analysing (Fig. 3a, b). The value estimation in unsampled location is not the function of neighbourhood values. The topology of such object is very close to fractal features (for example Koch curve, Sierpinski carpet) which are the true fractals in the sense of self similarity and scale effect (based on fractal geometry MANDELBROT, B., 1977). For this reason, we don't expect the effect of arealization (creation of concentric graduating isolines).

Figure 3 *Example of **a)** spatial dependence and **b)** non-dependence of variable in 2-dimensions with relevant semivariograms*

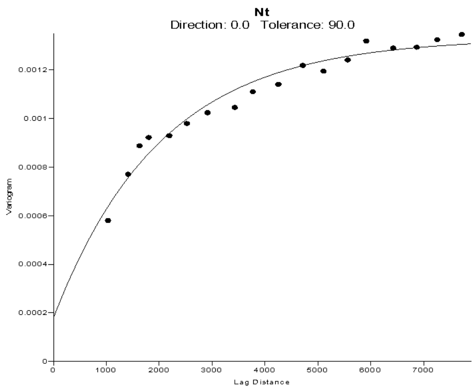
a)



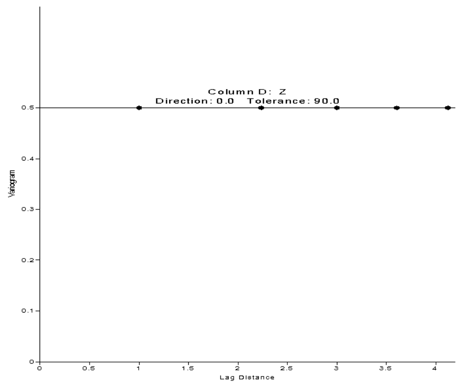
b)



a)



b)



CONCLUSIONS

There is a lot of work in map creation regarding the condition of terrain survey, soil sampling and spatial analyzing. We need to know the size and shape of observed region to set up the number of observation for efficient analyzing. The reference scale 1:50 000 allows interpretation of investigated parameter regarding to relative large area with explanation of basic landscape relationships. Graphical issue and analysing of spatial information represented by soil map creation provide efficient tool for interpretation of larger relationships within reference scale. Basic principles of spatial data analyzing are applied for extreme cases to investigate the limits of their utilization.

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SOIL ERODIBILITY IN THE CONDITIONS OF SLOVAKIA

Erodovateľnosť pôdy v podmienkach Slovenska

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ABSTRACT

Soil erodibility – is a function of the soil ability: to absorb water, to minimise surface runoff and to act as soil resistance against falling raindrops and water flux. Soil structure stability and its texture are useful indicators of the soil capability to resist erosion. Heavy clayey soils can be structurally labile to falling raindrops and quick water logging as well as they frequently include easily releasable and transportable soil particles causing high erodibility of the soil. Dispersed – saline soils are also highly vulnerable to the soil erosion. However, the soils with high amount of organic matter are less erosive than those with low organic matter content.

Keywords: soil erodibility, K-factor, soil texture, soil structure,

ABSTRAKT

Erodovateľnosť (erodibilita) pôdy – je funkciou schopnosti pôdy absorbovať vodu a minimaliozovať povrchového odtoku a jej odolnosti voči rozrušovaniu dopadajúcimi kvapkami a tečúcou vodou. Stabilita pôdnej štruktúry a jej textúra sú užitočnými indikátormi schopnosti pôdy odolávať erózii. Ťažké ílovité pôdy bývajú štruktúrne nestabilné voči dopadajúcim kvapkám a rýchlemu zamokrovaniu. Na povrchu často vytvárajú ľahko uvoľniteľné a transportovateľné pôdne častice, spôsobujúce vysokú erodibiltu pôdy. vysokú erodibilitu. Dispergované zasolené pôdy sú tiež náchylné na eróziu. Avšak pôdy s vysokým obsahom organickej hmoty vykazujú menšiu erodovateľnosť než pôdy chudobné na organickú hmotu.

Kľúčové slová: pôdna erodovateľnosť, K-faktor, pôdna zrnitosť,

INTRODUCTION

Soil erosion is the most serious degradation process that often leads to total fine-soil runoff and soil removal. Any other process causes effects for such a long time, in so large scale, and leads to total destruction of massive soil areas. In Slovak Republic the soil erosion expanded to more than a half of the farmland. Erosion does not cause only yield decrease and economic loss but it also brings water husbandry, energetic and ecological harm.

As the most significant parameter for the erosion risk evaluation together with factor R (rain affectivity) is the K-factor. These factors are principal parameters formulating relation between the rainfall amount (as erosion factor) and soil (as submitted by erosion factor). Their result causes soil loss at a concrete rainfall amount, as well as loss in the soil properties by standard sloping, slope length, and surface treatments. Soil erodibility is the function of the rainfall water absorption intensity in the soil and the soil resistance to superficial flowing water. The most significant soil properties for erodibility assessment are soil permeability, texture, organic matter content, mould structure, etc. The soil structure stability and the texture represent the most significant soil indicators to keep the soil functions.

MATERIAL AND METHODS

The soil, which is the subject of water action, (as an erosion factor) has many typical properties determining its resistance to erosion. In the case of the drop erosion, there are applied particular properties affecting partial mutual cohesion. In the case of the total rainfall erosion, soil resistance affects soil infiltration capacity. Direct influence affects soil particles cohesion. Indirect is represented by properties that have an effect on soil infiltration capacity. The greater the soil particle cohesion, the more energy is necessary for their release, so that they can get into the runoffs. On the other hand the greater soil infiltration capacity, the smaller is the runoff and its erosive and transportation ability.

Resulting from theoretical analyses, and experiments, rainfall water infiltration is primarily a function of textural composition, soil structure and moisture. The soil resistance to water destruction effects is function of organic matter contents and saturation of the soil sorption complex. The soil resistance to transportation activity depends mainly upon the textural composition.

Soil erodibility qualitative formulation is very demanding with aspects to participating factors amount. Most of authors consider soil texture as a basic property affecting soil structure and porosity, and jointly soil infiltration capacity.

When investigating textural composition effect on erosion intensity, it was found out that the sandy soils were least vulnerable to erosion. They are characterised by very permeable and less cohesive status. The coarser is the sand the resistant is the soil. The highest cohesion and erosion resistance have also clay soils that in spite of the low infiltration capacity have high cohesion because of high clay fraction content. The loamy soils are less resistant to erosion. They are medium permeable and considerably less cohesive due to high amount of slit particles. The lowest resistant can be found at soils developed from loess loams due to low infiltration rapidity and low content of the cementing particles (Antal, 1989).

In American literature, there was mentioned that soils with high clay fraction content have low value of the K-factor that is around 0.05 – 0.15. In sandy soils the K-factor ranges from 0.05 to 0.2. The loamy soils have K-factor 0.25 – 0.40. High K-factor values, above 0.4, possess soils with high dust particles content.

Soil resistance to erosion depends also from the soil structure. Soils with high structure stability have high infiltration rate and well resistance to destructive superficial runoff effects. Formation and maintenance of the soil structure stability is conditioned by the organic matter presence. 2 % of organic matter decrease causes permanent soil aggregates destruction (Kirkby, Morgan 1984). Organic matter content reduces soil erodibility, as well as increases soil infiltration, whereby reduces surface runoff and finally the resulting erosion.

Soil moisture also determines factor for erosion. High moist soils culminate in infiltration rate and soil aggregates are less resistant to washing out. The aggregates with lower moisture than hygroscopic index substantially decrease their resistance to washing out (Kutílek, 1978).

Soil erodibility factor

For soil erodibility assessment, there are most often used soil characteristics, e.g. texture, structure, organic matter content, etc. In literature devoted to soil erosion, there is mentioned relatively large number of methods for erodibility determination. However, the most frequently used is the method of Wischmeier, Smith, 1978, based on the input data on soil texture and structure, organic matter and soil profile permeability.

The most simple erodibility expression is textural index by (Zachar, 1996):

$$En = \frac{\%\ sand + \%\ silt}{\%\ clay}$$

where E_n = soil erodibility

As soil texture is only one of many parameters effecting soil erodibility, there was introduced factor of soil erodibility (K-factor) respecting many other important characteristics as organic matter content, quality of soil, structure and soil permeability.

Erodibility factor of Wischmeier and Smith (1978) is defined as a soil loss in $t.ha^{-1}$ per the unit of rainfall factor R at the standard plot – black fallow with slope of 9 % and sloping length of 22.13 m.

K-factor can be determined by several procedures. If content of the silt fraction and sand (0.001 – 0.1) is not higher than 70 %, then it can be calculated by the formula

$$100K = 2.1M^{1.14}\ (10^{-4})(12 - a) + 3.25(b - 2) + 2.5(c - 3)$$

where M = textural parameter [(% silt + % very fine sand) . (100 – % clay)]
a = organic matter (%)
b = soil structure class (cods 1 – silt, 2 – grained, 3 – crumby, 4 – platy)
c = class of soil profile permeability

Soil permeability classes

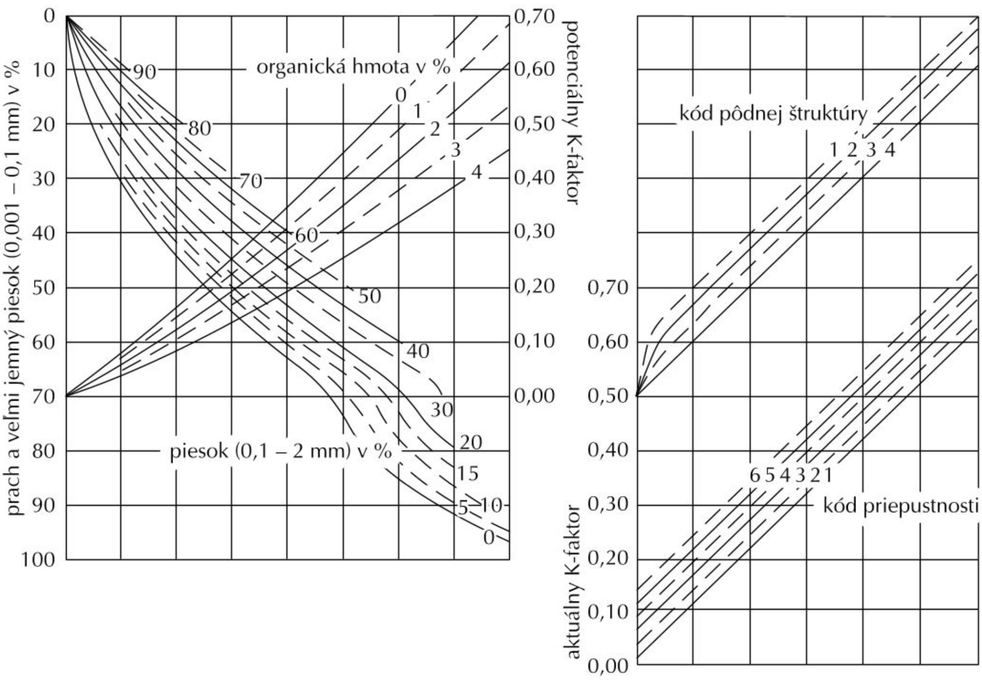
Soil permeability	Permeability design	K ($cm.h^{-1}$)	Soil characteristics	Soil moisture characteristics
1	very high	>15.0	Deep, well drained, sands, Chernozems of loess	Soil stays moist only for several hours
2	high	5.0 –15.0	Structural sandy loams to loamy sand, Chernozems and Orthic Luvisols on loess	Soil stays moist only for several hours
3	medium	1.5 – 5.0	Subsoil with strongly developed structure or loam	Soil stays moist only for several days
4	moderate	0.5 – 1.5	Medium permeable with cubic or weakly developed cubic (polyedric) structure	Soil stays moist more than week
5	low	0.15 – 0.5	Under permeable topsoil is compact clay or silt	Soil stays moist more than week
6	very low	< 0.15	Hard compact clay	Soil stays moist more than week

It's possible to read K-factors values directly from the monogram, but it is necessary to make correction to SI elements by multiplication with 1.31 coefficient (Wischmeier, Smith, 1978).

Needed data for this calculation are:

- % silt Φ = 0.002 – 0.1 mm
- % sand Φ = 0.1 – 2.0 mm
- % organic matter in topsoil
- soil structure data
- infiltration data of whole soil profile

Figure 1 *Nomogram to calculate K-factor*



RESULTS AND DISCUSSION

Determination of the erodibility factor mostly depends on the soil texture. Each area of the soil texture, as a whole, can be described by the data of fine earth (fine-grained soil) gained from an average sample. The main basic data for the calculation are: percentage content of clay, silt, sand and organic matter, following soil structure data coded in scale of 1 to 4 and capability of the infiltration data of the whole soil profile coded in scale of 1 – 6. When all these date are available, it is possible to calculate K-factor by the formula ($100K = 2.1M^{1.14}(10^{-4})(12 - a) + 3.25(b - 2) + 2,5(c - 3)$), initiated before, or it is possible to take it by nomogram. When some data are missing, soil erodibility K-factor can be very approximately estimated by the soil ecological units – BPEJ (main soil unit: HPJ – third and fourth place in 7-places code of BPEJ) and parental material (from General soil survey-KPP).

In Czech Republic, there are determined orientation values of K-factor for all main soil units (HPJ) of the Soil Quality Soil Information System (JANEČEK, 2002), except for some soil types with very variable properties.

Šarapatka, Dlapa, Bedrna (2002) present orientation K-factors value for selected soil type and soil texture in the Table 2.

Table 2 *Orientation value of the K-factor vulnerability for some soil texture and soil type to erosion*

Soil texture	K-factor	Soil type	K-factor
sandy	0.10 – 0.20	Cambisol	0.25
loam-sandy	0.21 – 0.30	Chernozem	0.45
sandy-loam	0.31 – 0.40	Luvisol	0.50 – 0.55
loam	0.41 – 0.50	Albic Luvisol	0.60
clay silt	0.51 – 0.70		

The K-factors values are calculated from average attributes of the individual soil types and soil structures. In summary, sandy (light) Luvisols will posses lower K-factor as the table demonstrates, on the other hand Cambisols with loamy will possess higher K-factor value. From the summary, clay soils and for Luvisoils in comparison with more sandy soils (for example Camisoles) have higher risk of the water erosion.

Mališel determined orientation values of the soil erodibility factor in Slovakia (1992) on the basis of 853 samples from the General Soil Survey (KPP). The K-factor was calculated according to nomogram and a given formula. In the set of HPJ with associated of the K-factor value some soil types and subtypes are missing. There are especially Fluxions, Mollie Fluxions and Chernozems from alluvial sediments.

To determine the K-factor value for missing soil, there were used all available data of texture organic matter content from laboratory analyses of these soil types from the General Soil Survey (KPP) database – 2 265 samples of Fluxions, 1 804 samples of Mollie Fluxions and 1 723 samples of Chernozems from lowland soils.

Representative properties of the lowland soils of Slovakia (according to KPP) to calculate the K-factor

Lowland sandy carbonate soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
01,19,35	9 – 14	4 – 6	4 – 6	1 – 5	40 – 55	30 – 45	0.9 – 2.5

Lowland sandy soils (without carbonate)

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
05,21,40	6 – 10	2 – 4	3 – 6	1 – 3	40 – 55	35 – 50	0.9 – 1.8

Lowland loamy carbonate soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
02,17,34, 36,19,	33.3 – 39.0	10.1 – 25.6	20.1 – 28.0	27.4 – 35.8	24.6 – 36.2	1.0 – 3.7	1.5 – 3.3 (FM)
							1.5 – 5.9 (others)

Lowland loamy soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
06,15,22	29.5 – 54.0	16.6 – 26.0	23.6 – 27.4	23.0 – 34.5	17.9 – 27.4	2.8 – 8.7	

Lowland clay carbonate soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
04,20,18,22	60 – 78	28 – 40	20 – 32	12 – 23	8 – 10	2 – 12	1.8 – 6.2

Lowland clay soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
07,23,24,41	59 – 86	27 – 38	25 – 47	13 – 35	0.1 – 7.8	0.2 – 3.1	1.7 – 3.2

Wet (gleic) carbonate soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
11,12,13,26, 27,28,	42 – 62	18 – 29	22 – 23	25 – 32	9 – 23	1.5 – 7.0	1.5 – 6.4

Wet (gleic) non-carbonate soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
11,12,26	42 – 56	18 – 25	22 – 32	25 – 29	14 – 18	2.2 – 3.2	1.4 – 5.8

Lowland superficially waterlogged soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
08,09	35 – 37	10 – 12	24 – 25	48 – 49	12 – 14	2.0 – 3.0	1.2 – 2.6

Lowland shallow soils

Main soil unit	Texture content (%)						Content of humus (%)
	< 0.01	< 0.001	0.001 – 0.01	0.01 – 0.05	0.05 – 0.250	> 0.250	
14,32,33	17 – 40	3 – 11	13 – 22	25 – 35	26 – 32	3 – 25	1.2 – 2.6

Table 3 *Informative values of the K-factor for soils of Slovakian lowlands*

Soil Subtype Signature	Main Soil Unit Code	Characteristics*	K-factor
Fam^{e}	01	Calcaric Fluvisol, sandy	0.15
FMm^{c}	02	Calcaric Fluvisol, loamy	0.31
FMm^{c}	03	Calcaric Fluvisol, clayey	0.29
FMm^{c}	04	Fluvisol (Eutric or Dystric), strongly clayey	0.34
FMm	05	Fluvisol (Eutric or Dystric), sandy	0.25
FMm	06	Fluvisol (Eutric or Dystric), loamy	0.31
FMm	07	Fluvisol (Eutric or Dystric), clayey	0.34
FM$_{G}$	08	Gleyic Fluvisol, loamy (at surface stagnic)	0.26
FM$_{G}$	09	Gleyic Fluvisol, clayey till strongly clayey (at surface stagnic)	0.29
FM$_{G}$	11	Gleyic Fluvisol, loamy	0.34
FM$_{G}$	12	Gleyic Fluvisol, clayey	0.26
FMp	13	Gleyic Fluvisol till pelic, strongly clayey	0.26
FM	14	Fluvisol shallow	0.16
FM	15	Fluvisol with mellow subsoil	0.31
ČMč	16	Haplic Chernozem, sandy, drying	0.20
ČMč^{c}	17	Haplic Chernozem mostly calcaric, loamy	0.30
ČMč^{c}	18	Haplic Chernozem, mostly calcaric, clayey	0.26
ČAm^{c}	19	Mollic Fluvisol, mostly calcaric, loamy, with favourite water regime	0.23
ČAm^{c}	19	Mollic Fluvisol, sandy, with favourite water regime	0.22
ČAm^{c}	20	Mollic Fluvisol, mostly calcaric, clayey	0.25
ČAm	21	Mollic Fluvisol, sandy	0.23
ČAm	22	Mollic Fluvisol, loamy	0.20
ČAm	23	Mollic Fluvisol, clayey	0.25
ČAm	24	Mollic Fluvisol, till pelic, strongly clayey	0.27
ČAG	25	Mollic Gleysol, mostly calacric, sandy	0.20
ČAG	26	Mollic Gleysol, mostly calcaric, loamy	0.22
ČAG	27	Mollic Gleysol, mostly calcaric, clayey	0.20
ČAG	28	Mollic Gleysol, mostly calcaric, strongly clayey	0.24
ČAG	28	Mollic Gleysol, mostly non-calcaric, strongly clayey	0.24
ČM	32	Haplic Chernozem, shallow, loamy, clayey	0.20
ČA	33	Mollic Fluvisol, shallow, loamy, clayey	0.21
ČMm^{c}	34	Calcari-Haplic Chernozem from alluvium , loamy or clayey with mellow subsoil, drying	0.21
ČMm^{c}	35	Calcari-Haplic Chernozem from calcareous alluvium, sandy	0.15
ČMm^{c}	36	Calcari-Haplic Chernozem from calcareous alluvium, loamy	0.39
ČMm	40	Haplic Chernozem from arenic parent material, sandy	0.15

* Signature of the main soil units is according to the Morphogenetic Soil Classification System (1991) and nomenclature is introduced according to World Reference Base for Soil resources (1998)

CONCLUSION

Usage of soil, since the ancient time, has had negative impact on soil quality, which increases with the increasing intensity. The soil degradation is the second oldest process of the environment degradation caused by a man. With increase of population the erosion was spreading. At present, soil degradation process has reached alarming intensity and become one of the most serious problems of the environment. The soil conservation problem belongs to the actual environmental tasks.

Among the soil-gradation processes, soil erosion has special position. In spite of the fact that soil chemical pollution can be very dangerous, it is possible to say that erosion is the most serious degradation process very often ending in total gentle soil runoff and soil liquidation. Other processes do not act as a long-term, as well as upon such large areas. Besides, any other process has had such destruction impact on so immense soil area as erosion in many parts of the world.

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ASSESSMENT, DESCRIPTION OF SOIL PROFILE IN THE CHEMICAL WASTE DUMP AND ITS IMPACT ON URBAN PLANNING

ZHODNOTENIE A POPIS PÔDNEHO PROFILU SKLÁDKY CHEMICKÉHO ODPADU A JEJ VPLYV NA URBÁNNE PLÁNOVANIE

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ABSTRACT

The soil information as one of the basic components of cities environment is needed for correct management of soil maintenance system in using urban areas. It intervenes in decision and control processes of planning cities development. Urban areas, influenced by contamination, degradation or erosion are inevitable to be monitored for their negative impact on urban (mainly children) population. The soil element has been neglected until now. Environment in cities of Slovakia has been monitored only through water and air elements. Methodology and monitoring of the soil element in the majority of European cities is equal with monitoring of air and water element. Therefore, elaboration of detailed methodology and monitoring of soil element is inevitable for Slovak urban areas (example city Bratislava). Contributions could be then applied in other Slovak cities. There is an accumulation of different atmospheric emissions of SO_2, NO_2, heavy metals and other pollutions from industrial, traffic and mining activities in the soils. It was established that anthropogenic activity changes not only chemical properties, but also morphological, physical and microbial properties of soils.

Keywords: anthrozem initial, chemical waste dump, NEL, PAH, ground waters

ABSTRAKT

Pôdna informácia ako jedna zo základných zložiek environmentu miest je potrebná pre správne riadenie systému udržateľnosti pôdy pri využívaní urbanizovanej krajiny a vo veľkej miere zasahuje do rozhodovacích a riadiacich procesov plánovania vývoja miest. Mestské územia ovplyvnené kontamináciou, degradáciou, či eróziou pôdy je nevyhnutné monitorovať pre ich negatívne účinky na mestskú (hlavne detskú) populáciu. Životné prostredie slovenských miest sa doteraz monitoruje cez vodnú zložku a ovzdušie. Pôdna zložka bola doteraz neprávom zatracovaná. Vo väčšine európskych veľkomiest je vypracovaná metodika a monitoring pôdnej zložky, ktorej význam je rovnocenný v porovnaní s monitoringom ovzdušia a vodnej zložky. Preto je nevyhnutné vypracovať podrobnú metodiku a monitoring pôdnej zložky i v slovenskom meste (príklad mesta Bratislava), ktorej prínosy budú v konečnom dôsledku aplikované v ostatných mestách. V pôde sa akumulujú rôzne atmosférické emisie SO_2, NO_2, ťažké kovy a ostatné polutanty z priemyselných, dopravných a bansko-ťažobných činností. Bolo zistené, že antropogénnou činnosťou sa menia nielen chemické vlastnosti pôdy, ale i morfologické, fyzikálne a mikrobiálne (nadmerný výskyt patogénov atď.) vlastnosti.

KĽÚČOVÉ SLOVÁ: antrozem iniciálna, NEL, PAU, podzemná voda, skládka chemického odpadu

INTRODUCTION

Mentioned locality is located in suburb Bratislava-Vrakuňa, where chemical waste dump was operated concerning some manufacturing activities of the Chemical factory Juraja Dimitrova, š.p., Bratislava (CHZJD). It presents an old ecological burden at present. Morphological performance of this territory as well as available information reveal that so-called Mlynske rameno was located here in the past. Its existence is documented in map presentation since 1919. Mlynske rameno was not a part of river-basis of Dunaj in this period. Only ground water flowed from eastern and south-east side of the city in this arm of the river. Ground water probably did not contain major share of floating and bed that would contribute to creation of bottom marshy sediments fulfilling insulant function in the future.

Mlynske rameno served also as wastewater drainage from Dynamit Nobel chemical production until the 60s in the 20th century. Left-hand arm is still visible. Probably this factor and neighborhood of CHZJD, Bratislava had major influence in creating chemical waste dump in this area. Concerning the past legislation, creation of impervious seal layers was not needed for this dump. However, it showed as a significant ecological problem in the future. The dump operated for almost 13 years and ended at the end of 1979. The thickness of waste was 1.5 – 2.5 m. Almost 90 thousand m^3 of waste was spread on 4,65 ha. Recultivation of dump started in 1980. Its essence was covering existing waste with inert material. As covering material, the soil from excavation site in Bratislava (Istropolis) was used. The general thickness of this soil is 2 – 3 m. Humus organic matter (approximately 22 000 m^3) was taken from the site of Gabcikovo water dam work.

The ground of this locality is created by quaternary fluvial gravel-sand deposits from the Danube River. Ground waters are created especially by infiltration of Danube water here. Their quaternary horizon has a free surface. Ground water flow is relatively intense in this location. Direction of flow is from north-west toward south-east. Concerning ground water contamination, water level and its fluctuation under the dump play significant role. Ground water includes relatively high content of disulphate (average 166.3 $mg.l^{-1}$), chloride (average 72.6 $mg.l^{-1}$), from organic materials increased content of NEL (average 0.63 $mg.l^{-1}$). The specific organic materials were identified. The most significant values belong to cyclohexane and benztiazol derivatives. NEL soil pollution was identified in 1997 at 61.8 – 38 600 $mg.m^{-3}$. The highest values were found in depth of 7 – 7.5 m. Disulphate volume in ground water reached 1 383 $mg.l^{-1}$. Intensive pollution at the depth of 40 m was published in work of J. TKAC, 1995. Increased pollution toward the surface came after opening of Gabcikovo dam. Regional raise of ground water contributed to the raising of the ground water beneath the dump. From 1996, ground water episodically comes to waste and, at the same time, invades zone of conjunction of pollution to sedimentary environment under the whole dump area.

Figure 1 *Heterogeneous waste establishing anthropogenic activity on dump chemical waste in locality Bratislava – Vrakuňa*

MATERIAL AND METHODS

The soil test pit was drilled according to the project APVT-27-022602 "Urban soils as environmental indicators of the life quality in the city (a Case of the city Bratislava)". Visual demonstration of the soil profile was presented during the international conference "Soil Anthropization VIII" on 28^{th} – 30^{th} in September 2004 in the Soil Science and Conservation Research Institute in Bratislava. The name of the test pit was set according to described horizons. Presented pit represents soil with anthrozem initial Adi-horizon (established by human) consisting of heterogenous displaced anthropogenic materials and soils mostly of building origin (brick, glass, plastic, iron linkage, glass cottonwool, thick anthromaterial). Soil created by building waste, of various technogenic stack and dumping hopper, is marked by weak compaction material, lower value capacity and specific weight. It is characterized by excessive permeability, instability of the water admissibility and occurrence of poruses matrix with high levels of eutrophication and nitrification. Aggregate soil structure is broken and in general soil material is in non-aggregate condition (massive or elementary).

Physical characteristics are heterogeneously conditioned by properties of anthropogenic substrata. On the basis of physical analysis grain fraction of soil, it has been determined according to FAO. By means of triangular diagram the percent representation of sandstone, siltstone and claystone fractions was determined. According to the percent representation of grain categories, according to Novak, classification groups were stated. Chemical as well as physical analyses were carried out in laboratories of Soil Science and Conservation Research Institute. Concerning chemical parameters, pH in H_2O, pH in $CaCl_2$, content of polycyclic aromatic hydrocarbon (PAH), content of polychlorine biphenyl (PCB), content of $CaCO_3$ in percentage, content of Cox in percentage were analyzed. Content of polycyclic aromatic hydrocarbon 1 (PAH1) is created by 16 compounds, content of polycyclic aromatic hydrocarbon 2 (PAH2) by 12 compounds according to Soil Protection Act num. 220/2004 (Slovak Republic).

RESULTS AND DISCUSSION

Table 1 *Textural analyse*

Sample	> 0.25 mm	0.25 – 0.05 mm	0.05 – 0.02 mm	< 0.02 mm	0.02 – 0.002 mm	< 0.002 mm
Adi	26.92	39.9	10.23	22.94	12.18	10.76
C1	19.24	37.92	14.94	27.89	12.13	15.76
C2	30.19	33.09	12.19	24.53	11.13	13.4
C3	34.45	33.87	9.57	22.11	8.15	13.95
C4	31.89	39.44	7.91	20.76	8.56	12.2

Table 2 Chemical analyse

Sample	ph in H_2O	ph in CaCl	$CaCO_3$ (%)	Cox (%)	Nt_{tot}
Adi	7.97	7.17	1.92	1.91	1 343
C1	8.17	7.17	0.96	1.22	
C2	8.37	7.59	1.43	0.8	
C3	8.39	7.62	0.66	0.47	
C4	8.45	7.79	2.86	0.64	

Table 3 Organic compounds analyse

Sample	Content PAH1	Content PAH2	Content PCB	Content of NEL
Adi	38.8	38.8	0.015	130
C1	8	8	2.1125	860
C2	21.1	20.8	not detected	110
C3	3.3	3.3	not detected	100
C4	3.3	3.3	not detected	290

Concerning organic contaminants in soil of Slovak Republic, polycyclic aromatic hydrocarbons (PAH) are especially monitored. PAH are kind of chemical substances that can cause cancer. These substances are able to change DNA structure of human being and so activate changes in the genetic information, which can result in serious oncological diseases, particularly when an individual is exposed for a long time to their activity. PAH occur in almost all elements of live nature, because they are continually created by the activity of warmth caused by decomposition of live matter, especially during anaerobic condition (exclusive oxygen). The highest concentration of PAH and their similar compounds are found in food grown near industrial factories, or in roasted, grilled, smoked, or else heated food. PAH have a character of wide area pollution that influences not only the character of environment of mentioned location. Other organic compounds have tendency of point pollution. This is proved by research on contaminated soils and its results.

Measured data of the organic compounds prove that limit values of polycyclic aromatic hydrocarbon (PAH) were exceeded in all samples. Limit value of dangerous substances according to the law No. 220/2004 on conservation and using agricultural soil is 1 mg/kg of dry substance PAH. The highest values are in samples Adi and C2. Limit value in soil horizon Adi is exceeded by 38 mg/kg, in horizon C3 by 20 mg/kg. Contents of polychlorinated biphenyls (PCB) exceeded limit value in soil horizon C1 – 2.1125 mg/kg. Limit value is stated at 0.05 mg/kg. Polychlorinated biphenyls are oily fluids that can occur in 209 various combinations of compounds. They were used as fillings of transformers, condensers, as hydraulic fluids, cooling mediums, colour ingredients, grease and others. Concerning their chemical character, PCB represent serious problem for human health and environment. They are strongly bioaccumulating. That means that they are accumulated in living organisms. Content of non-polar hydrocarbon (NEL) was highly exceeded in all soil horizons. The highest value was proved in soil horizon C1 (860 mg/kg). Limit value NEL is stated at 0.1 mg/kg. Water level and its fluctuation beneath the dump cause the highly exceeding values of PAH. Increased level of ground water causes penetration of chemical substances into the soil horizon.

Soil profile description (Anthrozem initial calcareous contaminated)

Ad (0 – 2 cm) – 10YR 6,5.5/4, dry, slightly hard, friable, sandy loam, weak subangular blocky, common roots, calcareous, 15 % presence of mixed anthro-gravels, distinct transition to

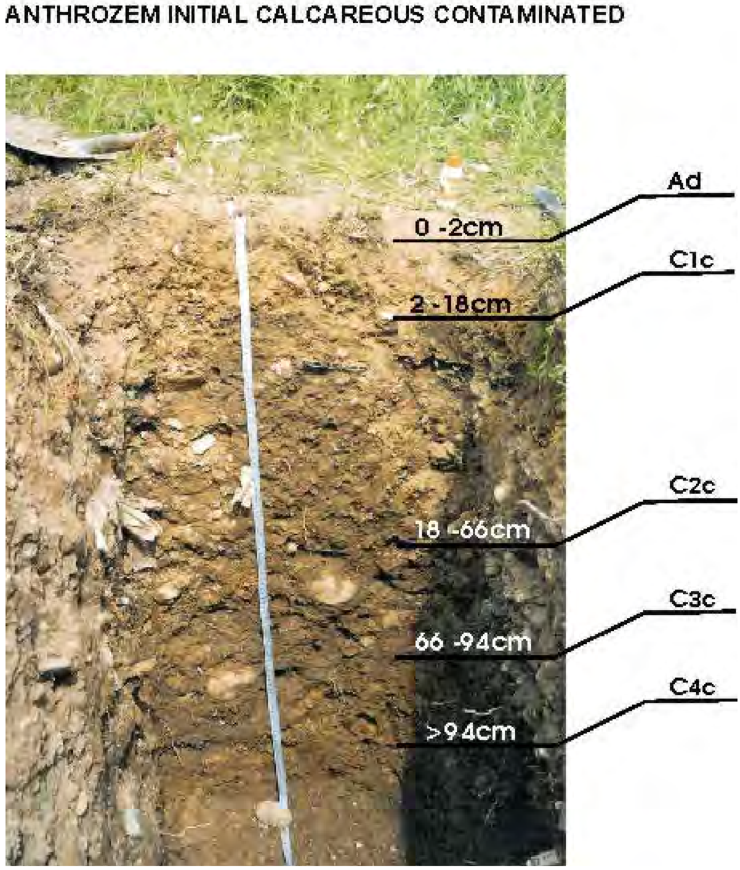
C1c (2 – 18 cm) – 10YR 4/6, 4/3, moderate moist, firm, sandy loam, weak subangular blocky to structureless, common roots, calcareous, 50 % tiny gravel, presents of fragments of brick, glass, plastic, wood, rarely coarse gravel, distinct transition to

C2c (18 – 66 cm) – 2,5Y 4/3, moderate moist, firm, sandy loam, structureless, few roots, calcareous, 60 – 70 % of gravel, 60 % tiny gravel, 15 % coarse gravel, distinct transition to

C3c (66 – 94 cm) – 2,5Y 4/4,5, moist, firm, loam to sandy loam, structureless, few roots, calcareous, 10 % of boulders, 40 – 50 % medium coarse gravels, presence of artefacts as building material, distinct transition to

C4c (>94 cm) – 10YR 6/5, 6/8, moist, firm, sandy loam, structureless, redox mottles > 25 %, few roots, calcareous, anthromaterial presence (brick, wire), gravel < 40 % (2 mm)

Figure 2 *Soil profile of dumpsite Vrakuňa classified as Anthrozem initial calcareous contaminated, deposit form, loamy, sandy, from technogenic material*



CONCLUSIONS

Following the analysis provided in the dump locality, we can assume, that it represents significant source of ground waters pollution. According to quality monitoring of ground waters for the needs of HOPV Slovnaft (Vilinovic, V. 2000) the pollution with aliphatic chlorinated hydrocarbon of 4 km^2 area is located south of the dump. Furthermore, there were found high levels of sulphated chloride, increased content of lead and non-polar extractable substances. There were also organic substances mainly chloridization hydrocarbon (cyclohexane) and benztiazol. Fluctuation together with water surface escalation causes contact of these substances with the soil element. Soil contamination is so spread that it is impossible to be completely removed. Certainly all the possible measures of decontamination have to be carried out in the most polluted areas. A garden area is located near the dump and its users use the contaminated water to sprinkle their vegetables. This can have negative impact on human organism. Certainly there is a need to decrease impact of contamination on health of inhabitants living in this locality. There is also a need for taking the preventive measures in the future development of urban planning of the Bratislava city (legislative, institutional, ecological, technical etc) concerning similar dump creation that negatively influence not only human society, but also the environment. In that case, there are two ways of disposal or dump influence reduction. First, the stabilization of dump in situ is preferred – subsoil isolation. Second, the total land rehabilitation is preferred – waste from dump is transported to another dump that is in compliance with all current legislative acts. More effective, economically and financially, is its utilization for the defined purposes – commercial centre, parking and others.

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COMPARISON OF PODZOLIC SOILS IN DIFFERENT GEOGRAPHICAL AND CLIMATIC CONDITIONS, AND PROBLEM OF THEIR CLASSIFICATION

Porovnanie podzolových pôd v rozdielnych geografických a klimatických podmienkach a problém ich klasifikácie

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ABSTRACT

Podzols of Slovakia with similar soils in tropical belt of Northeast Brazil were compared in this contribution. Podzolization process is running in rather different conditions (total rainfall amount and its distribution during year, temperature, moisture, mineralogical composition, mineralization of soil organic matter, altitude, cultivation, colour and structure of soil profiles, etc.).

Several soil profiles (15) of podzols in Slovakia were compared with similar (mostly chemically) soils of tropical region in Northeast Brazil. Comparable soil parameters were used (pH/H_2O and 0.2 mol.l^{-1} KCl, Cox, Nt, content of SiO_2, Al_2O_3, and Fe_2O_3 of annealed earth, base saturation (BS), texture according to FAO.

On the basis of obtained results it may be said that the soils near to podzolic soils of tropical regions of North-East Brazil opposite of podzols of Slovakia have little higher acidity (but lower than 5.0) with significantly lower humus content (strong decomposition of soil organic matter in tropical regions) and total nitrogen content (Nt). SiO_2/R_2O_3 ratio is lower than 1. Characteristic feature of studying soils in tropical regions consists of much higher content of clay and lower content of silt fraction opposite the podzols of Slovakia. In addition, morphological features are rather different (A-horizon is shallow with light colour, E-horizon is weakly visible, resp. sometimes can be absent). According to Brazilian soil classification system studying soils are classified as Podzólico Vermelho-Amarelo included into the Order Espodossolos. In comparison with the Slovak soil classification system these compared tropical soils are more near to Cambic Podzols. For their classification as Luvisols the following criteria are not fulfilled – occurrence of cutans on the surface of soil aggregates, percentage of saturation is often more than 40 % – not to be classified as e.g. Haplic Glossisols (WRB 1994).

