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Content

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SOIL PROPERTIES UNDER DAMAGED SPRUCE FORESTS IN THE MARTINSKÉ HOLE MOUNTAINS

PÔDNE VLASTNOSTI V PORASTOCH POŠKODENÝCH SMREKOVÝCH LESOV NA MARTINSKÝCH HOLIACH

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ABSTRACT

Damage of spruce forests has been observed for several years in the Martinské hole Mts. This paper deals with an evaluation of soil conditions at sites where damaged trees grow. We mostly focused on aluminium and nutrient content and heavy metal loads. Studied soils, which are Haplic Podzols and Skeleti-Histic Podzols, are extremely acid with low Ca, Mg and K plant-available contents, and also available P occurs in deficient amounts. We observed a high content of exchangeable aluminium, which is known for its phytotoxicity. We also analyzed Pb, Cr and Hg as toxic elements and there was observed lead contamination in soils and mercury overloads in needles. Also total Mg contents in the needles were insufficient when comparing with the optimum magnesium for the spruce tree. We suppose that these factors, together with surface water logging, reduce the vitality of spruce individuals and significantly participate to their degradation.

Keywords: cumulative soil stress, spruce, nutrients, aluminium, heavy metals, Martinské hole Mountains

ABSTRAKT

Na území Martinských holí možno už dlhšiu dobu pozorovať zhoršený zdravotný stav smrekových porastov, ktorý sa prejavuje žltnutím ihličia a úhynom jedincov, ktoré často vytvárajúcich súvislé porasty. Príspevok je venovaný štúdiu pôdneho prostredia pod takýmito porastmi a potenciálnemu vplyvu pôdnych stresových faktorov na zdravotný stav smreka v tejto oblasti. Pôdy, ktoré patria medzi podzoly kambizemné organozemné a podzoly kambizemné humusovo-železité, sú extrémne kyslé a s veľmi nízkym obsahom bázických katiónov. Zistený bol extrémne vysoký obsah výmenného hliníka v povrchových horizontoch, ktorý narúša prirodzený príjem živín rastlinami a pôsobí fytotoxicky. Preukázateľná je kontaminácia pôdy olovom, ako aj presiahnutie limitnej hodnoty ortuti v ihličí smreka. Zaznamenaný bol znížený obsah horčíka v ihličí, ako aj nízky obsah rastlinám prístupných živín v pôde, predovšetkým fosforu, vápnika, horčíka a draslíka. Spomínané špecifické pôdne podmienky spolu s povrchovým zamokrením pôdy sa vo vzájomnej interakcii podieľajú na zhoršenom zdravotnom stave smreka na Martinských holiach, ktorý následne vedie až ku degradácii týchto porastov.

Kľúčové slová: kumulatívny pôdny stres, smrek, živiny, hliník, ťažké kovy, Martinské hole

INTRODUCTION

In the 40´s of the 20th century, a significant damage of spruce stands has been recorded at the timberline of the Martinské hole Mts. (photographically documented by J. Futák). Although the area of damaged trees is not such extensive, the degradation is progressing. Spruce forest dying is not a new phenomenon in Slovakia. It is caused by natural factors (e.g. fires, diseases, pests, storms, dry periods) as well as anthropic factors (e.g. air pollution, overexploitation), and their interactions are very common. The literature refers to the following hypotheses of the forest degradation: (i) acidifiacation and aluminum toxicity, (ii) ozone influence, (iii) magnesium deficiency, (iv) nitrogen depositions and (v) multiple stress (Stanners, Bourdaeu, 1995). Most of these factors act through soil system. This work evaluates the status soil environment as a ground for understanding forest degradation, while we focus mostly on aluminium contents in soils, nutrient sinks and some heavy metals in soils and spruce needles.

Progressive acidification can lead to intensive leaching of soil nutrients, mobilization of stored heavy metals and other pollutants, and increasing mobility and phytotoxicity of aluminium. The last mentioned seems to be very important in soils rich in reactive aluminium. Al-toxicity is based on physiological impact on the root system of plants and also acts antagonistically to nutrient inputs of P, Ca, Mg, N, Fe and Mn. Therefore the roots of trees are shallow in extremely acid soils and they suffer from humidity oscillations. Al-toxicity is usually accompanied with high Fe and Mn concentrations, and low Mg and Ca contents in plant tissues (Kabata-Pendias, Pendias, 1992). Some soil processes regulate increasing of soil acidity, and are known as soil buffering systems (Ulrich, 1983). In acid soils, the neutralization runs through the dissolution of pedogenic phase containing aluminium, while various Al ions are released to the soil solution. Generally, two principal buffering mechanisms occur in acid soils. The first one includes the dissolution of mineral Al/Si-phase, while the second one, which occurs in extremely acid soils with enough of organic matter, is secured by Al-saturated organic matter (Wesselink et al., 1996).

Magnesium and potassium are not usually sufficiently fixed in acid soils and can be easily leached out, although there can act some natural barriers against their mobility. Therefore their deficiency usually occurs in studied soil environment. Magnesium, as the essential biogenic element entering chlorophyll and several enzymes in plants, can cause the chloroses and necroses if it is lacking in trees (Chapman, 1966). As a general phenomenon, a defficiency of Mg is being observed in extensive Europan areas, where it is indicated by yellowing of needles (Wellburn, 1994). Potassium is important nutrient affecting growing, photosynthetic reactions, enzyme activation or water regulation in plants. Trees with low K content suffer from weather extremes and a fungus attack (Chapman, 1966). Also phosphorus is an essential bioelement for trees. In terms of its availability for plants, mainly labile phosphates that easily penetrate to the soil solution are the most important for tree nutriment (Mengel, Kirkby, 1987).

Heavy metal effects are in many cases controlled by soil properties. The resistance of soils relies on clay minerals, organic matter, Fe, Mn and Al hydrated oxides, and on soil reaction (McLean, Bledsoe, 1992). With enough of specific organic compounds (especially humic acids), heavy metals are absorped or they form the inner-complexing compounds, and their mobility in profile is reduced. Generaly, most of heavy metals have a potential to become mobile at low pH. Lead (Pb), chromium (Cr) and mercury (Hg) were analysed for our purposes because Linkeš (1989) as well as Bucha et al. (1998) reported these heavy metals to occur in high contents in the study area. Lead belongs to the least mobile heavy metals. It is a common pollutant, which accumulates in the topsoil sa it has high affinity to the organic matter. Its mobility can increase in very acid conditions without enough of organic matter (Fergusson, 1990). Besides organic matter, the mobility of lead is conrolled by clay minerals, Mn oxides (Beneš, Pabianová, 1986), and Fe and Al hydroxides (Kabata-Pendias, Pendias, 1992). Chromium uptake by plants is limited because it mostly occurs in less mobile Cr^{3+} forms in soils (Kabata-Pendias, Pendias, 1992). In oxidic soils, Cr^{3+} changes to Cr^{6+}, which is mobile in strongly acid soils, and toxic. The reduction of Cr^{6+} is enforced by organic matter, while better conditions for Cr^{3+} forming occur in acid soils (Beneš, Pabianová, 1986). Mercury generaly accumulated in organic horizons for it is bounded by humic cubstances (Babčan, Ševc, 1994). The content of Hg in soils is also affected by the biomethylation, which produces toxic, volatile and plant-available compounds (Fergusson, 1990). Biometylation of Hg is a detoxication mechanism and a decrease in pH can cause an increase of biomethylation activity (Wilken, Hintelmann, 1990).