Keywords: Podzols, Podzólico Vermelho-Amarelo, Espodossolos, Red-Yellow Podzolic Soils, podzolization, soil classification, acid soils in Northeast Brazil and in Europe, soil properties

ABSTRAKT

V príspevku sú porovnávané podzolové pôdy Slovenska s podobnými pôdami (najmä svojím chemizmom) trópov severovýchodnej Brazílie. Podzolizácia tu prebieha v odlišných geografických a klimatických podmienkach (ročný úhrn zrážok a ich rozdelenie v priebehu roka, teplota, vlhkosť, mineralogické zloženie pôdy, mineralizácia pôdnej organickej hmoty, nadmorská výška, spôsob kultivácie, farba a stavba pôdneho profilu a pod.).

Bolo porovnávaných 15 pôdnych profilov podzolových pôd Slovenska s podobnými pôdami (hlavne chemickými vlastnosťami) tropických oblastí severovýchodnej Brazílie. Boli hodnotené len porovnateľné parametre vlastností pôd (stanovené tými istými, alebo porovnateľnými metódami pH/H_2O a v 0,2 mol.l^{-1} KCl, Cox, Nt, obsah SiO_2, Al_2O_3 a Fe_2O_3 vo vyžíhanej zemine, stupeň nasýtenia pôdy bázami (V), zrnitostné zloženie podľa FAO.

Na základe dosiahnutých výsledkov možno konštatovať, že pôdy blízke podzolovým pôdam tropických oblastí severovýchodnej Brazílie na rozdiel od podzolových pôd Slovenska sa vyznačujú mierne zvýšenou hodnotou pH (avšak nižšou ako 5,0) s výrazne nižším obsahom humusu (v tropických oblastiach je charakteristický výrazný rozklad pôdnej organickej hmoty) a nízkym obsahom celkového dusíka (Nt). Pomer SiO_2/R_2O_3 je v týchto pôdach nižší ako 1. Charakteristickou črtou týchto pôd je výrazne vyšší obsah ílu a nižší obsah prachu v porovnaní s podzolovými pôdami Slovenska. Taktiež rozdielne sú aj morfologické znaky (A-horizont je plytší a oveľa svetlejší v porovnaní s podzolmi mierneho pásma, E-horizont je často slabo viditeľný, niekedy aj chýba). Podľa Brazílskeho klasifikačného systému pôd sú tieto pôdy označované ako Podzólico Vermelho-Amarelo a v novšom ponímaní sú zaraďované do triedy Espodossolos (Palmieri et al., ex. Eswaran et al., 2003). V našom ponímaní majú tieto pôdy však bližšie ku kambizemiam podzolovým. Pre ich zaradenie medzi luvizeme (podzolové) nie sú splnené nasledovné kritériá, ako napr. výskyt kutanov na povrchu agregátov a hodnota V je často vyššia ako 40 % (neplatí V< 30 % v porovnaní s morfogenetickým klasifikačným systémom pôd Slovenska).

Kľúčové slová: Podzoly, Podzólico Vermelho-Amarelo, Espodossolos, Red-Yellow Podzolic Soils, podzolizácia, klasifikácia pôd, kyslé pôdy severovýchodnej Brazílie a Európy, vlastnosti pôdy

INTRODUCTION

Occurrence of podzols in temperate climatic regions is determined by the presence of poor and acid rocks mostly in cool and humid areas. In addition, their occurrence is possible also in warmer regions with lower altitude but on the bottom of such soils there must be present extreme poor and very acid rocks (e.g. quarzite, quarzite sand, etc.). It is possible that these soils were created during older phases of holocene, resp. during the late würm. Podzols in temperate and humic climatic areas are characteristic with high content of soil organic matter where also E-horizon is often humous, which is mostly allochtonous and created from overlapping young delluvial sediments and/or with admixture of silty loams especially in lower areas. Structure of such soil profile is very complicated.

Podzols, resp. the soils very near to these soils (especially by chemical properties) which occur in tropical belt of North East Brazil – are situated mostly in semiarid zone, where the high rainfall amount per year (> 1350 mm) is located only during the wet period (half of November to half of May) with mean year temperature between 30° and 40°C. Moisture of air is running near to 100 %. Kaolinite is predominant clay mineral (primary acidity of soils) of these soils which occur on old weathered material mostly from before Cambrium age (crystalline slates, granites, metamorphic rocks, etc.). These soils are often rubificated especially in deeper part of soil profile caused by the movement of Fe^{3+} and sesquioxides. Their height zonality does not exceed altitude 1 100 m over sea what is the highest pick of this territory (Serra Maranguape).

Soil properties and morphology of soil profiles of tropical belt of Northeast Brazil are rather different opposite podzols in Europe. They are probably much older in comparison with podzols in Slovakia (predominance of kaolinite). In addition, they have rather different genesis, results of which is a specific forming of soils and their properties in tropics, as well.

MATERIAL AND METHODS

File of 15 soil profiles of podzols in Slovak conditions with similar soils in tropic belt of Northeast Brazil were compared. We have selected such soil profiles in Brazil which are classified as podzols (Podzólico Vermelho Amarelo – mostly Equivalente Eutrófico) there. These soils were classified as„Red-Yellow Podzolic Soils" and in Soil Taxonomy belong often to Ultisols. Configuration of diagnostic horizons of brasilian soil profiles is given according to the 7th Approximation (Soil Survey Staff, 1960). Comparable soil parameters were selected (use of the same analytical methods, resp. near to them) as follows:

- pH/H_2O and KCl (soil : water ratio 1 : 2.5) potentiometrically
- exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) and percentage of base saturation
- C_{ox} – by chromiumsulphur acid extraction
- N_t according to Jodlbauer´s method
- clay mineral composition on the basis of rtg analyses (ŠÁLY and MIHÁLIK, 1970 and archives of State University of Ceará, Fortaleza)
- content of SiO_2, Al_2O_3 and Fe_2O_3 oxides of annealed earth (from clay fraction)
- texture (FAO)

The first obtained results were created on the basis of the running cooperation between Soil Science and Conservation Research Institute in Bratislava and State University of Ceará in Fortaleza, Brazil.

RESULTS AND DISCUSSION

Under podzolization process is understood a vertical movement of Al, Fe and organic matter into the deeper part of soil profile (ŠÁLY, 1982). In addition, it would be interesting how this process is running in rather different climatic conditions especially in tropics which are characteristic with intensive decomposition of soil organic matter where the movement of organic matter and sesquioxides is limited by the interval of wet period (about 6 months), when all rainfall amount is accumulated in this period. The main condition for podzolization process running is acidity of soil, what can be caused by lack of bases and by the presence of very poor rocks, as well as and/or it is going about previous leaching of bases. Creation of raw humus (mor) is in correlation with increasing acidity of soil, what is the second condition of podzolization process. Finally, the third condition for podzolization process running is a leaching type of water regime, as well.

The next phenomena is the occurrence of E-horizon, which is especially in humid and cool regions often strongly humous and mostly allochthonous and created often from overlapping young delluvial sediments with admixture of silty loam. Association of podzols in tropical regions is mostly situated on clayey material. Its components frequently include relict horizons, which can be often rubificated. These tropical (acid) soils are mostly deep with low content of gravels with slightly visible E-horizon, which can be sometimes absent. According to our knowledge these tropical (acid) soils are especially morphologically near to Cambic Podzols. In the following part the comparison of podzols of Slovakia with similar soils of tropical soils in Northeast Brazil is described. In the Table 1 the basic soil properties (pH and base saturation) are given.

Table 1 *pH and BS values in podzols of Slovakia and NE Brazil*

Soil	Horizonation	Depth in cm	Colour of soil	pH/H_2O			pH/KCl			BS (%)		
				min.	max.	x	min.	max.	x	min.	max.	x
1	Aop	0 – 10	10YR(7.5YR) 2/1 – 3/3	3.7	4.1	3.9	2.8	3.6	3.3	6.0	30.9	17.9
	Ep	20 – 30	10YR(7.5YR) 3/4 – 5/3	4.0	4.7	4.4	3.5	4.1	3.8	7.0	40.0	22.0
	Bs	35 – 45	10YR(7.5YR) 3/6-5/8-6/6	4.3	4.8	4.6	3.7	4.3	4.1	1.0	40.0	23.6
2	A_1,A_{11}	0 – 10	10YR(7.5YR) 3/1 – 5/2	4.3	5.9	5.2	3.6	4.9	4.4	12.0	65.0	44.5
	A_3,A_{12}	20 – 30	10YR(7.5YR) 4/1 – 5/4	4.6	5.6	5.1	3.7	4.5	4.2	12.0	65.0	41.8
	B_{1t},B_{21t}	35 – 45	10YR(7.5YR) 5/6 – 7/6	4.7	6.0	5.2	3.9	4.6	4.1	11.0	61.0	38.8

1 – podzols of Slovakia, 2 – podzols of Northeast Brazil, x – arithmetic mean, BS – base saturation

On the basis of given data (Tab. 1) podzols in Slovakia are mostly very acid (pH/KCl < 4.0) and non-saturated (BS < 30 %), what is typical for this type of soils. Their acidity and very low saturation depends on acid to very acid soil substrates, from which these soils arised. In addition, these soils are situated mostly in higher humid areas with leaching of bases under predominated coniferous forest where acid organic covered material together with leaching of bases increase the acidity of upper part of soil. There, the pH values are the lowest (Tab. 1).

Podzols of tropical regions of Northeast Brazil are characteristic with a little higher pH value as well as a higher saturation opposite podzols in Slovakia. These soils are situated on even-tempered components of relief (Caatinga – savanna) or also in mountainous regions (Cerradó), where their altitude practically does not exceed 1100 m over sea, what is the highest pick of this territory (Serra Maranguape). It is going about more or less deep soils on old acid rocks from before Cambrium age. Their influence on acidity of surface horizons is not so significant as in European podzols (mostly shallow soils with high content of gravels with high level of acid rocks and their strong influence on acidity of soils). Acidity of tropical soils is mostly caused by kaolinite presence – it is classified as solid acid (Betechtin, 1955).

Podzols in Slovakia are characteristic with high content of humus (mean value is 19.7 %) – Tab. 2, where also underlying horizons are often humous (influence of accumulation of mor in conditions of humid and cool climate mostly under coniferous forest.

Table 2 *Organic carbon and total nitrogen in podzols of Slovakia and NE Brazil*

Soil	Horizo-nation	Depth in cm	C_{ox} (%)			humus (%)			N_t (%)			C:N
			min.	max.	x	min.	max.	x	min.	max.	x	x
1	Aop	0 – 10	8.52	14.48	11.43	14.68	24.96	19.70	0.77	1.13	0.93	12.29
	Ep	20 – 30	2.81	7.49	5.46	4.84	12.91	9.41	0.22	0.52	0.40	13.65
	Bs	35 – 45	1.02	4.86	3.22	1.76	8.38	5.55	0.06	0.22	0.15	21.46
2	A_1,A_{11}	0 0 10	0.72	2.92	1.45	1.24	5.03	2.50	0.05	0.20	0.10	14.50
	A_3,A_{12}	20 – 30	0.29	2.17	0.90	0.50	3.74	1.55	0.03	0.15	0.08	11.25
	B_{1t},B_{21t}	35 – 45	0.25	0.98	0.66	0.50	1.69	0.96	0.02	0.07	0.05	13.20

1 – podzols of Slovakia, 2 – podzols of Northeast Brazil, x – arithmetic mean

Content of humus in podzols of Northeast Brazil is significantly lower (2.5 %) opposite European podsols. This is caused by intensive decomposition of soil organic matter (Tab. 2). Therefore the humus horizons of described tropical soils in comparison with European podzols are more light and shallow.

Figure 1 *Podzol in temperate climate (Slovakia)*

Figure 2 *Soil profile in Serra Maranguape (Podzólico Vermelho, NE Brazil)*

Very important parameter in evaluation of quality of soil organic matter and forms of humus is content of total nitrogen (Nt). Podzols in Slovakia contain higher amount of total nitrogen opposite the similar soils in tropics. Obtained mean value of 0.93 % Nt according to criteria of Bielek (1998) means it has a very high content in soil. Content of total nitrogen in soils of tropic regions is very low (0.10 % and less). Also C : N ratio is interesting in compared soils. It was found out that with the increasing of productivity of soils C : N ratio is more narrow and often exceed value under 10 in the most fertile soils (BIELEK, 1998). In addition, it was found out that in little fertile soils only slight mineralization of nitrogen is running because it is more pretentious on loss of organic carbon and energy (BIELEK, 1996). Therefore in spite of higher content of total nitrogen (especially in podzols of Slovakia) in compared soils mineralization of nitrogen is very low.

Next of the very important parameters of development of soils in rather different geographical and climatic conditions is chemical composition of insoluble remains of rocks (Tab. 3).

Table 3 *Chemical composition of insoluble remains of rocks (% of annealed earth from clay fraction)*

Soil	Horizo-nation	Depth in cm	SiO_2 (%)			Al_2O_3 (%)			Fe_2O_3 (%)			$\frac{SiO_2}{R_2O_3}$
			min.	max.	x	min.	max.	x	min.	max.	x	
1	Aop	0 – 10	50.62	58.81	53.21	25.91	30.04	27.54	7.77	14.10	9.71	1.43
	Ep	20 – 30	50.50	57.13	53.50	26.63	30.07	28.91	7.77	10.03	8.94	1.41
	Bs	35 – 45	46.03	54.66	49.95	27.61	32.67	29.39	7.75	15.67	10.71	1.24
2	A_1,A_{11}	0 – 10	3.60	20.40	9.46	3.00	17.90	7.76	0.30	7.00	2.96	0.88
	A_3,A_{12}	20 – 30	5.10	20.00	10.66	4.00	17.40	8.64	0.60	6.80	3.18	0.90
	B_{1t},B_{21t}	35 – 45	6.50	23.20	14.76	5.10	21.70	12.38	1.00	8.70	4.50	0.87

1 – podzols of Slovakia, 2 – podzols of Northeast Brazil, x – arithmetic mean

Result of chemical weathering in different geographical and climatic conditions consists of significant changes in chemical composition of oxides content. The most significant changes are visible in content of quartzite (SiO_2), which is predominantly occurring in podzols of Slovakia where its content is slightly decreasing with depth. In soils of tropical regions of Northeast Brazil is the content of SiO_2 significantly lower and its content is increasing with depth opposite the podzols in Slovakia. This mineral (as quartzite acid form – $H_2SiO_3.nH_2O$) can be considerably dispersed and leached. In slovak podzols also higher content of Al_2O_3 and Fe_2O_3 was determined (Tab. 3). Concrete changes in chemical composition of soil opposite insoluble remains of rocks of compared soils are given also in $SiO_2 : R_2O_3$ ratio. This one is in podzols of Slovakia higher than 1, in soils of tropics is lower than 1. Leaching of SiO_2 ($H_2SiO_3.nH_2O$) into the deeper part of soil profile is connected with desilication (laterization) process. Extension of these soils in conditions of Northeast Brazil often creates their association with Latosols (Fig. 3).

Figure 3 *Latosol in Pacoti (NE Brazil)*

Concrete changes in chemical composition of compared soils are determined also by different texture (Tab. 4).

Table 4 *Textural composition of podzols in Slovakia and Northeast Brazil*

Soil	Horizonation	Depth in cm	Mechanical fractional composition in %		
			2 – 0.05 mm	0.05 – 0.002 mm	< 0.002 mm
1	Aop	0 – 10	46.53	49.07	4.40
	Ep	20 – 30	51.70	44.93	3.37
	Bs	35 – 45	64.62	32.55	2.83
2	A_1,A_{11}	0 – 10	60.20	21.20	18.60
	A_3,A_{12}	20 – 30	59.60	15.40	25.00
	B_{1t},B_{21t}	35 – 45	50.00	14.40	35.60

1-podzols of Slovakia, 2-podzols of Northeast Brazil

On the basis of given data (Tab. 4) it may be concluded that the described soils in tropic regions of Northeast Brazil contain much more of clay fraction (< 0.002 mm) and lower amount silt fraction (0.05 – 0.002 mm) opposite podzols in Slovakia. The content of sand fraction (2 – 0.05 mm) is higher in surface layer of soils in tropics and lower in the deeper part of soil profile opposite to the soils of temperate climate.

On the basis of comparison of given parameters it may be also concluded that the podzols of tropical belt of Northeast Brazil (classified in Brazil as Podzólico Vermelho Amarelo) are characteristic with slight acidity and higher saturation (Equivalente Eutrófico, port.) also with significantly lower content of humus (strong decomposition of soil organic matter in tropics) and very low content of total nitrogen (Nt). The SiO_2/R_2O_3 ratio is lower than 1. Moreover, the soils have higher content of clay fraction (more than 18 %) as well as lower content of silt fraction (about 20 %) opposite podzols in temperate climate.

In addition, compared soils are rather different also concerning structure of soil profile. Humus horizon of tropical podzols is light-coloured (low content of humus) and shallow opposite podzols of temperate climate, E-horizon is more or less visible, sometimes can be absent, B-horizon is characteristic with significant content of clay but without cutans. Transition to C-horizon is gradual (through B/C-hor.) where typical C-horizon can be determined in depth of several meters. Chemical properties of these sediments and soils is influence by their chemical and mineralogical composition (kaolinite) as well as parental rock. Movement of Fe, Al and clay in soils of tropics is limited by the duration of wet period; during dry period is predominated stabilization of described components. According to Brazilian Soil Classification System (Palmieri et al. ex. Eswaran et al., 2003) compared soils of tropic belt of Northeast Brazil are classified in the Order Espodossolos (where also Podzólico Vermelho Amarelo belong) with high – activity clay. According to some principles of Morphogenetic Soil Classification System in Slovakia (Šály et al., 2000) their classification is not so simple, because any cutans were observed here. Also their classification as Haplic Glossisols (WRB 1994) is not unambiguous where the base of saturation (BS) must be less than 30 % (in evaluated tropical soils is often higher than 40 %).

According to the criteria of Morphogenetic Soil Classification System of Slovakia (Šály et al., 2000) the acid soils of tropic belt of Northeast Brazil are more similar to Cambic Podzols

– WRB 1994 (Kambizeme podzolové), which often occur in association with Latosols (Fig. 3). It is going about the soils in which thickness of B-horizon is more than 50 cm and silt to clay ratio is lower than 0.6 with content of clay more than 35 % (Palmieri et al., ex. Eswaran et al., 2003) what was determined also in our case (Tab. 4). Described soils are expressively extended in Brazil with total area of 38.5 % (Palmieri et al., ex. Eswaran et al., 2003).

CONCLUSIONS

Podzolization process is running in acid conditions if pH value is lower than 5.0 what is in correlation with creation of raw humus (mor) under leaching. These conditions can be in various parts of world more or less different (intensity, duration of soil forming factors, etc.) and so process of podzolization can be inhibited, resp. interrupted (e.g. during dry period). Compared acid soils of tropic belt of Northeast Brazil are characteristic with little higher pH value and degree of saturation opposite podzols in temperate climate. By the influence of strong decomposition of soil organic matter described soils in tropical regions contain significantly lower amount of humus with light-coloured and shallow A horizons what is in correlation with structure of soil profile which is often more or less different opposite podzols in temperate climate (above all in humid and cool regions). According to Brazilian Soil Classification System, described and studied soils in Northeast Brazil are classified as Espodossolos (Podzólico Vermelho – Amarelo), former classified as „Red-Yellow Podzolic Soils" and in Soil Taxonomy often belong to Ultisols. In relation to criteria of Morphogenetic Soil Classification of Slovakia these tropical soils, by comparison of basic chemical properties as well as by structure of soil profile, are more similar to Cambic Podzols (Kambizeme podzolové). These soils are often rubificated and situated in soil association with Latosols. Finally, these soils belong to the most extended soils of Brazil (near to 40 % of total area).

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LIMIT VALUES INDICATING VULNERABILITY OF ECOLOGICAL FUNCTIONS OF FLUVISOLS IN THE REGION STREDNÉ POHRONIE

Indikátory zraniteľnosti ekologických funkcií fluvizemí v Strednopohronskej oblasti

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ABSTRACT

In this paper evaluation of the main indicators of selected ecological Fluvisol functions (filtration, accumulation, buffering) regarding inorganic contaminants (heavy metals) is presented. The factor analysis shows the main indicators that potentially influence selected ecological functions of soil regarding heavy metals. There are direct indicators like mobile content and total content of heavy metals, soil pH value and indirect indicators like content and quality of organic matter, soil texture, depth of humic horizon and soil texture.

Critical values that determine soil vulnerability of ecological functions are multidimensional, developmental numeric or point evaluating values. The soil samples of fluvisols, located in Stredne Pohronie region, used as arable land developed on recent river sediments were collected from the depth 0 – 10 cm. Soil reaction, content of organic matter, exchange cations and the first step of sequential chemical extraction method proposed by Zeien and Brummer [ref. 10] to determine mobile contents of Cd and Pb were used. Testing values of critical metals contents and mobility in relation to soil properties were derived. Critical values by law 220/2004 (law of agricultural soil protection) for system soil – plant were taken for starting values in stepwise multiple regression. Critical values of indicators were determined proposed multiple regression analysis for Cd: $Cd_m > 1.0$ mg.kg^{-1}, pH < 5.47, $C_{ox} < 1.59$, exchangeable $Ca^{2+} < 4.35$ cmol. kg^{-1}, for Pb: $Pb_m > 0.1$ mg.kg^{-1}, pH < 6.4, $C_{ox} < 1.99$, exchangeable $Ca^{2+} < 6.79$ cmol. kg^{-1}.

Keywords: Fluvisols, ecological soil function, indicators, vulnerability of soil functions

ABSTRAKT

Pri stanovení minimálneho súboru indikátorov vzhľadom na ekologické funkcie pôd sme vychádzali z nasledovných podmienok: indikátory musia byť súčasťou existujúcej databázy ČMS – pôda a na základe výsledkov faktorovej analýzy majú priamy alebo nepriamy vplyv na sledované ekologické funkcie pôd. Faktorovú analýzu sme aplikovali na súbor vytvorený z kľúčových lokalít ČMS-pôda a na základe výsledkov faktorovej analýzy sme stanovili nasledovný akceptovateľný súbor indikátorov ekologických funkcií pôd: priame indikátory – mobilný obsah ťažkých kovov, celkový akumulovaný obsah ťažkých kovov, hodnota pôdnej reakcie a nepriame indikátory – obsah a kvalita organickej hmoty v pôde, hrúbka humusového horizontu, celková pórovitosť a obsah ílových častíc menších ako 0,01 mm. Príspevok je zameraný na stanovenie kritickej agregácie indikátorov ekologických funkcií fluvizemí lokalizovaných v Strednopohronskom regióne. Vzhľadom na prírodné pomery v interakcii s ľudskými aktivitami patrí táto oblasť k oblastiam zaťaženým acidifikačno-metalickou záťažou. Kritické zaťaženie aciditou predstavuje 4 keq.ha^{-1}.rok^{-1}. Táto oblasť patrí k senzitívnym oblastiam, ktoré si vyžadujú monitorovanie pôdnych indikátorov. Hodnoty pôdnej reakcie fluvizemí sa pohybujú v oblasti slabo kyslej až neutrálnej, obsah organickej hmoty je stredný. V prípade mobilného obsahu kadmia nedošlo k prekročeniu kritickej hodnoty stanovenej pre systém pôda - rastlina, v prípade olova na 30 % sledovaných lokalít je obsah olova vyšší ako kritická hodnota 0.1 mg.kg^{-1} (zákon č. 220/2004 Z.z.). Výsledky Spearmanovej korelačnej analýzy ako aj limitné hodnoty pre mobilný obsah kadmia a olova sme využili ako odrazové údaje pre tvorbu modelov s pomocou postupných viacnásobných lineárnych regresií. Agregácia limitných hodnôt idikátorov zraniteľnosti ekologických funkcií sledovanej skupiny fluvizemí pre Cd, Pb, predstavuje kritický stav, v ktorom nie sú schopné plne zabezpečovať svoje ekologické funkcie, Cd: $Cd_m > 1.0$ mg.kg^{-1}, pH < 5.47, $C_{ox} < 1.59$, výmenný $Ca^{2+} < 4.35$ cmol. kg^{-1}, pre Pb: $Pb_m > 0.1$ mg.kg^{-1}, pH < 6.4, $C_{ox} < 1.99$, výmenný $Ca^{2+} < 6.79$ cmol. kg^{-1}.

Kľúčové slová: ekologické funkcie pôdy, indikátory, zraniteľnosť ekologických funkcií pôd

INTRODUCTION

Life quality and long term prosperity of people depend on a healthy and sustainable environment. Important part of the healthy environment creates a healthy soil. Soil degradation is process that decrease basal and potential ability of soil to secure all its functions. Soil has limited capability to eliminate negative anthropogenic activities. Soil degradation poses a threat to soil itself and to the other parts of environment. From the anthropic point of view, the soil functions can be divided into production and non-production. The non-production soil functions can be divided into ecological and socio-economic (Barančíková, Madaras, 2002). The filtration, accumulation, transforming and transporting, buffering function, biological habitat and gene reserve are the main ecological functions of soil. Vulnerability of ecological functions is a degree of approach to critical limit values of selected indicators (Juráni, 1996). The aggregation of critical limit values of indicators can cause negative changes in different part of environment.

In this paper the evaluation critical limits of the main indicators of selected Fluvisols functions (filtration, accumulation, buffering) regarding inorganic contaminants (heavy metals) is presented. Many metals are toxic in the terrestrial environment, even at rather low concentrations. Heavy metal contaminants decrease soil quality and affect the quality of the biomass production and the aqueous environment. The harmful effects of heavy metals comprise to malfunction of soil microbial processes, plant uptake that transfers the contaminants into food chains, injury to sensitive plants leaching of soil contaminants into groundwater and into surface waters, or erosion of soil materials into surface waters (Hansen at al., 2001).

MATERIAL AND METHODS

Status of indicators of the main ecological soil functions have been observed in the frame of Partial Monitoring System - in key network. Aggregation of critical limit values of indicators have been observed in the frame of Partial Monitoring System – in special network (10 soil samples), which represents Fluvisols in Stredne Pohronie region. The soil samples of Fluvisols used as arable land (plant Zea mays) and developed on recent river sediments were collected from the depth 0 – 10 cm in the first decade of the August.

In the soil samples exchangeable pH value pH/$CaCl_2$, exchange cations (Fiala, 1999) were analysed. Organic carbon content (C_{org}) was determined by wet combustion. Humus fractionation was determined by Kononovova and Beľčikova method (1961) in which the amount of humic acid carbon – C_{HA} and fulvic acid carbon – C_{FA} and the ratio of optical densities measured in humic acid solution at 465 nm and 665 nm (Q_6^4) were determined (Fiala, 1999). By selective sequential extraction procedure (Zeien & Brümmer, 1989) mobile fraction of heavy metals were determined. The statistical program STATGRAPHICS 5.0 was used.

RESULTS AND DISCUSSION

Stredné Pohronie region is situated at territory with enhanced acid load deposition 4 keq/ha/y (Závodský et al., 1996) combined with metal pollution. The raised acid – metal loads contribute to environmental quality deterioration. Stredné Pohronie region is evaluated as disordered region (4. degree of 5 degree scale) (MŽP SR, SAŽP, 2002).

Soil samples Fluvisols from locations situated in inland Hron River were collected in distances 50 to 200 meters from Hron River. Hron River is recipient of sewages from engineering industry, petrochemical industry as well as pharmaceutical industry. In the last five years, Hron river deposition moves in the range I. – IV. degree (MŽP SR, SAŽP, 2002). The level of deposition increases with high intensity of traffic exhausts in this region. Fluvisols contain materials deposited by water with addition of deposition of atmosphere. On the basis of the development of depositions, Stredné Pohronie region belongs to sensitive regions that deserve special attention as well as make regular observation (monitoring) of selected indicators of soil vulnerability.

The ecological functions are determined by indicators selected according to factor analysis (Makovníková 2004). The critical values indicate soil vulnerability of ecological functions, multidimensional, developmental numeric or point evaluating values. These indicators include the total variation of processes as well as show the interactions between measured properties. The varimax rotation was used in order to increase the share of second or third factors in the explanation of the total variation (Meloun, Militký 1994).

The factor analysis showed the main indicators, which potentially influence selected ecological functions of soil regarding heavy metals (Makovníková, 2004). There are direct indicators like mobile content or total content of heavy metals, soil pH value and indirect indicators like content or quality of organic matter, soil texture, depth of humic horizon and soil texture. These indicators have influence on filtration, accumulation and buffering functions with various intensity. With aspect to synergic effect of indicators, it is necessary to consider critical aggregation of soil indicators.

Cadmium and lead belong to the main inorganic contaminants in this region. Cadmium and lead have not essential biological functions and are highly toxic to plants and animals.

The basic parameters of Fluvisols are in Table 1.

Table 1 *Mean, minimum, maximum values of soil parameters*

indicator	Fluvisols		
	Arithmetic mean	Minimum	Maximum
pH in $CaCl_2$	6.71	5.99	7.20
Cox in %	3.18	2.12	4.50
Ca^{2+} in cmol/kg	11.88	4.00	18.99
Mg^{2+} in cmol/kg	3.53	0.90	6.27
K^+ in cmol/kg	0.41	0.03	0.78
mobile Cd in $mg.kg^{-1}$	0.008	0.005	0.015
mobile Pb in $mg.kg^{-1}$	0.072	0.021	0.224

As you can see from the Table 1, soil reaction of Fluvisols move in the range moderately acid to neutral. Medium content of organic matter, higher depth of humic horizon (from 25 to 35 cm) influence positively filtration function of Fluvisols. Majority part of exchangeable cations is created with calcium cation. Soil pH has major effect on the solubility of cadmium and lead. Cadmium is the most mobile in acidic soils with the range of pH 4.5 – 5.5 (HANSEN et al., 2001) but in moderately acid range the mobile cadmium content decreases rapidly. Lead is reported to be least mobile among the heavy metals. The situation is rather different, when the sources of lead are anthropogenic. Consequently, anthropogenic deposition can increase lead mobility. It is very difficult because the relative contribution of lead to soils have been estimated to 80 – 90 % from atmospheric deposition (ALLOWAY, 1990). Atmospheric lead is only slowly associated with organic matter and Mn, Fe as well as Al hydroxides. The soil is able to eliminate pollutants by interaction with inorganic and organic soil components and to prevent pollution of another part of environment. This natural attenuation, despite of moderately and neutral pH value, content of organic matter and content of carbonate, is not sufficient in this region. The part of atmospheric deposited lead remains in mobile form and can cause contamination of plant parts as well as contamination of groundwater.

Critical limit values of mobile heavy metal content determines new law No. 220/2004 (Law of acricultural soil protection) in relationship between soil – plant. In the case of cadmium were the obtained values of mobile cadmium content lower than critical limit value (0.1 $mg.kg^{-1}$). The different situation was in the case of lead. Mobile lead content higher than critical limit value (0.1 $mg.kg^{-1}$) were found in 30 % of analysed samples.

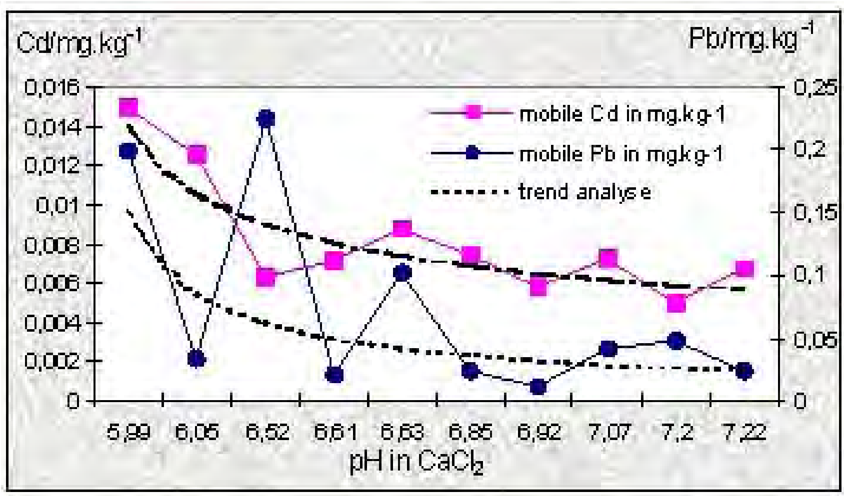
The relationship between direct and indirect indicators of soil vulnerability of Fluvisols is determined by Spearmann rank correlation coefficients (Table 2).

Table 2 *Spearmann rank correlation coefficients (Fluvisols)*

	pH in $CaCl_2$	Cox in %	Ca^{2+} in cmol/kg	Mg^{2+} in cmol/kg	K^+ in cmol/kg	mobile Cd in mg.kg	mobile Pb in mg.kg^{-1}
pH in $CaCl_2$	1	0.43	**0.83**	-0.24	**0.78**	**-0.63**	**-0.53**
Cox in %	0.43	1	**0.66**	0.26	0.44	-0.39	-0.29
Ca^{2+} in cmol/kg	**0.83**	**0.66**	1	-0.16	**0.72**	**-0.71**	-0.36
Mg^{2+} in cmol/kg	-0.24	0.26	-0.16	1	-0.24	0.19	0.27
K^+ in cmol/kg	**0.78**	0.44	**0.72**	-0.24	1	**-0.58**	-0.14
mobile Cd in mg.kg^{-1}	**-0.63**	-0.39	**-0.71**	0.19	**-0.58**	1	0.26
mobile Pb in mg.kg^{-1}	**-0.53**	-0.29	-0.36	0.27	-0.14	0.26	1

Substancial relationships of indicators are marked bolt. Soil pH value, exchangeable Ca^{2+} content and exchangeable K^+ content have major influence on the solubility of cadmium that is in agreement with many authors (Hooda and Alloway 1996, Gupta et al. 1996, Makovníková 2000, Vácha et al. 2002). pH value has major effect on lead solubility. Mobile cadmium and lead content in context with pH values shows Figure 1.

Figure 1 *Mobile Cadmium and Lead Content in Context with pH Values*



Critical limit values for mobile cadmium and lead content in system soil – plant (Law No. 220/2004 on agricultural soil protection) and obtained results in Spearmann rank analysis were used in the process stepwise multilinear regression analysis (as linear are considered parameters of model equations) to evaluate actual critical values of indicators for Fluvisols. Reliability of used models is characterised by R – squared (Tables 3a, 3b).

Table 3a *Regression equations and multiple regression model for cadmium*

Regression equations	R – squared	Calculated values
Cdm = 0.1341 – 0.006248 . $pH/CaCl_2$ (1) **Critical limit value Cdm = 0.1 $mg.kg^{-1}$**	-0.86	$pH/CaCl_2$ = 5.47
$pH/CaCl_2$ = 5.88502 + 0.25789 . Cox (2) calculated value $pH/CaCl_2$ =	0.55	Cox =1.59 %
$pH/CaCl_2$ = 5.8033 + 0.075984.Ca^{2+} (3) calculated value $pH/CaCl_2$ = 6.4	0.83	Ca^{2+} = 4.35 $cmol.kg^{-1}$
$pH/CaCl_2$ = 6.22677 + 1.11632 . K^+ (4) calculated value $pH/CaCl_2$ = 6.4	0.70	K^+ = 0.67 $cmol.kg^{-1}$
multiple regression model Cdm = 0.001553 . $pH/CaCl_2$ – 0.000742 . Ca^{2+} + 0.002049 . Cox (5) R – squared = 0.92		

Cdm – mobile cadmium content

Table 3b *Regression equations and multiple regression model for lead*

Regression equations	R – squared	Calculated values
Pbm = 0.698 – 0.0932 . $pH/CaCl_2$ (1) **Critical limit value Pbm = 0.1 $mg.kg^{-1}$**	-0.53	$pH/CaCl_2$ = 6.4
$pH/CaCl_2$ = 5.88502 + 0.25789 . Cox (2) calculated value $pH/CaCl_2$ = 6.4	0.55	Cox = 1.99 %
$pH/CaCl_2$ = 5.8033 + 0.075984 . Ca^{2+} (3) calculated value $pH/CaCl_2$ = 6.4	0.83	Ca^{2+} = 6.79 $cmol.kg^{-1}$
$pH/CaCl_2$ = 6.22677 + 1,11632 . K^+ (4) calculated value $pH/CaCl_2$ = 6.4	0.70	K^+ = 0.155 $cmol.kg^{-1}$
multiple regression model Pbm = 0.0149 . $pH/CaCl_2$ – 0.00927 . Ca^{2+} + 0.01831 . Cox (5) R – squared = 0.54		

Pbm – mobile lead content

With substitution of critical limit value (mobile lead content) in first model equation (1) was calculated critical ph value. Critical values were determined for cadmium and for lead. Aggregation of critical values of indicators is in Table 4.

Table 4 *Calculated limit values for cadmium and lead*

Indicator	for Cd	for Pb
Mobile content of Cd and Pb in $mg.kg^{-1}$	> 0.1	> 0.1
pH in $CaCl_2$	< 5.47	< 6.40
Cox in %	< 1.59	< 1.99
Ca^{2+} in $cmol.kg^{-1}$	< 4.35	< 6.79
K^+ in $cmol.kg^{-1}$	< 0.67	< 0.16

Vulnerabilty of Fluvisols in Region Stredné Pohronie

The buffer functions determine pH value in moderately acid to neutral range, medium content of organic matter, medium content of exchangeable Ca^{2+} and higher depth of humic horizon. On the basis of carbonate buffer system controlling soil acidification belong Fluvisols to moderately resistant soils according acidification. The soil is able to eliminate pollutants by interaction with inorganic and organic soil components and to prevent pollution of another part of environment. This natural attenuation, despite of moderately and neutral pH value, content of organic matter and content of carbonate, is not sufficient in region Stredné Pohronie. In the case of lead the aggregation of indicators of vulnerability is critical and can caused negative changes in the environment. Fluvisols, located in region Stredné Pohronie, belong to soils that shall be observed and regularly investigated the state and development of indicators of vulnerability.

CONCLUSIONS

The investigating of the critical aggregation of selected indicators of soil vulnerability shows the actual resistance of soil types in concrete conditions, in concrete region with concrete pollutions. The determination of state and development of indicators is way how to can prevent entering of heavy metals to get into food chain and into underground waters.

The „first help" for soil should be the support of soil natural attenuation. Increasing of soil natural attenuation belongs to the effective tools for complex and systematic protection of investigated region in regard to sustainable environment.

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WOFOST BASED CROP YIELD AND PRODUCTION FORECASTING SYSTEM ON SOIL SCIENCE AND CONSERVATION RESEARCH INSTITUTE (SSCRI)

Systém odhadu úrod a produkcie poľnohospodárskych plodín prostredníctvom modelu WOFOST na Výskumnom ústav pôdoznalectva a ochrany pôdy (VÚPOP)

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ABSTRACT

Demand on preliminary crop yield and production forecasting during the vegetation period noticed increased trend in the present time and it conditions development and progression of methods used in this field. There are several methodologies (models) based on different principles. Generally, the effective model (based on principle of biomass estimating from vegetation indexes determined by remote sensing methods) and functional models (based on agro-meteorological, soil and crop modelling) are utilized on SSCRI. The WOFOST model belongs to the category of functional models and it deals with weather, soil, crop and phenological data. Consecutively, other additional data are utilized such as statistical data or data obtained from process of regional inventory. The submitted article attends to describe and explain the process of crop yield forecasting as well as agricultural plants production and several related sub-processes by the WOFOST model (the WOFOST calibration possibilities on the condition of Slovak Republic, the WOFOST requirements on input data, scale or methodology aspects of crop yield forecasting, etc.). The article also deals with the problem and possibilities of the crop yield and production estimates quality and precision improving. Presented theoretical aspects and methodology of WOFOST utilization that will be used on SSCRI in 2005 bring detailed view on some problems connected with WOFOST utilization in the process of crop yield and production forecasting. In comparison with the WOFOST usage in previous years (through the WOFOST data calibration, solving the problem of data formats, data spatial validity and related methodological aspects of WOFOST utilization) presented alternative will be applied on pilot sites and will contribute to the more precise and realistic estimates.

Keywords: System of crop yield and crop production forecasting, WOFOST model, WOFOST calibration, Elementary Modelling Unit (EMU), weather file, crop file, soil file, regional level, local level

ABSTRAKT

Narastajúci trend, zaznamenaný v oblasti odhadu úrody a produkcie významných poľnohospodárskych plodín realizovanom priebežne počas vegetačného obdobia, podmienil snahu o ďalší vývoj, resp. zlepšenie metodológie využívaných modelov.

V poľnohospodárskej praxi sa v procese odhadovania úrod a produkcie využíva množstvo metód a metodických postupov založených na značne rozdielnyh princípoch. WOFOST, dynamický, deterministický, biofyzikálny a agrometeorologický model patrí do skupiny funkčných modelov, ktorých princíp spočíva v spracovávaní meteorologických, fenologických, pôdnych a rastlinných parametrov. Aspekt "reálnosti" resp. spresnenia odhadov vyžaduje využívanie ďalších, prídavných údajov – napr. štatistických údajov týkajúcich sa osevných plôch a dosiahnutých úrod, prípadne údajov získaných z regionálnej inventarizácie..

Predkladaný článok sa venuje opisu a vysvetleniu procesu odhadu úrod a produkcie poľnohospodárskych plodín a jeho čiastkových procesov prostredníctvom modelu WOFOST (napr. kalibrácia modelu, analýza vstupných údajov, konverzia údajov do formátu vyžadovaného modfelom WOFOST, atď.). Súčasne načrtáva možnosti zlepšenia a spresnenia odhadovania úrod. Prezentovaný náčrt metodického postupu a teoretických aspektov modelu WOFOST prináša detailný pohľad na problémy a sporné oblasti týkajúce sa využívania modelu WOFOST v procese odhadu úrod a produkcie poľnohospodárskych plodín. V porovnaní s postupom odhadu úrod uplatneným v minulých rokoch, prezentovaný alternatívny postup, ktorý bude aplikovaný v tomto roku na pilotných územiach, by mal prispieť k zlepšeniu kvality, spresneniu a "zreálneniu" odhadov.

KĽÚČOVÉ SLOVÁ: Systémodhadovaniaapredpovedaniaúrodaprodukciepoľnohospodárskych plodín, WOFOST model, základná modelovacia jednotka, súbor klimatických parametrov, súbor rastlinných parametrov, súbor pôdnych parametrov, regionálna úroveň, lokálna úroveň

INTRODUCTION

WOFOST originated in the framework of interdisciplinary studies on world food security and on the potential world food production by the Centre for World Food Studies (CWFS) in cooperation with the Wageningen Agricultural University, the Plant Research International and Alterra (BOGAARD, van DIEPEN at all., 1998). WOFOST was used for various studies as well for production simulation of annual field crops all over Europe for the Joint Research Centre (JRC – Ispra) of the Commission of the European Communities. Consecutively WOFOST was incorporated into Crop Growth Monitoring System (CGMS) (SUPIT, van der GOOT, 2002).

In Slovak Republic, the agriculture monitoring with remote sensing activities (MARS), which includes the crop yield prediction as well, started in 1994. Since 1998 Soil Science and Conservation Research Institute (SSCRI) has been solving the task of crop yield prediction on the base of contracts with Ministry of Agriculture of the Slovak Republic (MoA).

At SSCRI, the process of crop yield forecasting is based on two different trends:

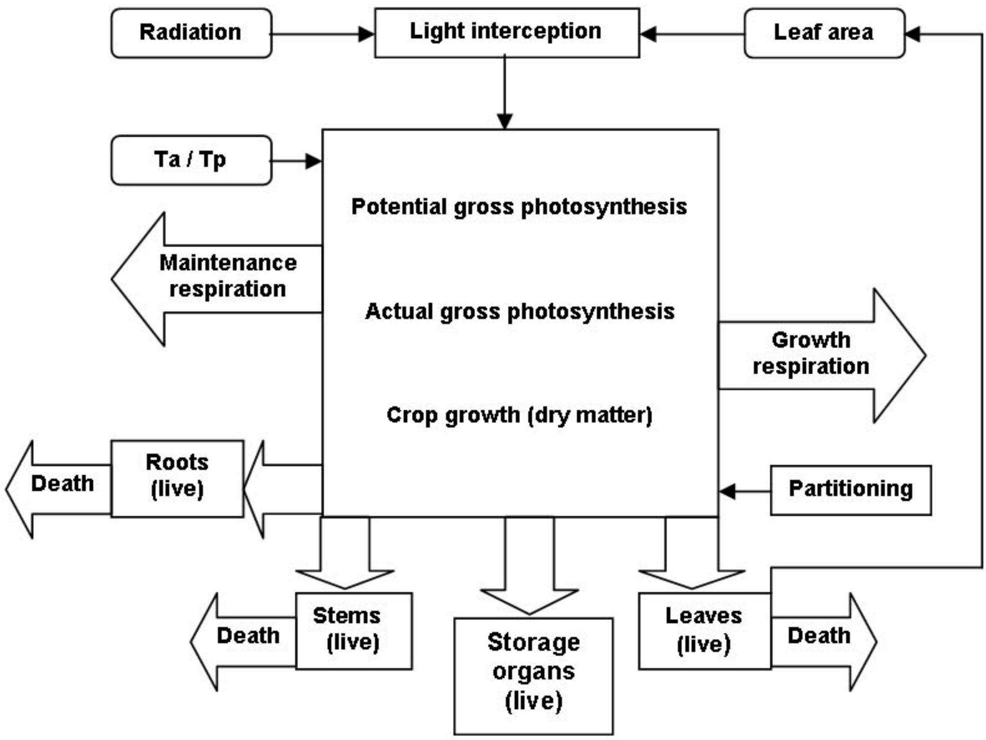
- agro-meteorological and bio-physical model WOFOST utilization
- remote sensing methods (NDVI values) and statistical methods (historical crop yield values) utilization.

The comparison of predicted crop yields achieved by WOFOST model and actually reached crop yield values refers to relatively remarkable differences. This fact caused that WOFOST has had to be calibrated to the conditions of Slovak Republic (till now only meteorological files have been partially calibrated). Solution of the problem relates to system of procedures connected with crop growth simulation as well as to methods used to interpret results, and other issues. Thus, the task to improve crop yield estimates has to cover all crop growth simulation partial operations (with input data processing starting and the evaluating of crop yield estimates ending).

MATERIALS AND METHODS

The WOFOST represents an explanatory, quantitative, dynamic, biophysical and agro-meteorological model. The model is based on the idea of crop phenological development, growth and yield formation from its emergence till maturity, which notably depends on crop genetic and physiological properties and environmental conditions. The process of crop growth modelling in WOFOST includes and integrates several sub-processes related to each other. There is a possibility to express crop growth continuance from quality and quantity point of view and through mathematical and physical relations express the rate of crop development as well as crop yield and crop production. The WOFOST crop growth simulation principles are given in Figure 1.

Figure 1 *Crop growth processes simulated by WOFOST. T_a and T_p are actual and potential transpiration rate (de Koning et al., 1993).*



Principally, WOFOST allows to simulate the growth of any annual crop growing at any location, for which required specific crop, weather and soil data exist. General WOFOST input requirements are described in table 1 (in supplements).

WOFOST enables to model the crop growth on several levels, specifically as potential production without drought stress, where the crop growth is determined by irradiation, temperature and plant characteristics only. Atmospheric CO_2 is assumed to be constant and as a limited production where the crop growth is determined by irradiation, temperature, plant characteristics as well as by the effect of the availability of water and plant nutrients (water-limited or nutrient limited production). Model

The WOFOST represents simulation model without reference to geographical scale. Its application to region relies on selection of representative points with accurate required input data, followed by spatial aggregation or interpolation (BOOGAARD, H. L., van DIEPEN, C. A..at all, 1998).

Joint Research Centre (JRC) Ispra, specifically the Institute for the Protection and Security of the Citizens (ISPS) – the AGRIFISH Unit in cooperation with Meteoconsult and Alterra solve the needs of timely information on the agricultural production to be expected in the current season on European level (for EU member and access states).

An overview of WOFOST data input and data pre-processing on the level of European Union is given in Table 1.

Table 1 *Overview of WOFOST data inputs and data pre-processing on European level (EU)*

Field	File name	Data source	Data processing oriented to data preparation	Input data format spatial validity
Weather	weather file	The European network of weather stations	station selection, station qualification, data interpolation	grid 50 x 50 km interpolated weather data
Soil	soil file	European soil database European soil map (1:1 000 000) FAO soil map (1:5 000 000)	pedotransfer rules application	SMU (soil mapping unit), STU (soil typological unit), estimated soil retention, hydraulic conductivity and soil workability data for standardized soils
Crop	crop file	European crop characteristics database European crop knowledge database	information collecting (data derived from literature, field observation and trials)	crops regions required crop parameters

RESULTS AND DISCUSSION

Generally, annual increased demand on crop yield estimates information for individual regions during the vegetation season and evokes the necessity of estimates to be improved (with the aim to improve the estimates quality and precision). SSCRI makes an effort to notice the trends. Through the WOFOST data input calibration on the conditions of Slovak Republic, the crop yield forecasting system methodology development and estimates interpretation methods development should lead the estimates to approximate to really achieved yields in the best possible way.

The system of crop yield forecasting does not represent the WOFOST model and its application on existing data only. The system includes amount of procedures (with data processing and data conversion to WOFOST model starting and process of crop yield forecasting and estimated results interpretation ending).

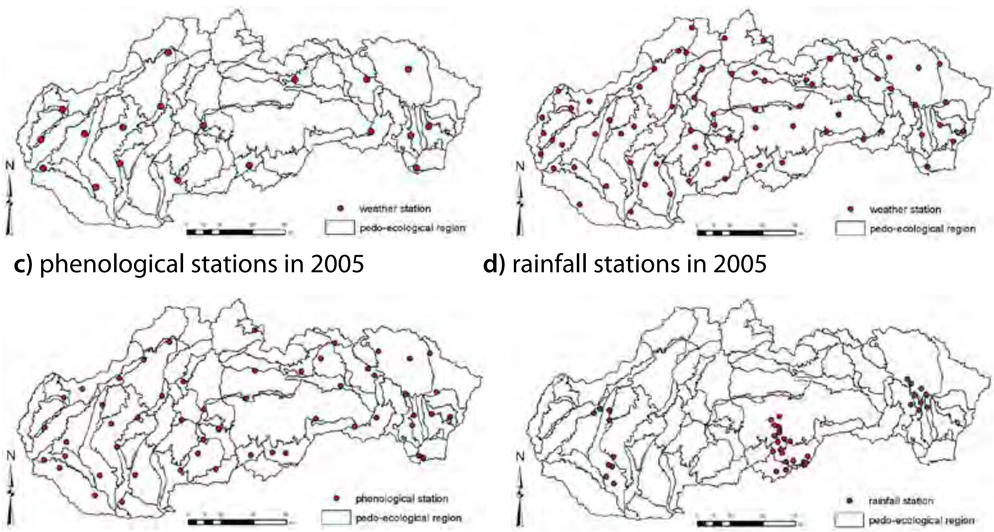
1. WOFOST input and additional data, data analyses and data processing

Weather data, rainfall data and phenological data authority is Slovak Hydrometeorological Institute (SHI). The data represent the network stations measurements (spatial distribution of used weather, phenological and rainfall stations for WOFOST crop yield simulation campaign in 2003 and 2005 is given on Figure 2).

Figure 2 *Distribution of data sources for WOFOST crop yield simulation campaign*

a) weather stations in 2003 **b)** weather stations in 2005

c) phenological stations in 2005 **d)** rainfall stations in 2005



SSCRI is soil databases authority. Its databases enable to prepare the soil files with accordance the WOFOST requirements. An overview of WOFOST data input and their evaluation on the level of Slovak Republic from the accessibility and the completeness point of view is given in Table 2 in supplements.

The system of crop yield and production estimates and estimates interpretation requires even usage of additional data. Regional inventory, based on interpretation of high resolution satellite data (LANDSAT, IRS, SPOT), enables to exactly quantify the sown crop location and crop planted area. Data esnters to the sub-process of crop production simulation. Regional inventory data authority is SSCRI. Historical (statistical) crop planted areas and crop yield and production data per administrative regions enable the statistical methods (trend analyse, correlation method, etc.) to be used in the process of crop yield simulation. The data authority is the Statistical Office of Slovak Republic (CSO SR).

Data analyses and data processing represent the "base procedures" for crop yield and production forecasting itself.

Weather, rainfall, crop, phenological and soil data obtained from authorities represent measured parameter values on weather, rainfall or phenological stations, respectively on selected soil profiles. The data are distributed in point format. Theoretically, there are several ways in which the data would be used (as a point data, as a data converted to polygon format or as interpolated data to raster (grid) format). The possibilities of data utilization in point format or in raster format requires dense and representative network of data measurements, developed precise methods for the interpolation process and also amount of work, time and experiences. At the present, the most realistic way seems to be the possibility to use data converted to polygon format. The principles of point data conversion to polygon format depend on the character of individual parameters.

Weather data utilization is conditioned by weather data conversion to WOFOST required structural format (for details see Supit, van der Goot, 2002, etc.) and specified weather stations spatial validity. There is possibility to specify wider weather stations spatial validity boundaries in accordance with the climate regionalization of Slovak Republic (Lapin at all, 2002) or in accordance with climate codes included in pedo-ecological units numerical codes (agro-climate regions of the Slovak Republic) (Džatko, 1989). For the purposes of crop yields and productions forecasting the agro-climate regions will be used. Agro-climate regions marked out more precise spatial interpretation, which respects the utilized agricultural areas boundaries. The agro-climate regionalization enables to specify only the wider, marginal weather station spatial validity extent. The problem of the regional spatial validity of weather stations specification has to be solved in the future.

Soil data utilization, similarly the weather data usage, depends on soil data conversion to WOFOST format (for details see Supit, van der Goot, 2002, etc.) and spatial differentiation of relevant soil parameters. Soil point data are represented by the selected soil profiles database (KPP), which includes general soil (profile related), morphological, physical and chemical properties. Soil texture is one of the most important soil parameters with the relevant influence on crop yield. The spatial aspect of soil texture distribution is expressed by pedo-ecological units differentiation over the Slovakia. The pedo-ecological regions represent relatively homogenous areas delimited on the base of agricultural utilization types originating by pedo-ecological units aggregation, respectively pedo-ecological sub-regions aggregation (Džatko, 2002). Each pedo-ecological region can be statistically described by an individual textural categories` area share (regional weight coefficients). The representation of texture fractions for each regional textural category can be determined (averaged value from individual soil profiles in the selected region) to represent the input to process of deriving by WOFOST required soil parameters. For the WOFOST crop growth simulation and input soil file is important the information about ground water table occurrence. Because of the lack of ground water data, the ground water influence will be not considered.

Crop data utilization is problematic since the integral crop characteristics and crop knowledge database of Slovak Republic, which would contribute the crop file calibration on condition of Slovakia, does not exist. Thus, the WOFOST default European crop files will be used.

The phenological data represents point data with the necessity of conversion into polygon format as well. The phenological stations spatial validity would be specified in accordance with climate regions (Lapin at all, 2002) or agro-climate regions (Džatko, 1989).

2. System of crop yield and production forecasting proposal

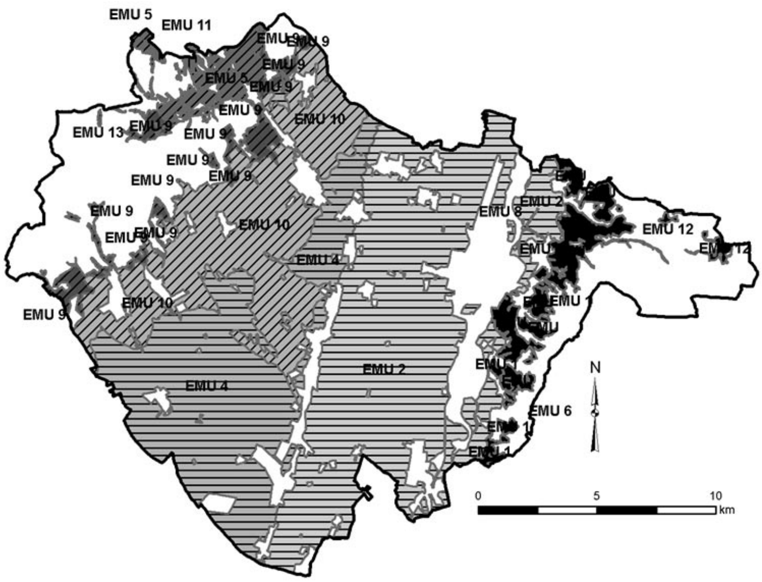
As it was mentioned, the system of crop yield and production forecasting represents amount of procedures related to data acquiring, processing, conversion to WOFOST model, model operating or process of crop yield forecasting and estimated results interpretation. The system operation requires several theoretical aspects related to spatial unit specifying. The scale level or methodology issues have to be solved as well.

The base, the smallest spatial unit for which the crop growth is simulated and crop yield and crop production is estimated, is called as an elementary modelling unit (EMU). Principle of EMU delimitation consists on overlaying and intersection of climate regions, soil regions and administrative units illustration is given on Piešťany district example - Figure 3. In 2005 the EMU principle of reference area delimitation in the process of crop yield forecasting will be applied only on pilot sites at local and regional scales.

The scale aspect (spatial aspect) of the system of crop yield and production forecasting specifies the character and size of the reference area for which crop yield forecasting is interpreted. It determines the estimates resolution level, the aggregation or interpolation methods of estimates interpretation and level of accurateness or generalization as well.

At state level, the country is considered as representative and reference area. Regional level refers to the administrative units (counties, districts) or natural regions (pedo-ecological unit, geomorphological region, etc.) as the reference areas for crop yield and production estimates interpretation. The agricultural farm and pertinently individual parcels are the reference areas at local scale. In the 2005, crop yield and production forecasting campaign will be carried out at all mentioned levels by SSCRI. They represent republic and regional level (counties, districts and at local level. The methods of crop yield estimates calculated at different levels and scales and different reference areas that will be used on SSCRI are described in the Table 3 in supplements.

Figure 3 *Principle of EMU delimitation on the Piešťany district example. The EMU 1, EMU 2,…, EMU 14 represent real existing different combinations of climate and pedo-ecological regions over the administrative unit (district Piešťany).*



The methodology aspect of the system of crop yield and production forecasting relates to selection of appropriate data format and methods used in the process of crop yield and production forecast. Generally, there are two possible ways of solution mentioned problem. First way relates to utilization of point and raster data (includes the process of conversion point data into the raster format by several methods of interpolation). The second way represents the point and vector data utilization and includes the process of conversion point data into the vector format. The advantages, disadvantages and real possibilities applicable in this field at present time are mentioned in above text. To replenish, the way of point and raster data utilization would be more precise and more effective and it would be allowed to estimate crop yield for each selected point or area. The problem of raster data applicability will be solved in the future. An overview of the point, polygon and raster data utilization in 2005 is described at the Table 3 in supplement.

The crop yield and production forecasting by WOFOST model enables to estimate the potential values. Regional inventory contributes to crop yield estimates to be more realistic (quantitative aspect). The satellite images interpretation enables to specify the real crop planted areas and to eliminate unreal pedo-ecological and climate regions combination (EMUs) for each reference area. In 2005 campaign, data obtained from regional inventory would be utilized only for selected farms (at local scale), pertinently at regional level for selected districts (pilot sites).

CONCLUSIONS

The system of crop yield forecasting does not represent only the WOFOST model and its application on existing data. The system includes amount of procedures (with data processing starting and process of crop yield estimating ending).

Data processing is related to data obtaining, data arrangement, or data conversion into by WOFOST required format. Sufficient data accessibility on Slovak Republic enables to pre-process data usable at several spatial scale levels, actually at state and regional level. There is a lack of detailed (point) data and necessity for time and work needed for pre-processing as well some problems with data utilization at local level.

The individual input point data spatial validity specifying (weather station – agro-climate region, selected soil profile – pedo-ecological region, etc.) enables to convert point data to polygon format. This way is appropriate for data utilization at small scales (state and regional). More complicated is data conversion to raster format, which would be more appropriate for data utilization at local scale. Data interpolation to raster would enable specification of the parameter value for each selected point and consequently estimate the crop yield for each point as well. The mentioned problem has to be solved in close future.

The basic smallest spatial unit, for which the crop yield and production is estimated is Elementary Modelling Unit (EMU). The EMU represents the area specified by overlay and intersection of agro-climate and pedo-ecological regions and selected administrative or natural region. Each administrative unit (districts, county or state) consists of one or more EMUs and the final crop yield estimate is derived as a crop yield weighted average of all EMUs located on administrative unit area.

In 2005 crop yield and production forecasting campaign at SSCRI, the estimates will be carried out at the state level (Slovak Republic) and regional level (counties and districts). On pilot sites (selected districts representing regional level and selected agricultural farms representing local level), the described alternative forecasting methodology will be tested.

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Table 1 *WOFOST input requirements. For details see http://www.supit.cistron.nl/*

Field	Input file	Relating processes and sub-processes	Required parameters
Weather	meteo	global radiation evapotranspiration	station name, reference year, station location - latitude, longitude, altitude, maximum temperature and minimum temperature, rainfall, wind speed, vapour pressure, sunshine, long-term averages
	rainfall	rainfall	station name, reference years, precipitation
Soil	soil	root zone soil water balance – infiltration, evaporation, plant transpiration, percolation, capillary rise, ground water influence	soil name, soil water retention parameters (including soil moisture at wilting point, at field capacity and at saturation), hydraulic conductivity parameters (including hydraulic conductivity of saturated soil, percolation rate root zone and subsoil) soil workability parameters
Crop	crop	crop growth, assimilation, assimilates conversion into biomass, maintenance respiration, partitioning dry matter to plant organs, death rates, water use, rooting, nutrient usage	crop name, region, mean day of sowing, emergence or flowering, emergence parameters, phenology parameters, initial parameters, green area parameters, assimilation parameters, conversion of assimilates into biomass parameters, maintenance respiration parameters, partitioning parameters, death rates parameters, water use parameters, rooting parameters, nutrients parameters
General WOFOST run conditions	site	soil characteristics that are not specialized I soil file, nutrient balance, root zone soil water balance	menu option for soil file, ground water influence, non-infiltrating fraction, presence or absence of drain, maximum surface storage capacity of water, initial available soil moisture in total rootable soil, initial depth of ground-water table, drainage depth, maximum rootable soil depth, maximum fraction of rain not- infiltrating into the soil, basic (potential) supply of N, P and K by soil, recovery fraction of fertilizer N, P, K
	timer	time-related aspect of simulation	input files and data references, first year for crop growth simulation, number of years the crop growth to be simulated , first year of rainfall data to be used, numbers of runs for which rainfall has to be generated, option to start simulation, option to determine the end of simulation, option to output summary water balance, option to output interval , description (name)of crop, soil, weather station, rainfall station, start day of water balance
	rerun	new variables and their values defining aspect for consecutive WOFOST re-runs	values of changed variables
	run option	required run options storage	start/stop option, production level (simulation of potential crop growth, water limited crop growth, nutrient crop growth, name of timer file, site file, rerun file, output filename for summary output of potential and water limited production, etc

Table 2 *Overview of WOFOST input data on the level of Slovak Republic*

Field	File name (data)	Data source	Data owner	Data utilization	Missing data (would be refilled:)	Historical data	limitation
weather	weather file	Monitoring System of Meteorology and Climatology database network of weather stations	SHI	* 15 stations in 2003 30 stations in 2004 68 stations in 2005	by long-term daily parameter averages on individual weather station or according to station reference to climate regions	since 1989 untill 2005	medium-term regional forecast absence
	rainfall file	Monitoring System of Meteorology and Climatology database network of rainfall stations	SHI	* to 2005 rainfall files did not use in 2005 38 rainfall stations located in 4 districts (model areas)	by long-term daily rainfall averages	since 1989 untill 2005	–
soil	soil file	Soil Profile Analytical database (KPP_DB) Pedo-Ecological Units database (PEU_DB)	SSCRI	* to 2005 WOFOST default soil files in 2005 regional defined soil data	–	–	regional calibration of pedotransfer rules absence
crop	crop file	European crop characteristics database European crop knowledge database	–	* WOFOST default crop files	–	–	regional calibration of crop parameters absence

* required data according to tab. 1

Table 3 *Overview of crop yield forecasting methodologies that will be utilized at different spatial level in 2005*

Level	Reference area	Input data	Data format	Complement data	Results (relation)
state	Slovak Republic (NUTS 1)	crop yield estimated results per counties			averaged counties results
regional	counties_1 (NUTS 3)	crop yield estimated results per districts			averaged districts results
	counties_2 (NUTS 3)	weather – averaged weather parameter for each agro-climate region	polygon		$Ye_{ra,T} = W_{ra,T} * Y_{ra,(T-1)} / W_{ra,(T-1)}$
		soil – averaged soil parameters for Slovak Republic	polygon	weight coefficient $c_x = S_x/S_{ra}$	$Yfin\_e_{ra,T} = \sum_{x=1}^{5} c_x * Ye_{ra,T}$
		crop – WOFOST default crop files	polygon		$\sum_{x=1}^{5} c_x = 1$
		phenology – averaged phenological parameters for each county	polygon		
	districts (NUTS 4)	weather – relevant weather station	point		$Ye_{ra,T} = W_{ra,T} * Y_{ra,(T-1)} / W_{ra,(T-1)}$
		soil – averaged soil parameters for Slovak Republic (for 5 texture categories)	polygon	weight coefficient $c_x = S_x/S_{ra}$	$Yfin\_e_{ra,T} = \sum_{x=1}^{5} c_x * Ye_{ra,T}$
		crop – WOFOST default crop files	polygon		$\sum_{x=1}^{5} c_x = 1$
		phenology – relevant phenological station	point		
	pilot sites (Piešťany, Šaľa, Rimavská Sobota and Vranov districts)	weather – relevant representative weather station	point	DTM	
		rainfall – relevant representative rainfall station	point		$Ye_{iT} = Wi_t * Yi_{(Tt-1)} / Wi_{(T-1)}$
		soil - averaged soil parameters for each pedo-ecological region	polygon	weight coefficient $c_i = S_i(EMU_i)/S_{ra}$	$Yfin\_e_{ra,T} = \sum_{i=1}^{5} c_i * Ye_{iT}$
		crop – WOFOST default crop files	polygon	regional inventory	$\sum_{i=1}^{n} c_i = 1$
		phenology – relevant phenological station	point		
local	pilot sites (Kočín and Selice agricultural farms)	weather – relevant representative weather station	point	DTM	
		rainfall – relevant representative rainfall station	point		$Ye_{itT} = Wi_T * Yi_{(T-1)} / Wi_{(T-1)}$
		soil – data from selected soil profile located on parcel, pertinently interpolated data	point, raster	weight coefficient $c_i = S_i(EMU_i)/S_{ra}$	$Yfin\_e_{ra,T} = \sum_{i=1}^{n} c_i * Ye_{iT}$
		crop – WOFOST default crop files	polygon	regional inventory	$\sum_{i=1}^{n} c_i = 1$
		phenology – real phenological data obtained from farm	point		

c_x – weight coefficient , S_x – the share of selected textural caregory area in reference area ,c_i – weight coefficient, S_i (EMU_i) – the area of EMU_i, S_{ra} – area of whole reference area, YeiT – estimated EMUi yield in T year, Wi_T– WOFOST calculated parameter in T year, $Wi_{(T-1)}$ – WOFOST calculated parameter in T-1 year, W_{ra} – WOFOST calculated paremeter for reference area, $Yfin\_e_{ra,T}$ – final estimated yield for reference area in T year

CROP YIELD PREDICTION BASED ON SATELLITE IMAGES UTILIZATION

Odhad úrod poľnohospodárskych plodín pomocou satelitných obrazových záznamov

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ABSTRACT

The European Commission (EC) attempts to regulate the common agriculture market to secure food supplies and to provide food at reasonable prices through its Common Agricultural Policy (CAP). Behalf the adaptation on the common agricultural market of Slovak Republic with other European Union (EU) member states markets, it is necessary to carry out preliminary yield predictions of strategic agricultural crops during their vegetation period. Since 1988, according to the CAP, the EU Joint Research Centre (JRC) Ispra, Italy has realized the EU project Monitoring Agriculture with Remote Sensing (MARS). The MARS (Monitoring Agriculture with Remote Sensing) Unit of the JRC is now running in an operational context the Mars Crop Yield Forecasting System (MCYFS). The MCYFS is based on simulation of agro-meteorological crop growth parameters, low resolution satellite data analysis and statistical analysis and forecasts.

Satellite images from AVHRR sensor of NOAA satellite and VEGETATION sensor of SPOT satellites will be used in the 2005 Campaign of yield prediction for strategic agricultural crops utilizing remote sensing in Slovak Republic. Two vegetation indicators will be analysed: the Normalized Difference Vegetation Index (NDVI) and Dry Matter Productivity (DMP).

Keywords: crop yield prediction, satellite images, NOAA-AVHRR, SPOT VEGETATION, Normalized Difference Vegetation Index (NDVI), Dry Matter Productivity (DMP)

ABSTRAKT

Európska Komisia (EK) sa prostredníctvom spoločnej poľnohospodárskej politiky (CAP) snaží kontrolovať spoločný trh s poľnohospodárskymi komoditami, zabezpečiť dostatok potravín a udržiavať ceny potravín na adekvátnej úrovni. V záujme prispôsobenia stratégie trhu s poľnohospodárskymi plodinami Slovenskej Republiky trhom krajín Európskej únie (EÚ), je dôležité vykonávať priebežný odhad a predpoveď úrod strategických poľnohospodárskych plodín priebežne počas vegetačného obdobia. Spoločné výskumné stredisko (JRC Ispra) rieši od roku 1988 projekt Monitoring poľnohospodárstva pomocou diaľkového prieskumu Zeme (MARS). Oddelenie monitoringu poľnohospodárstva pomocou diaľkového prieskumu Zeme (MARS Unit) JRC momentálne prevádzkuje systém predpovede úrod (MCYFS). Tento systém je založený na simulácií agro-meteorologických parametrov rastu plodín, analýze satelitných obrazových záznamov s malým rozlíšením a štatistických analýzach a predpovediach.

V roku 2005 budú pri odhade úrod poľnohospodárskych plodín pomocou diaľkového prieskumu Zeme použité satelitné obrazové záznamy so senzora AVHRR satelitu NOAA a senzora VEGETATION satelitov SPOT. Dva hlavné indikátory vegetácie budú analyzované: vegetačný index NDVI a produkcia suchej hmoty (DMP).

KĽÚČOVÉ SLOVÁ: odhad úrod, satelitné obrazové záznamy, NOAA-AVHRR, SPOT VEGETATION, vegetačný index (NDVI), produkcia suchej hmoty (DMP)

INTRODUCTION

For effective operation on European Union (EU) common agricultural market, as well as in individual states, it is very important to carry out the preliminary yield prediction of strategic agriculture crops during their vegetation period. Consequently, the EU member states collect necessary data and consecutively use them for estimating and predicting crop yield on national scale.

History

European Union Joint Research Centre (JRC), Ispra started in 1988 with the project of Monitoring Agriculture with Remote Sensing (MARS). During the last 14 years from its conception the MARS project went through several Research Framework Programs related to studying, developing and implementing a number of methodologies and techniques in order to answer the requests of European Commission (EC). After several years of research in co-operation with Member States and pre-operational phase, the MARS (Monitoring Agriculture with Remote Sensing) Unit of the JRC is now running in an operational context of the Mars Crop Yield Forecasting System (MCYFS). The main pillars of the system are:

- observed meteorological data collection, processing and analysis
- simulation of agro-meteorological crop growth parameters
- low resolution satellite data analysis
- statistical analysis and forecasts (ROYER et al., 2004).

The Slovak Republic (SR) started with MARS activities in 1994 and since 1998 Soil Science Conservation Research Institute (SSCRI) has been solving problem of the crop yield forecasting on the basis of the contract with Ministry of Agriculture of the SR (MoA) (SCHOLTZ et al., 2004). The crop yield prediction is based on remote sensing methods using low resolution satellite systems and WOFOST agro-meteorological model. The satellite images from low resolution satellite systems have been used on SSCRI for crop yield prediction since 2003.

MATERIALS AND METHODS

In the 2005 Campaign satellite images from AVHRR sensor of NOAA satellite and VEGETATION sensor of SPOT satellites will be used. Two vegetation indicators will be analysed: the Normalized Difference Vegetation Index (NDVI) and Dry Matter Productivity (DMP).

Satellite systems

Thanks to their large field-of-view, low resolution (LR) satellite systems have good synoptic view and temporal frequency: the individual scenes have enormous width (up to 3000 km), which enables the entire Earth surface to be scanned every day. The intrinsic drawback is of course situated in the low spatial resolution, with pixels of about 1km^2 (ROYER et al., 2004).

Since 1978, 12 different NOAA satellites have been launched (Table 1).

Table 1 Overview of NOAA satellites

Satellite	Operation period
TIROS-N	19.10.1978 – 30 .1.1980
NOAA6	27.7.1979 – 5.3.1983 and 3.7.1984 – 16.11.1956
NOAA7	19.8.1981 – 7.6.1986
NOAA8	20.7.1983 – 12.6.1984 and 1.7.1985 – 31.10.1985
NOAA9	25.2.1985 – 7.11.1988
NOAA10	17.11.1986 – 16.9.1991
NOAA11	8.11.1988 – 11.4.1995
NOAA12	14.5.1991 – 14.12.1998
NOAA13	9.8.1993 – 21.8.1993 – failed
NOAA14	30.12.1994 – present
NOAA15	13.5.1998 – present
NOAA16	21.9.2000 – present

The Advanced Very High Resolution Radiometer (AVHRR) is the main sensor on-board of the NOAA satellite platforms, which spin around the earth in a near-polar orbit at a height of about 833 km and with a frequency of about 14.1 cycles per day. The AVHRR is imaging sensor which measures the radiance emitted or reflected by the earth-atmosphere system in 5 spectral bands, with a spatial resolution of 1.1 km sub-nadir (Royer et al., 2004).

Table 2 Characteristics of the AVHRR spectral bands

Band Nr.	Band width (μm)	Spectral domain	Note
1	0.58 – 0.68	Visible (VIS)	
2	0.725 – 1.00	Near-infrared (NIR)	
3A	1.58 – 1.64	Shortwave-infrared (SWIR)	during day
3B	3.55 – 3.93	Middle-infrared (MIR)	during night
4	10.3 – 11.3	Thermal-infrared (TIR_1)	
5	11.5 – 12.5	Thermal-infrared (TIR_2)	

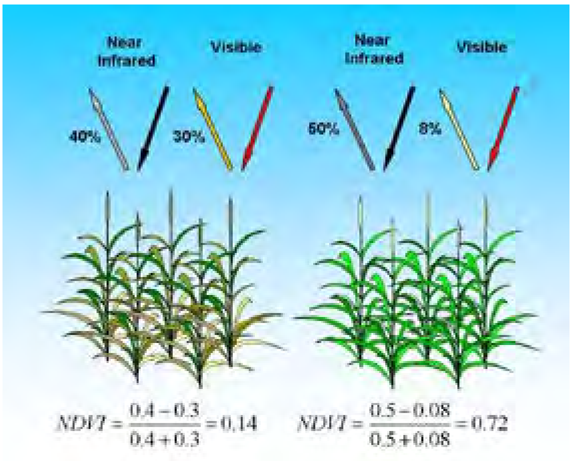
The series of SPOT satellites are a French initiative. SPOT1, 2 and 3 were launched in 1986, 1990 and 1993 and carried only high resolution HRV sensor with 20m resolution in multi-spectral mode (Green: 0.50 – 0.59 μm, Red: 0.61 – 0.68 μm and NIR: 0.78 – 0.89 μm) and 10 m for panchromatic band. With SPOT4 which was placed in orbit in 1998, the HRV sensor was extended with a MIR band (1.58 – 1.75 μm) and renamed to HRVIR, but also new low resolution sensor was added (1.15 km): VEGETATION (or VGT for short). On May 24th, 2002 SPOT5 was launched with as payload upgraded version of HRVIR (10 m/5 m resolution) and a copy of the previous VGT sensor (Royer et al., 2004).