MATERIAL AND METHODS

The study area is located at the timberline nearby the ridge of the Martinské hole Mountains (Lúčanská Malá Fatra Mts.). In October 2001, three soil profiles (S1, S2, and S3) were sampled at various sites with damaged spruce forests. Besides soil samples, we collected samples of 1-3 year-old needles from damaged and healthy spruces. Soil profiles were clasified by WRB 1998 (FAO-ISRIC-ISSS, 1998) as Haplic Podzol (S1, S2) and Skeleti-Histic Podzol (S3). Soil samples were air-dried at room temperature and passed through a 2 mm sieve to remove stones and plant debris. Active and exchange soil reaction (pH in H_2O and pH in KCl) and total organic carbon (C_{org}) by wet combustion) were analyzed according to Hraško et al. (1962). Exchangeable acidity (EA), sum of base cations (SOB), cation exchange capacity (CEC) and base saturation (BS) were determined by the Godlin's method according to Hraško et al. (1962) and total nitrogen (N) by Kjeldahl (Hraško et al., 1962 modif. by Anonymus, 1995). Humic substances were extracted by an alkaline extractant and separated to fulvic acids (FA) and humic acids (HA) according to Fiala et al. (1999). The content of organic carbon in HA and FA was analysed by the wet combustion technique as with C_{org}. The quality of HA and FA was determined spectrophotometrically as the optical coefficient $Q^4/_6$ measured at wavelengh of 400 and 600 nm. Exchangeable aluminium (Al_{ex}) was measured in soil extracts with 1N KCl solution as proposed by Sokolov (Fiala et al., 1999). Partical size distribution of soils was estimated by the pipette method according to Novák (Hraško et al., 1962). The content of available forms of phosphorus and potassium (P, K) was measured using the Mehlich II extractant (Fiala et al., 1999). Mercury in soils and needles was analysed by ASS on the one-purposed mercury analyser TMA 254. Lead, chromium and magnesium, both in soil and needle samples, were determined by AAS on the Perkin-Elmer analyser after the total dissociation by HNO_3 and $HClO_4$ mixture. The limits of heavy metals in soils were evaluated according to "The regulation of Ministry of Agriculture of Slovak republic on the highest available contents of harmful substances in soils, and on the assessment of organizations justified to determine the veridical values of these substances" from the year 1993. Studied heavy metals (Pb, Cr, Hg) in needles were evaluated according to Maňkovská (1996), and Mg in needles according to Stefan et al. (1996).

RESULTS AND DISCUSSION

All horizons of studied Podzols are extremely acid and pH-H_2O varies between 3.5 in surface horizons and 4.9 in subsurface ones. In addition to soil acidity, studied soils are dystric, with base saturation less than 30 % over the profile. Topsoil horizons are rich in organic carbon and features of histic horizons are visible in profiles S1 and S3. The ratio of organic carbon and total nitrogen indicates low resources of nitrogen for microbial activity, as common for Podzols in humid conditions. Studied Podzols can be classified as loamy and sandy-clay when addressing the particle size distribution. More information on basic chemical and physical properties is summarised in Table 1.

Table 1 Basic properties of studied profiles

Profile	Horizon	Depth [cm]	pH H_2O	pH KCl	C_{org} [%]	EA	SOB	CEC
						[cmol$^+$.kg^{-1}]		
S1	O(h)	5 – 0	3.46	3.27	29.77	18.8	0.8	19.6
	Aop	0 – 9	4.04	3.65	5.70	15.4	0.8	16.2
	Bsv1	9 – 19	4.39	3.79	3.90	14.0	0.8	4.8
	Bsv2	30 – 40	4.02	3.86	3.83	14.6	0.5	15.1
	B/C	50 – 60	4.33	4.05	2.63	12.8	0+	12.8
S2	Aop	0 – 7	3.67	2.89	13.20	17.8	6.8	24.6
	Bsh	7 – 18	3.76	3.50	2.78	16.6	0.8	17.4
	Bsv	18 – 28	4.30	3.94	1.95	13.0	0.8	13.8
	B/C	30 – 40	4.41	4.06	0.48	8.8	0^+	8.8
S3	Oh	10 – 0	3.51	3.17	46.48	18.8	2.4	21.2
	A/B	0 – 13	4.12	3.65	5.70	16.6	2.8	19.4
	Bsv	30 – 40	4.88	4.22	0.84	10.0	0^+	10.0

Profile	Horizon	Depth [cm]	BS [%]	N [%]	C/N	clay [%]	silt [%]	sand [%]	Alex [mg.kg^{-1}]
S1	O(h)	5 – 0	4.1	0.98	30.4	histic mezic			860
	Aop	0 – 9	4.9	0.42	13.6	7.6	27.2	65.2	495
	Bsv1	9 – 19	5.4	0.28	13.9	3.7	25.8	70.5	405
	Bsv2	30 – 40	3.3	0.19	20.2	6.6	21.1	72.3	383
	B/C	50 – 60	0^+	–	–	5.1	16.7	78.2	232
S2	Aop	0 – 7	27.6	0.76	17.4	5.0	15.0	80.0	675
	Bsh	7 – 18	4.6	0.15	18.5	4.4	24.0	71.6	698
	Bsv	18 – 28	5.8	–	–	5.2	19.6	75.2	338
	B/C	30 – 40	0^+	–	–	0.4	17.3	82.3	187
S3	Oh	10 – 0	11.3	1.26	36.9	histic sapric			990
	A/B	0 – 13	14.4	0.33	17.3	4.8	22.4	72.8	540
	Bsv	30 – 40	0^+	–		0^+	17.2	82.8	128

Notes: (-) not determined, (0^+) under detection limit of the method

The accumulation of humus on soil surface is common in studied Podzols for mineralization is inhibited under strongly acid and humid soil conditions. Humification process leads to forming of acidic humic substances with domination of fulvic acids (FA), where the ratio of HA/FA is highly under 1 (Table 2). Fulvic acids are soluble and can migrate through the profile, what is a part of podzolization process. During migration, the fulvic acids can potentially increase the mobility of heavy metals. Following the optical coefficient $Q^4/_6$, fulvic acids with more aromatic character can be observed in the topsoil, while lighter fractions are distributed over profile ($Q^4/_6$ of FA increases with depth). The optical coefficient indicates that the quality of HA has different distribution over profile when compared to FA. It seems common that higher values are in spodic horizons. The distribution of organic matter over profile is affected by histic processes on soil surface.