Vegetation indicators

The Normalized Difference Vegetation Index (NDVI) is a measure of the amount and vigour of vegetation at the surface. The magnitude of NDVI is related to the level of photosynthesis activity in the observed vegetation. When sunlight strikes objects, certain wavelengths of this spectrum are absorbed and the rest wavelengths are reflected. The pigment in plant leaves, chlorophyll, strongly absorbs visible light (from 0.4 to 0.7 μm) for its usage in the process of photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm). The more leaves that plants have, the more these wavelengths of light are affected (SANDHOLT). As a consequence it is a good indicator of the amount and condition of the vegetation. The Normalized Difference Vegetation Index is defined as the difference between the visible (RED) and near-infrared (NIR) bands, over their sum.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Figure 1 *Normalized Difference Vegetation Index (NDVI)*



The calculations of NDVI for a given pixel always result in a number that ranges from -1 to +1. The NDVI of terrestrial vegetation steadily increases with canopy cover from 0.15 (bare soil) up to 1 (dense canopies). On the other hand, water bodies have negative NDVI, while clouds are characterized by values around zero (Royer et al., 2004).

Compared to the VIS and NIR bands of NOAA AVHRR, the RED and NIR channels of SPOT VGT are narrower and their position is better adapted to the absorbance/reflectance spectrum of the plant pigments (chlorophyll) (Royer et al., 2004). On the NOAA AVHRR sensor the NIR measures all the way from 0.72 μm to 1.1 μm which includes area of considerably water vapour absorption by atmosphere form 0.9 μm to 0.98 μm (SANDHOLT). This fact explains why, in general, the VGT NDVI values are somewhat higher than those of AVHRR (the AVHRR VIS covers not only the RED but also part of the GREEN) (Royer et al., 2004).

Monteith (Monteith, 1972) provided the most general formulation for the Dry Matter Productivity (DMP, in kg DM/ha/day), that is the increase in dry matter biomass on a daily base.

$$DMP_1 = R_1 \,.\, 0.48 \,.\, fAPAR_1 \,.\, \varepsilon(T_1) \,.\, 10\,000$$

R_1 [J/m²/day] is the incoming shortwave solar radiation (200 – 3 000 nm), which is composed on the average comprises 48 % of PAR (Photosynthetic Active Radiation: 400 – 700 nm), and $fAPAR_1$ [-] is the PAR-fraction absorbed by the green vegetation. The efficiency term $\varepsilon(T_1)$ [kg DM/JPAR] accounts for the conversion of this absorbed energy into biomass (radiation use efficiency) and for the losses related to the transport of photosynthesis products, the maintenance of the standing biomass, etc. The definition of $\varepsilon(T_1)$ seems to be very complex but here it is simply approximated as a function of the daily temperature T_1. The function $\varepsilon(T_1)$ is non-linear and bell-shaped: it reaches a maximum at a temperature of 22°C and approaches zero for temperatures below 0°C and above 40°C. The factor 10 000 [$m_¿$/ha] obviously transforms the square meters into hectares, a more common unit in agro-statistics (Royer et al., 2004).

The linear relationship between fAPAR and NDVI has often been demonstrated in literature (Myneni and Williams, 1994). Hence, the *fAPAR*-values are estimated for each 1km-pixel from the NDVI-imagery by means of the equation *fAPAR* = A + B . NDVI, in which the intercept A and slope B are adapted as the sensor type. A "heuristic" calibration on Belgian data (Eerens et al., 2000) yielded the following values: A = -0.269, B = 1.68 for NOAA-AVHRR, and A = -0.247, B = 1.54 for SPOT-VGT. At the level of *fAPAR*, all differences between both sensors should now have disappeared (Royer et al., 2004).

R_1 and T_1 are two daily provided meteorological inputs of the approach on a "very low" resolution (worse than the resolution of the NDVI images) (Royer et al., 2004).

Methodology

The objective of the crop yield prediction system is to provide the most likely, precise, accurate, scientific, traceable and independent forecast for the main crops' yields (Genovese et al., 2004).

The system consists of a linear regression model combining the mean yield, a linear time trend and a linear regression function to explain the residual variation. The linear time trend represents the influence of long-term economic and technological dynamics such as increased fertiliser application, improved crop management methods, new high yielding varieties, etc. on yields. The residual variation is modelled as a function of crop growth indicators derived from satellite images. The crop growth indicators account the inter-annual yield variation that results from weather variability (Genovese et al., 2004).

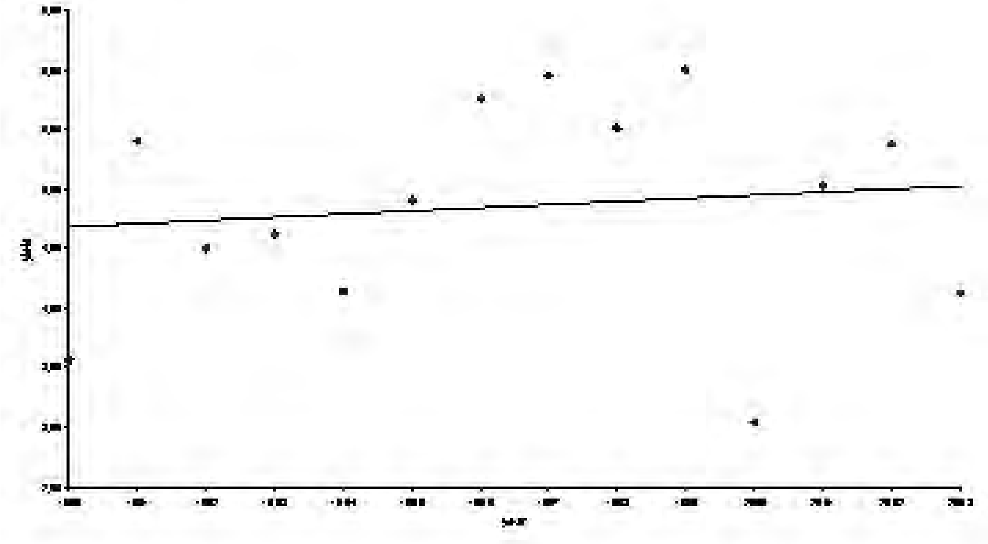
$$\text{yield} = f_1(\text{trend}) + f_2\ (\text{satellite data})$$

1. Yield trend analysis. Based on results of Palm and Dagnelie (1993) and de Koning et al. (1993) a linear trend will be used which sufficiently describes the increasing of yields.
2. Regression analysis of remote sensing data. Three indicators are analysed ($NDVI_{AVHRR}$, $NDVI_{VGT}$ and DMP_{VGT}) by regression analysis to find out the year with the most similar indicators development.
3. Yield forecast. Difference from yield trend line and yield in year find out by regression analysis of remote sensing data is added to yield predicted by the yield trend analysis.

RESULTS AND DISCUSSION

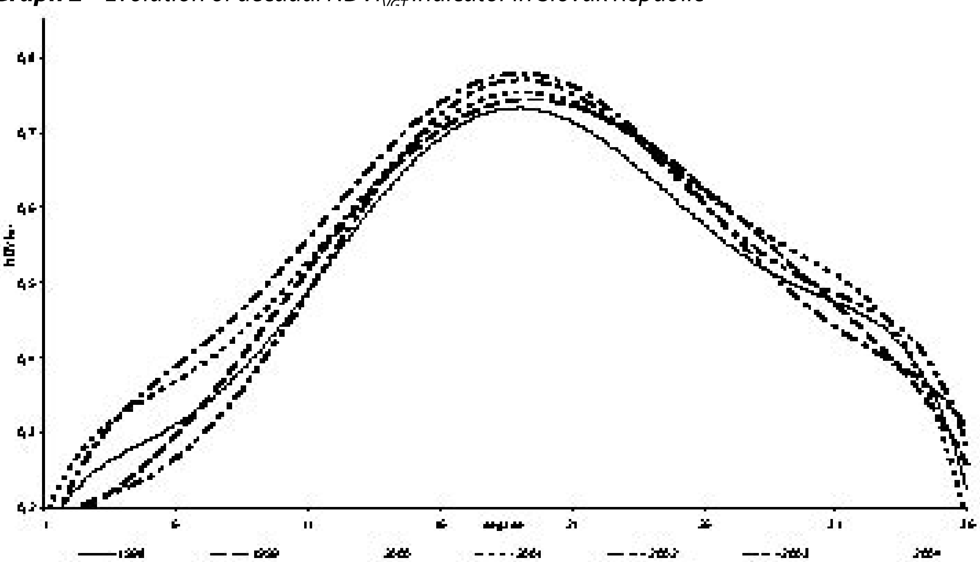
The period after 1990, in Eastern Europe countries, should be taken for yield trend analysis to exclude sharp changes caused by political changes around 1990 (GENOVESE et al., 2004).

Graph 1 *Yield trend analysis of grain maize*



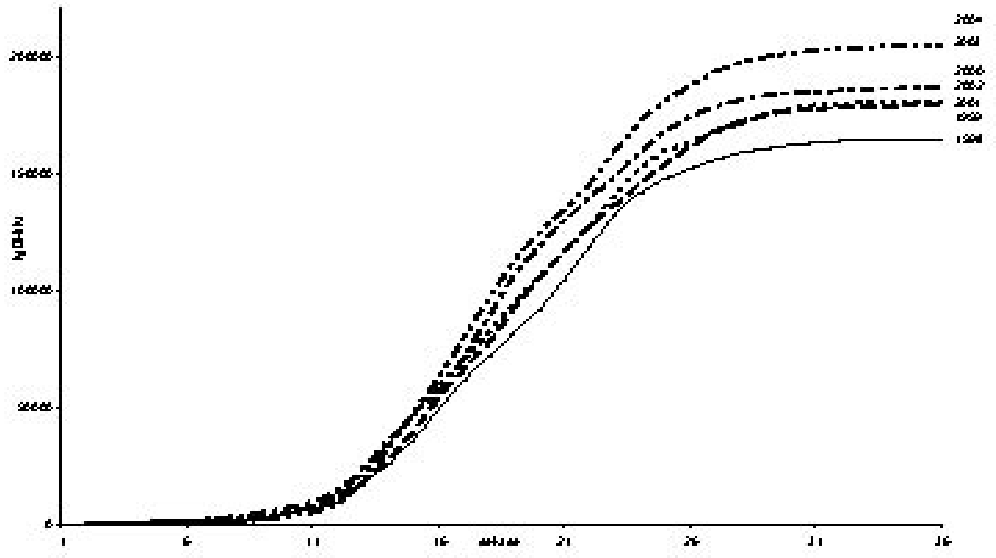
For NDVI indicators the decadal synthetic images are used by Maximum Value Compositing (MVC). The first two decades of each month comprise 10 days, while for the third one the number of days varies with the month (8,9,10 or 11).

Graph 2 *Evolution of decadal $NDVI_{VGT}$ indicator in Slovak Republic*



There is in general no direct correlation between the satellite-registered DMP of a crop at a given moment and the yield of the utile parts at harvest time. The final yield rather results from the history of the crop. This history can be quantified in someway by means of cumulative DMP starting from the emergence date of the crop (Eerens et al., 2001).

Graph 3 *Evolution of cumulative decadal DMP indicator in Slovak Republic*



CONCLUSIONS

The advantage of crop yield prediction carried out on Soil Science and Conservation Research Institute is the fact that it is able to present preliminary prediction during vegetation season.

The satellite images from low resolution satellite systems have been used on SSCRI for crop yield prediction since 2003. The comparison of yield predictions carried out by SSCRI, Statistical Office of the Slovak Republic and JRC in the 2003 Campaign found out that the predictions are similar, but SSCRI predictions were more various (better predictions, but worse predictions occur too). The comparison of the yield predictions of the last campaign could not be done because official yields of 2004 Campaign have not been published yet. The results of the 2004 Campaign of the crop yield predictions have been presented to MoA already. The MoA expressed satisfaction with the project and we hope that improvements developed for 2005 Campaign, mentioned in this article, will improve the quality of the systems (especially the accuracy of predictions).

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ORTHORECTIFICATION OF SATELLITE IMAGES FOR THE 2004 CAMPAIGN OF CONTROL WITH REMOTE SENSING

ORTOREKTIFIKÁCIA SATELITNÝCH OBRAZOVÝCH ZÁZNAMOV PRE KAMPAŇ 2004 KONTROLY DIAĽKOVÝM PRIESKUMOM ZEME

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ABSTRACT

The subsidies play a key role in agricultural sector and contribute to the prosperity of agricultural subjects. The subsidies to agricultural sector represent major part of European budget and that's why there is taken an emphasis to control the rightfulness of reception of subsidies. European Commission considers this fact and uses more methods of control. The most effective method is the Control with Remote Sensing. This method allows to control large areas in short time and costs relatively less.

To increase the precision and reliability of controls European Commission tries to catch the trend to use satellite images with very high resolution. To process these data high level of quality is required, especially concerning the geometric precision. Many methods of orthorectification exist and each has its own requirements for the quality of input data. European Commission realizes importance of geometric accuracy of used satellite images and defines strict criteria. Several types of satellite images (high and very high resolution) and methods of orthorectification were used in the 2004 campaign of Control with Remote Sensing in Slovak Republic. Results of orthorectification of 2004 campaign satellite images were markedly better than the maximum allowed thresholds defined by European Commission.

KEYWORDS: orthorectification, quality control, satellite image, IKONOS2, ground control point (GCP), independent check point (ICP)

ABSTRAKT

Dotácie hrajú kľúčovú úlohu v sektore poľnohospodárstva a vo výraznej miere prispievajú k zabezpečeniu prosperity poľnohospodárskych subjektov. Treba zdôrazniť, že sa nejedná o malú položku a preto je kontrole oprávnenosti poberania dotácií venovaná veľká pozornosť. Európska Komisia si uvedomuje dôležitosť tohto procesu pričom používa viacero metód kontroly. Najefektívnejšou je kontrola pomocou metód diaľkového prieskumu Zeme, keďže za krátky čas a relatívne málo peňazí umožňuje skontrolovať rozsiahle územie.

Pre zvýšenie presnosti a vierohodnosti kontroly sa Európska Komisia snaží zachytiť trend, ktorým je využívanie satelitných obrazových záznamov s veľmi vysokým rozlíšením. Využitie takýchto vstupných údajov kladie vysoké nároky na kvalitu spracovania, najmä čo sa týka geometrickej presnosti. Existuje mnoho metód diferenciálneho prekreslenia obrazu – každá z týchto metód má špecifické nároky na vstupné údaje, hlavne čo sa týka ich kvality. Európska Komisia si uvedomuje dôležitosť geometrickej presnosti používaných satelitných obrazových záznamov a preto striktne definuje záväzné požiadavky. V rámci kampane 2004 Kontroly metódou diaľkového prieskumu Zeme v Slovenskej republike sa využili viaceré druhy satelitných obrazových záznamov, s vysokým aj veľmi vysokým rozlíšením, a teda aj rôzne druhy metód diferenciálneho prekreslenia obrazu. Výsledky diferenciálneho prekreslenia satelitných obrazových záznamov použitých v kampani 2004 sú výrazne lepšie ako maximálne prípustné hodnoty definované Európskou Komisiou.

KĽÚČOVÉ SLOVÁ: diferenciálne prekreslenie obrazu, kontrola kvality, satelitný obrazový záznam, IKONOS2, vlícovacie body, nezávislé kontrolné body

INTRODUCTION

On the basis of Common Agriculture Policy (CAP) all Member States (MS) of European Union (EU) are required to create Integrated Administrative and Control System (IACS). Operational IACS is one of the basic conditions of maintaining structural funds of EU. Basic components of IACS are: Land Parcel Identification System (LPIS), application administrative system and integrated control system. Member States are compulsory to control minimum of 5% of the applications for subsidies for arable and forage land.

The control process contains two main tasks: control of grown crop and control of cultivated area. There are two main methods of controls:

- On-the-Spot (OTS) control – classical field inspections. Cultivated area is mainly measured by DGPS.
- Control with Remote Sensing (CwRS) – using Remote Sensing methods.

In CwRS a set of High Resolution (HR) multispectral images as SPOT, Landsat and IRS (mainly 3 or 4) are used for precise identification of grown crop. Since 2004 Very High Resolution (VHR) images from IKONOS2, QuickBird-2, EROS-A1 and SPOT 5 Supermode have been used for precise measurement of cultivated area.

Soil Science and Conservation Research Institute (SSCRI) has had experience in CwRS since 2001. 2003 pilot project was in the frame of pilot projects in EU Candidate Countries coordinated by Joint Research Centre, Ispra (JRC). In 2003 JRC also solved a pilot project of using VHR images in CwRS. Year 2004 was the first year with the usage of VHR images in CwRS campaign and this year was also the first year of practical application of CwRS in Slovak Republic.

The 2004 campaign

In 2004 campaign 1 % of the applications were controlled through OTS control and 6.4 % with CwRS. In 2004, Control with Remote Sensing was performed by SSCRI based on multi-annual agreement with Agricultural Paying Agency (APA).

Slovak administration decided to have two control sites for CwRS:

– the first site (PODU) located on Podunajska nížina is represented by circle with 25km radius. In this site the SPOT 5 images with resolution of 3m were used for area measurement.
– the second site (VRAN) located on eastern part of Slovakia near Vranov nad Topľou and Strážske cities is defined by square 20×20km. In this site the images from IKONOS2 satellite with resolution of 1m were used for area measurement.

MATERIALS AND METHODS

Satellite systems

Based on resolution the satellite systems are divided into categories:

- Coarse Resolution (CR) – pixel size 500 m – 1 500 m. Satellites: NOAA, SPOT Vegetation, ...
- Medium Resolution (MR) – pixel size 30 m – 500 m. Satellites: MERIS, MODIS, ...
- High Resolution (HR) – pixel size 3 m – 30 m. Satellites: Landsat, IRS, SPOT, ASTER, ...
- Very High Resolution (VHR) – pixel size 1 m – 3 m. Satellites: QuickBird-2, IKONOS2, Orbview-3, EROS-1A, SPOT 5 Supermode

Orthorectification

Orthorectification is a process of digital transformation of satellite image from central projection to the orthogonal cartographic projection with elimination of distortion due to sensor lens system, inclination of satellite and terrain elevation.

There is a need to use input data of appropriate quality to get the best results of orthorectification:

- satellite images suitable for orthorectification. There is a need to use satellite images without geometric pre-processing.

Table 1 *Types of satellite images product suitable for orthorectification*

Satellite	Product
QuickBird-2	Ortho Ready Standard
IKONOS 2	Geo Ortho Kit
OrbView-3	BASIC Express a BASIC Enhanced
EROS-A1	Level 1A
SPOT 5	Level 1A

- suitable digital elevation model (DEM). Precision of DEM defined by EC is in Table 2.

Table 2 *Precision of DEM for orthorectification*

Resolution	Inclination	$RMSE_z$
HR		10 – 20 m
VHR	< 15°	< 5 m
VHR	> 15°	< 2 m

- suitable ground control points (GCPs). They should be not only of appropriate quality (EC define that the quality of GCPs should be three times better than the final product) but also their good arrangement is important (European Commission, 2003b).

There are two main methods used for orthorectification:

- **Physical models:** these methods exactly describe the transformation between object coordinates and coordinates of satellite image. They are based on physical parameters of sensor (focal length, coordinates of principal point, pixel size and lens distortion), parameters of satellite position and sensor rotation. These methods are mainly based on collinearity equation (DI et al., 2002). It is the same principle as is used in photogrammetry (ČERŇANSKÝ 1986).
- **Rational function models:** these methods approximate the transformation between object coordinates and coordinates of satellite image based on ration of functions. Mainly 4 polynomial functions of third order are used.

The usage of physical model or rational function model depended on publication of sensor parameters by satellite provider and implementation of the models in software.

MATERIALS

Satellite images were provided by JRC during the campaign.

Table 3 *Scenes of 2004 campaign*

Site	Platform	Acquisition date	Pixel size	Cloud cover	DEM grid
PODU	SPOT 5	22. 4. 2004	10 m	0 %	20 m
	SPOT 4	8. 6. 2004	20 m	1 %	20 m
	SPOT 5	**4. 8. 2004**	**2.8 m**	**0 %**	20 m
	SPOT 5	**9. 8. 2004**	**2.8 m**	**8 %**	20 m
	SPOT 2	21. 7. 2004	20 m	0.5 %	20 m
VRAN	SPOT 2	15. 4. 2004	20 m	0 %	40 m
	SPOT 4	14. 6. 2004	20 m	0 %	40 m
	IKONOS 2	**8. 6. 2004**	**1 m**	**12 %**	**5 m**
	IKONOS 2	**8. 6. 2004**	**1 m**	**12 %**	**5 m**
	EROS-A1	**15. 6. 2004**	**2 m**	**0 %**	**5 m**
	EROS-A1	**5. 7. 2004**	**2.1 m**	**0.5 %**	**5 m**
	SPOT 5	19. 7. 2004	10 m	1 %	20 m

Selection of **Ground Control Points** (GCPs) and **Independent Check Points** (ICPs) requires practise and precision. They are considered as "well defined" in the context of resolution of the images. Well defined points are represented by features easily visible and exactly identifiable on the ground (in the case of IKONOS) or other source as digital orthophotos (in the case of HR images) and on satellite image as well.

Ground control points and ICPs used for orthorectification of HR and SPOT 5 Supermode images were measured on digital orthophotomaps.

To orthorectify the VHR IKONOS2 images another source of measurement had to be used to fulfill the requirements on accuracy of GCPs and ICPs – the geodetic static phase carrier Global Positioning System (GPS) measurement with post processing. Two Leica GS20

GPS receivers were used – one as reference station situated on known geodetic point and one as rover on measured GCP or ICP. The minimum observation time was 15 minutes. The measurement was post-processed in Leica SKI-PRO PC Office software with the use of local transformation. Local transformation uses 5 points with 5 cm horizontal accuracy. Coordinates of geodetic points for the measurement were obtained from Geodetic and Cartographic Institute Bratislava.

Figure 1 *Known geodetic point*

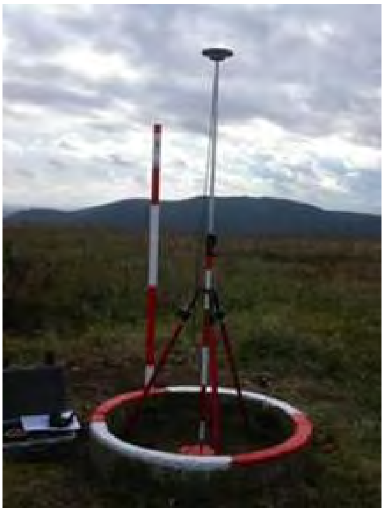


Figure 2 *Picture of GCP with the rover station*

Field documentations were made out for each measured point which consists of four parts: general information (project name, location, surveyors, equipment, methodology and date), field sketch (satellite image, photo or sketch), description (description of the point) and measurement results (datum, coordinates, accuracy of measurement and transformation key).

Digital Elevation Models (DEMs) used for the orthocorrection of HR and VHR images were procured externally – based on photogrammetric methods.

RESULTS AND DISCUSSION

Orthorectification

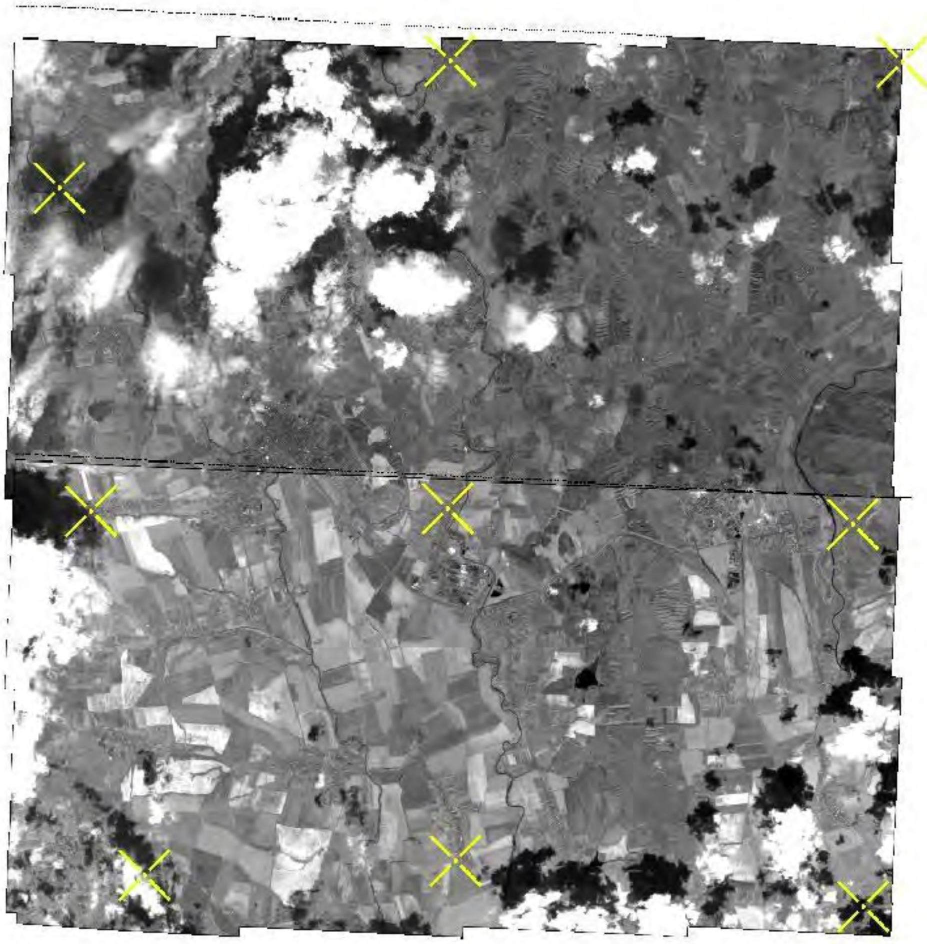
Geometric corrections of satellite images were performed in Erdas Orthobase 8.6.

Spot pushbroom model was used to orthorectify HR multispectral images as SPOT2, SPOT4, SPOT5. For orthorectification of SPOT5 Supermode images orbital pushbroom model was used.

IKONOS2 images were orthorectified by IKONOS RPC model with rational polynomial coefficient (RPC) files provided with images.

For HR and SPOT 5 Supermode images 16 – 20 GCPs were used and measured on "master images" – digital orthophotomaps. For IKONOS2 6 GCPs per scene (with three in the overlap) from field survey (GPS measurement) were obtained.

Figure 3 *Distribution of GCPs on IKONOS2 images*



European Commission defines geometric accuracy of orthorectified images based on absolute Root Mean Square Error (RMSE) on check points (European Commission, 2004a).

Table 4 *Maximum allowed 1D RMSE*

Data type	RMSE
IKONOS2	2.5 m
SPOT 2, 4 multispectral	30 m
SPOT 5 multispectral	15 m
SPOT 5 Pan Supermode	5 m

These are 1-dimensional RMSE values – applied separately for the X and Y direction. Root Mean Square Error on GCPs residuals had to be better then 0,5 of tolerance for geometric accuracy in Table 4 (European Commission, 2003b). The values in Table 4 represent approximately 1,5 of pixel size of the images and along with the above mentioned the results of the orthorectification should be then under 0,75 (approximately) of pixel size.

Table 5 Results of orthorectification

Scene		Number of GCPs	Source of GCP	$RMSE_X$ [m]	$RMSE_Y$ [m]	$RMSE_{XY}$ [m]
PODU						
SPOT 5	– 22.04.2004	20	d. orthophotomap	4.75	4.00	6.21
SPOT 4	– 08.06.2004	20	d. orthophotomap	5.49	5.96	8.10
SPOT 2	– 21.07.2004	20	d. orthophotomap	6.81	7.34	10.01
SPOT 5	– 04.08.2004	16	d. orthophotomap	1.50	1.51	2.93
SPOT 5	– 09.08.2004	16	d. orthophotomap	1.43	1.46	2.92
VRAN						
SPOT 2	– 15.04.2004	17	d. orthophotomap	5.00	6.92	8.54
SPOT 4	– 14.06.2004	16	d. orthophotomap	3.27	4.36	5.45
SPOT 5	– 19.07.2004	16	d. orthophotomap	3.97	3.61	5.37
IKONOS0 - PAN	– 08.06.2004	6	GPS	0.49	0.59	0.76
IKONOS0	– 08.06.2004	6	d. orthophotomap	1.00	1.24	1.59
IKONOS1	– 08.06.2004	6	GPS	0.59	0.20	0.62
IKONOS1-PAN	– 08.06.2004	6	d. orthophotomap	1.15	1.36	1.78

All results of orthorectification fulfilled the above mentioned criteria and even the geometric accuracy of orthorectification (Table 5), mainly less than 0,5 pixel size of the image, was reached.

Quality control

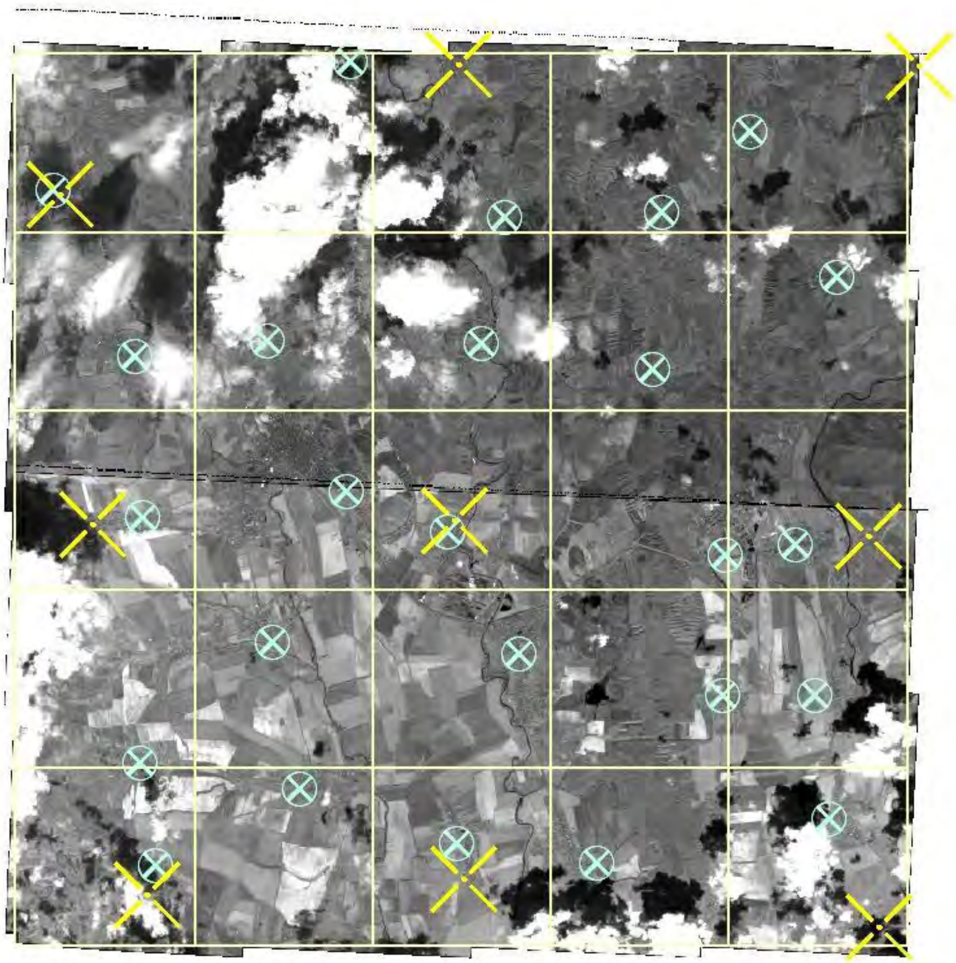
Quality control of orthorectification consisted of two phases:

- visual control through boundary check of LPIS vector layer
- measurement of discrepancies on independent check points (ICPs)

Independent check points (ICPs) are commonly used to evaluate the overall accuracy of geometrically corrected images. Methodology of ICPs measurement was the same as in the case of GCPs. Independent check points for the quality control of HR images were determined from digital orthophotomaps and for VHR images from field survey (GPS).

Quality control of HR images was performed on 16 ICPs. For purposes of quality control of IKONOS2 images 25 ICPs were measured which were different from GCPs – 15 ICPs per scene and 5 in overlap. Points in overlaps help reduce the total number of measured points by GPS which is the most time-consuming part of the process.

Figure 4 *Arrangement of ICPs in Vran site*



Orthorectification was performed correctly as it can be seen from the results of quality control of orthorectification. The reached results are very satisfying – all requirements on geometric accuracy were fulfilled in all cases and even the results are three times better.

Table 6 *Quality control of orthorectified satellite images*

Scene	Number of ICPs	d_X		d_Y		$RMSE_x$			$RMSE_y$			$RMSE_{xy}$		Pixel size [m]
		max [m]	threshold [m]	max [m]	threshold [m]	pixel	[m]	threshold [m]	pixel	[m]	threshold [m]	pixel	[m]	
SPOT2 – 15. 04. 2004	17	19.80	28.20	18.40	28.50	0.47	9.40	30	0.48	9.51	30	0.47	9.45	20
SPOT5 – 22. 04. 2004	16	9.66	14.76	11.51	14.86	0.49	4.92	15	0.50	4.95	15	0.49	4.94	10
SPOT4 – 08. 06. 2004	16	23.63	15.10	9.68	23.80	0.25	5.04	30	0.40	7.94	30	0.33	6.65	20
IKONOS0-P-08. 06. 2004	15	0.80	1.40	1.90	2.60	0.46	0.46	2.5	0.88	0.88	2.5	0.70	0.70	1
IKONOS0-M-08. 06. 2004	15	1.70	3.20	2.20	3.30	0.27	1.06		0.27	1.10		0.27	1.08	4
IKONOS1-P-08. 06. 2004	15	1.10	1.16	2.80	4.38	0.39	0.39	2.5	1.46	1.46	2.5	1.07	1.07	1
IKONOS1-MS-08.06.2004	15	3.20	4.64	2.40	5.00	0.39	1.55		0.42	1.67		0.40	1.61	4
SPOT4 – 14. 06. 2004	16	15.30	17.90	11.60	27.10	0.30	5.96	30	0.45	9.02	30	0.38	7.64	20
SPOT5 – 19. 07. 2004	16	6.90	12.70	6.70	12.60	0.21	4.22	15	0.21	4.20	15	0.21	4.21	10
SPOT2 – 21. 07. 2004	16	9.80	12.10	7.70	14.10	0.20	4.03	30	0.24	4.70	30	0.22	4.38	20
SPOT5 – 04. 08. 2004	16	2.60	4.50	2.60	3.90	0.50	1.51		0.00	1.29		0.47	1.40	3
SPOT5 – 09. 08. 2004	16	3.30	4.30	2.30	3.50	0.47	1.42		0.39	1.17		0.43	1.30	3

Quality control of DEM

The qualities of DEMs were controlled on the same points as were used for orthocorrection and quality control of the VHR images.

Table 7 *Quality control of DTM*

DEM	Number of ICPs	d_z [m]		$RMSE_z$		Grid [m]
		max [m]	threshold [m]	[m]	threshold [m]	
VRAN_DTM_5m	25	3.10	3.94	1.32	5	5
VRAN_DTM_40m	25	2.85	4.24	1.41		40

On both DEMs the determined values of $RMSE_z$ were under requirement and declaration.

CONCLUSIONS

Orthorectification and the quality control of satellite images are very important part of Control with Remote Sensing. Other activities as boundary check of the parcels and crop checks are done trough these images. Usage of satellite images with inappropriate geometric accuracy would lead to doubts in evaluation and control of the dossiers chosen for the Control with Remote Sensing. That's the reason why there is an emphasis on these issues and European Commission creates strict criteria as well. There are many obligatory documents related to this problematic published by European Commission.

In the last years there were many studies dealing with methods of orthorectification of VHR images. The tests demonstrate that these methods are robust and satisfactory results of orthorectification could be reached but there is a need to use precise input data. In the 2004 campaign of Control with Remote Sensing there were reached very good results of orthorectification, three times better than was maximum allowed accuracy in most cases.

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THE GEOREFERENCED DATABASE OF AGRICULTURAL SOILS OF SLOVAKIA

Georeferencovaná databáza poľnohospodárskych pôd Slovenska

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ABSTRACT

Since the year 2003, various activities have started at Soil Science and Conservation Research Institute to follow international trend in building a modern soil database as well as to effectively utilize existing potential of the Complex Survey of the Agricultural soil of Slovakia (KPP). The efforts resulted in development of new digital soil database. The Geo-referenced Database of Agricultural Soils of Slovakia – GDPPS has been designed as a database representation of KPP results. It is supposed to serve as the complex and modern dataset on regional, national and European level.

Keywords: Geo-referenced database of agricultural soils of Slovakia, Complex Soil survey of Agricultural Soils of Slovakia, Soil information system

ABSTRAKT

V súvislosti s vývojom medzinárodných trendov v budovaní údajových báz o pôde, ako aj vzhľadom na snahu o čo najúčinnejšie využitie existujúcich archívnych materiálov Komplexného prieskumu pôd Slovenska (KPP) pri tvorbe informácií o pôde/pôdnom kryte a krajine odštartovali v rámci Výskumného ústavu pôdoznalectva a ochrany pôdy v roku 2003 viaceré aktivity. Tieto aktivity vyústili do návrhu Georeferencovanej databázy poľnohospodárskych pôd Slovenska – GDPPS ako databázovej reprezentácie výsledkov KPP. GDPPS je do budúcnosti uvažovaná ako komplexná a moderná databáza vlastností poľnohospodárskych pôd/pôdneho krytu Slovenska s možnosťou aplikácie najmä na regionálnej a štátnej, ale aj európskej úrovni.

Kľúčové slová: Georeferencovaná databáza poľnohospodárskych pôd Slovenska, Komplexný prieskum poľnohospodárskych pôd Slovenska, informačný system o pôde

INTRODUCTION

Over the last 20 years, many national digital soil databases have been built up across the Europe based on national soil survey results (Heineke at al., 1998). Majority of the digital geo-referenced soil databases are represented as complex digital datasets on geographical and analytical properties of soil/soil cover in different scales depending on national soil survey quality. Beside these national activities, the European Soil Bureau attempts to develop a modern georeferenced soil database at the European level in small and detailed scales (LAMBERT at al., 2002, FINKE at al., 2003).

In Slovakia, the Complex Survey of Agricultural Soils - KPP (NĚMEČEK at al., 1967; HRAŠKO et BEDRNA 1970), accomplished in the years 1961 – 1970, is the basic source of data on soils/soil cover for the agricultural land. Despite the fact that data on soil/soil cover originating from KPP are of high quality, they are still stored in analogue archive and so far they are digitalized only from a part.

In 1980, creation of the Digital Soil Profile Database based on KPP results started (LINKEŠ at al., 1984; LINKEŠ at al., 1988). Resulting database contains nearly 18 000 records with related attribute data on general and analytical properties of soil profiles. Because of a time consuming work, only so called "selected soil profiles" were included into the database. In order to improve the data storage as well as to approximate the database attributes to the applicable soil data standards in field of soil classification the original soil database was re-edited in years 1999 – 2002 (SKALSKÝ 2000; SKALSKÝ et BALKOVIČ 2002). Obtained database referred to as Digital Database of Selected Soil Profiles of KPP – KPP-DB v.1.0 (SKALSKÝ 2002) is actually the only digital database based on KPP results and it serves as the basic digital dataset on agricultural soils analytical properties in Slovakia.

MATERIAL AND METHODS

Source data

The KPP survey resulted in a huge research material collection and archivation in the analogue form. The graphical set of survey results is represented by operate maps (scale 1:5 000 and 1:10 000). During the survey, the operate maps were used to record the localisation of survey pits (soil profiles) and to delineate the borders of soil units regions (soil taxonomic units, soil textural units, surface stoniness and waterlogging).

The survey reports represent the text block coupled to operate maps. The survey reports are related to an individual agricultural subject area (cooperative farm, state enterprise, individual farmer) representing the KPP survey unit. Besides general description of the area surveyed, (natural conditions, agricultural characterization, etc.) the survey reports contain attribute data on soil profiles:

- morphological description of soil profile and selected analytical properties (for topsoil and subsoil) of nearly 180 000 soil profiles (so-called basic soil profiles – BP)
- morphological description of soil profile and selected physical and chemical properties (for all genetic horizons) of nearly 18 000 soil profiles (so-called selected soil profiles – SP, already included in KPP-DB v. 1.0)

On the base of primary survey results the final outputs were processed during the KPP period:

- set of thematic maps (in scale 1:10 000) representing soil units regions (soil types, soil texture, surface stoniness and waterlogging)
- set of thematic maps (in scale 1:50 000) representing the generalised results of above mentioned maps on district level (completed with map of soil substrate units).
- survey reports on district level including general description of region (natural conditions, agricultural conditions), generalized data on soils/soil cover and thematic maps (1:250 000) on selected soil properties.

Digitalization of source data

The KPP operate maps (1:5 000 and 1:10 000) are thought to be used as the analogue source for digitalization of data on spatial distribution of soils, localization of soil profiles and other feature-related attributes defined by map legend or map labels. The survey reports are used as a source for digitalisation of the attribute data on soil profiles.

Operate maps of KPP enter into the process as the geo-referenced images (the Digital Archive of KPP Operate Maps). Using the GIS software ArcGIS View 8.3 all thematic data recorded on the maps is digitalized on-screen. The feature objects (soil units regions, soil profiles) are after digitalization stored as Environmental Systems Research Institute (ESRI) Shape geo-referenced data files.

The DBase data format is used to store the attribute data after being digitalized from survey reports. Because of high-powered work coupled to survey report data digitalization, only the selected attributes are assigned to be gained:

- selected profile attributes are digitalized for SP in order to complete and examine KPP-DB v.1.0 records
- only objective morphological and exact analytical attributes (for soil profile/horizon) are digitized for BP in order to avoid the surveyor's subjectivity in resulting data records and rationalize the database building

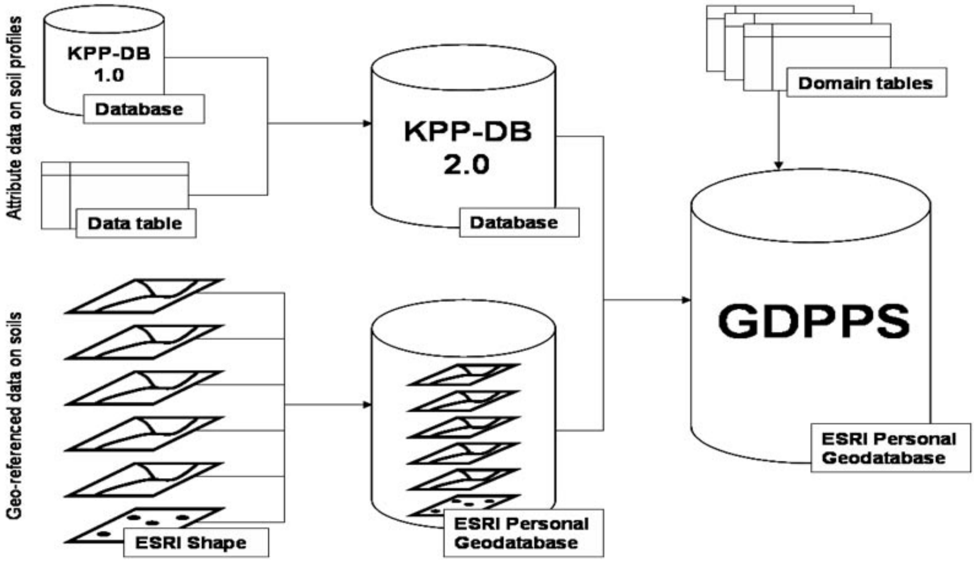
The map section of the Derived State Map in the scale 1:5 000 was chosen as the elementary reference area for building the GDPPS. Spatial extent of data digitalized depends on agricultural land share within the landscape and it referrs to the time period the KPP were done (1961 – 1970).

Data integration

The data are stepwise integrated into the predefined database structure (Figure 1) after they are digitalized from source materials. Spatial elements of GDPPS (soil units regions, soil profiles localization) are next integrated and the geo-referenced data archive is created (ESRI Personal Geodatabase). Consecutively, geographic reference system is defined for the whole dataset (national S-JTSK reference system). In the following step, the attribute data on soil profiles (digitalized from survey reports, KPP-DB v. 1.0 data) are integrated and so new database – KPP-DB v. 2.0 containing data for both BP and SP is created and appended to already existing Geodatabase. At last, the final relations between the database entities and between the database entities and domain tables are defined.

To define relations between database entities, the primary database keys and the foreign ones have to be designed and implemented into data structure. In GDPPS identification number of polygon – ICP, identification number of soil profile – ICS and number of horizon (when needed) are used as primary/foreign keys for data entities (see supplements, Tables 3 – 12).

Figure 1 *Integration of digitalized data to predefined database structure*



In order to record correctly and/or in accordance to applicable soil standards, the GDPPS non-analytical thematic attribute values are standardized. The data domain tables are created and applied to standardize the attribute values. Besides the data standardization, there are also other reasons assumed to employ the domain tables in the database structure:

- to complete description of attributes with auxiliary information (further description, explanations, values range, etc.)
- to avoid redundancy in data tables when the data items are described in more details (the same value might be repeated for several records/tables)

The domain tables created and used for GDPPS data standardization are listed in the Table 1 in supplements.

To provide the GDPPS relation to other official datasets (state information system, other soil/landscape databases) some foreign domain tables are also employed to standardize the attribute values related to e.g. administrative regionalization or pedo-ecological regionalization (see Table 8 in supplements).

RESULTS AND DISCUSSION

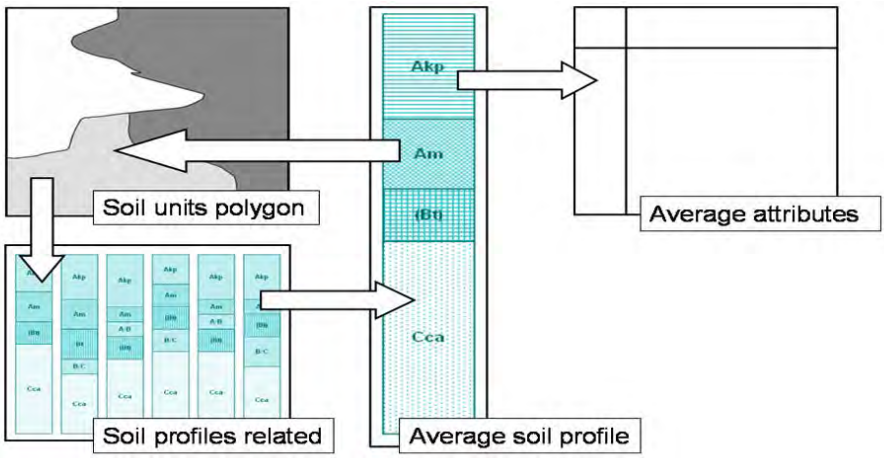
GDPPS database is designed as the database representation of KPP analogue data on agricultural soils/soil cover. In order to increase the GDPPS functionality, besides the KPP data used also some survey rules have been realized in GDPPS database structure:

- in KPP survey regular grid of point observations were considered as the main source of data on spatial differentiation of soil cover and the data on basic morphological soil properties – the basic soil profiles
- based on the observation points grid the soil units polygons were delineated on the maps

- additional point grid was set up in KPP survey to describe delineated soil units polygons in more details (morphological and analytical properties of soils) – the selected soil profiles

The above mentioned rules define causal spatial relationships between the GDPPS database spatial entities (soil polygons vs. soil profiles) which can be of high benefit in case the GDPPS data are interpreted in some way (Figure 2).

Figure 2 *The GDPPS functionality – employing of the KPP survey rules*



Regarding both the KPP source data and the survey rules GDPPS, database structure was designed (Figure 3). Based on source KPP data origin, totally 7 database entities were selected to be included in GDPPS (domain tables are not assumed to be the GDPPS entities).

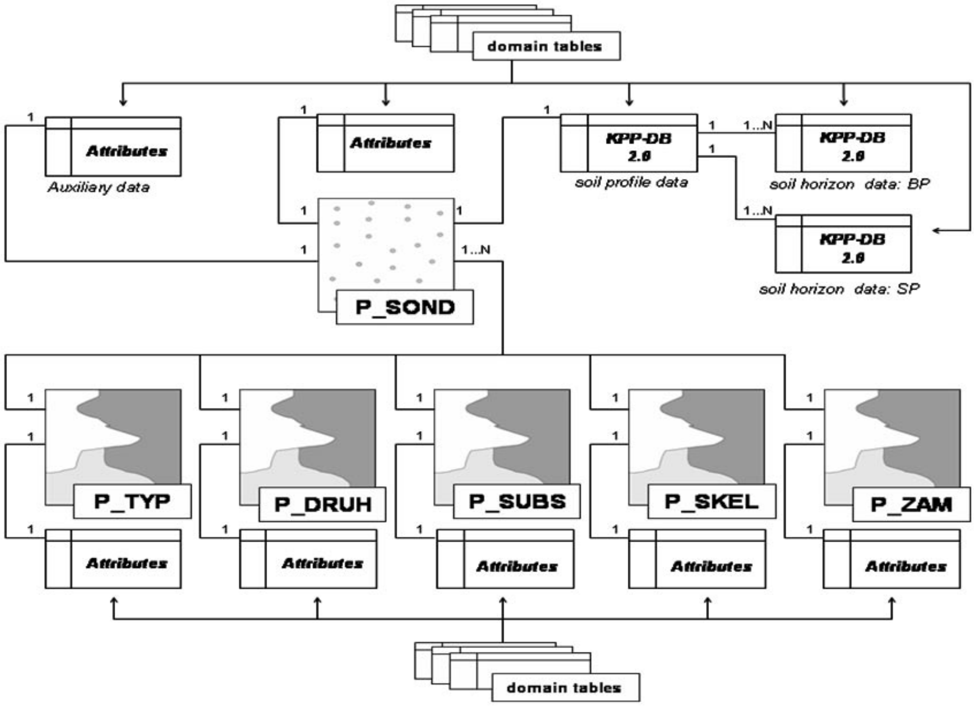
Both the subset of spatial and the subset of non-spatial entities can be distinguished from the GDPPS database entities. The subset of spatial database entities is represented as the geo-referenced vector data including:

- polygon spatial entities – soil taxonomic unit, soil textural unit, substrate unit, stoniness unit and waterlogging unit
- point spatial entities – localisation of soil profile

The subset of non-spatial database entities is represented by KPP-DB v. 2.0, as the soil profile database without direct spatial reference. The spatial representation of KPP-DB v. 2.0 is realized by the relation to spatial entities (soil profile localization). In more details the GDPPS database entities are described in Table 2 in supplements.

The database relations between the database entities are carried out in GDPPS to provide its full functionality.

Figure 3 *Entity-relationship diagram of GDPPS*



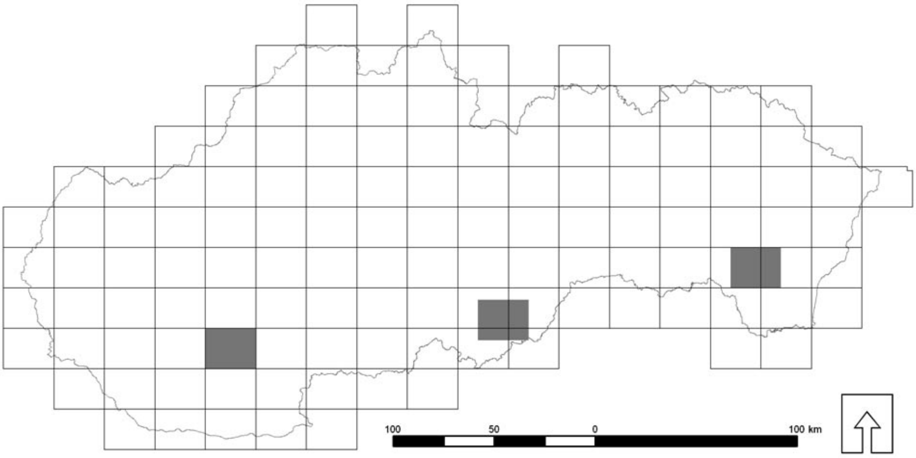
Properties of the real-world objects (entities) are in the GDPPS represented by database entity attributes. The KPP source data attribute extent was the main restriction affecting the selection of attributes used for description of the database entities in GDPPS. In general, the GDPPS database entities attributes follow the KPP defined set and only some small adjustments have been done to complete the attributes for GDPPS:

- hard-to-interpret, hard-to-digitalize, too biased or irrelevant KPP attributes were excluded of the final set (e.g. soil colour, soil structure, moisture, soil consistence, type and amount of soil neoformations, landscape position of soil profile)
- new attributes have been defined to be used as primary/foreign database keys

The attributes of database entities included into the GDPPS are listed and briefly described in Tables 3 – 12 in supplements.

Because of the high-powered and time consuming work coupled to KPP data digitalization and integration, the GDPPS building is assumed to be the long-term activity (5 – 10 years depending on available capacities). By now, data for 3 elementary reference areas have been completed (Figure 4), completing of another 12 – 15 elementary reference areas is expected in 2005.

Figure 4 *The area of Slovakia split out into individual elementary reference areas for GDPPS building and areas finished to the day (grey-filled).*



CONCLUSIONS

The project "Building of soil data-knowledge system as the baseline for creation of information about soil cover and landscape" sponsored by the Ministry of Agriculture of Slovakia started in 2003 in order to create new-fashioned soil database from existing data on soils/soil cover. To meet the project aims the best, the soil data-knowledge system – UZS were proposed as the conceptual frame for building two geo-referenced databases based on KPP results:

- Georefernced database of agricultural soils of Slovakia – GDPPS as the database representation of KPP results
- Raster base of agricultural soils of Slovakia – RBPPS – as the specific approximation of GDPPS data

Both databases GDPPS and RBPPS are supposed to serve as the data subsystem of the wider defined UZS. Continually built knowledge subsystem is suggested to be represented by knowledge database on the level of data processing and level of data application closely related to data subsystem (database structure). The UZS is assumed to be used as the powerful tool/data input for creating exact, spatial and dynamic information about agricultural soils/soil cover and agricultural landscape.

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SUPPLEMENTS

List of supplements:

Table 1 *List and description of GDPPS domain tables and its target application*

DOMAIN	APPLICATION FIELD	DATA STANDARDISED*)
soil_depth	coding and auxiliary description, depth of soil profile, 4 category scale (Number)	KPP-DB v.2.0
stonines_kvality	coding ant auxiliary description, volume of stones in soil horizon, 5 category scale (Number)	KPP-DB v.2.0
stonines_kvantity	coding and auxiliary description, type and size of stones in soil horizon, 10 category scale (Number)	KPP-DB v.2.0
soil texture 1	coding and auxiliary description, soil texture of genetic horizon or topsoil/subsoil horizon, 7 category scale (Text)	KPP-DB v.2.0 P_DRUH
soil texture 2	coding and auxiliary description, soil texture of genetic horizon or topsoil/subsoil horizon, 15 category scale (Text)	KPP-DB v.2.0
stoniness_category	coding and auxiliary description, category of stoniness (amount and size) of topsoil/subsoil horizon, 6 category scale (Text)	P_SKEL
waterlogging	coding and auxiliary description, category of waterlogging of soil profile, 4 category scale (Text)	P_ZAM
genetic_hor_AG[1]	coding and auxiliary description, genetic horizon signature according to GA[1], continually built domain (Text)	KPP-DB v. 2.0
genetic_hor_MKSP[2]	coding and auxiliary description, genetic horizon signature according to MKSP[2], continually built domain (Text)	KPP-DB v. 2.0
soil_unit_AG[1]	coding and auxiliary description, taxonomic soil unit according to AG, continually built domain (Text)	KPP-DB v. 2.0 P_TYP
soil_unit_MKSP[2]	coding and auxiliary description, taxonomic soil unit according to MKSP, continually built domain (Text)	KPP-DB v. 2.0 P_TYP
soil_subst_AG[1]	coding and auxiliary description, soil substrate category according to AG, continually built domain (Text)	KPP-DB v. 2.0 P_SUBS
soil_subst_MKSP[2]	coding and auxiliary description, soil substrate category according to MKSP, continually built domain (Text)	KPP-DB v. 2.0 P_SUBS

*) Explanations of abbreviations used do find in Table 2.
[1] AG – Genetic-agronomical soil classification (Němeček et al. 1967)
[2] MKSP – Morfogenetic classification system of soils of Slovakia (COLLECTIVE 2000)

Table 2 *Brief description of GDPPS database entities*

DAT. ENTITY	DESCRIPTION
P_TYP	Polygon vector data, attribute database contains data on feature identification (ICP) and data on taxonomic soil unit (variety level) according to AG and MKSP.
P_DRUH	Polygon vector data, attribute database contains data on feature identification (ICP) and data on soil textural class (according to Novak textural classification) for topsoil and first subsoil genetic horizon.
P_SUBS	Polygon vector data, attribute database contains data on feature identification (ICP) and data on dominant and sub-dominant soil substrate category according to AG and MKSP.
P_SKEL	Polygon vector data, attribute database contains data on feature identification (ICP) and data on stoniness of topsoil and subsoil horizon
P_ZAM	Polygon vector data, attribute database contains data on feature identification (ICP) and data on waterlogging of soil profile.
P_SOND	Point vector layer, attribute database is divided into 2 separate tables: • general data table – data on identification (ICS), data used for relations (foreign keys) • auxiliary data table – data on quality evaluation and data used for relations to analogue KPP archive
KPP-DB v. 2.0	Digital soil database containing data on KPP soil profiles. Attribute data are stored in several separate tables with defined relations in between: • general data table – data on identification (ICS) and general soil profile data (soil classification, selected morphological parameters, etc.) • basic soil profiles data table – data on identification (ICS, number of horizon) and data on morphological and analytical properties of genetic horizons • selected soil profiles data table – data on identification (ICS, number of horizon) and data on morphological and analytical properties of genetic horizons

Table 3 *Soil type polygon layer (P_TYP) attributes description*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICP	Text	identification of polygon	primary key
TAX_AG	Text	taxonomic soil unit	taxonomic soil unit according to AG
TAX_MK	Text	taxonomic soil unit	taxonomic soil unit according to MKSP

Table 4 *Soil texture polygon layer (P_DRUH) attributes description*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICP	Text	identification of polygon	primary key
ZRN_OP	Text	soil texture class	soil texture class according to Novak classification, topsoil/subsoil
ZRN_O	Text	soil texture class	soil texture class according to Novak classification, topsoil
ZRN_P	Text	soil texture class	soil texture class according to Novak classification, subsoil

Table 5 *Soil substrate polygon layer (P_SUBS) attributes description*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICP	Text	identification of polygon	primary key
SUB_AG_1	Text	soil substrate category	soil substrate category according to AG, dominant substrate category
SUB_AG_1	Text	soil substrate category	soil substrate category according to AG, sub-dominant substrate category
SUB_MK_1		soil substrate category	soil substrate category according to MKSP, dominant substrate category
SUB_MK_2	Text	soil substrate category	soil substrate category according to MKSP, sub-dominant substrate category

Table 6 *Stoniness polygon layer (P_SKEL) attributes description*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICP	Text	identification of polygon	primary key
SKEL	Text	stoniness category	stoniness category according to KPP survey guide (Němeček et al., 1967), topsoil/subsoil

Table 7 *Waterlogging polygon layer (P_ZAM) attributes description*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICP	Text	identification of polygon	primary key
ZAM	Text	waterlogging category	waterlogging category according to KPP survey guide (Němeček et al., 1967),

***Table 8** Soil profile localization point layer attributes description – general data*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICS	Text	identification of profile	primary key
TS	Text	type of profile	type of soil profile (basic/selected) is defined
SUR_X	Number	x – coordinate	x-coordinate, geographic reference system S-JTSK
SUR_Y	Number	y – coordinate	y-coordinate, geographic reference system S-JTSK
SMO_SEK	Text	map section	map section of the Derived State Map in scale 1:5 000, foreign key
SMO_ML	Text	map sheet	map sheet of the Derived State Map in scale 1:5 000, foreign key
ZM_10	Text	map sheet	map sheet of the Basic State Map in scale 1:10 000, foreign key
TM_50	Text	map sheet	map sheet of the Topographic Map in scale 1:50 000, foreign key
ICP_PTYP	Text	identification of polygon	P_TYP data layer polygon identification, foreign key
ICP_DRUH	Text	identification of polygon	P_DRUH data layer polygon identification, foreign key
ICP_SUBS	Text	identification of polygon	P_SUBS data layer polygon identification, foreign key
ICP_SKEL	Text	identification of polygon	P_SKEL data layer polygon identification, foreign key
ICP_ZAM	Text	identification of polygon	P_ZAM data layer polygon identification, foreign key
ICP_KRAJ	Text	identification of administrative region	identification of NUTS3 administrative region (kraj), foreign key
ICP_OBEC	Text	identification of administrative region	identification of NUTS4 administrative region (obec), foreign key
ICP_KU	Text	identification of administrative region	identification of administrative region according to cadastre, foreign key
ICP_PER	Text	identification of polygon	pedo-ecological regions data layer identification, foreign key

***Table 9** Soil profile localization point layer attributes description – auxiliary data*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICS	Text	identification of profile	primary key
SUBJ_KPP	Text	KPP survey unit	agricultural subject surveyed, foreign key (relation to analogue data archive)
POD_KPP	Text	name of surveyor	name of surveyor responsible for soil profile description
ROK_KPP	Number	year of survey	year of survey/sample collection/samples analysis
OPER_VEKT	Text	name of operator	name of operator responsible for digitalisation of data from operating maps
DAT_VEKT	Text	date of digitalisation	date of digitalisation of operation map, MM/YYYY
OPER_ZAP	Text	name of operator	name of operator responsible for digitalisation of data from survey reports
DAT_VEKT	Text	date of digitalisation	date of digitalisation of survey report, MM/YYYY
POZN_ZAP	Text	note	additional data on source data quality defined by operator (survey reports)

Table 10 *Attribute description of KPP-DB v. 2.0 – general data table*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICS	Text	identification of profile	primary key, foreign key
TS	Text	type of profile	type of soil profile (basic/selected) is defined
TAX_AG	Text	taxonomic soil unit	taxonomic soil unit according to AG
TAX_MK	Text	taxonomic soil unit	taxonomic soil unit according to MKSP
SUB_AG_1	Text	soil substrate category	soil substrate category according to AG, dominant substrate category
SUB_AG_1	Text	soil substrate category	soil substrate category according to AG, sub-dominant substrate category
SUB_MK_1		soil substrate category	soil substrate category according to MKSP, dominant substrate category
SUB_MK_2	Text	soil substrate category	soil substrate category according to MKSP, sub-dominant substrate category
ZRN_O	Text	soil texture class	soil texture class according to Novak classification, topsoil
ZRN_P	Text	soil texture class	soil texture class according to Novak classification, subsoil
HLBKA_P	Text	soil depth	soil depth category
POCET_H	Number	number of horizons	number of described genetic horizons

Table 11 *Attribute description of KPP-DB v. 2.0 – basic soil profiles data table*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICS	Text	identification of profile	primary key, foreign key
C_HOR	Number	number of horizon	number of horizon (1 – 5), primary key
OZN_H_AG	Text	signature of horizon	signature of genetic horizon according to AG
OZN_H_AG	Text	signature of horizon	signature of genetic horizon according to MKSP
HLB_HOR	Number	depth of horizon	depth of genetic horizon lower boundary from surface (cm)
ZRN_NO	Text	soil texture class	soil texture class according to Novak classification
SKEL_TYP	Number	volume of stones	volume of stones, size and type
SKEL_TYP	Number	volume of stones	volume of stones, quantity (%)
PH_V	Number	soil acidity	soil acidity (KCl), only for topsoil and first subsoil horizon
IL_CEL	Number	clay content	clay content (fraction < 0.01 mm), only for topsoil and first subsoil horizon (%)

Table 12 *Attribute description of KPP-DB v. 2.0 – selected soil profiles data table*

ITEM NAME	DAT. TYPE	DATA ITEM	DESCRIPTION
ICS	Text	identification of profile	primary key, foreign key
C_HOR	Number	number of horizon	number of horizon (1 – 5), primary key
OZN_H_AG	Text	signature of horizon	signature of genetic horizon according to AG
OZN_H_AG	Text	signature of horizon	signature of genetic horizon according to MKSP
HLB_HOR	Number	depth of horizon	depth of genetic horizon lower boundary from surface (cm)
ZRN_TR	Text	soil texture class	soil texture class according to texture triangle diagram (MKSP)
ZRN_NO	Text	soil texture class	soil texture class according to Novak classification
SKEL_TYP	Number	volume of stones	volume of stones, size and type
SKEL_TYP	Number	volume of stones	volume of stones, quantity (%)
IL_CEL	Number	clay content	content of clay, fraction < 0.01 mm (%)
IL_FYZ	Number	clay content	content of clay, fraction < 0.001 mm (%)
PR_J	Number	silt content	content of silt, fraction 0.001 – 0.01 mm (%)
PR_H	Number	silt content	content of silt, fraction 0.01 – 0.05 mm (%)
PIE_J	Number	sand content	content of sand, fraction 0.05 – 0.25 mm (%)
PIE_H	Number	sand content	content of sand, fraction 0.25 – 2.00 mm (%)
PIESOK	Number	sand content	content of sand, fraction 0.05 – 2.00 mm (%), estimated value
PRACH	Number	silt content	content of silt, fraction 0.002 – 0.05 mm (%), estimated value
IL	Number	clay content	content of clay, fraction < 0.002 mm (%), estimated value
OBJ_HM	Number	bulk density	bulk density (g/cm^3), estimated value
PH_A	Number	soil acidity	soil acidity (H_2O)
PH_V	Number	soil acidity	soil acidity (KCl)
KARB	Number	carbonate content	calcium carbonate content (%)
KVK	Number	cation exchange capacity	cation exchange capacity (mval/kg)
SVB	Number	sum of exchangeable bases	Sum of exchangeable bases (mval/kg)
NSK	Number	base saturation	base saturation (%)
HUMUS	Number	humus content	humus content (%)
FOSF	Number	available phosphorus	content of P_2O_5 (mg/kg)
DRAS	Number	available potassium	content of K_2O (mg/kg)

A CONTRIBUTION TO THE ANTHROPOGENIC SOILS UNDERSTANDING

Príspevok k pochopeniu antropogénnych pôd

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ABSTRAKT

A trial to achieve unified perceiving of anthropogenic soils, according to their definition and characteristics, is presented especially regarding anthropogenic soils classification. Also a proposal explaining terminological situation in many new emerged terms (like anthropogenic soil, urban soil, man-made soil, artificial soil, cultivated soil, etc.) is provided in aspect to find internationally acceptable consensus. A comparison methodology of classification criteria principles has been applied using several world-wide and some national concepts of anthropogenic soil classification systems. It is necessary to note that diagnostics, definition and classification of cultivated soils developing "in situ" well match in many countries. A task for solution has to be focused on soils occurring in urban, industrial, traffic and mining areas (soils developing from removed and/or transported materials i.e. soils of "ex-situ").

Keywords: anthropogenic soil, terminology, definition, diagnostics, classification

ABSTRAKT

Je prezentovaný pokus dosiahnuť jednotné pochopenie antropogénnych pôd z hľadiska ich definície a charakteristík zvlášť s ohľadom na klasifikáciu antropogénnych pôd. Sú tiež predložené návrhy, ktoré by objasnili terminologickú situáciu novovzniknutých termínov (ako antropogénna pôda, urbánna pôda, človekom vytvorená pôda, umelá pôda, kultivovaná pôda, atď.) s cieľom nájsť medzinárodne akceptovaný konsenzus. Bola zvolená metodológia komparácie klasifikačných kritérií, pričom sa využili niektoré svetové a niektoré národné koncepty klasifikačných systémov antropogénnych pôd. Je potrebné poznamenať, že definícia, diagnostika a klasifikácia kultivovaných pôd tvorených „in situ" je dobre porovnateľná v mnohých krajinách. Problémom sú však pôdy vyskytujúce sa v urbánnych, priemyselných, dopravných a banských územiach, t.j. pôd vyvíjajúcich sa z premiestnených alebo transportovaných materiálov, t.j. pôd „ex-situ".

Kľúčové slová: antropogénna pôda, terminológia, definícia, diagnostika, klasifikácia

INTRODUCTION

In many soil classification systems terms such as urban soils, anthropogenic soils and man-made soils are perceived by soil scientists very variously, and those different terms often can confuse them. Terminological unity promotes urban and anthropogenic soils research in many aspects: to enable better understanding of these soils, their definition, characteristics and functions. Also problems of the soil classification and mapping could be solved with better facilities.

A large number of new anthropogenic soil classification systems has emerged over the world. According to our experience, these soils can be divided into group of cultivated soils and other soils affected by human. A general concept for cultivated soils classification is profound transformation of soil profile by deep ploughing, trenching and other manners of cultivation (fertilizers addition) what causes remarkable rebuilding of soil profile (homogenization, changed morphology, humus accumulation, changed physical-chemical properties etc.).

A task for solution has to be focused on other soils – occurring in urban, industrial, traffic and mining areas (urban soil, man-made soils). Soils are unique by the fact that in some systems they are not considered as soils, or they are presented like soil bodies, or substrate soils. Definition of these soils is not clear. It seems to be thought that a new definition of these soils or non-soils has to be elaborated regarding human as the dominating soil-forming factor.

Some common characteristics can be found: they are so-called substrate soils formed under anthropogeomorphic processes (ISSS-ISRIC-FAO 1998) with simple construction of soil body as A-C, or A-C-D profiles, very young by their age, heterogeneous in vertical profile (often stratification, buried horizons, artefacts presence, etc.) and in high pedo-diversity. In the soil profile initial pedogenetic process is dominating, in what the initial top horizon often inherits (copies) properties of anthropogenic substrata.

Therefore, the anthropogenic substrata classification (human-removed, human-replaced material „ex situ") is the most important feature for their differentiation. Also variety of anthropic processes that control formation of these soils can allow to create new differentiation and classification criteria.

MATERIAL AND METHODS

The first step was to recognize and review some well-known definitions of anthropogenic soils in efforts to find differences. By comparison of several systems of anthropogenic soils and urban soils systems we have striven to outline criteria principles for those soil groups. We have recognized and measured following systems: FAO (1994), WRB (1998), Soil Taxonomy (Ahrens, Engel 1999), Russian (Shishov et al.), German (DBG 1998) and French (Blaize 1998) anthropogenic soil classification systems and considered also urban soil classification involved by Burghardt (2002) and Stroganova et al. (1998). In addition, some comparison between Slovak and Russian anthropogenic soils classification has been made recently (Sobocká et al., 2001).

According to definition of **FAO-Unesco** (1994), the Anthrosols (AT) are soils in which human activities have resulted in a profound modification or burial of the original soil horizons through removal or disturbance of surface horizons, cuts and fills, secular additions of organic materials, long-continued irrigation, etc. A fimic A-horizon is defined as a man made surface layer 50 cm or thicker commonly containing artefacts as bits of brick and pottery though its depth.

Soil units: Aric Anthrosol (ATa), Fimic Anthrosol (ATf), Cumulic Anthrosol (ATc) and Urbic Athrosol (ATu).

According to the **World Reference Base** (1998), the Anthrosols (AT) are defined as soils that have been transformed by anthropedogenetic processes in such way that the original soil is no longer recognizable or survives only as a buried soil. Anthric horizon comprises a variety of surface layers that originate from long-continued cultivation. The characteristics and properties of these horizons depend much on the soil management practices used.

Distinguished are terric, irragric, hortic, and plaggen horizons. They must be at least 50 cm deep to provide diagnostic.

Soil units: Hydragric Anthrosol, Irragric Anthrosol, Cumulic Anthrosol, and Hortic Anthrosol.

Anthropic Regosols consist of anthropogenic soil materials or show evidence of profound modification by human activity. Also anthropogenic soil material is defined and refers to unconsolidated mineral or organic material resulting largely from land fills, mine spoil, urban fill, garbage dumps, dredging… produced by human activities, distinguished on garbic, spolic and urbic soil materials.

Soil Taxonomy USDA (1999) defines two anthropogenic surface horizons: anthropic and plaggic epipedon and two subsoil horizons agric and sulphuric. A separate group of Anthrosols has not yet been included in the Soil Taxonomy, although new suggestions have emerged (Bryant et al. 2003). According to their definition: anthropogenic soils are defined as those soils that have been profoundly altered by anthropogenic soil processes and have morphological characteristics and properties that are irreversible, or very slowly irreversible.

Soil units: they are not included as separate order.

Soil classification of Germany (DBG 1998) includes only soils with markedly transformed soil profile by human activities into the group of anthropogenic soils (Terrestric Cultosols), in such a way that the original horizontation is not recognizable. As diagnostic horizons are defined: plaggen (E), trenched (R) and migrare (M).

Soil units: Colluvisol (YK), Plaggen (YE), Hortisol YO), Rigosol (YY), Treposol (YU).

French classification of anthropogenic soils (Blaize 1998) distinguishes between entirely man-made soils (artificial or transported materials) and soils initially of natural origin, which have been so transformed by man´s actions that original solum is unrecognizable or buried.

Soil units: Anthroposol transformed, Anthroposols artificial, Anthroposol reconstructed. Those can be completed by qualifiers related to man´s activities: hortic, deeply ploughing, fimic, plaggic, irragric, urban, stripped, levelled, mixed, compacted, contaminated, sealed, leptic, ruderic, paddy, terraced, transported form.

Russian classification of anthropogenic soils (Shishov et al. 1998) defines Agrozems – soils whose profiles have got an agrogenically modified homogeneous topsoil more than 25 cm deep underlain by subsoil or parent material. Agrogenically transformed horizon holds a regular ploughing horizon and other artificial displacements (mechanical perturbation) of one or several natural horizons, application of organic and mineral fertilizers, or other chemicals. Human-modified horizons differ from their natural analogues by the mass arrangement and some physical and chemical parameters. As horizons are differentiated: Agro-peat (PT), Agro-peat-mineral (PAT), Agro-light-humus (PY), Agro-dark-humus (PU), Post-abrasive (PB) and Chemically polluted (X).

Soil units: Agrozems, Abrazems, Akvazems, Chemodegradozems.

Technogenic surface formation is a new term involved by the Russian soil scientists (Tonkonogov, Lebedeva 1999) for man-made soil bodies. They imitate natural soils, or they may be specific as non-soil. They are remnants of human activities consisting of natural substrates mixed with artificial materials.

Soil units: Kvazizems: Replantozems, Urbikvazizem, Naturfabricats: Abralit, Litostrat, Organolitostrat, Organostrat, Artifabricats: Artiindustrat, Artiurbostrats, Artifimostrat, Toxifabricats: Toxiindustrat, Toxiurbostrat, Toxifimostrat, Toxilithostrat, Toxiabralith.

Stroganova et al. (1998) suggested a new term for strongly transformed soils in cities – Urbanozems with definition of Urbic horizon. It is deeper than 50 cm laying on cultural layer, mixed or filled rocks which are also more than 50 cm thick. Soil profiles comprise of set U-horizons. Contemporarily it has involved soils occurring in the urban environment: natural, human-transformed (urbo-soil, urbanozem, chemozem) and man-made (urbotechnozem).

Soil units: Urbanozems: Agrourbanozems, Nekrozems, and Ekranozems; Chemozems: Industrizems, and Intruzems; Urbotechnozems: Replantozems, and Constructozems.

Burghardt in his new proposal (2002) divides urban soils into two main groups:

1) as those with lack morphologic changes in profile (i.e. without any recognizable feature of soil-forming processes) Rough soils, Fenosols, Relicted soils,
2) soils with some recognizable features of soil-forming processes changes: Atmospheric dust sediment, Compacted soils, Skeletal and gravel soils, Deep-accumulated soils, Hydromorphic soils, Chemically altered soils, Reductomorphic soils, Dialeimmasols, Intrusols, Leached soils.