Table 2 The content of humic and fulvic acids and their optical coefficients

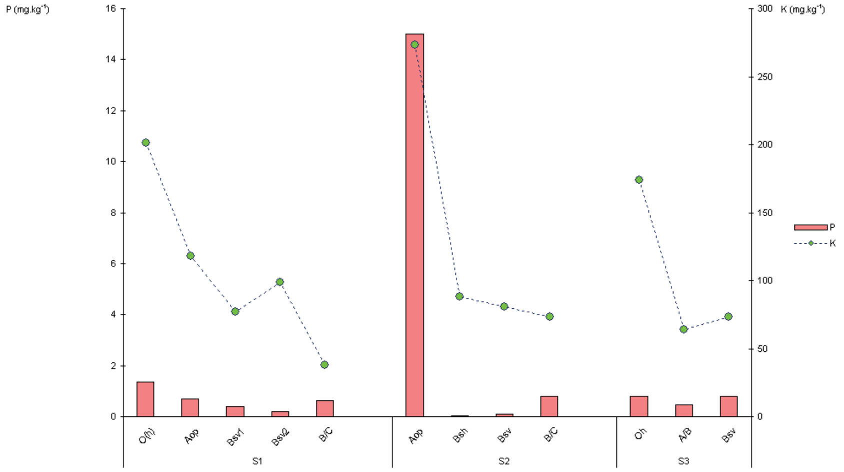
Profile	Horizon	Depth [cm]	HA [%]	FA [%]	HS [%]	HA/FA	$Q^4/_6$ HA	$Q^4/_6$ FA
S1	O(h)	5 – 0	1.19	2.95	4.14	0.40	4.8	13.3
	Aop	0 – 9	1.50	2.39	3.89	0.63	4.2	14.6
	Bsv1	9 – 19	0.67	1.47	2.14	0.46	4.1	18.4
	Bsv2	30 – 40	0.57	1.38	1.95	0.41	4.7	23.2
	B/C	50 – 60	0.44	1.46	1.90	0.30	5.5	25.6
S2	Aop	0 – 7	1.77	2.33	4.10	0.76	4.5	12.9
	Bsh	7 – 18	0.68	1.26	1.94	0.54	4.9	15.0
	Bsv	18 – 28	0^+	1.72	1.72	–	–	21.8
	B/C	30 – 40	0^+	0.79	0.79	–	–	29.5
S3	Oh	10 – 0	2.82	4.54	7.36	0.62	5.0	10.8
	A/B	0 – 13	0.91	2.13	3.04	0.43	4.5	8.40
	Bsv	30 – 40	0^+	0.96	0.96	–	–	23.9

Notes: HA – humic acids, FA – fulvic acids, HS – humic substances, $Q^4/_6$ – optical coefficient at 400 and 600 nm

In these strongly acidic soils, aluminium is released in high quantities into soil environment through dissolution of mineral Al-fraction or from Al-saturated humic substances, mostly fulvic acids. Therefore aluminium becomes dominant in the sorption complex and in the soil solution. Prevailing of Al represents a significant stress for plants. In our samples, the highest values of the Al_{ex} were determined in surface horizons, especially in profiles S3 (990 mg.kg^{-1}) and S1 (860 mg.kg^{-1}) – notice Table 1. Its content decreases with soil depth as a function of increasing soil reaction. A comparison with results of the soil monitoring (Kobza et al., 2002) indicates that studied soils belong to extremely Al-rich as obtained results of exchangeable aluminium are higher than any values reported from monitored profiles. Hence the stressing effect would be very high in these soils.

The unfavourable environment for plants is also enforced by low contents of plant-available phosphorus. In soils with high contents of reactive aluminium, phosphates are usually fixed through specific or non-specific adsorption (Gebhardt, Coleman, 1974). It is evident that phosphorus contents are low in topsoil horizons of S1 and S3, where high aluminium concentrations occur, compared to S2 profile (Figure 1). Contrary to phosphorus, potassium appears not deficient.

Figure 1 Distribution of plant-available P and K in studied soils



Contents of Pb, Cr and Hg in soil samples are evaluated with respect to A, B, and C reference indices according to "The regulation of Ministry of Agriculture of Slovak republic about the highest available contents of harmful substances in soils" from the year 1993 (hereinafter referred to as the Regulation). A-limit is the reference value, which determines the background amount of a heavy metal, which is calculated from humus content and clay in each of horizons according to particular formula from the Regulation. Soil contamination is indicated by B threshold, while C-value indicates the contamination, which requires inevitable implementation of relevant decontamination remedies. The measured values of Pb, Cr and Hg, and values of A, B, and C limits according to the Regulation, are summarized in Table 3. We can notice the overloads of Pb with respect to its A-limit in topsoils of S1 and S2 profiles. Soil contamination over B-limit (150 mg.kg^{-1}) was determined in topsoil horizon of S3 profile. Higher Pb contents in topsoils reflect its natural accumulation in humus, and it also indicates its atmospheric depositions. Chromium contents do not exceed reference values of A-limit. Higher content of mercury exceeding its reference A-limit was measured in the topsoil of S3 profile, but it does not exceed its B limit for contamination.

Table 3 Pb, Cr and Hg contents in soils and limit values of A, B and C according to the Regulation of Ministry of Agriculture of Slovak republic about the highest available contents of harmful substances in soils from the year 1993

	Horizon	Pb [mg.kg^{-1}]				Cr [mg.kg^{-1}]				Hg [mg.kg^{-1}]			
			A	B	C		A	B	C		A	B	C
S1	O(h)	83.9	109.3	150	600	37.1	96.0	250	800	0.266	0.314	2	10
	Aop	80.4	67.4			38.5	95.2			0.184	0.243		
	B/C	26.8	59.6			46.6	90.2			0.132	0.225		
S2	Aop	125.8	77.8			33.6	90.0			0.228	0.256		
	B/C	20.5	51.2			73.8	80.8			0.015	0.203		
S3	Oh	198.3	137.9			32.9	95.6			0.375	0.363		
	Bsv	16.7	51.4			68.9	80.0			0.027	0.202		

Also needles were taken from degraded and healthy spruce trees from the study area. The results of analyses are summarized in Table 4. The limit value of Pb, which is 5 mg.kg^{-1} (Maňkovská et al., 1996), was not exceeded in any samples. Neither chromium contents exceeding its limit of 0.8 mg.kg^{-1} (Maňkovská et al., 1996) were recorded. However, the limit value of Hg in needles, which is referred to be 0.1 mg.kg^{-1} (Maňkovská et al., 1996), was exceeded in two samples. The overload occurred in needles of healthy spruce near the profile S1 (0.17 mg.kg^{-1}) and in needles of degraded spruce standing nearby S3 profile, where mercury overreached its limit almost for 100 % (0.197 mg.kg^{-1}). The overload of Hg significantly participates in deterioration of spruce conditions because even a low concentration of Hg may be very toxic for plants. When comparing damaged and healthy trees, there was not significant difference as for contents of observed heavy metals.