RESULTS AND DISCUSSION

Definitions

Studying mentioned definitions of anthropogenic soils, it can be observed a close similarity to each other. Anthropogenic soils are presented as those formed under anthropogenic soil-forming processes. These soil-forming processes are modified and controlled by human actions. They may have either not common, unique properties, or behaviours that is distinct from existing natural soils.

Question 1: Do we consider man-made soils, or technogenic surface bodies, or urban soil as a soil? To answer this question there is desirable to clarify a role of human in impact on soil. There are many various anthropogenic activities affecting soil dating in the late history. They can be listed from cultivated practices to other influence (weak or strong, negative or positive) till the destruction or destroy of soil cover (cut and fill).

If we accept cultivated practices as a dominating human-induced impact (e.g. Anthrosols in WRB), similarly we have to respect other human-induced activities showing in new soil profile construction. For example man-made soils (newly constructed soils) are classified like Regosols, Leptosols etc. i.e. they are included in natural soil groups! In this aspect the human factor is not respected or totally neglected mainly in world soil classification systems.

Terminology: anthropogenic soils

The term of "anthropogenic soils" could be considered as a general terminological classification concept related to the anthropogenic soil units only.

Terminology: urban soils

The term of "urban soil" has been involved by Burghardt (1994) as a general terminological concept for soils occurring in urbanized, industrial, traffic and mining areas. The main reason for their differentiation from other soils is their location in above-mentioned areas. These soils are easily clustered according to the anthropogenic environment in which they are developed. Mine soils could be defined as those formed on mined lands, urban soils could be defined as those formed in urban environment, likewise industrial soils are formed in industrial areas (Sobocká 2001). Therefore clustering of urban soils depends upon the location and management control that is an entirely different concept in contrary to the anthropogenic soils.

According Stroganova (1998) Urbanozem is the central concept for soils in town and cities, although soils of towns comprise as prevailingly man-made soils or profound transformed soils, as well as superficially transformed soils and natural soils (e.g. city forest soils).

Question 2: where is a boundary of urban soils? Is it an administration city boundary or only closely delineation of sealed and or consumption areas?

Question 3: Do we distinguish Urbanozem like classification concept and urban soils as managing concept?

First trials in urban soil classifications have been involved by Burghardt (1994) and Stroganova et al. (1998). However, in these classification systems we encounter a lack of firmly stabilized diagnostic features or horizons with the adequate explanation of each horizons or layer. Also exact distinction of anthropogenic soil horizon, soil layer, substrate layer, etc. is not well-known.

Cultivated soils developing "in situ"

According to our experience, definitions of cultivated soils are quite well matched in many international soil systems. A general principle of cultivated soils classification is profound transformation of soil profile by deep ploughing, trenching and other manner of cultivation (fertilizers addition) what causes remarkable rebuilding of soil profile (homogenization, changed morphology, humus accumulation, changed physical-chemical properties etc.).

In all systems cultivated horizons are defined. Their differentiation is made according to the various manners of soil cultivation. We can find many analogue soil types among many world and national soil systems, e.g. comparable soil units for soils deeply cultivated in gardens are: Aric Anthrosol (FAO), Hortic Anthrosols (WRB), Hortisols (Germany), Anthroposol transformed, hortic (France), and Cultizems, gardening (Slovakia).

Man-made soils developing "ex-situ"

The real problem is to define so-called man-made soils. Here we have found many various interpretations following very divergent classification concepts, as can be found in concepts of urban soil classifications. In many cases, man-made soils are classified according to natural soil classification (e.g. Regosols, Rendzinas, etc. in German classification concept or Entisols and/or Inceptisols in Soil Taxonomy). Further they are classified according to the technogenic surface bodies (Russian classification concept), the Anthroposol artificial or in French reconstructed classification system and or like anthrozemic soil types (Slovak classification concept). The differentiation criterion for man-made soils in Slovak classification system (Sobocka et al. 2000) is human-removing, or transportation of soil or substrate material and spreading on other places.

The intention to include the man-made soils into the anthropogenic soils assumes to present a new definition of soil. To find an answer on the *question 1* is a task for soil scientists in the international frame.

On the other side, anthropogenic substrate or parent material is an inevitable compound of soil, many times without any recognizable soil horizon development, which can cause much frustration for those attempting to identify the major reason for their existence, behaviour, properties and location (Sencidiver, Ammons 2000). If soil scientists incline to accept these soils as into anthropogenic soil groups, they have to recognize basic characteristics. According to morphology they are very young by their age, so-called substrate soils having A-C, or A-C-D profiles. Very often, there is recognizable a soil heterogeneity at the horizontal level. In the same way, heterogeneity at vertical level is typical like stratification of soil horizons or soil layers, buried and relict horizons or their remnants presence.

Physical characteristics are typical of extremely: high content of skeleton, high content of silt particles, disturbance of aggregate structure, heavy compaction, or abnormal permeability. Typical for those soils is presence of anthroskeletal compounds such as: coal, ashes, slag, asphalt, domestic waste and sewage sludge, building wood, plastic material, paper, textile, artificial glass, brick, cinder, concrete, steel, metal, and organic bio products. Chemical characteristics: like possible presence of risk elements (heavy metals, organic compounds), abnormal content of Fe, Al, salts, etc, changes in pH, surplus uptake of Ca, Mg, N, P, etc., can be also taken into consideration.

Classification of anthropogenic soils in Slovakia

The Morphogenetic Soil Classification System Slovakia (2000) includes one anthropogenic soils group that involve two entirely diverse soils: CULTIZEMS (cultivated soils) and ANTHROZEMS (man-made soils).

By combining the methodology and our endeavour to find comparable soil type analogue, in most classification systems, we have decided to divide this group into two independent anthropogenic soil groups (Sobocká 2003). The proposed classification system is being discussed as a new approximation, not the final version. Therefore, we will work on it further including new aspects of anthropogenic substrata elaboration.

Cultizemic soil types: the principle of soil group division is profound transformation of the soil profile by the deep tillage, trenching, cultivation, fertilizers application, etc.

Anthrozemic soils types: they are perceived like man-made soils with following Anthrozemic diagnostic Ad-horizon characterization. It is the top horizon formed by man from heterogeneous removed materials of natural, natural-technogenic and technogenic provenance with various properties, having thickness of > 1 cm, organic carbon content > 0.3 %, possible presence of artefacts (brick fragments, glass, plastic materials, iron, slags, coal). The thickness of removed (transported) materials must be > 35 cm. As varieties of the horizon are anthrozemic, initial Adi-horizon (< 10 cm) represents primitive stage of soil forming process from anthropogenic substratas, whereas anthrozemic recultivated Adr-horizon has evidence of re-cultivated measures supporting vegetation growth. Anthrozemic soils have commonly a simple construction of soil body consisting of the A-C or A-C-D profiles.

According to Sobocká et al. (2000) anthropogenic substrata (which is central concept of these soils) is classified in Slovakia as follows: natural, natural-technogenic and technogenic substrata. Its occurrence does not correspond with climatical, geological, geomorphological, nor pedological conditions of the site, but depends upon human transport and deposits of very heterogeneous skeletal, sand or loam materials, commonly with various humus content.

CONCLUSION

We have tried to suggest an internationally acceptable definition of two very often used terminological terms of "urban soils" and "anthropogenic soils" in efforts to coincide common research in this field.

Herein, we have introduced classification of soil units that are analogously defined in foreign classification systems. Cultivated soils are relatively well matched with other similar systems in the world. In addition, we have registered a lot of heterogeneous man-made (anthrozemic) soil types, though in uncertain total number. At last, we want to emphasize deficiency in research of these soils.

Comparing among several foreign classification systems of anthropogenic soils and urban soils, we have attempted to elaborate the new anthropogenic classification system of Slovakia comparable with similar systems in the world.

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RECENT SOIL EROSION ESTIMATION USING ^{137}Cs TECHNIQUE

Odhad recentnej erózie pôdy využitím techniky ^{137}Cs

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ABSTRACT

Monitoring of soil erosion on the large area (in our case in the scope of Slovakia) is very problematic, especially from the suitable monitoring method and monitored localities density point of view. In correspondence with objective of monitoring of soil erosion, two methods on the determination of presence soil erosion processes in concrete area have been compared. The first one is the method based on the empirical calculation of average soil loss in accordance with USLE (Universal Soil Loss Equation). The second one is the method using ^{137}Cs determination. This technique is relatively popular in many countries and using this method it is possible to estimate soil erosion intensity in definite time period (recent erosion). It is based on radioisotope caesium distribution in the soil profiles (pedological sites) located in the direction of water erosion influence.

Determined values of accumulated soil matter (using caesium profile distribution) confirm presence of extreme soil erosion. They are nearly identical with results calculated according to USLE (applied in concrete conditions of studied localities). Obtained values of soil matter accumulation (determined by method of caesium) are probably higher because we have analysed caesium only to the depth of 0.40 m and the depth of accumulated humus horizon is 0.50 m (at both erosive transects).

Keywords: monitoring of soil erosion, USLE, ^{137}Cs

ABSTRAKT

Monitorovať vplyv erózie na poľnohospodársku pôdu v rámci väčšieho územia (v našom prípade v rámci Slovenska) je veľmi problematické najmä z pohľadu použitia vhodnej metódy sledovania ako aj z hustoty rozmiestnenia záujmových lokalít (eróznych transektov). Dôležité je zvoliť si vhodnú metódu na získanie údajov o prítomnosti erózno-akumulačných procesov. V zhode s cieľom čiastkovej úlohy monitoring erózie využívame okrem metódy založenej na výpočte priemernej straty pôdy podľa USLE aj metódu merania intenzity vplyvu erózno-akumulačných procesov na pôdu použitím rádioaktívneho izotopu ^{137}Cs (ako značkovacieho prvku). Je to v súčasnej dobe vo viacerých krajinách pomerne populárna a používaná metóda stanovenia intenzity priebehu erózie za určité časové obdobie (recentná erózia). Jeho distribúciu stanovujeme v pôdnych profiloch sond lokalizovaných po spádnici erózneho transektu.

Zistené hodnoty dosiahnuté využitím metódy stanovenia distribúcie izotopu cézia v pôdnych profiloch sledovaných eróznych transektov potvrdzujú prítomnosť extrémnej

erózie pôdy. Sú takmer zhodné s hodnotami priemernej ročnej straty pôdy vypočítanej podľa USLE. Pravdepodobne však budú o niečo väčšie, nakoľko sme v akumulačnej časti transektu izotop cézia stanovovali len do hĺbky 0,40 m a z popisu pôdnych profilov vyplýva, že hĺbka akumulovaných humusových horizontov je väčšia (0,50 m).

Kľúčové slová: monitoring erózie pôdy, USLE, ^{137}Cs

INTRODUCTION

Soil erosion is a natural process. It begins by soil surface disintegration caused by raindrops kinetic energy. It is followed by transport of soil particles. Finally, it ends by sedimentation of soil matter at the slope depression. This process has a great significance in the modelling of land relief and degradation of agricultural soil as well. In the same way, result of erosion processes impacting the soil can irreversibly damage physical, mechanical and profile soil properties, as well. Soil erosion is frequently accelerated by irrational human activity.

Collecting information on intensity of soil erosion in the concrete conditions (soil erosion monitoring) can be used as a base for effective measures application to combat soil erosion. Monitoring of erosion influence on the soil in the scope of large area (in our case in the scope of Slovakia) is very problematic. Important is to choose appropriate method to obtain available information about presence of erosive-accumulative processes. Two methods to determine presence of soil erosion processes in concrete area in correspondence with objective of monitoring of soil erosion are used. The first one is the method based on the empirical calculation of average soil loss in accordance with USLE (Universal Soil Loss Equation). The second one is the method measuring intensity of influence of the erosive-accumulative processes on the soil using ^{137}Cs (as a tracer). This technique is relatively popular in many countries and used for estimation of soil erosion intensity in the definite time period (recent erosion). We have determined radioisotope caesium distribution in the soil profiles (pedological sites) located in the direction of water erosion influence.

MATERIAL AND METHODS

In this contribution, there are given possibilities of using the recent erosive-accumulative processes estimation method (using ^{137}Cs) on the example of two erosive transects where we have been monitoring water erosion influence on the soil in the space (spatial heterogeneity).

Monitored localities (Nováky and Trstená) are situated at the arable land in erosion sensitive areas (rainfall intensity, soil erodibility, gradient of slope and land use etc.). Erosive transects (catenas) have been located on the basis of terrain survey. The primary requirement for choosing of study locality has been the relief of surrounding area. Erosive catena (transect) consists of:

a) top plateau of the slope (represented by water erosion, doesn't influence soil – referential soil profile)
b) erosive part of the slope (represented by water erosion, strongly influences soil – erosive soil profile)
c) accumulative part of the slope (represents accumulated soil – accumulative soil profile)

Three pedological sites were uncovered and precisely morphologically described. Every of these sites was situated in characteristic part of erosive catena (referential, erosive, accumulative). Transects have been oriented in the direction of water erosion impact. Soil samples for the determination of ^{137}Cs concentration were taken from the depths of soil profile 0 – 0.10, 0.30 – 0.35 and 0.35 – 0.40 m. Caesium analyses were done by semiconductor gammaspectrometric method in Nuclear Power Stations Research Institute in Trnava.

We have used technique based on the determination of ^{137}Cs concentration in the soil profile (profile distribution) for the erosive-accumulative processes indication. Caesium is used as a tracer of erosion because it is not naturally distributed in the soils. ^{137}Cs radioisotope can be emitted from the thermonuclear explosions or from nuclear power stations accidents. The presence of ^{137}Cs in soil dates back to the year 1945 when the first thermonuclear explosions and testing nuclear weapons started. At present, caesium is infiltrating the soil especially from the nuclear power stations accidents (Chernobyl in 1986).

This method is based on the measure of ^{137}Cs distribution in soil profile. Caesium has relatively homogenous distribution in the topsoil of arable land (to the depth of 0.25 – 0.30 m) and its distribution in the soil of grassland is to the depth 0.05 – 0.10 m. ^{137}Cs is comparatively stable in the soil because it is strongly fixed on the surface of colloidal particles of soil and its period of disintegration is approximately 30 – 35 years. Vertical movement of this isotope in the soil profile is not possible, so its concentration significantly decreases with the depth of the soil. This scheme relates to soils not affected by the processes of erosion, of course. Noticeable decreasing or increasing of caesium distribution in upper parts of soil profile can be caused only by processes of soil erosion (Linkeš, Lehotský, Stankoviansky, 1992; Fulajtár, Janský, 2001).

Measured profile distribution of caesium in individual parts of erosive catena (referential, erosive, accumulative) can be helpful for the estimation of recent erosion development. It is the erosion which was running at the studied localities approximately in the last 30 – 35 years (the most intensive anthropogenic fallout of ^{137}Cs was measured from the fifties to the half of the seventies). This method can help us to obtain valuable information on soil erosion development during the period of most intensive agricultural progress. We presume significant acceleration of soil erosion in this period. Recent erosion has been determined on the basis of difference between depth of measurable concentration of caesium in soil profiles from accumulative and referential part of transect.

We have used well-known Wischmeier-Smith´s equation (USLE – Universal Soil Loss Equation) for the determination of potential water erosion influence on the soil in the certain conditions (Wischmeier, Smith, 1978). Quite accurate results on potential water erosion (mean annual soil loss in ton per ha per year) has been obtained using this equation in particular conditions. Universal soil loss equation is expressed by multiplication of two direct factors (rainfall, soil erodibility) and four indirect factors (length of slope, steepness of slope, cropping and management, conservation practices).

Physical properties have been analysed in accordance with the standard analytical methods used in the framework of Partial Monitoring System – Soil, in the laboratory of Soil Science and Conservation Research Institute, Bratislava (Fiala et al., 1999).

RESULTS AND DISCUSSION

Monitored locality Nováky

Studied locality is located on the South of a chemical factory in a rolling hilly relief (Hornonitrianska kotlina). The sub-region is warm, moderately humid, with temperate winter and medium annual total precipitation of 750 mm (Landscape atlas of the Slovak Republic, 2002). Deep medium heavy soils originating on the deluvial polygenetic loams are typical for this part of the country. Erosive catena is situated on the slope with 8 – 11 degrees inclination (arable land) with total length of 740 m. Sunflowers grow at the erosive transect. The Haplic Stagnosols (WRB, 1994) are characteristic for the all monitored parts of the catena. The soil profile depth (especially in depth of humus horizon) is the only one difference in individual parts of the studied locality. Humus horizon thickness is 0.25 m at the top of the slope (referential part) and also at the erosive part. Humus horizon is mixed with the subsoil, as it is visible at the erosive part of the transect. The thickness of humus horizon is 0.50 m at the accumulation part of the transect.

We have used the Universal Soil Loss Equation (USLE) for potential erosion determination. The average amount of water necessary for erosion translocation of the soil matter has been determined (45.25 t/ha/year) on the basis of USLE application in the local conditions. The soil at the monitored transect is impacted by extreme erosion. Significant influence has inclination and length of the slope, soil properties, growing plant, intensity and amount of the precipitation. The limit value for soil loss is 30 t/ha/year (according to Act on agriculture land use and protection N 220 from the year of 2004). Calculated average soil loss value has exceeded this limit. Farmer or agricultural company is obliged to implement effective protective measures to stop or minimize undesirable influence of erosion.

Erosive-accumulative processes presence at the erosive catena has been demonstrated in the distinct profile distribution of the radioisotope caesium, too (Fig. 1). At the referential and erosive part of the transect, we have found out a classic scheme of caesium profile distribution (^{137}Cs has been determined only in the topsoil horizon 0 – 0.25 m, under this horizon have been caesium values practically unmeasured). Accumulation of soil matter is realized in the accumulation part of slope (base) and for this reason ^{137}Cs has been determined to the depth of the 0.40 m (accumulation of soil matter transported by erosive processes). This value is approximately the same like the concentration determined in the topsoil of referential profile.

Measured values of caesium in the soil profiles of individual parts of monitored catena help us to estimate the presence of recent erosion. We can do it on the basis of difference between depth of still measurable concentration of caesium in the soil profiles from accumulative and referential part of the transect. In this case, the intensity of the average annual accumulation of the soil matter is 3.75 mm and it represents (for the actual bulk density 1.32 g.cm^{-3}, Tab 1.) approximately 49.5 t/ha/year of the accumulated soil matter. The determined value is nearly identical with the value calculated according to USLE applied in concrete conditions of the locality. Depth of the accumulated humus horizon is 0.50 m and we have taken the soil samples for the caesium analyses only from the depth of 0.40 m and from this point of view the determined value of soil matter accumulation is probably higher.

Figure 1 *^{137}Cs profile distribution (Nováky)*

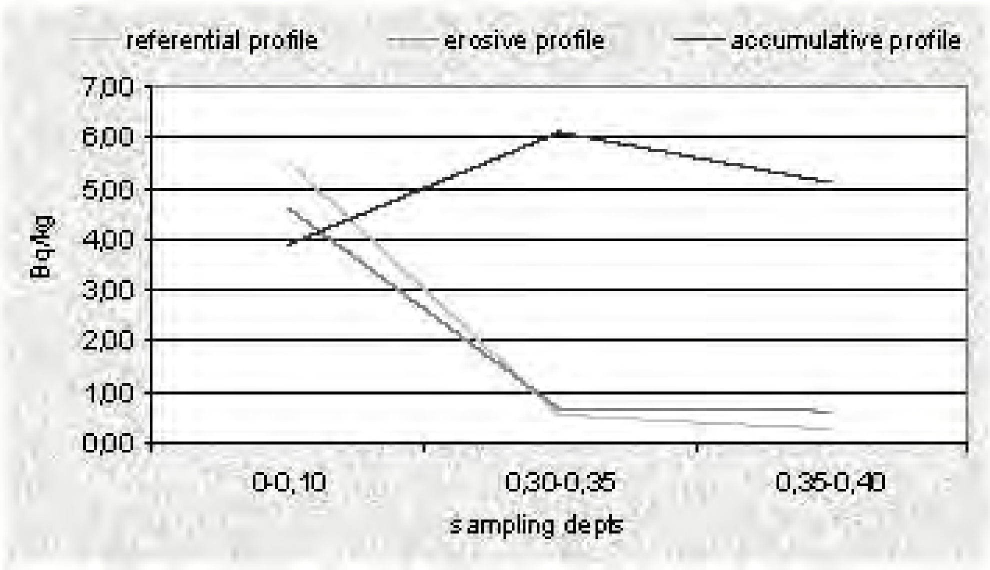

Table 1 *Physical properties changes in individual parts of erosive transect (Nováky)*

Transect Nováky	Sampling depth (m)	Bulk density (g.cm^{-3})	Porosity (%)
referential profile	0 – 0.10	1.56	37.64
	0.30 – 0.35	1.55	42.87
erosive profile	0 – 0.10	1.41	47.56
	0.30 – 0.35	1.50	45.43
accumulative profile	0 – 0.10	1.32	50.45
	0.30 – 0.35	1.40	48.33

Monitored locality Trstená

This erosive catena is located (on the SE from Trstená) in the very rolling heterogeneous relief (Oravská kotlina). The sub-region is characterised by moderately cool weather with mean annual total precipitation of 850 mm (Landscape atlas of the Slovak Republic, 2002). The monitored locality has deep, medium heavy soils (Stagni-Cambisols) originating on the flysch (weathered sandstones), a typical rock for this part of the country. The studied locality is situated on the slope with the 7 – 10 degrees inclination (arable land) with length of 370 m. Potatoes have grown at the whole transect in the time of study. The Haplic Stagnosols (WRB, 1994) are characteristic for the all monitored parts of the catena. Profile depth (especially depth of humus horizon) is different in individual parts of studied locality (humus horizon thickness in referential profile is 0.30 m, in erosive profile is 0.25 m and in accumulative profile is 0.50 m).

Average amount (38.33 t/ha/year) by water erosion translocated soil matter has been calculated using the USLE method. On the basis of this result we have determined extreme soil erosion on this studied area. This calculated average soil loss value exceeds limit value for soil loss (30 t/ha/year) and so owner of the agricultural soil (farmer, agricultural company) has to implement soil protection measures to stop following soil degradation.

The concentration of caesium in accumulative soil profile (in the depth of 0.40 m) is approximately at the same level in comparison to the profile of erosive and referential part of the monitored locality but only in the depth of 0.10 m (Fig 2). We have found out a classic scheme of caesium profile distribution in the referential soil profile (^{137}Cs was determined only in the topsoil horizon 0 – 0.30 m). We can calculate average annual accumulation of the soil matter on the basis of difference between the depth of still measurable concentration of caesium in the soil profile from the accumulative and referential part of the studied area. Height of the translocated soil matter layer has been 2.5 mm. It represents (for the actual bulk density 1.35 g.cm^{-3}, Tab. 2) approximately 33.75 t/ha/year of the accumulated soil matter. Determined value of the soil matter accumulation is probably higher because we have analysed caesium only to the depth of 0.40 m.

Figure 2 *^{137}Cs profile distribution (Trstená)*

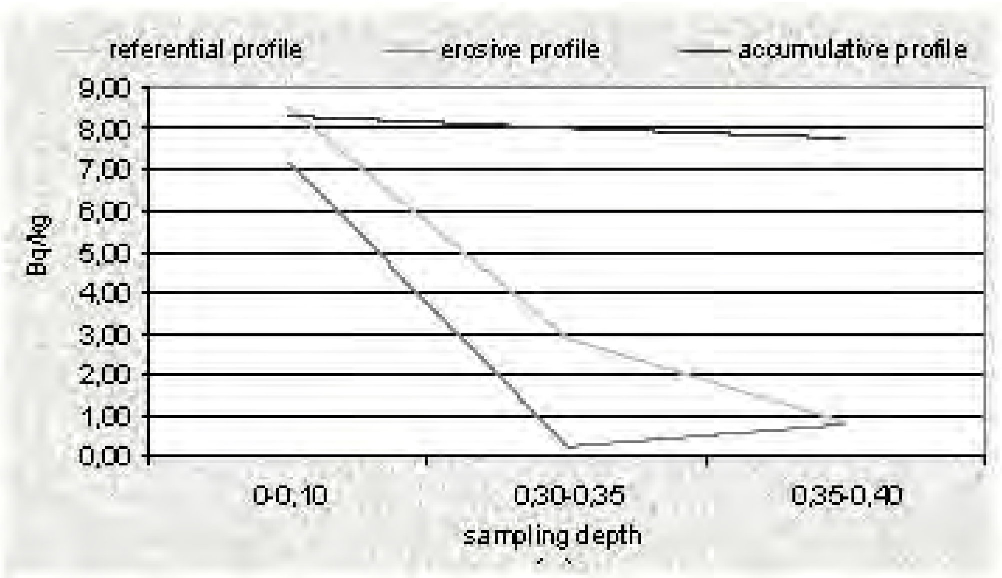

Table 2 *Physical properties changes in individual parts of erosive transect (Trstená)*

Transect Nováky	Sampling depth (m)	Bulk density (g.cm^{-3})	Porosity (%)
referential profile	0 – 0.10	1.32	50.34
	0.30 – 0.35	1.63	40.43
erosive profile	0 – 0.10	1.55	40.20
	0.30 – 0.35	1.61	41.27
accumulative profile	0 – 0.10	1.35	49.06
	0.30 – 0.35	1.51	44.39

CONCLUSIONS

We have determined presence of the erosive-accumulative processes at both monitored localities using the Universal Soil Loss Equation (USLE) in the concrete conditions (depending on locality relief, growing plant, soil properties, intensity and amount of precipitation). The soil of the studied erosive transects is influenced by the extreme soil erosion. The calculated values of the average annual soil loss exceeded the limit value determined for deep soil. Owner of the agricultural soil (farmer, agricultural company) has to implement soil protection measures to stop following soil degradation (stop or minimize undesirable influence of erosion) according to the Act No. 220/2004, § 5, subsection 2.

The measured values of caesium in the individual parts soil profiles of the monitored catena are helpful for estimation of recent erosion presence. It is the erosion which has been running at the studied localities approximately for the 30 – 35 years (in the period of most intensive agricultural progress). In that time, the most intensive radioactive falling down to the ground has been measured. Recent erosion has been estimated on the basis of difference between the depth of the measurable concentration of caesium in the soil profiles from the accumulative and referential part of the transect.

Determined values of the accumulated soil matter (using of caesium profile distribution and USLE) confirm presence of the extreme soil erosion. Classic scheme of the caesium profile distribution has been monitored in the referential soil profiles (^{137}Cs was determined only in the topsoil horizon 0 – 0.30 m) of both studied localities. The obtained results of the accumulated soil matter (using of caesium profile distribution) have been nearly identical with the values calculated according to the USLE applied in concrete conditions of the localities. The soil matter accumulation results (determined by method of caesium) are probably higher because we have analysed ^{137}Cs only to the depth of 0.40 m and the depth accumulated humus horizon is 0.50 m (at both erosive transects).

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AUTOMATIC CLASSIFICATION OF DIGITAL ORTHOPHOTOMAP OF AGRICULTURAL LANDSCAPE

Automatická klasifikácia digitálnej ortofotomapy poľnohospodárskej krajiny

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ABSTRACT

Classification as one of the image processing methods brings simplification into obtaining of a big amount of information contained in satellite or aerial imagery.

The aim of this study is to show possibility of extracting agricultural parcels from orthophotomap using object oriented approach. The inspiration along with challenge to use this method in agriculture was given by the existence of LPIS (Land Parcel Identification System) in Slovak Republic as a part of IACS (Integrated Administrative and Control System).

The process of the object oriented classification involves two steps, multiresolutional segmentation and classification. As each image analysis deals with structures of a certain spatial scale, the average image objects size must be free, adaptable to the scale of interest. This is achieved by a general segmentation algorithm based on homogeneity definitions in combination with local and global optimisation techniques. The scale parameter is used to control the average image object size. Different homogeneity criteria for image objects are based on spectral and/or spatial information. Object features are used by means of fuzzy logic to build class descriptions. The result of the classification is a network of classified image objects with concrete attributes, concrete relations to each other and concrete relations to the classes in the class hierarchy. Classification was evaluated by comparison of the results with the LPIS layer and vectorized orthophoto.

Keywords: object oriented image analysis, segmentation, classification, feature extraction

ABSTRAKT

Klasifikácia je jedna z metód spracovania obrazu, ktorá prináša zjednodušenie v získaní množstva informácií obsiahnutých v družicových alebo leteckých snímkach.

Cieľom predkladaného príspevku je poukázať na možnosť extrakcie poľnohospodárskych parciel z ortofotosnímok s použitím objektovo orientovaného prístupu. Inšpiráciou a súčasne i výzvou použiť túto metódu v poľnohospodárstve bola existencia Identifikačného systému poľnohospodárskych parciel (LPIS) v Slovenskej republike, ktorý je súčasťou Integrovaného administratívneho a kontrolného systému (IACS).

Objektovo orientovaná klasifikácia pozostáva z dvoch krokov a to, viacúrovňová segmentácia a následná klasifikácia segmentov. Ako každá obrazová analýza, aj táto sa zaoberá s problémom štruktúry určitej priestorovej mierky, priemerná veľkosť objektov musí byť voľne prispôsobiteľná mierke záujmu. To je dosiahnuté segmentačným algoritmom založeným na definovaní kritéria homogenity v kombinácii s lokálnymi a globálnymi optimalizačnými metódami. Priemerná veľkosť objektov je daná parametrom veľkosti. Použitie rôznych kritérií homogenity pre obrazové objekty sa zakladá na spektrálnych a/ alebo priestorových informáciách. Pre vytvorenie popisu tried sa používajú vlastnosti objektov prostredníctvom fuzzy logiky (princíp neurčitosti). Výsledkom klasifikácie je sieť klasifikovaných obrazových objektov s konkrétnymi atribútmi, konkrétnymi reláciami medzi sebou a reláciami k triedam v hierarchii tried. Klasifikácia bola hodnotená porovnaním dosiahnutých výsledkov s vrstvou LPISu a s vektorizovanou ortofotosnímkou.

KĽÚČOVÉ SLOVÁ: objektovo orientovaná obrazová analýza, segmentácia, klasifikácia, extrakcia prvkov

INTRODUCTION

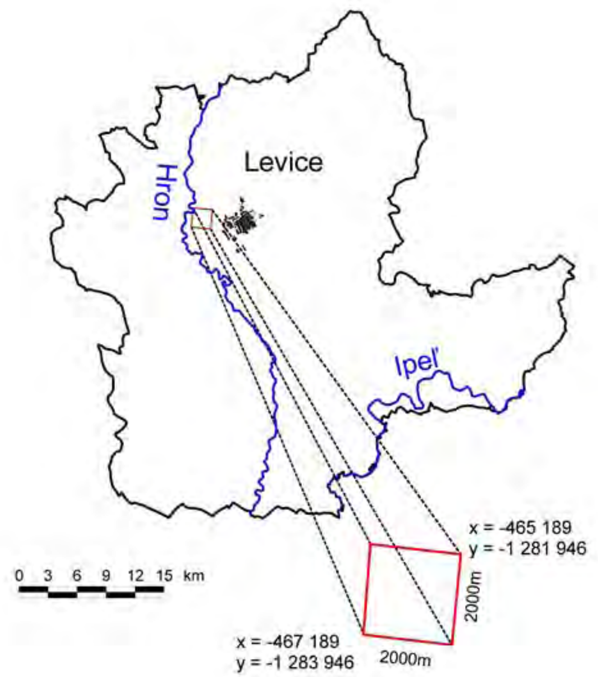
Remote sensing imagery of a large variety of spaceborne and airborne sensors provides a huge amount of data about the Earth surface for global and detailed analysis, change detection and monitoring. To maximize the profit from these sources an automatic and effective classification method is needed. Most of the methods use spectral characteristic and the analysis is based on pixels. Pixel is in the case of relatively homogenous area (agricultural land, lakes, rivers) too small and for the purpose of identification of smaller objects (tree crowns) too big.

One of the recent years` popular methods is the object oriented classification. The latest publications (BAATZ, M., SCHÄPE, A., 2000; BLASCHKE, T., STROBL, J., 2001; HALOUNOVÁ, L., 2002, 2003) validated superiority of the new method. The basic difference, especially when compared to pixel-based procedures, is that the classification is not done on single pixels, but rather on image objects extracted in a previous image segmentation step. The basis of the new approach is the use of important information (spectral characteristic, shape, texture, contextual information) included in meaningful image objects and their mutual relations.

MATERIALS AND METHODS

The test area is situated in the eastern part of Podunajská nížina (Danubian lowland) near town Levice (Fig. 1), which represents intensively cultivated arable land. Study area of the experiment is segment of 2000 x 2000 pixels (2 x 2 km) from the digital colour orthophotomap with scale of 1:10 000. This orthophotomap was processed in 2001 as a part of the project "Digital orthophotomap and Digital Terrain Model (DTM) of the lower reach of river Hron" (by the members of Department of Cartography, GIS and Remote Sensing at University of Natural Sciences in Bratislava).

Figure 1 *Area of interest*

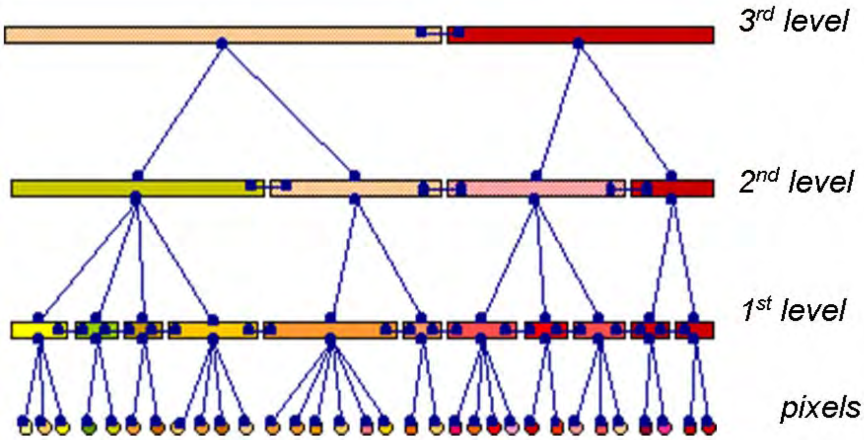


Segmentation

Segmentation is the subdivision of an image into separated regions. The segmentation procedure following a relatively general homogeneity criterion is in most cases not able to directly extract the final areas or objects of interest. For the object oriented approach to image analysis, image objects resulting from the segmentation procedure are intended to be rather image object primitives serving as information carriers and blocks building for the further classification or other segmentation processes. In this sense, the best segmentation result is one that provides optimal information for further processing. For this purpose ***multiresolution segmentation*** was developed, a new, patented segmentation procedure. It allows the large knowledge free extraction of the homogeneous image object primitives in any chosen resolution, especially considering the local contrasts. Generally, it can be applied to a very large range of data types; it works on an arbitrary number of channels simultaneously and is suited for textured or low contrast data (Benz U. et al., 2004).

Different techniques for segmentation can be used to construct a hierarchical network of image objects, which represents image information in different spatial resolutions simultaneously. The image objects are networked, so that each image object "knows" its context (neighbourhood) its super-object and its sub-objects, see Fig. 2. Thus, it is possible to define relations between objects and to utilize this kind of local context information. This hierarchical network is topologically definite, i.e., the border of a super-object is consistent with the borders of its sub-objects. The area represented by a specific image object is defined by the sum of its sub-objects' areas. Each level is constructed based on its direct sub-objects, i.e., the sub-objects are merged into larger image objects on the next level.

Figure 2 *Hierarchical network of image objects* (eCognition User Guide 3, 2003)



The hierarchical network of image objects provides possibilities for innovative techniques:

- Structures of different scales can be represented simultaneously and so classified in relation to each other.
- Different hierarchical levels can be segmented based on different data.
- The shape of the image objects can be corrected based on a regrouping of sub-objects (eCognition User Guide 3, 2003).

Classification

Usually, classification means assigning a number of objects to a certain class according to the class's description. Thereby, the class description is a description of the typical properties or conditions the desired classes have. Then the objects become assigned (classified) according to whether they have or have not met these properties/ conditions. In terms of database language, one can say the feature space is segmented into distinct regions, which leads to a many-to-one relationship between the objects and the classes. As a result, each object belongs to one definite class or to no class.

Classic classifiers in the remote sensing (e.g., maximum-likelihood, minimum-distance or parallelepiped) thereby assign a membership of 1 or 0 to the objects expressing whether the object belongs to a certain class or not. Such classifiers are usually called hard classifiers since they express the objects' membership to a class only in a binary manner. In contrast, soft classifiers (mainly fuzzy systems and/or Bayes classifiers) use a degree of membership/ a probability to express an object's assignment to the class. The membership value usually lies between 1.0 and 0.0, where 1.0 expresses full membership/ probability (a complete assignment) to a class and 0.0 expresses absolutely no membership/ improbability. Thereby the degree of membership/probability depends on the degree to which the objects fulfil the class-describing properties/ conditions. The main advantage of these soft methods lies in their possibility to express uncertainties about the classes' descriptions. It makes possible to express each object's membership in more than just one class or the probability of belonging to other classes, but with different degrees of membership or probabilities. With respect to image understanding, these soft classification results are more capable of expressing uncertain human knowledge about the world and so lead to classification results closer to human language, thinking and mind. In other words: soft classifiers are more accurate than their hard counterparts.

Regarding classification methods, they can basically be separated into supervised and unsupervised methods. While supervised methods ask the user how the desired classes look, unsupervised methods are almost user independent. They rather can be seen as statistical grouping methods sorting objects by their properties into clusters with similar properties. Since unsupervised methods work almost automatically, supervised methods have to be trained by the user – usually either by taking samples or by describing the classes' properties. Therefore, the class-describing information must be as accurate, representative and complete as possible, which is in most cases effectively impossible.

Comparing unsupervised and supervised classification methods; each has its advantages and disadvantages. The unsupervised methods are noticeably faster than supervised ones, but since they are just a special way of sorting algorithms, their results have to be interpreted by the user – what can be tough in some cases and leads to numerous repetitions of the classification with slightly adjusted parameters. Another advantage of unsupervised classifiers is their ability to analyse the objects' statistics completely and systematically. Thus, the results of the unsupervised classification can give useful indications of detectable classes. However, in general, formulate uncertainty is only possible if related to the classification parameters, not to the classes and their properties themselves. In contrast, supervised classification methods can be more labour intensive since the user has to describe the classes' properties either explicitly or by taking samples as typical representatives. Their advantages are at first their usually higher quality and a priori counting and naming of the classes, at second the possibility to formulate explicit class-related uncertainty. In cases of misclassifications, especially the latter point eases the investigation for these reasons. However, the class descriptions themselves are also easier to understand since they should be a result of human reasoning and thus easier to investigate. (eCognition User Guide 3, 2003)

RESULTS AND DISCUSSION

The workflow of the whole experiment consists of few steps (Fig. 3) but the main stress of the work is on the object oriented image analysis. The concept behind the experiment is that important semantic information necessary to interpret an image is not represented in single pixels, but in meaningful image objects and their mutual relationships. The basic difference, especially when compared to pixel-based procedures, is that this tool does not classify single pixels, but rather image objects that are extracted in a previous image segmentation step. The process of the object oriented classification involves two steps, multiresolution segmentation and classification.

The first step of the image analysis is to identify image objects. The aim is to divide the image into homogenous objects using the parameters scale, colour, shape, smoothness and compactness. These parameters govern size, shape and spectral variation of each object. Single pixel objects are merged into bigger ones using an iterative procedure resulting in objects with similar heterogeneity. Applying this procedure at increasing scales, building on the segmentation results of the previous scale, larger objects are created whose borders are defined by those of the lower layers.

Segmentation in the projects were realised in three levels using the parameters as shown in table 1. The smallest non-target objects (buildings, roads, trees) were extracted on the lowest level and the agricultural parcels (larger and more heterogeneous) on higher levels with the use of higher scale parameter.

Figure 3 *Scheme of the experiment*

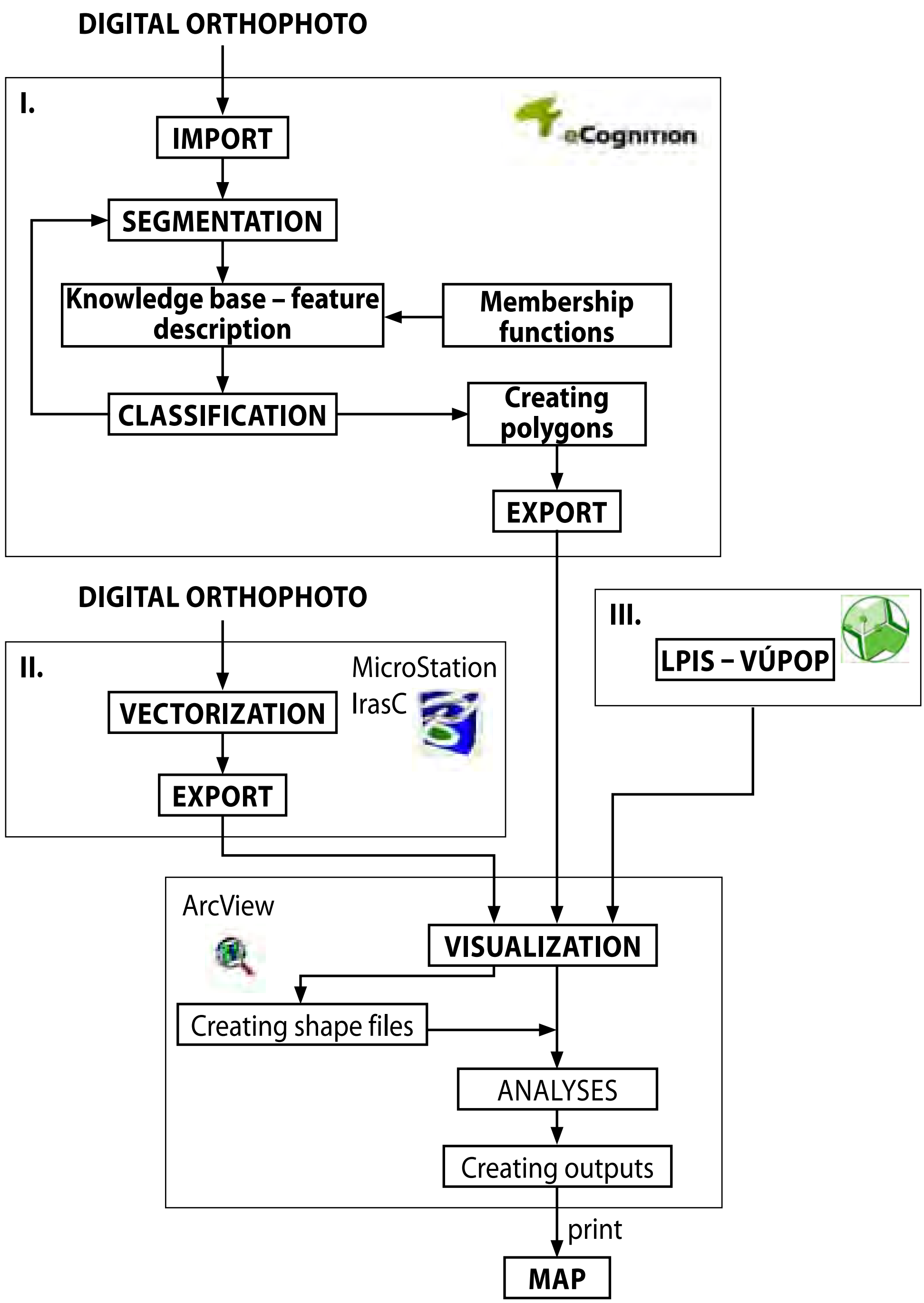


Table 1 *Parameters of segmentation processes*

Project	Level	Scale parameter	Composition of homogeneity criterion			
			Color	Shape	Shape	
					Smoothness	Compactness
hron_1	3	200	0.8	0.2	0.9	0.1
	2	40	0.9	0.1	0.9	0.1
	1	20	0.9	0.1	0.9	0.1
hron_2	2	200	0.8	0.2	0.9	0.1
	1	30	0.9	0.1	0.9	0.1
hron_3	1	40	0.7	0.3	0.8	0.2
	2	100	0.8	0.2	0.7	0.3
	3	400	0.8	0.2	0.7	0.3
hron_4	1	40	0.6	0.4	0.9	0.1
	2	120	0.8	0.2	0.9	0.1
	3	180	0.8	0.2	0.9	0.1

There are different supervised classification techniques and different methods to train and build up knowledge base for the classification of the image objects e.g. Feature View.

The feature view renders each image object in the current view according to its value for the selected feature. It allows to visualize the properties of image objects in a graphical way. Therefore, it provides an intuitive access to the peculiarity of a certain feature over all image objects in a scene. The feature view is a powerful tool to find features separating different classes of image objects.

Class descriptions in the projects were performed using the fuzzy approach of fuzzy sets on object features, defined by membership function. For the class description, there were used object features a a mean value of certain canals, brightness, ratio, etc.

The frame of the knowledge base for the analysis and classification of image objects is the so-called class hierarchy. It contains all classes of the classification scheme. The classes can be grouped in a hierarchical manner allowing the passing down of class descriptions to child classes on the one hand, and meaningful semantic grouping of classes on the other (Fig. 4). Level 1 contains features beyond interest and level 2 contains target features of the experiment.

Figure 4 *Example of classification with Class Hierarchy*

The next step after the classification is vectorization. Polygons are used to display outlines of image objects. They are developed for explicit shape analysis of image objects or they can be used for the vector export of results. Later, the vectorization image objects are held simultaneously in raster and vector representations. The results of classification were exported in a shape format with attached attribute tables linked with the image layer.

The analyses of results were realized in Arc View 3.2. The result of classification was compared with the layer of the LPIS made by the SSCRI. There were found many differences between the layers caused by time lag (1999-orthophoto and 2003-LPIS), and only few parcels matched (Figure 5, Table 2).

Figure 5 *Comparison of parcel boundaries derived from LPIS and classification*

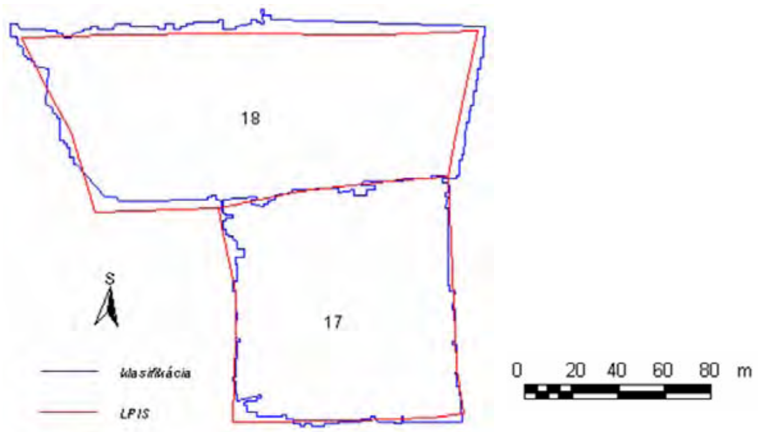


Table 2 *Comparison of the area of agricultural parcels declared by LPIS and results of classification*

LPIS – 2003				Classification [C] – 1999				LPIS – C	
ID	A [m^2]	A [m^2]	L [m^2]	ID	A [m^2]	A [m^2]	L [m^2]	A [m^2]	%
6	58 042	5.80	1 014	6	56 662	5.67	1 173	0.14	2.38
7 + 8	101 319	10.13	1 289	7 + 8	101 808	10.18	1 598	0.05	0.48
12	6 324	0.63	324	12	7 224	0.72	518	0.09	14.23
13	8 563	0.86	374	13	8 632	0.86	513	0.01	0.80
17	9 442	0.94	391	17	9 266	0.93	525	0.02	1.86
18	11 937	1.19	492	18	12 835	1.28	625	0.09	7.52

A = area, L = length

The areas of agricultural parcels were evaluated as European Commission defines in the Technical Recommendations. Technical tolerance does not exceed 5 % of the agricultural parcel area measured or 1.5 m perimeter buffer for all measured parcels. The buffer tolerance is calculated multiplying the parcel perimeter with a buffer width. If the difference (positive or negative) between the areas declared and measured at the parcel level is less than the technical tolerance, then the declared area is retained; if this difference is greater than the technical tolerance, the measured area is retained (Table 3).

Table 3 *The use of the technical tolerances*

ID	TT [1.5 m]	LPIS – TT	LPIS + TT	C	accept
	A [ha]	A [ha]	A [ha]	A [ha]	
6	0.15	5.65	5.96	5.67	YES
7 + 8	0.19	9.94	10.33	10.18	YES
12	0.05	0.58	0.68	0.72	–
13	0.06	0.80	0.91	0.86	YES
17	0.06	0.89	1.00	0.93	YES
18	0.07	1.12	1.27	1.28	–

TT = technical tolerance

To ensure applicability of this method in this aspect, another comparison was made. New layer of agricultural parcels was created by the visual interpretation of the orthophotomap in Micro Station and IrasC similar to the LPIS. The evaluation of 13 identical parcels was made the same way as mentioned above (Table 4). From the 13 parcels 10 were accepted according to the technical tolerance defined in the Technical Recommendation (Table 5).

Table 4 *Comparison of the area of agricultural parcels derived by the vectorization and results of classification*

Vectorization [V] – 1999				Classification [C] – 1999				V – C	
ID	A [m^2]	A [m^2]	L [m]	ID	A [m^2]	A [m^2]	L [m]	A [m^2]	%
2	580 549	58.05	3 077	2	584 264	58.43	3 999	0.37	0.64
4	24 467	2.45	798	4	25 384	2.54	950	0.09	3.75
5	66 071	6.61	1 064	5	66 452	6.65	1 375	0.04	0.58
6	55 910	5.59	995	6	56 662	5.67	1 173	0.08	1.34
8	101 634	10.16	1 289	8	101 808	10.18	1 598	0.02	0.17
10	21 004	2.10	742	10	21 206	2.12	1 052	0.02	0.98
11	330 470	33.05	2 273	11	331 355	33.14	2 828	0.09	0.27
12	6 395	0.64	324	12	7 224	0.72	518	0.08	12.96
13	8 035	0.80	360	13	8 632	0.86	513	0.06	7.43
14	5 360	0.54	352	14	5 116	0.51	444	0.02	4.57
16	5 814	0.58	316	16	6 806	0.68	366	0.10	17.05
17	9 682	0.97	398	17	9 266	0.93	525	0.04	4.31
18	12 418	1.24	503	18	12 835	1.28	625	0.04	3.35

The use of technical tolerances in this case acknowledged rightness of the classification. The classification can help to determine arable and forage land from colour orthophotos. However, it is more time consuming than visual interpretation. On the other hand, it offers more useful information that a human eye can perceive.

Table 5 *The use of technical tolerances*

ID	TT [1.5 m]	V – TT	V + TT	C	accept
	A [ha]	A [ha]	A [ha]	A [ha]	
2	0.46	57.59	58.52	58.43	YES
4	0.12	2.33	2.57	2.54	YES
5	0.16	6.45	6.77	6.65	YES
6	0.15	5.44	5.74	5.67	YES
7	0.19	9.97	10.36	10.18	YES
10	0.11	1.99	2.21	2.12	YES
11	0.34	32.71	33.39	33.14	YES
12	0.05	0.59	0.69	0.72	–
13	0.05	0.75	0.86	0.86	–
14	0.05	0.48	0.59	0.51	YES
16	0.05	0.53	0.63	0.68	–
17	0.06	0.91	1.03	0.93	YES
18	0.08	1.17	1.32	1.28	YES

CONCLUSIONS

The strong need for automated technologies, available state-of-the-art image analysis procedures – basically pixel-based approaches – are limited. Typically, they have considerable difficulties dealing with the rich information content of the VHR data; they produce a characteristic, inconsistent salt-and-pepper classification, and they are far from being capable to extract objects of interest. Therefore, the vast majority of operational projects can be realized only by means of massive human interaction.

The object oriented approach is opening new paths and perspectives. This powerful and universal method for the object oriented image analysis significantly extends range of the image analysis applications and turns remote sensing data into more accurately classified geographic information for various purposes. In case of using multispectral images, many other analyses can be made e.g. soil erosion, fertilization, as well irrigation.

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SPATIAL VARIABILITY OF SOME PHYSICAL PROPERTIES IN ARABLE SOILS OF DIFFERENT TEXTURE WITH REGARD TO SOIL COMPACTION

Priestorová variabilita niektorých fyzikálnych vlastností v orných pôdach s odlišnou zrnitosťou so zreteľom na ich zhutnenie

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ABSTRACT

In this paper the spatial variability of soil physical properties in dependence on sampling area (sampling from the the centre of the site of area of 1 m^2 opposite area of 314 m^2 – area of monitoring site) and different soil texture (light – sandy, medium heavy – loamy and heavy – clayey soil) are analysed.

Physical properties needed to assess soil compaction as bulk density (p_d), total or no-capillary porosity (P_T or P_N), maximal capillary capacity (MCC), retention water capacity (RWC) and minimal air capacity (MAC) are compared.

Within followed localities influence of compacting by means of farm mechanisms on arable soil is indisputable. In two used ways of sampling significant differences at p_d, P_T, P_N a MAC between topsoil and subsoil within single soil profiles and all soil textures were found out (excepting sampling from the centre of the site on heavy soil), whereas subsoil was more compacted (cumulative effect of all pressures on soil).

In the case of comparison of sampling ways (sampling area size of 1 m^2 opposite 314 m^2), the sampling from the centre of the site showed as not representative in the scope of subsoil on light soil and topsoil on heavy soil.

P_N, MAC, P_T a p_d opposite MCC and RWC were more variable then single soil properties.

It is interesting that only slightly higher variability of the majority of measured physical properties was in subsoil by sampling from the centre of the site (1 m^2) and, on the contrary, in topsoil only with more expressive distinction at sampling from the whole site (314 m^2) by the all soil textures. With reduction of sampling area the risk of the site to be not-representative increases (mainly in topsoil) and, on the contrary, with its enlargement the variability of followed properties can decrease (first of all in subsoil).

Keywords: soil physical properties, spatial variability, soil sampling area, soil profile distribution, soil compaction

ABSTRAKT

V tomto príspevku je analyzovaná priestorová variabilita fyzikálnych vlastností v závislosti od veľkosti plochy odberu (odber vzoriek zo stredu lokality z plochy 1 m^2 oproti odberu z celej lokality o ploche 314 m^2) a zrnitosti (ľahká – piesčitá, stredne ťažká – hlinitá a ťažká – ílovitá pôda).

Porovnané sú fyzikálne vlastnosti potrebné k určeniu zhutnenia pôd ako sú objemová hmotnosť (ρ_d), celková (P_T) a nekapilárna (P_N) pórovitosť, maximálna kapilárna kapacita (MCC), retenčná vodná kapacita (RWC) a minimálna vzdušná kapacita (MAC).

Na sledovaných lokalitách na ornej pôde je nesporný vplyv zhutňovania poľnohospodárskymi mechanizmami. Boli zistené preukazné rozdiely v ρ_d, P_T, P_N a MAC medzi ornicou a podornicou v rámci jednotlivých pôdnych profilov pri oboch spôsoboch odberu vzoriek a všetkých pôdnych druhoch (s výnimkou odberu z centra lokality na ťažkej pôde - nereprezentatívny odber), pričom hutnejšia bola podornica (kumulatívny efekt tlakov na pôdu).

V prípade porovnania spôsobov odberu (veľkosť odberovej plochy 1 m^2 oproti 314 m^2) ako nereprezentatívny sa ukázal odber zo stredu lokality v rámci podornice na ľahkej pôde a ornice na ťažkej.

Čo sa týka pôdnych vlastností variabilnejšie boli P_N, MAC, P_T a ρ_d oproti MCC a RWC.

Zaujímavosťou je, že nepatrne väčšia variabilita väčšiny sledovaných fyzikálnych vlastností bola v podornici pri odbere zo stredu lokality (1 m^2) a naopak v ornici len s výraznejším rozdielom pri odbere z celej lokality (314 m^2) a to pri všetkých pôdnych druhoch. Zmenšovaním plochy odberu vzoriek narastá riziko z nereprezentatívnosti lokality (hlavne v ornici) a opačne s jej rozširovaním môže poklesnúť variabilita sledovaných fyzikálnych vlastností (predovšetkým v podornici).

KĽÚČOVÉ SLOVÁ: fyzikálne vlastnosti pôdy, priestorová variabilita, veľkosť plochy pre odber pôdnych vzoriek, profilová distribúcia, zhutňovanie pôdy

INTRODUCTION

Variability of physical properties on agriculture soils can be considerable. Influences are primary, natural in dependence on soil texture, climatic conditions, period of measurement during a year, auto-regulation ability of soil physical state. However, they may be secondary caused by man, mainly technogenic (pressure of farm machines, rate and organisation of field crossings, way of cultivation – with tillage or non-tillage, grown crop, quality of farming – increasing of resistance of soil combat physical degradation). Spatial variability also depends on sampling area, sampling net density as well as type of physical properties. From these soil characteristics, the soil bulk density will by necessary to measure with respect to threat of increasing soil compaction. In addition, the next properties as are totally or no-capillary porosity (P_T or P_N), maximal capillary capacity (MCC), retention water capacity (RWC) and minimal air capacity (MAC) are important. Ranges of some soil physical properties are given in Table 1 (KUTÍLEK 1978). The bulk density ranks between the most little varying in comparison with the next. Within the frame of pedotop on area of several hectares and in a genetic-morphologic homogeneous soil its variation coefficient is less than 15 % (KUTÍLEK 1993 – Table 1). ZEMÁNEK (2002) found out range of the bulk density variability 1.15 – 1.40 $g.cm^{-3}$ on area of one hectare in a grid of 10 x 10 m (121 points) in a medium heavy soil. On the other hand, the plant requirements in dependence on soil texture necessitate the soil physical properties limits needed for evaluation of soil compaction. By means of conventional cultivation the topsoil is periodically ploughed. In the subsoil all pressures affecting soil cumulate to reach a steady state, according to ERICKSON (1975), after 7 – 10 years.

Table 1 *Variability of some physical properties (KUTÍLEK 1978*, 1993**)*

Soil properties	Range of variability*	Variation** coefficient %
clay content (< 0.002 mm, % of weight.)	13.4 – 68.3	15 – 35
silt content (0.02 – 0.002 mm, % of weight.)	8.6 – 46.3	–
sand content (2 – 0.02 mm, % of weight.)	76.6 – 0.02	15 – 35
organic matter content (% of weight.)	0.5 – 1.6	35 – 70
bulk density ($g.cm^{-3}$)	1.10 – 1.60	< 15
particle density ($g.cm^{-3}$)	2.60 – 2.76	< 15
total porosity (% of vol.)	23.5 – 61.0	–
water content at total saturation (% of vol.)	23.2 – 56.5	< 15
saturated hydraulic conductance	2.6 – 78.0	> 70

Explanations: ** variation coefficient % (categories): < 15 % low, 15 – 35 % medium, 35 – 70 % high, > 70 % very high

MATERIAL AND METHODS

Spatial variability of soil physical properties was followed within the framework Soil monitoring of SR on monitoring sites representing different soil textures (light – plot L, medium heavy – plot M and heavy – plot H). Research plots are located from warm and dry to moderate moist climatic regions with inclination less than 5° and at elevation of 122 – 163 m. The next data about plots are given in Table 1 and 2.

Table 2 *Basic information on research plots*

Research plots	Texture	Soil type**	Soil depth (m)	Clay fraction (%)		Crop
				< 0.001*	< 0.01*	
L	light, sandy	Haplic Arenosols	0 – 0.1	2.77	6.14	winter wheat
			0.3 – 0.4	3.09	6.98	
M	medium heavy, loamy	Haplic Chernozems	0 – 0.1	20.91	39.91	winter rye
			0.3 – 0.4	22.84	41.22	
H	heavy, clayey	gleyic Fluvisols	0 – 0.1	25.27	65.95	sunflower
			0.3 – 0.4	28.19	72.36	

* size of grain in *mm*, ** by WRB 1994, COLLECTIVE 2000

Table 3 *Some next soil characteristics on research plots*

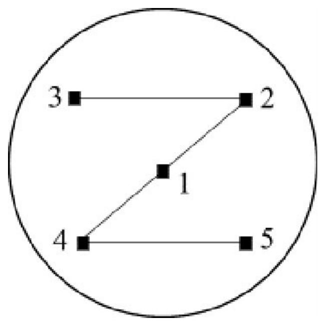
Research plots (depth)	Moisture* (% of weight)	Humus (%)	$C:N_t$	$C_{HK}:C_{FK}$	pH(KCl)
L 0.1	7.5 ± 7	1.6	10.9	1.11	5.71
L 0.4	3.4 ± 16	0.4	11.4	–	6.56
M 0.1	17.8 ± 4	2.5	8.3	1.63	7.22
M 0.4	10.2 ± 3	1.5	9.2	–	7.37
H 0.1	21.7 ± 3	2.8	7.6	0.8	5.00
H 0.4	21.6 ± 10	2.0	8.8	–	5.88

* Soil moisture at sampling – x ± sx % (arithmetic mean ± variation coefficient)

Two ways of sampling were performed– from the whole site (circular shape with a radius of 10 m and area of 314 m²) and from the centre of the locality (1 m²). Samples were taken in the spring (June) from the topsoil 0 – 0.1 m (whole locality – 5, centre – 4) and also from the subsoil 0.3 – 0.4 m (whole locality – 5, centre – 7) by scheme (Figure 1).

In samples, the basic physical and hydrophysical properties were determined (bulk density p_d, totally or no-capillary porosity P_T or P_N, maximal capillary capacity MCC, retention water capacity RWC and minimal air capacity MAC). These characteristics (excepting P_N) are required at assessment of soil compaction by the Law No. 220/2004. Obtained data were statistically evaluated according to the t-test of paired samples (ŠMELKO, 1988)

Figure 1 *Monitoring site – scheme of sampling*



RESULTS AND DISCUSSION

Figure 2 *Texture curves of some layers on the plots*

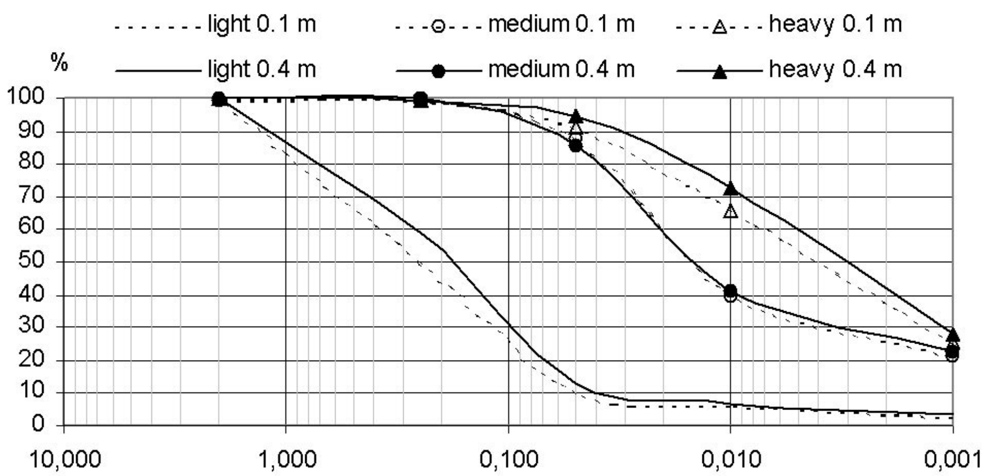


Table 4 *Soil physical properties on monitored localities with different texture – values from the whole locality and from the centre of the locality*

Texture – Way of sampling	Soil depth (m)	Statistics	p_d	P_T	P_N	MCC	RWC	MAC
			$g.cm^{-3}$	% of volume				
Light soil – whole locality	0 – 0.10	x ± sx %	1.40 ± 6	46.5 ± 7	19.2 ± 21	22.5 ± 7	20.3 ± 8	24.0 ± 19
		x_{min}	1.31	42.02	13.82	19.65	17.70	18.92
		x_{max}	1.52	50.64	24.99	23.75	22.15	30.99
	0.30 – 0.40	x ± sx %	1.60 ± 1	40.1 ± 2	13.3 ± 6	21.7 ± 5	19.7 ± 6	18.3 ± 8
		x_{min}	1.57	39.20	12.55	20.40	18.15	16.62
		x_{max}	1.62	40.90	14.32	23.30	21.30	19.80
Light soil – centre of locality	0 – 0.10	x ± sx %	1.39 ± 2	47.3 ± 3	22.1 ± 12	20.5 ± 6	16.5 ± 13	26.8 ± 10
		x_{min}	1.38	46.77	20.55	19.61	15.10	25.02
		x_{max}	1.41	47.71	23.57	21.75	18.26	28.10
	0.30 – 0.40	x ± sx %	1.65 ± 2	37.6 ± 4	11.8 ± 12	22.6 ± 4	18.0 ± 20	14.9 ± 12
		x_{min}	1.60	34.94	9.91	22.01	13.44	12.56
		x_{max}	1.72	39.57	13.26	24.55	23.42	17.29
Medium heavy soil – whole locality	0 – 0.10	x ± sx %	1.22 ± 9	53.9 ± 7	15.1 ± 30	35.3 ± 4	31.3 ± 4	18.6 ± 27
		x_{min}	1.06	50.16	10.66	32.90	29.35	13.56
		x_{max}	1.33	59.38	20.58	36.85	32.50	24.38
	0.30 – 0.40	x ± sx %	1.38 ± 3	48.0 ± 2	10.7 ± 22	34.6 ± 6	31.9 ± 5	13.4 ± 12
		x_{min}	1.33	46.82	7.90	31.90	29.30	11.51
		x_{max}	1.43	49.45	13.35	37.15	33.40	14.92
Medium heavy soil – centre of locality	0 – 0.10	x ± sx %	1.22 ± 8	53.8 ± 7	13.6 ± 25	36.1 ± 5	31.7 ± 5	17.7 ± 23
		x_{min}	1.14	48.98	10.35	35.59	30.68	13.00
		x_{max}	1.35	56.89	16.10	36.76	32.88	21.30
	0.30 – 0.40	x ± sx %	1.36 ± 4	49.5 ± 4	8.9 ± 23	37.5 ± 4	34.7 ± 3	12.0 ± 17
		x_{min}	1.31	46.23	6.26	37.01	33.89	8.83
		x_{max}	1.45	51.54	10.99	38.70	35.64	14.48
Heavy soil – whole locality	0 – 0.10	x ± sx %	1.21 ± 8	54.7 ± 7	14.7 ± 55	38.2 ± 10	35.8 ± 10	16.4 ± 44
		x_{min}	1.07	49.93	4.98	33.40	31.25	6.63
		x_{max}	1.34	60.03	25.18	43.30	41.10	26.63
	0.30 – 0.40	x ± sx %	1.40 ± 2	47.7 ± 2	3.5 ± 55	43.3 ± 4	41.6 ± 4	4.4 ± 46
		x_{min}	1.36	46.81	1.40	41.75	39.85	2.40
		x_{max}	1.42	49.00	6.25	45.65	44.45	7.25
Heavy soil – centre of locality	0 – 0.10	x ± sx %	1.39 ± 4	47.9 ± 4	4.8 ± 32	41.8 ± 2	39.8 ± 2	6.1 ± 29
		x_{min}	1.33	46.09	2.79	41.27	39.48	3.88
		x_{max}	1.44	50.17	6.51	42.21	40.48	8.21
	0.30 – 0.40	x ± sx %	1.42 ± 3	47.1 ± 3	4.5 ± 34	41.5 ± 3	40.0 ± 2	5.2 ± 44
		x_{min}	1.36	44.88	2.27	40.27	38.77	0.42
		x_{max}	1.48	49.41	7.35	43.43	41.54	8.22

Explanations: p_d – bulk density, P – porosity non-capillary ($_N$), total ($_T$), MCC – maximal capillary capacity, RWC – retention water capacity, MAC – minimal air capacity, x + sx% – arithmetic mean + variation coefficient, $x_{min\ (max)}$ – minimum (maximum)

In this paper, the spatial variability of some physical properties from distinct large areas of 1 m^2 as against 314 m^2 within each locality is interpreted with respect to soil texture and soil compaction. On the basis of obtained results (Figure 2, Table 1) is clear that there is texturally different soil on the single site (by Novak classification: light – sandy, medium heavy – loamy and heavy – clayey).

From spatial variability of physical properties point of view the influence of the way of sampling respective sampling area (1 m^2 opposite 314 m^2) on the state of the physical properties, within the whole soil profile as well as separately in topsoil and subsoil was evaluated. The obtained results in form of basic statistical characteristics are represented in Table 4.

Concerning variability of the soil profile, the topsoil opposite subsoil was less compacted in two ways of soil sampling and also in the all soil textures with the exception of the centre of the locality in the heavy soil with even state. The significant differences were found out at bulk density, P_T, P_N and MAC (Table 5). It is a consequence of regular ploughing. According to VALIGURSKÁ, LHOTSKÝ (1985) the soil compaction caused by pressures of 60 – 100 kPa is removable by means followed cultivation. Here was sampled probably on the place of the most compacted topsoil (no-representative sampling). In non-ploughed subsoil all pressures on soil are cumulated after some period (7 – 10 years) and certain rate of loading it comes up to a steady state (ERICKSON 1975). The single parts of the soil profile were different only sporadically in hydrophysical characteristics (MCC, RWC). Higher variation coefficients of physical properties and also the values of P_N confirm the more loose state of topsoil opposite subsoil.

Table 5 *Results of t-test about significance of difference of soil physical properties between values from topsoil (0 – 0.1 m) and from subsoil (0.3 – 0.4 m)*

Texture	Soil depth (m)	Statistics	pd	PT	PN	MCC	RWC	MAC
			$g.cm^{-3}$	% of volume				
Light soil	whole locality	α	0.006**	0.012*	0.029*	0.409	0.537	0.047*
		t	3.76	3.22	2.65	0.87	0.64	2.34
	centre of locality	α	0.000**	0.000**	0.000**	0.030*	0.665	0.000**
		t	14.31	12.52	10.43	2.63	0.45	10.21
Medium heavy soil	whole locality	α	0.016*	0.011*	0.088	0.583	0.528	0.059
		t	3.04	3.29	1.94	0.57	0.66	2.20
	centre of locality	α	0.003**	0.009**	0.007**	0.084	0.001**	0.004**
		t	4.23	3.46	3.60	1.97	4.73	4.00
Heavy soil	whole locality	α	0.012*	0.012*	0.025*	0.022*	0.015*	0.019*
		t	3.21	3.21	2.75	2.83	3.10	2.93
	centre of locality	α	0.150	0.283	0.786	0.364	0.804	0.509
		t	1.59	1.15	0.28	0.96	0.26	0.69

Explanations: a – level of significance; */** = 0.05/0.01, t – t-value, (next abbreviations as in Table 4)

In the case of influence of way of soil sampling the area of 1 m^2 opposite 314 m^2 is considerably different and it naturally assumes also higher occurrence of mistakes from being not-representative. According to the results of the t-test on difference of mean values

(Table 6), this mistake was taken down in 11 cases mainly in the topsoil of the heavy soil as well as in the subsoil of the light soil and first of all by the characteristics as is the bulk density, P_T, P_N and MAC. The interesting findings are in the variation coefficients (Table 4). In the case of bulk density, P_T, P_N and MAC the higher variation coefficients within sampling from the centre of the site (1 m^2) are in the subsoil and, on the contrary, within sampling from the whole site (314 m^2) in topsoil. It is most likely a consequence of the linear character of compaction caused by wheels of farming machines. The pressures on soil more than 150 kPa reaches in depth more than 0.4 m in dependence on contact area when the reached depth is a quadruple of wheel width (Erickson 1975; Valigurská, Lhotský 1985; Lhotský et al., 1983; Lhotský 2000). The hydrophysical properties MCC and MAC were more variable in the topsoil by two the ways of sampling.

The soil texture state influenced more the mean values (MAC, P_N, MCC, RWC) respectively variation coefficients (MAC, P_N) of some physical properties but less the impacts of the way of sampling (sampling area size 1 m^2 opposite 314 m^2).

Table 6 *Results of the t-test about significance of difference of soil physical properties between values from the centre of the locality and from the whole locality*

Texture	Soil depth (m)	Statistics	pd	PT	PN	MCC	RWC	MAC
			$g.cm^{-3}$	% of volume				
Light soil	0 – 0.10	α	0.951	0.890	0.445	0.186	0.059	0.511
		t	0.06	0.14	0.80	1.45	2.20	0.69
	0.30 – 0.40	α	0.030*	0.012*	0.038*	0.141	0.452	0.007**
		t	2.64	3.21	2.88	1.63	0.96	3.77
Medium soil	0 – 0.10	α	0.769	0.828	0.985	0.998	0.836	0.863
		t	0.30	0.22	0.02	0.003	0.21	0.18
	0.30 – 0.40	α	0.568	0.218	0.337	0.027*	0.008**	0.331
		t	0.60	1.34	1.02	2.26	2.78	1.03
Heavy soil	0 – 0.10	α	0.020*	0.019*	0.038*	0.075	0.060	0.033*
		t	2.88	2.94	2.53	2.05	2.19	2.62
	0.30 – 0.40	α	0.305	0.495	0.299	0.036*	0.057	0.512
		t	1.10	0.71	1.11	2.52	2.22	0.69

All explanations as in Table 5

CONCLUSIONS

Soil sampling area can play an important role at surveying of real state of soil physical properties. In agricultural soils these can be considerably variable already on small area under the influence of process of soil compaction.

It is interesting that the slightly higher variability in majority of measured physical properties was in the subsoil in the sampling from the centre of the site (1 m^2) and, on the contrary, in the topsoil only with more expressive distinction in the sampling from the whole site (314 m^2) and all soil textures. With reduction of sampling area the risk of the site to be not-representative increases (mainly in topsoil) and, on the contrary, with its enlargement the variability of the measured properties can decrease (first of all in the subsoil).

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CURRENT CLIMATIC CHANGE AND SOILS OF SLOVAKIA

Prebiehajúca klimatická zmena a pôdy Slovenska

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ABSTRACT

The paper is dedicated to basic knowledge set about predicted impact of climatic change on soil resources of Slovakia. This theme was researched by the authors in 2004 and in details also in the former years. On the base of climatic scenarios modelled on conditions of Slovakia and knowledge about historical soil development in our country and abroad, a pedo-climatic scenario was elaborated. On the base of that issues we can predict these main impacts:

a) climatic change will cause dominating effects of very slow retrograding development of soil units and its catenas,
b) in conditions of Slovakia to compared to neighbouring countries there will be recognized only small differences in soil properties and characteristics,
c) in time horizons defined by climatologists, most of soil units at the type and subtype categories will not change, only soil erosion and local gleyic and salinization processes can be recognizable in soil profiles, which can result in new ordination in classification,
d) the more significant differences can be expected at soil properties and characteristics like organo-mineral complex change, chemical changes, diverse oxidation-reduction conditions, etc.,
e) generally, there is predicted increasing of production potential on arable land including grassland.

Keywords: climatic change, soil units, prognosis, soil development

ABSTRAKT

Práca uvádza súbor základných poznatkov z riešenia problematiky dopadu klimatickej zmeny na pôdny fond Slovenska. Táto problematika bola autormi riešená v roku 2004, ale podrobne tiež v predchádzajúcich rokoch.

Na základe scenárov klimatickej zmeny rozpracovaných na podmienky Slovenska a poznatkov o historickom vývoji pôd u nás a v zahraničí bol vypracovaný pedoklimatický scenár, na základe ktorého prognózujeme tieto hlavné dopady:

a) v dôsledku klimatickej zmeny bude dominovať veľmi pomalý retrográdny vývoj pôdnych jednotiek a pôdnych katén,
b) v podmienkach Slovenska (v porovnaní s inými štátmi) nastanú u pôd len malé zmeny v pôdnych znakoch a vlastnostiach,

c) v časových horizontoch uvádzaných klimatológmi sa prevažná väčšina pôdnych jednotiek na úrovni typu a subtypu v podstate nezmení. Meniť sa budú erózne procesy a lokálne tiež glejové a salinizačné procesy, ktoré môžu zapríčiniť zmenu pôdnych jednotiek,

d) výraznejšie a vážnejšie zmeny nastanú u pôdnych vlastností a charakteristík, akými sú zmeny organo-minerálneho komplexu, zmeny chemizmu, zmeny oxidačno-redukčných podmienok a pod.,

e) všeobecne sa predpokladá zvýšenie produkčného potenciálu orných pôd, vrátane horských trávnych porastov.