Table 4 Total Pb, Cr, Hg and Mg contents in needles of damaged and healthy spruce individuals

Profile	Spruce	Pb [mg.kg^{-1}]	Cr [mg.kg^{-1}]	Hg [mg.kg^{-1}]	Mg [mg.kg^{-1}]
S1	damaged	1.43	0.399	0.062	308
	healthy	< 1.2	0.400	0.170	727
S2	damaged	1.8	0.524	0.197	554
	healthy	< 1.2	0.327	0.039	866
S3	damaged	1.93	0.318	0.060	486
	healthy	< 1.2	0.138	0.034	796

Generally low contents of magnesium were recorded in needles of damaged spruce individuals in the study area (308 – 554 mg.kg^{-1}) whereas moderate contents were measured in healthy trees (727 – 866 mg.kg^{-1}). In terms of a magnesium optimum, which is at about 15 000 mg.kg^{-1} (according to Stefan et al., 1997 in Bucha et al., 1998), the content of magnesium is insufficient in both cases, and magnesium is a deficient nutrient in studied trees.

As for comparison, we offer comparable numbers of the same elements being analysed in 1 – 3 year-old needles of healthy spruce trees from Nízke Tatry, Kremnické vrchy and Vysoké Tatry Mts., which could serve as a reference for our study material (notice Table 5). The contents of Cr are comparable with results of our study material. Higher contents of Pb were noticed in samples from the Kremnické vrchy and Vysoké Tatry Mts., but they do not exceed the limit of 5 mg.kg^{-1}. Generally lower Hg contents were measured in the reference material compared to that from the Martinské hole Mts. Total magnesium occurs in similar ranges in samples from mentioned mountains as in our study area. A comparison with needle samples of healthy spruces, which grow in similar soil conditions, shows only small differences in contents of analyzed elements, except of Hg, which exceeds its limit in the Martinské hole Mts.

Table 5 Reference contents of studied heavy metals and Mg in spruce needles analysed from different localities in Slovakian high mountains

Locality	Soil type	Pb [mg.kg^{-1}]	Cr [mg.kg^{-1}]	Hg [mg.kg^{-1}]	Mg [mg.kg^{-1}]
Nízke Tatry Mtn.	Entic Podzol	< 1.2	0.30	0.023	512
Kremnické vrchy Mtn.	Skeleti-Leptic Andosol	2.94	0.25	0.035	344
Vysoké Tatry Mtn.	Haplic Podzol	2.58	0.45	0.014	755

CONCLUSIONS

The results indicate that there exists a cumulative stress of several soil factors, which are suboptimal to spruce trees, and which may decrease the vitality of spruce stands. Highly acidic soils are extremely unsaturated by base cations and plant nutrients. These extreme soil conditions, together with a potential for mobility of heavy metals, represent a limiting factor to production of spruce tree. In terms of mechanisms buffering soil acidity, increasing acidity results to storing of higher quantities of exchangeable aluminium in the root zone of trees, while it shows high contents especially in the topsoil horizons. Extremely high contents of exchangeable aluminium, somewhere nearly 1 000 mg.kg^{-1}, may affect shallow and flat root system of spruce directly, or indirectly by inhibition of other nutrients. There was observed some deficiency in phosphorus in soils as extremely acid soils, which are rich in aluminium, tend to fixate it, and make it not available for plants. In addition, a contamination of soils by lead exceeding the B-limit was identified in topsoil of Skeleti-Histic Podzol, and mercury overload was noticed in needle samples, what may also cause a serious threat for trees. Lead and chromium contents do not exceed their limit values in plants. Finally, Mg stocks are suboptimal in spruce needles. All mentioned soil phenomena, together with local intensive surface water logging, affect this environment, where spruce trees grow under stressing conditions and create relatively labile ecosystems.

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SOCIO-ECONOMIC ROOTS OF SOIL DEGRADATION

SOCIO-EKONOMICKÉ PRÍČINY DEGRADÁCIE PÔDY

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ABSTRACT

Soil, similarly to other natural resources, is used by human for safeguarding his harmonic life. Mentioned natural resource should remain for disposal in the same/adequate quality even to future generations. Despite this the existing status of soil quality is still fare from the desired reality. Immediate reasons of soil degradation are often remarkable and attract attention of soil scientists and policy makers. To them belong:

- insufficient respect to the principles of a good agricultural/forest practice and relevant legislation
- giving long-term precedence to the importance of production function over the other ecological ones
- lack of utilisable information on soil protection in individual economic sectors
- lack of broad public awareness in protection of soil as a natural resource
- the economic activities affect soil quality not only in industrial and urban areas, but also in an agricultural and forest sector
- migration of rural population to the cities
- building of infrastructure, industrial enterprises and parks for provision of permanent economic growth
- misunderstanding of the essence of ownership relations to the soil.

Behind immediate reasons of soil degradation it is possible to find deeper causes, closely related to human thinking and activities. Favouring economic view in contrast to environment, private and group interests to cross societal ones, short term benefits to long-term ones, promotion of excessive consumption as well as permanent need to increase the economic growth of individuals or purpose-built groups - that all are masked driving forces of soil and environment degradation necessary to take in account at provision of the sustainable soil use.

There is still great resistance to accept close relationship of people with environment of Earth and its skin – soil. All reasons of soil and land degradation are the result of human activities that through creative thinking permanently affects surrounding reality. Till now, the human has intensively changed the state of environment that is reflected in the soil degradation. From the mentioned reason, it is the highest time to start the positive changes of the human himself.

KEYWORDS: soil degradation, causes of soil degradation

ABSTRAKT

Pôdu, podobne ako ostatné prírodné zdroje, má človek k dispozícii pre zabezpečenie harmonického života. Uvedený prírodný zdroj by mal zostať k dispozícii v rovnakej resp. vhodnej kvalite aj pre nasledujúce generácie. Napriek tomu súčasný stav kvality pôdy je vzdialený od požadovanej reality.