KĽÚČOVÉ SLOVÁ: klimatická zmena, pôdne jednotky, prognóza, vývoj pôd

INTRODUCTION

Problems of climatic change impact on soils of Slovakia have been studied by authors of this essay since 1996 (ŠURINA et al., 1996; ŠURINA, SOBOCKÁ 1998; ŠURINA 1999).

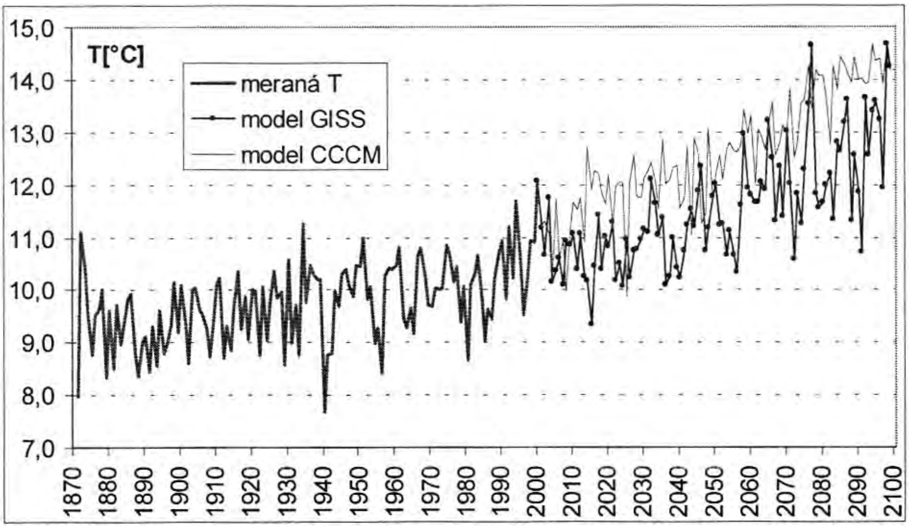
Since that time some new more precise scenarios of climatic change have been modelled and specified by our climatologists for the conditions of Slovakia (LAPIN, MELO 1999; LAPIN, MELO 2002). Alongside of the GCMs scenario they are primarily the latest scenarios of interconnected atmospheric-oceanic simulations CCCM1997 and CCCM2000 (Canada) and GISS 1998 scenario (USA). The CCCM2000 scenario is in degree of completion now but at present still not published and available for this study.

Our aim is, on the ground of mentioned accessible particularized scenarios, to predict and formulate the pedo-climatic scenario of predicted soil cover changes on the territory of Slovakia and to define homochronous soil-forming and anthropogenic processes and alterations.

CLIMATIC CHANGE PROGNOSIS

According to LAPIN (2004) in the year 2002 the CO_2 concentration was higher by the 33.5 % and the methane by the 159 % as before the year 1750 – beginning of industrial revolution. CO_2 concentration – due to uncontrolled burn up of fossil fuels on the Earth –has risen only by the 20 % since 1950. The presumption is that near 2060 the CO_2 content in atmosphere will increase twofold. According to GCMs scenarios the mean annual temperature will increase by 2 – 4 °C near 2100. It is supposed the sum of summer precipitation on the South of Slovakia will decrease and slightly increase during winter time. By LAPIN, the temperature in Orava region will be the same or some of the same as in today's Danube Lowland. Rate of climatic change will be presumed cause of short extreme droughts and rainfalls. By MELO (2003) the best results for Slovakia were reached using the models CCCM 2000 and GISS 1998. The CCCM 2000 scenario supposes doubling the GHGs concentration in atmosphere between the years 1980 and 2050, and simulated mean annual temperature will increase by the 2.2 °C in Slovakia and by the 1.8 °C on the Earth. MELO presents in the same article very interesting table presenting up to now and prognostic mean annual temperatures for Hurbanovo in the period 1871 – 2100 according to the both mentioned scenarios (Chart 1).

Chart 1 *Mean annual air temperature (°C) for Hurbanovo in the 1871 – 2100 period (measured in 1871 – 2000 period and according to the GISS 1998, and the CCCM 2000 models in the 2001 – 2100 period)*



According to the 3rd National Report about Climatic Change (Staff 2001) and new regional scenarios for Slovakia region (CCCMprep and GISSprep) we can expect slight warming up in winter period and comparable in summer. The sum of precipitation will be higher in winter season while in summer they will stay unchanged in practice.

The mentioned Report to the time horizon of 2075 presumes:

- Prolongation of so-called big growing season (BGS – temperatures ≥5 °C) in southern parts of Slovakia for 50 days (i.e. 20 %), in North agricultural territories for 40 days (24 %). Prolongation of main growing season (MGS – temperatures ≥10 °C) on South of Slovakia is supposed for 43 days (23 %) and on the North for 84 days (93 %).
- Sum of temperatures will be increasing in southern parts of Slovakia during BGS for 1138,0 °C (32 %), in North for 913,0 °C (55 %).
- Sum of temperatures will be increasing in southern parts of country during MGS for 1111,0 °C (36 %), in the lowest parts for 802,0 °C (69 %).
- Sum of precipitation during MGS will increase for 27 mm (8 %) in the South and for 202 mm (77 %) in the North.
- To the time horizon 2075 the sum of evapotranspiration will change rather slowly or not at all. On the South of Slovakia it will rise probably by the 27 mm (6 %) but on the North even by 68 mm (20 %).

From the point of view of biomass potential production of agricultural soils there are positive data.

As Lapin (2004) presents, under the notion *climatic change* are understood only those changes related by anthropogenic rise of greenhouse effect in atmosphere since the beginning of industrial revolution in 1750. But we have still only a little information about the present natural trend of climatic change – if it concurs or counteracts with anthropogenic activity and as well if and how those natural influences concurs mutually. We mean of course short and medium term natural influences as are 11th and 33rd years periodicities of sun spot zone peaks, as well as questions of periodic ecliptic gradient change, change of elliptical Earth-path eccentricity ellipticity), influence of precession movement of the Earth's axis on climatic changes, crossing clouds of cosmic dust through our solar system and many others. Only such complex evaluation of natural and anthropogenic factors influence on climate would facilitate more precise prognostication of present climatic change.

PROGNOSIS OF CLIMATIC CHANGE IMPACT ON SOILS OF SLOVAKIA

During the last 100 years the mean annual temperatures in Slovakia rose by the 1.1 °C. At the same time, the sum of precipitation decreased approximately by 20 % in the South and by 10 % in the North. Relative air humidity droped down about 2 – 6 % particularly in spring months and trend of the annual sum of the potential evapotranspiration significantly rose up (about 125 mm since 1901). Also this entry testifies that we can not speak about expected climatic change but that this change really exists already and even with exceptionally noticeable indicia mainly during the last century.

General natural relations and regularities of soil development in Slovakia

Soil is vivified and permanently evolving three-dimensional natural-historical formation created by influence and on the contact with atmosphere, biosphere hydrosphere and lithosphere. If any of these spheres is missing, any soil will come into existence but only a sediment – organic, organ mineral or inorganic.

However, during the next development of soil alone some of the soil-forming factors or conditions may become – and usually are – dominant. This dominancy then determines a specific soil-forming process. Under its influence the soil in initial stadium of development changes itself and gains specific morphologic, physical, chemical and biological characteristics and properties.

By many soil scientists, the most important soil-forming component is the climate condition. On the territory of Slovakia for instance if the loess is for a long time exposed to influence of soil forming components in the conditions of evaporative regime (warm, dry – steppe climate), the initial Calcaric Regosol changes into Calcari-Haplic Chernozem. When the climate conditions changes and rainfall becomes to predominate the evapotranspiration (cool, wet climate), the Calcari-Haplic Chernozem will develop to a Calci-Luvic Chernozem and if the sum of precipitation rises or affects for a longer time, the soil unit it will develop to Luvic Phaeozem, Haplic Luvisol or even to the Albic Luvisol. Similar developing sequences form by the climate influence from different parent materials, too. They are well-observed on soil maps displaying also very well regularities of altitudinal, latitudinal, oceanic and submontane (peri-mountain) zonality.

Prognosis of the climatic change impact on soils in Slovakia

According to the climatic change scenarios, it is possible to anticipate a general trend to retrograde development of soil catenas – climosequences. Retrograde soil-forming processes will have a continuous progress, soil characteristics and properties will be continuously changed but the soil units itself will change very slowly and in any of mentioned time horizons they will not change into another soil unit – with only minor exceptions in small extreme localities.

It is necessary to realize that there are soils with relatively rapid formation and termination, with rapid formation and slow termination and with slow formation and slow termination. The last one can be monitored as a soil relicts already in the territories where the present climate is far from the climate that could be able to condition such soil development – e.g. today, the soils classified as the relict Tchernitzas (Endogleyi-Haplic Chernozems – acc. to the WRB – 1998) developed originally from the alluvial sediments in warm climate environment and now recognizable on meanwhile created river terraces in cool climate conditions of the North Slovakia. To such soils belong also some southward occuring Haplic Luvisols developed from the loess where were at least 5000 years the chernozemic climate conditions.

Some soil-forming processes on the contrary can run relatively quickly. For instance the gleying process and forming of gleyic horizon at this process can come true throughout few years but its extinction lasts some centuries and even thousands of years. The same fact is valid for processes of salinization, secondary calcification, etc. Relatively fast alterations may be expected at the arenic soil units especially developed from very acid parental materials, e.g. from the wind-blown sands of Záhorská Lowland. On the sand-dune cuts there we can follow today`s very nice examples of multiple polycyclic developments of Arenosols, Arenic Cambisols and even Podzols during the Holocene. Bublinec (1974) estimates that mature Podzols have been developed here within of 400 – 500 years. We suppose that climatic conditions here in a short time will be not suitable for podzolic process but the initial and chernozemic soil-forming process will continue.

Generally in temperate climate zone, it is expected only a little increase of the total sum of precipitation especially during wintertime, increasing of evapotranspiration – on the South of Slovakia small one but on the North even by the 36 % (till 2075). Negative influence of higher temperatures on amount of soil organic mass could be fully recompensated by the higher amount of organic matter from natural vegetation and farming products. Their growth could be more intensive under the stronger photosynthesis. Our temperature zone in confrontation with other zones of the Earth will overcome relatively small changes in soils.

For the prediction of the climatic change influence we went from the evapotranspiration scenarios created according to the models valid for Slovakia (Tomlain, 1997) and from another new sources, mentioned in References (Špánik, Tomlain 1997; Bielek, Šurina 2000; Bielek, Šurina 2002; Sobocká, Šurina 2004). In general, we can say that the natural soil-forming processes will not alter basically on the most part of Slovakia within the time horizon of 2075 and the basic taxonomic soil units in our classification categories type and subtype will not transform into the others. Some alterations may occur at some arenic soils or at improperly cultivated soils.

- The consequence of awaited higher CO_2 concentration at higher temperature will be a higher accumulation of the soil organic matter. In consequence of photosynthesis at higher CO_2 content, the factitious greenhouse effect of the Earth will heighten the growth index and the water capacity efficiency by vegetation (Brinkman – Sombroek, 1996).
- Increased evapotranspiration and soil organic matter accumulation will heighten microbial activity. The production will be accompanied by higher amount of the root mass, rhizoid secretions, mycorrhizal colonization, etc.
- Expected higher aridity with progressive soil profile drying, higher soil aeration and oxidization of soil matter will cause the other site accelerated mineralization of soil organic mass. However, this process will be not critical and will be compensated by the above mentioned processes. The growth of aridity should be followed mainly in the South parts of Slovakia roughly up to an altitude of 400 m. Predominance of the mentioned processes will depend on sufficiency of water provision for these areas with high evapotranspiration.

- Higher decomposition of organic matter will give rise to the higher partial tension of CO_2 in soil with higher releasing of nutrients from weathering minerals, e.g. K, Mg, and P.
- Changes in clay minerals and coarser mineral fractions, too, will be hardly noticeable in the time horizon of 2075. If any, they could be followed at Lithosols and Arenosols soil units.
- In the lowlands evaporative water regime is supposed to dominate. It means that the entire territory of Haplic Luvisols will be in„chernozemic" climate conditions with higher evapotranspiration then precipitation. The habitus of these soils should express themselves in steadier soil structure, higher permeability and in better conditions for plant rooting.
- The increase of ground water mineralization is expected mainly in the lowland territories. There, overbore in areas with shallow depressions can be expected mild to moderate salinization and/or alkalization of soils, in some parts of Slovakia even process of solodization (the East Slovakia Lowland).
- Soil pH will be in principle without more remarkable changes – only with exceptions in case of mentioned salinization/alkalinization. There are suppositions that mild increase of pH will be in subsoil horizons of soils developed from carbonate parent materials. It means that e.g. leached Rendzic Leptosols could slowly change to Rendzic Leptosols, and Haplic Chernozems to Calcari-Haplic Chernozems, etc.
- In the territories predisposed to water and wind erosion, there are expected adverse effects of the sudden and intensive all the year round storms. It relates mainly to the loess hilly-lands, especially to their convex parts with insufficient soil protection from erosion. Here is a danger that the original soil units Chernozems and mainly Haplic Luvisols will change to Calcaric Regosols.
- The most resistant soils towards the climatic change will be mainly our best soils as are Chernozems (from non-convex localities), Mollic Fluvisols and Haplic Luvisols – it means soils with the most stabile soil structure having suitable cation exchange capacity, permeability and humus content.
- The worst resistency will have sandy soils with weak structure stability and low cation exchange capacity and low humus content.
- Generally we cannot expect in stated time horizons that soil units and soil forming processes will change basically. Only gradual changes of hydrologic and physico-chemical regimes and partly morphological changes will be identified throughout this century.
- The consequences of global climatic change on soils will be consecutive and they will not appear at once. They will demonstrate themselves with 10 – 20 years prorogation. The first visible changes we can see to the end of this century.
- We can not exclude some climatic change influence on starting mechanism of toxic pollutants accumulated in soils, sediments and in ground waters as a result of natural landscape balance violation (Hekstra 1989).
- The first and the quickest positive demonstrates of the global climatic change will be visible in the short time horizon in soils with high ground water table (gley processes).
- The first and the quickest negative demonstrates will be visible on similar localities with strongly mineralized high ground water tables (salinization and alkalinization hazard). The erosion will affect uppermost the sandy soils of Záhorie Lowland and soils developed from loess on convex parts of loess hills.

To the conclusion it is necessary to say that the global climatic impacts will be sometimes hardly identifiable in the surroundings of anthropically intensive exploited (or injured) soils. Those direct anthropogenic changes will become evident much earlier and in intense degree and will change not only soil properties but the soil profile morphology, too.

CONCLUSIONS

Well-developed scenarios of global climatic change and our knowledge about existing development of our soils enabled us to predict their next developmental changes:

- In consequence of climatic change, very slow retrocedent development of soils and soil catenas will be dominating – climosequences.
- In our climatic zone – to compare with others – the soils will overcome through small changes in their characteristics and properties only.
- In the time horizons presented by climatologists the most of our soil units on the level of Type and Subtype in essence will not convert to others. Alterations will be in erosion processes and locally in gley and saline/alkaline processes and subsequently in related soil units, too.
- More substantial alterations will be in soil properties and characteristics: organo-mineral alterations, modifications in chemism, red-ox changes, etc.
- Production potential of soils will be higher on arable lands and on grasslands, too.

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SOILS SUITABILITY FOR SUGAR BEET GROWING

Vhodnosť pôd pre pestovanie cukrovej repy

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ABSTRACT

The work objective is to differentiate rural land of Slovakia with aspect to the possibility of effective sugar beet growing. The differentiation is based on pedo-climatic and production economical parameters. By soil categorization, correlation relationships between site properties (soil and climatic conditions) and crop biological and agrotechnical requirements were considered. Sugar beet requirements were included into yield databases using the software filters in the way that the given site property excluded or limited the crop growing. This was reflected in predicted production. The prediction was subsequently interpolated into four suitability categories: soils non suitable for sugar beet growing, less suitable soils, suitable soils, and very suitable soils.

The database was formed, and each of the Bonited Pedo-Ecological Units (BPEU) was added into it as well as particular category for sugar beet growing. By mediation of the Geographic Information System on the BPEU distribution in Slovakia, the map of soil suitability categories for sugar beet growing was also generated. In Slovakia, there is 20 % of farmland very suitable for sugar beet growing, 18 % suitable, 3 % less suitable, and 59 % non suitable soils for sugar beet growing, according to our calculations. From potentially arable soils, very suitable soils for sugar beet growing take 29 %, suitable 27 %, less suitable 5 %, and non suitable 39 %, respectively.

In the paper, these categories were characterized in details and specifically from the view of geographic, soil, climatic, productivity, economic and energetic parameters.

Keywords: sugar beet; soil suitability, agricultural landscape categorization

ABSTRAKT

Pri kategorizácii poľnohospodárskej krajiny podľa vhodnosti pre pestovanie cukrovej repy sme zohľadňovali korelačné vzťahy medzi vlastnosťami stanovišťa (pôd, klímy) a biologickými i agrotechnickými požiadavkami tejto plodiny. Požiadavky plodiny boli zapracované pomocou softwérových filtrov tak, že daná vlastnosť stanovišťa buď pestovanie vylučovala, resp. ju obmedzovala, čo sa odrazilo na výške predpokladanej produkcie. Táto bola následne interpolovaná do štyroch oblastí vhodnosti pôdy pre pestovanie cukrovej repy - pôdy nevhodné, málo vhodné, vhodné alebo veľmi vhodné. Následne bola vytvorená databáza, v ktorej každej bonitovanej pôdno-ekologickej jednotke (BPEJ) bola priradená konkrétna kategória vhodnosti pre pestovanie cukrovej repy. Prostredníctvom geografického informačného systému o rozšírení BPEJ na Slovensku potom bolo možné vytvoriť mapu priestorového rozšírenia kategórii vhodnosti pôd pre pestovanie cukrovej repy.

Z výsledkov vyplýva, že 20 % poľnohospodárskej krajiny Slovenska má pre pestovanie tejto plodiny veľmi dobré podmienky, 18 % má podmienky vhodné, 3 % málo vhodné a 59 % nevhodné. Z potenciálne orateľných pôd zaberajú veľmi vhodné pôdy pre pestovanie cukrovej repy 29 %, vhodné 27 %, málo vhodné 5 % a nevhodné 39 %.

Tieto oblasti sú v príspevku charakterizované z hľadiska pôdno-klimatických i produkčno-ekonomických parametrov.

KĽÚČOVÉ SLOVÁ: cukrová repa, vhodnosť pôd pre pestovanie cukrovej repy, kategorizácia poľnohospodárskej krajiny

INTRODUCTION

Efficacy of the sugar beet growing depends particularly on environmental soil and climatic conditions. These factors fully affected these crop productional and economic assumptions. Although genetic and breeding factors with aspect to pedo-climatic conditions heterogeneity do not play negligible role, individual regions have variable rate of suitability for this crop growing.

The Sugar beet requirements for the environment are known enough from many specialized publications. FORCHTSAM and PRCHALA (1960) mentioned, sugar beet was our most important industrial crop, grown particularly in beet-growing district (on 22 – 25 % arable land), less in corn belt. Unsuitable are very heavy and water-logged soils. KORBÍNY and FACUNA (1978) limited 6 zones of the sugar beet growing suitability, whereby they respected fact, high yields were registered only on warm enough soils, sufficiently supplied with moisture and nutrients, deep, loamy to silty soils on loesses, loessial covers and alluvial sediments in czernozemic and luvisol regions. HRAŠKO and BEDRNA (1988) mentioned the most suitable soils for sugar beet were very deep soils (roots reach depth 1.2 m), loamy soils rich enough on dust particles (soils with good structure), with neutral to weak alkaline soil reaction, high sorption capacity, good porosity 46 – 55 % and bulk density up to 1.4. Non suitable were gleyic and pseudogleyic horizons. DEMO et al. (1998) stated, sugar beet required structural soils, well aerated. Less suitable to non suitable were water-logged and cold soils, or soils very light and dry. According to KOVÁČ et al. (2003) the sugar beet was very demanding crop with aspect to soil. It required deep, humous, loamy to silty soils.

Present computer technique development, particularly use of geographic information systems (GIS), enabled substantially more precise quantification of innovated databases based on existing soil information systems. Soil suitability categories were spatially itemized for purposes of agricultural crops growing.

This paper objective is on the example of the sugar beet to demonstrate just these methods.

MATERIAL AND METHODS

For outlining the regions of soil suitability for barley growing, the bases for us were the crop exact and potential data. Because growing suitability is predominantly judged on the basis of really reached production, this factor played decisive role at the categories formation. The concrete data on yields and this crop growing economics in period 1990-1998 were obtained from 281 agricultural subjects farming in heterogenous natural conditions, and in 1997 – 2003 from all the districts of Slovakia.

Both, production and economical parameters of successful barley growing, are directly connected with pedo-climatic conditions. Data of the Slovak climatic regions were analysed and applied, as well as data of sloping, stoniness, soil depth, soil types and subtypes, soil point values, and typological-production soil categories. These data were obtained from the Appraisal Information Database of the Soil Science and Conservation Research Institute Bratislava by mediation of the Bonited Pedo-Ecological Units (BPEU) presentation

The dependence of the indicators studied from the soil production potential in analysed farms (expressed by average point value in 100-point scale) was tested by non linear polynomial regression analysis. Subsequently potentially possible yields of the sugar beet, its share in cropping system as well as potential economical parameters (yields, costs, profit, or loss) was calculated using regression equations for each of the BPEU, and added to database. Soil rate of the suitability for the sugar beet growing was differentiated and qualified using the Geographic Information System ARC INFO, based on vector bonity maps (scale l: 5000) and area distribution of the factors studied. All economical indices used in the work were calculated without government subsidies. The background used:

- Soil Science and Conservation Research Institute database of the Bonited Pedo-Ecological Units (BPEU) data and their point evaluation in 100 point scale (Džatko, 2002),
- Soil categorization by their allegiance to climatic region, sloping category, texture and stoniness (Linkeš et al., 1997),
- Typological-production farmland categorization (Džatko, 2002) and database of the productional and economical parameters by the BPEU (Vilček, 1999),
- Real spring barley yields, their economical parameters (receipts, yields and costs) and real cropping system structure of arable land,
- Energhetic equivalents for the barley growing energy production were calculated by the methodology of authors Strašil (1987) and Preininger (1987).

All the economical indexes used in the paper are cited without the government subsidies.

RESULTS AND DISCUSSION

The sugar beet is from the long-term point of view of the cropped land development in Slovakia one of the most important agricultural crops. In the period 1970 – 2003 (34 years) this crop harvested areas ranged between 30 856 ha in 2002 to 62 197 ha in 1981. In the recent years, a relative decrease in the area was registered.

According to the statistical data of the last seven years (1997 – 2003), the total number of districts with sugar beet was 41. Today 47.7 % of sugar beet is grown only in 6 districts (Levice, Galanta, D. Streda, Nitra, Trnava, Topoľčany).

Sugar beet yield development in the recent 34 years (1970 – 2003) particularly reflected annual climate specificums. Lowest yield was registered in 1976 (27.41 $t.ha^{-1}$), the highest in 2002 (43.48 $t.ha^{-1}$). Statistical review of this crop yields by the Slovakian districts during 1997-2003 showed, the crop highest production potential was registered in the districts: Piešťany (48.11 $t.ha^{-1}$), Partizánske (44.48 $t.ha^{-1}$), Šaľa (43.93 $t.ha^{-1}$), Bánovce nad Bebravou (43.41 $t.ha^{-1}$) and Hlohovec (42.02 $t.ha^{-1}$).

From our foregoing works shows up that the soil production potential of the sugar beet is used only by 80 %. By our opinion, remarkable reserves are particularly in this crop proper distribution within the conditions most suitable for it.

When forming soil suitability categories for sugar beet, our work was based on polyfunctional analysis of selected pedo-ecological and economical parameters markedly influencing this crop growing prosperity. Such analysis proved expressive dependence of the production and economical characteristics on pedo-climatic conditions.

Sugar beet growing successfulness was influenced by many other factors, not analysed with us. When delineating, the suitability zones were not respected, e.g. actual soil reaction (pH). Well known is the fact that sugar beet on acid soil, not limed soil, cannot be prosperous. Genetically acid soils were classified as less suitable for sugar beet. Similar principle was used also for sandy, dry and water-logged soils. Based on available data, by help of inductive method four groups of farmland suitability were limited for sugar beet growing.

Very suitable soil group – 19.8 % of the total farmland, i.e. 29.2 % of the potentially arable soils. Included are soils with stable temperature and moisture regime (Chernozems, Phaeosols, Fluvisols and Luvisols) in the Danubian Lowland (particularly Trnava Hilly Land, Hron Hilly Land and Nitra Hilly Land), texturally medium heavy to heavy soils of the Chvojnická Hilly Land, Lučenec-Košice Depression and Eastslovakian Lowland.

Soil parameters structure of the group:

Soil-climatic regions: 00 – very warm, very dry, flat (49.9 %), 01 – warm, vry dry, flat (32.7 %)

Soil types: Chernozems (33.0 %), Phaeosols (20.5 %), Fluvisols (22.7 %) and Orthic luvisols (17.9 %)

Slopes: sloping 0 – 3° occupies 87.6 %, and sloping 3 – 7° occupies 12.4 % soils of the group

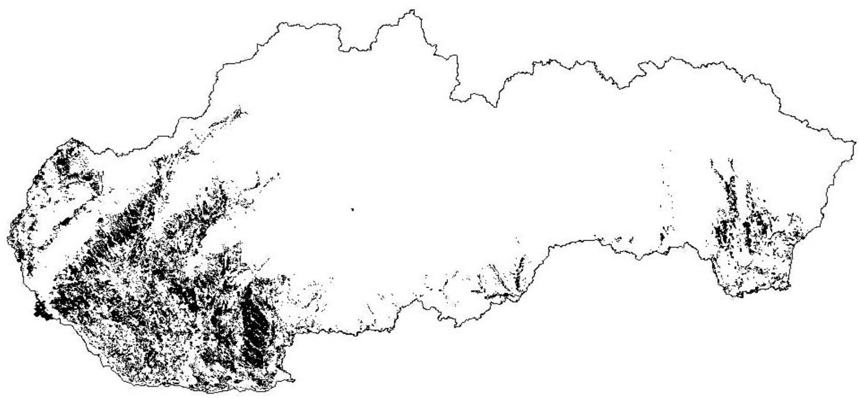
Soil skeleton: soils prevailingly without skeleton (95.1 %)

Depth: deep soils (97.3 %)

Texture: medium heavy soils (loamy – 65.2 %) to heavy (silty – 24.7 %)

Soil point value: 55 – 100 points.

Figure 1 *Very suitable soils for the sugar beet growing*



This group includes arable land with the sugar beet production potential above 42.0 t.ha^{-1}. Mean yield reaches level of 44.5 t.ha^{-1}. On these soils, sugar beet can have more than 6 % of the cropping system. By typological-production farmland categorization, the sixth highest most productive soil categories ranging from most productive arable land to less productive ones (O1 – O6) occur there. Sugar beet growing enables profit higher than 6 700 Sk.ha^{-1}, and profitability rate exceeds 22 %. Bioenergy produced was on the level of 159 – 163 GJ.ha^{-1}.

The group of suitable soils – occupies 18.2 % of the Slovak farmland, i.e. 26.7 % of the potentially arable soils. It is geographically identified mainly by central part of the Danubian Lowland, western part of the South Slovak Basin, East Slovak Lowland and Basin of Košice.

Soil parameters structure of the group:

Soil-climatic regions: 00 – very warm, very dry, flat (35.4 %), 01 – warm, very dry, flat (22.8 %), 02 – sufficiently warm, dry, hilly (10.3 %), 03 – warm, very dry, flat, continental (11.8 %, 04 – warm, very dry, basin-like, continental (8.2 %)

Soil types: Fluvisols (29.7 %), Chernozems (21.5 %), Orthic luvisols (20.3 %), Phaeosols (14.5 %), and Regosols (10.2 %)

Slopes: sloping 0 – 3° occupies 74.0 % and sloping 3 – 7° occupies 25.9 % soils of the group

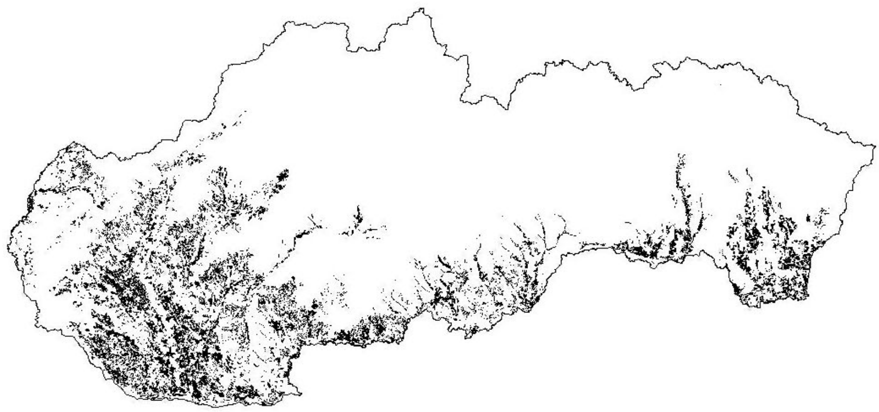
Soil skeleton: skeletonless soils – 95.3 %

Depth: deep soils (98.5 %)

Texture: medium heavy soils (loamy – 61.0 % and sandloamy – 5.2 %) to heavy (silty – 16.2 %)

Soil point value: 40 – 96 points.

Figure 2 *Suitable soils for the sugar beet growing*



The sugar beet potential yield in this region is – 35.5 to 42.0 t.ha^{-1}, whereby mean yield is 38.9 t.ha^{-1}. In the cropping system, the sugar beet can be spread approximately on 2 – 6 %. By typological-production itemization of the Slovak soils, the most productive arable land to low productive arable land (O1 – O7) is included. This soil group profit of sugar beet growing can reach 4 500 Sk.ha^{-1} and profitability rate of 16 %. Bioenergy produced introduces value of 140 – 160 GJ.ha^{-1}.

Low suitable soil group – the area represents only 3 % of the farmland and 4.5 % of the potentially arable Slovak soils. Included can be East Slovak Hilly Land, southern parts of the Basin of Košice, Lučenecká and Košická Basin.

Soil parameters structure of the group:

Soil-climatic regions: most spread are 03 – warm, very dry, flat, continental (34.7 %), 04 – warm, very dry, basin-like, continental (21.2 %), 05 – relatively warm, dry, basin-like continental (31.8 %)

Soil types: Cambisols (11.2 %), Dystric planosols (88.3 %)

Slopes: sloping 0 – 3° – plain (58.2 %) to 3 – 7° moderate sloping (41.8 %)

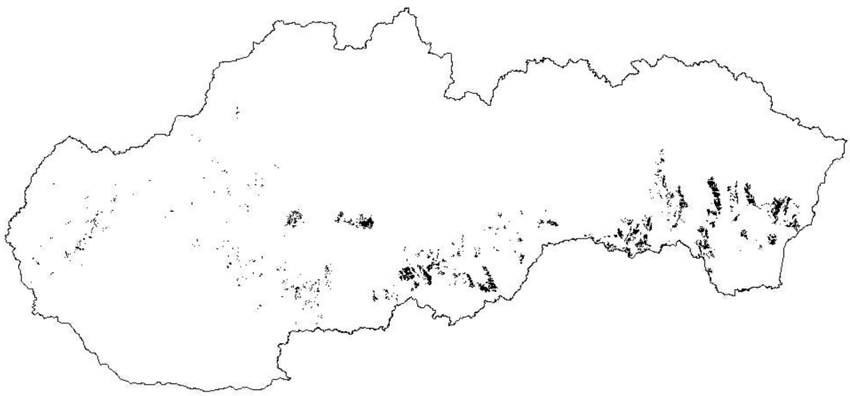
Soil skeleton: dominating are skeletonless soils (87.3 %)

Depth: deep soils (94.3 %)

Texture: medium heavy soils (loamy – 88.1 %) to heavy (silty – 10.1 %)

Soil point value: 45 – 78 points.

Figure 3 *Less suitable soils for the sugar beet growing*



The sugar beet yield range is 30.3 to 35.5 $t.ha^{-1}$. By typological-production soil classification we can find a very productive arable land to low productive fields (O3 to OT3). The profit approximately of 1200 $Sk.ha^{-1}$ and profitability rate up to 5 % can be reached. Bioenergy produced is 120 – 140 $GJ.ha^{-1}$.

The group of non suitable soils – in Slovakia for the sugar beet growing is 58.8 % of farmland non suitable as well as 39.6 % of the arable soils. They are particularly soils located under the 49° of the North latitude, dryable and extremely heavy to pelic soils of lowlands, sloping, stony and shallow soils mainly in the Central and Northern Slovakia.

Soil parameters structure of the soil group:

Soil climatic regions: 07 - moderately warm, moderately moist (19.6 %), 08 – moderately cold, moderately moist (14.4 %), 09 – cold, moist (11.2 %), 10 – very cold, moist (19.0 %)

Soil types: Cambisols (57.8 %), Rendzinas (7.3 %), Regosols (6.4 %), Fluvisols (5.3 %)

Slopes: sloping 3 – 7° (20.0 %), 7 – 12° (31.1 %), 12 – 17° (18.9 %), above 17° (12.9 %)

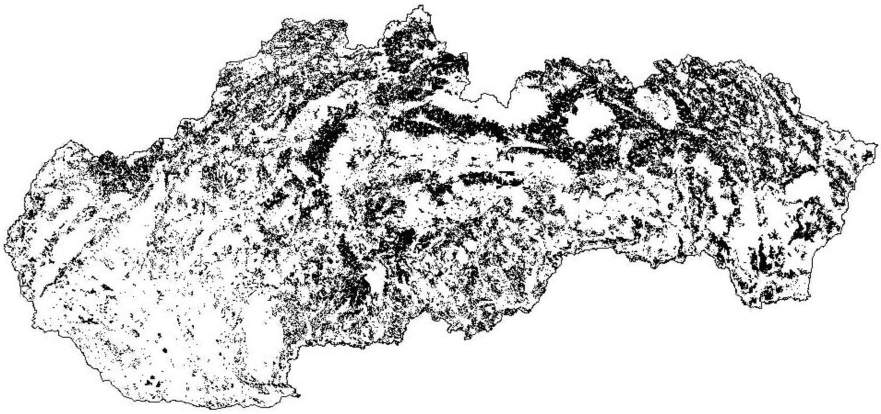
Soil skeleton: weakly stony (23.2 %), strongly (13.4 %), to very strongly stony (41.6 %) soils

Depth: deep soils (33.9 %), medium deep (24.4 %) to shallow soils (41.7)

Texture: light soils (sandy and loamsandy – 6.8 %), medium heavy (loamy – 58.0 % and sandloamy – 17.6 %), heavy (silty – 15.6 %) and very heavy soils (clayey – 2.0 %)

Soil point value: under 40 points.

Figure 4 *Soils non suitable for the sugar beet growing*



The sugar beet yields on these soils are under 30 t.ha, i.e. this crop should not be incorporated into the cropping system. Both, economically and energetically, sugar beet growing is not profitable in this soil group.

CONCLUSION

In the paper presented soil categorization for the sugar beet growing suitability brings more detailed analysis of the territory pedo-climatic conditions (based on basic mapping unit BPEU) into the beet-growing district and zones of the main crops growing suitability, and contemporarily associates economical and energetical aspects of the crop growing. By means of the GIS, application used for any Slovak region can be presented, whereby the system enables possible further analyses and more detailed categorizations, when using other, supplementary parameters. So this is an open system that does not„sharply" articulate (by straight line) individual categories, but mosaic like, whereby it is based on the crop and site concrete characteristics.

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THE MEMORIAL OF PAVEL JAMBOR (1938 – 2005)

On the 9th June 2005, our colleague, excellent soil scientist of the Soil Science and Conservation Research Institute in Bratislava (SSCRI) and a long-term editor of the SSCRI Proceedings – Dr. Pavel Jambor, deceased.

During his professionally active life, he was entrusted by several significant positions at the Soil Science and Conservation Research Institute. The most significant one was probably the deputy director of the SSCRI. Beyond, he acted as a president of the Slovak Soil Science Society for several elective periods (1992 – 2005). He was a foundation member of the Pedological section of the Slovak Society for Agricultural, Forest, Food and Veterinary Sciences at the Slovak Academy of Sciences (1973). Moreover, his membership embraced Czechoslovak Agricultural Academy (1964 – 1989), Slovak Academy of Agricultural Sciences (1993), and various scientific boards and international societies (IUSS, ECSSS, ESSC). In the same way, Dr. Jambor chaired the Soil erosion working group in one of the COST actions, and in the ARGEDONAU international program.

His further activities included active participation on national and international projects, as well as related journalistic activities. He was a co-ordinator of a number of international and national scientific projects referring to physical soil degradation. Dr. Jambor was an author of the "Manual for Anti-Erosion and Control Agrotechnic Systems". His work was trying to establish symbiosis of a pure soil science, practical soil and land assessment with the aspects of services provision to farmers. There were famous his newspaper articles published for agricultural practice. Besides, he worked as an editor of many scientific proceedings published by the Institute. He is author and co-author of approximately 120 scientific publications, contributions including four books: "Main Factors of Land Production Potential (1984)", "Soil and Plant Nutrition (1985)", "Methodology for Anti-erosion Land Management (1998)", "Aspects of the Erosion by Water in Austria, Hungary and Slovakia (2003)". Incomplete remained his four-language pedological dictionary, which will be issued in memoriam.

In Slovakia, Dr. Jambor was considered as a prominent specialist in soil erosion oriented on soil protection. His high reputation as an applied soil scientist was acknowledged by a Fándly Medal in memoriam (2005), and Diploma for soil science development of the Slovak Academy for Agricultural Sciences.

Dr. Pavel Jambor will forever remain in our memory. Results of his work can serve as a source of inspiration for those who follow his steps.

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