Bezprostredné príčiny degradácie pôdy sú často viditeľné a priťahujú pozornosť pôdoznalcov, ako aj expertov pre tvorbu politík. K nim patria:

- nedostatočné rešpektovanie zásad správnej poľnohospodárskej/lesohospodárskej praxe a prislúchajúcej legislatívy
- dlhodobé uprednostňovanie významu produkčnej funkcie pred ostatnými ekologickými
- nedostatok využiteľných informácií o ochrane pôdy v jednotlivých hospodárskych sektoroch
- nedostatočné povedomie širokej verejnosti vzhľadom k ochrane pôdy ako prírodného zdroja
- hospodárske aktivity ovplyvňujú kvalitu pôdy nielen v priemyselných a urbánnych oblastiach, ale aj v sektore poľnohospodárstva a lesníctva
- migrácia vidieckeho obyvateľstva do miest
- budovanie infraštruktúry, priemyselných podnikov a parkov pre zabezpečovanie trvalého ekonomického rastu
- nepochopenie podstaty vlastníckych vzťahov v pôde.

Za bezprostrednými príčinami degradácie pôdy možno nájsť hlbšie príčiny, úzko spojené s myslením a aktivitami človeka. Uprednostňovanie hospodárskych záujmov pred ekologickými, súkromných a skupinových pred celospoločenskými, krátkodobých ziskov pred dlhodobými, podporovaním nadmernej spotreby ako aj trvalej potreby ekonomického rastu jednotlivcov a účelových skupín – to všetko skryté hybné sily degradácie pôdy a životného prostredia, ktoré treba brať do úvahy pri zabezpečovaní trvalo udržateľného využívania pôdy.

Existuje veľká rezistencia prijať užší vzťah ľudí so životným prostredím Zeme a jej pokožkou – pôdou.

Akékoľvek príčiny degradácie pôdy a krajiny sú výsledkom aktivít človeka, ktorý prostredníctvom tvorivého myslenia neustále ovplyvňuje okolitú realitu. Človek doteraz usilovne menil stav životného prostredia, čo sa odzrkadlilo v degradácii pôdy a ostatných prírodných zdrojov. Z uvedeného dôvodu je najvyšší čas zahájiť pozitívne zmeny človeka samotného.

Kľúčové slová: degradácia pôdy, príčiny degradácie pôdy

INTRODUCTION

Soil, similarly to other natural resources, is used by human for safeguarding his harmonic life. This natural resource should remain for disposal in the same/adequate quality even to future generations. Despite this, the existing status of soil quality is still fare from the desired reality. Many documents and papers (e.g. Bielek, 1999; Bujnovský et al., 2004; EEA, 2005; European Commission, 2002; European Commission, 2006; Lal, 1997; van Camp et al., 2004) refer to soil degradation as the prominent environmental problem and the necessity to sustain this resource in long-term span. Processes of soil degradation decrease its capacity to provide ecological functions, essential for human life (e.g. Bujnovský, Juráni, 1999; deHaan, 1996; Lal, 1997; Warkentin, 1997; Yaalon, Arnold, 2000). Moreover, soil degradation has close relationship to other environmental and societal problems such as floods/drought occurrence, food and water sufficiency & quality with direct impact on population health evolution.

Recently, significant part of the soil science activities was focused on understanding the evolution of soil parameters and properties at a concrete soil use & management as well as evaluation of the soil state through monitoring that serves as the information support for the legislation development and the realisation of necessary soil protection measures. Although this area of activities is still under the progressive development, the analysis of driving forces that directly or indirectly initiate/promote the soil degradation is perceived as very actual (e.g. European Commission, 2002; EEA 2005; van Camp et al., 2004). Moreover, as Meyer and Turner II (1994) introduce, human activities are the main issue of present changes of biosphere state and its development. Understanding of these activities and societal forces that cause them has a special significance for creation of necessary measures.

MATERIAL AND METHODS

The examination of soil degradation is focused on driving forces that are part of *DPSIR analysis* (European Commission, 1999). In accordance to Loveland, Thompson (2002), drivers of environmental changes are socio-economic factors while physical, environmental and natural factors are considered rather as pressures.

The paper presents basic/accustomed and more complex view on reasons that directly or indirectly cause the soil degradation. In the line with Lambin (2005), the second approach is based on *in depth analysis* of factors that cause environmental degradation or may impede the adoption of more sustainable management practices including also individual behaviour with respect to the natural resources use and management. In a broader context the environment deterioration mentioned below embraces even the soil degradation.

RESULTS AND DISCUSSION

Basic analysis of the soil degradation

The type and degree of the soil degradation is affected by concrete soil use. Generally, the intensity of soil degradation decreases in order: industrial area > urban area > agricultural sector > forestry sector. Immediate reasons of the soil degradation are often remarkable and attract attention of scientists and policy makers. First of all, it is necessary to mention the insufficient respect to the principles of good agricultural/forest practice and relevant legislation (erosion, compaction, loss of SOM, and partially as well acidification and pollution in agriculture; erosion and landslides in forestry). Mentioned corresponds with many findings (e.g. Brogan et al., 2002; European Commission, 2000; Jones, 2002). Giving long-term precedence to the importance of soil production function over the remaining ecological ones represents significant cause of the soil degradation. Till now, soil has been considered as the basic production tool that serves to farmer to gain the economic benefit. As Cairns (2003) presents, unsustainable practices can generate impressive short-term profits, but simultaneously generate even more impressive long-term loses. It is necessary to stress that principally soil preservation is not consistent with permanently increasing benefit from its production use. Even today there is still, around the world, a stress on the need of sustaining the soil production function to feed the growing world population, though the real problem is somewhere else – regional surplus of agricultural commodities does not always meet the threatened group of global population. Economic activities affect soil quality not only in industrial and urban areas (compaction, pollution), but also the soil in agricultural and forest sector (acidification, pollution). Migration of rural population to the cities creates pressure for increase of housing construction, and so sealing of another soil. Building of infrastructure, industrial enterprises and parks for provision of permanent economic growth was/is often realised on account of soil/environmental degradation including preference to the sealing of new agricultural/forest soil instead of brown fields restoration.

Non-negligible is also incomprehension of the essence of ownership relations to the soil. Soil in the private sector is usually considered as property that serves *exclusively* for owner purposes. The types of ownership alone cannot satisfactorily solve the problem of soil/land degradation. Property rights, even the private, should also encompass duties or responsibilities, especially in the case of natural resources. As Cairns (2002) introduces, there is a conflict between environmental protection and property rights. Human "rights" cannot be met if these activities endanger the ecological life-support system. Property rights are still misused or not understood, because instead of repairing environmental damage that occurred many years ago the human society is engaged in endless legal battles to see if present property owners can be held accountable. It is necessary to stress that human can no more consider the soil/land as commodity exclusively belonging to him – in fact he is only a steward that should maintain the soil in the same quality for next generations.

It is possible to state that importance of the soil for the human society is still not adequately appreciated. Except of the agriculture, there is a lack of utilisable information on soil protection in other soil uses. Although the results of soil science research are usually used at development of soil protection legislation and relevant educational/methodology publications, many expert and scientific knowledge does not have satisfactory application in practical life. Even though regular environmentally focused training of farmers or forest users brings some progress, the remaining broad population remains far from problems of soil degradation. Moreover, in the last period acceleration of natural disasters and human tragedies (poverty, epidemics, local war conflicts, criminality increase, etc.) masks and shifts the problems of soil degradation and its societal effects into background of human attention. Even in these disasters and tragedies the man has his fingers.

In harmony with Gordon et al. (2001), efficient use and protection of natural resources, soil inclusive, assumes three basic factors: adequate information, motivation for sustainable use of soil/environmental resources, and required capacity to adopt the necessary measures in daily life. While creation of knowledge and information is in the process of permanent development, the motivation to adopt sustainable use of the soil and other environment resources is weak, and often scarce capacities are used insufficiently when individual instead crosscutting oriented solutions are preferred.

The attitude of the society to the soil, as introduced by Yaalon and Arnold (2000), is given by how the broad public understands or perceives the importance of soil functions and services that support its existence. They see the role of soil scientists in development of information support for strategic and operative decisions, as on state and local level, so in bridging the possible gaps and differences between efforts in different levels (local, state) of soil use and management. The mentioned role of the soil scientists should be understood rather as immediate, prospectively broadened.

Broader view at the causes of soil degradation

Despite the broad lack of peoples` willingness to search and solve primary roots of soil degradation (other environment components inclusive) and long-term tendency to ascribe results of human activities to the general global changes, insufficiency of finances or lack of other capacities – the problem of gradual soil degradation still persists and is even deepening (on a global level). As it follows from many sources (e.g. Engel, Engel, 1992; Gore, 1992; Meyer, Turner II, 1994; Meadows et al., 1993; Raskin et al., 1998; Tibbs, 1999), all reasons of land degradation are closely related to the human activities.

As Gatzweiler et al. (2001) introduce, sustainable use of natural resources has an ethical dimension. The development of strong governmental regulatory programmes alone will probably not solve the environmental problems linked to agricultural practices. To change the situation one must know which set of rules produce the situation. Traditionally, policy regulations in hand with the market are considered as major tools for solving current environmental problems (e.g. EEA, 2006; Nicolaisen et al., 1991; OECD, 2005). In fact, market has limited capacity to solve these problems that cannot be solved only by internalisation of external costs as they have deeper social roots.

There exist more societal forces and phenomena that directly or indirectly affect state and evolution of environment and so, they become politically significant. Besides economic, political, social and cultural factors, market, advertising, demographic or population factors and technical development it is important to stress also human convictions, beliefs, values, attitudes, behaviour (individuals, household, communities and the whole public) [Brandt et al., 1999 cit. in Bürgi et al., 2004; Campbell, 1998; EEA, 2005; Goodwin et al., 1997; Meadows et al., 1992; Meyer, Turner (1994); National Res. Council, 1999; Raskin et al., 1998; Stern et al., 1997; Wachtel, 1998]. It is necessary to mention that the individual groups of driving factors have a different hierarchical position and common denominator of all these drivers is the satisfaction of human needs.

It is necessary to mention that individual groups of driving factors have a different hierarchical position. Common denominator of all these drivers is the satisfaction of human needs.

Main interest of people is concerned on growth of material/economic sufficiency. The level of satisfaction still increases and usually is compensated by material consumption demonstrated in many papers (e.g. Cairns, 2003; Campbell, 1998; Durning, 1992; Goodwin et al., 1997; Meyer, Turner, 1994). As Meadows et al. (1993) introduce, the predominance of growth in human activities is broadly perceived as positive process. Most societies, rich or poor, seek some kind of expansion as a remedy for their most immediate and important problems. Until other solutions are found to legitimate problems of the world, people will cling to the idea that growth is the key to a better future, and they will do all to produce higher growth. But, as it follows from many papers (e.g. Durning, 1992; Gore, 1992; Littlewood, 1997; Wachtel, 1998), economic growth is not panacea for environmental quality – indeed, it is not even the main issue. Moreover, the meaning of human life is more than daily satisfaction of many own desires.

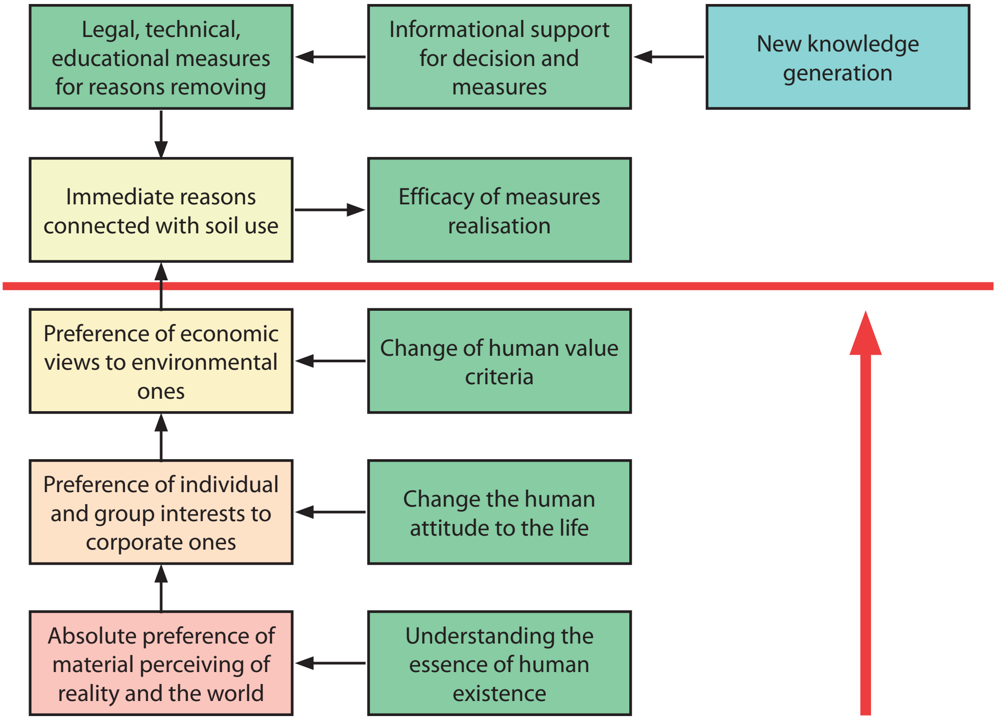
The mapping of values, convictions and attitudes to promote consumption is very urgent for understanding the roots of degradation of soil and other environmental components. To the cultural factors that promote the desire to consume, as it introduce Goodwin et al. (1997), belong social pressures, advertising, shopping that itself has become a primary cultural activity, government and mass market. Television belongs to the major forces that influence attitude of human mind and consequently his desire and consumption style of life. Besides, it encourages the entertainment on account of knowledge and especially wisdom.

Change of people behaviour formulas represents more serious area waiting on positive changes. One of ideas, that for long-term liquidates Earth environment is the conviction on insufficiency of issues to cover all people life demands and following „necessity" to compete or battle for these issues. It is our usual reality that is considered as normal. From the long-term view, the strategy "who of whom" is necessary to be changed into the strategy of cooperation to benefit all. According to Wachtel (1998), the competitive oriented society cannot create real preconditions for mutual cooperation of people/stakeholders as they maintain competitively behaviour and thus the competitiveness of existing system.

Present world closes people into cycle of work and consumption that undoubtedly affects the environment degradation. The change of the existing system seems as necessity. Decisive will be not only the state authority power growth but also the growth of individual and collective awareness. It is inevitable to perceive the activities on system level as the initiative starting positive changes on individual level. Besides, continuation in recent state role at environment protection can promote command & control process of population. This process is based on belt-tight principle. Higher prices in the name of environmental protection (water, air, refuses etc.) prepare good business platform for another economy activities, which will increase simultaneously with consumption (after all, economic growth and consumption must increase for any price). As WACHTEL (1998) introduces, without a change in values and grounding assumptions the political and institutional changes will be themselves superficial and have the basic structure of life unchanged.

In fact, reasons (driving forces, pressures) as well as necessary measures are vertically and horizontally structured phenomena (see Figure 1). The deeper level of the insight the more difficult is to accept mentioned problems and related ways of solution. The bottom line one is most probably taboo.

Figure 1 Levels of reasons and measures



Favouring economic view to environmental, private and group interest to cross societal ones, short term benefits to long-term ones, promotion of excessive consumption as well as permanent need to increase the economic growth of individuals or purpose-built groups – those all are masked driving forces of soil and environment degradation necessary to take into account at provision of sustainable soil use. It is inevitable to consider that all interrelates with everything, though we have not direct evidence or knowledge. The people place value to things they want to get as individuals and society. One of root questions is what the people want and what they really do to reach it. Recent decisions of people lead to the soil and environmental degradation...

TO CONCLUDE

Soil/land preservation against degradation starts at the change of mind attitude, preferences, motivation, behaviour, and desires, attitudes of the man to the environment that supports his sustainable life. Soil preservation to degradation should be a matter of whole society – not only the soil scientists, farmers, policy makers. Thus, measures that aim to moderate soil/land degradation should have cross-cutting character to receive more complex and deeper insight into the system (human thinking and activities in the whole ecosystem) and soil/environmental research should necessarily have also sociological dimension as indicated by several literary sources (National Research Council, 1999). Otherwise, solving of soil/land degradation problem in "shallow waters" can serve only to adequate "shallow" results.

While recent changes in science and technology progress are remarkable, positive changes in area of human mind & thinking, human attitudes, way of acting and systems of beliefs move forward very slowly and with difficulties. Till now, the man has intensively changed the environment state reflected in the degradation of soil and other natural resources. Every system is maintained until people do not decide to change it. From mentioned reasons there is the highest time to start the positive changes of human being himself as from the system level, so the individual one.

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POTENTIAL USE OF ORGANOMINERAL COMPLEX (OMC) AT BIOREMEDIATION OF SOIL CONTAMINATED WITH ORGANIC (PCP) AND INORGANIC (Pb,Cd) POLLUTANTS

POTENCIÁLNE VYUŽITIE ORGANOMINERÁLNEHO KOMPLEXU (OMK) PRI BIOREMEDIÁCII PÔD KONTAMINOVANÝCH ORGANICKÝMI (PCP) A ANORGANICKÝMI (PB, CD) POLUTANTAMI

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ABSTRACT

In the present document, we have determined the PCP biodegradation and possibility of decrease of the available forms of heavy metals (HM) in soils amended with an organomineral complex (OMC) prepared from humic acids (organic part) bound on zeolite (inorganic part). Both components of OMC have excellent sorption properties, are of natural origin and therefore suitable to be used in the environment. Biodegradation of PCP has been studied at three real completely characterized soil samples, Chernozem, Fluvisol, and Regosol, with and without the addition of OMC. The soils have been sterilized and bioaugmented with the bacterial isolate *Comamonas testosteroni* CCM 7530. The immobilization effect of OMC in relation to PCP depends on the concentration of humic acids (HAs), the PCP concentration, and the content of organic carbon in soil. OMC has appeared to be a good trap for PCP with potential applications in remediation technology because it has reduced the potential toxicity of PCP to microbial community by lowering its bioavailability and thus facilitated its biodegradation. Efficiency of OMC in the decrease of mobile forms of heavy metals has been also determined. Preliminary results show decrease of Cd and Pb mobile forms in Cambisol and Fluvisol at their treatment with OMC in comparison to soil alone.

KEYWORDS: bioremediation, humic acids, heavy metals, organomineral complex, pentachlorophenol, zeolite

ABSTRAKT

V prezentovanom príspevku sú zhrnuté výsledky týkajúce sa využitia organominerálneho komplexu (OMK) pripraveného na báze humínovej kyseliny (HK) izolovanej z lignitu a zeolitu. Obe zložky OMK disponujú vynikajúcimi sorpčnými vlastnosťami, sú prirodzeného pôvodu a teda vhodné pre použitie v prírodnom prostredí. OMK bol využitý pri retenčných a biodegradačných experimentoch v troch pôdnych vzorkách (černozem, fluvizem, regozem) kontaminovaných PCP a pri sledovaní zníženia mobility ťažkých kovov (ŤK) v pôdach. Bolo zistené, že imobilizačný efekt vo vzťahu k PCP závisí na koncentrácii HK v OMK, použitej koncentrácii PCP a obsahu pôdneho organického uhlíka. Predbežné výsledky týkajúce sa účinku OMK pri znižovaní mobilných foriem ŤK poukazujú na zníženie mobility Cd a Pb. Zníženie prístupných foriem Cd sa odzrkadlilo aj v znížení jeho koncentrácie v zrne jačmeňa pestovaného na sledovaných pôdach.

Kľúčové slová: biodegradácia, humínové kyseliny, ťažké kovy, organominerálny komplex, pentachlórfenol, zeolit

INTRODUCTION

Environmental contamination by anthropogenic toxic substances presents one of the most important social issues. Among them, chlorophenols and certain heavy metals (HM) are very dangerous for all compartments of environment.

Chlorophenols have been defined as dangerous pollutants because of their toxicity and persistence in the environment. Therefore, they are listed in the EC list of dangerous substances and the US EPA list of priority pollutants. PCP, the main component of wood stabilizer, is also a microbial breakdown product of many pesticides commonly used in agricultural production (Häggblom and Valo, 2001). Extensive pollution of the environment with PCP has stimulated intensive research on the microorganisms able to degrade PCP under a variety of conditions (McAllister et al., 1996; Wittmann et al., 1998; Tuomel et al., 1999).

HM are accumulated mainly on the surface of soil aggregates or they are soluble in soil solution (Hronec et al., 2002). They are not degradable, accumulate in soil, and can serve as a source of contamination of another compartments (air, water). Among HM, cadmium and lead are the two most dangerous HM.

The degradation of PCP in soil is affected mainly by the soil organic matter concentration and composition, clay mineral content, and moisture content (Barančíková, Szaboová, 2000). Reasons for its slow or absent biodegradation in the environment may include insufficient number and poor survival of PCP degraders and environmental stress of PCP on their cell membranes (Dercová et al., 2004). Bioaugmentation with a massive inoculum of indigenous degraders grown in a laboratory may potentially improve PCP biodegradation (Colores et al., 1995) and introduce an economical and ecological alternative for PCP decontamination technology.

Mobility and accumulation of heavy metals in the soil is a result of interaction processes between soil components and contaminants, which depend on the physical-chemical properties of contaminant, soil reaction, content and quality of soil organic matter, redox potential, content and quality of clay fraction and metal oxides (Yong et al., 1992). Ecotoxicological risk of heavy metals is determined by their bioavailability. Remediation of heavy metals can be realized in two ways:

- elimination of HM (high concentration of HM at small contaminated area)
- immobilization of HM (lower concentration of HM at larger contaminated area) by immobilization, transformation, bioaccumulation, biosorption, etc. (Hansen et al., 2001).

Some remediation technologies are primarily used at highly contaminated locations. Most agricultural soil is, however, not extremely contaminated. Soil itself can only partly sorb contaminants and reduce their horizontal and vertical transfer, e.g. into nutrition chain or groundwater (Christodoulatous et al., 1994). The soil organic matter, especially HAs, play the key role in reducing available contaminants from the soil. HAs readily interact with organic and inorganic contaminants. Their excellent sorption properties depend on their chemical structure and composition. HAs isolated from different matrices have different sorption capacities with regard to binding of heavy metal and organic contaminants. Our previous study confirmed that the origin and age of soil and lignite matrices have considerable effect on the structure and properties of the isolated HAs. Lignite HAs contain a 20-fold higher content of organic carbon than agricultural soil (Barančíková et al., 2003; Kučerík et al., 2003).

Microorganisms also play a role in the binding process by conditioning the xenobiotic molecules for binding onto soil particles (Sarkar et al., 1988).

Immobilization processes observed in soil are of great environmental importance as they may lead to a considerable reduction in the bioavailability and, as a result, of the toxicity of xenobiotics, e.g. pesticides (Hatzinger, Alexander, 1995). The ability of soil to retain organic/inorganic contaminants is attributed to adsorption phenomena and chemical reactions occurring at active surfaces of humic substances and mineral particles; some xenobiotics can also be retained through entrapment within the soil matrix (Calderbank, 1989; Bollag et al., 1997).

Our study has focused on the immobilization of PCP in OMC particles and the influence of OMC on mobility of heavy metals. OMC has been prepared by binding HAs to zeolite under laboratory conditions and takes advantage of the excellent sorption properties of both components. The objective of this work has been to provide a study of the sorption and biodegradation of PCP in soil with and without addition of OMC, efficiency of OMC to decrease mobile forms of HM and the influence of Cd and Pb uptake by plants.

MATERIAL AND METHODS

1. Microorganisms

Used bacterial strains have been *Micrococcus varians* CCM 2253, *Comamonas testosteroni* CCM 7530 strains RF2 and VM (both isolated from a has beente water treatment plant), and *Alcaligenes xylosoxidans,* isolated from long-term contaminated soil and identified and maintained at the Czech Collection of Microorganisms, Masaryk University, Brno, Czech Republic.

2. Chlorophenols

Stock solutions of the chlorophenols (2-chlorophenol, 3-chlorophenol, 4-chlorophenol, 2,3-dichlorophenol, 2,4-dichlorophenol, 2,5-dichlorophenol, 2,6-dichlorophenol, 2,4,5-trichlorophenol, 2,4,6-trichlorophenol, and PCP) have been prepared in dimethylsulfoxide (DMSO).

3. Characteristics of soil and lignite HAs

Soil samples (Gleyic Fluvisol, Calcaro-haplic Chernozem, and Arenic Regosol) have been collected from topsoils of key monitoring sites of the Soil Monitoring System of the Slovakia. Lignite has been obtained from Hodonín (Czech Republic) and zeolite (clinoptilolite) from Nižný Hrabovec (Slovakia).

Organic carbon content (C_{org}) has been determined by wet combustion (Nikitin, 1972). HAs from soil samples and lignite have been isolated according to the IHSS method (Swift, 1996). Because of a high percentage of C_{org} in lignite in comparison to the soil samples, a 10-fold higher amount of 0.1 N NaOH has been used for isolation of lignite HA.

4. Preparation of OMC

HAs have been dissolved in 0.01 M NaOH at the following concentrations: 5, 25, 50, 100, 200, 500, 1000, and 2000 mg l^{-1}. 50 ml HA solution has been added to 10 g zeolite. Blanks have been prepared by mixing zeolite with 0.01 N NaOH for 12 h at laboratory temperature. Solid phase (OMC) has been centrifuged, washed with distilled water, and dried at 50 °C.

5. Adsorption of PCP onto OMC and soil

Mixture of soil and OMC have been prepared (5 % OMC (w/w)). The mixture has been transferred into 100 ml Erlenmeyer flask fitted with ground glass stopper, 50 ml distilled water has been added, and a solution of PCP in DMSO has been admixed to give a final PCP concentration of 10 mg.l^{-1}. The sample has been placed on a rotary shaker (180 rpm) at 28 ˚C for 1 h. The solid phase has been removed with centrifugation (15 min at 5 000 rpm), and the supernatant has been decanted, extracted, and analyzed by HPLC. All measurements have been performed in triplicate.

6. Desorption of PCP from OMC and soil

Upon termination of the adsorption experiment and centrifugation, the sediment sample has been quantitatively transferred to a 100 ml Erlenmeyer flask fitted with a ground stopper. The pH value of the sediment sample has been adjusted to acid rains pH (ca pH = 4) and placed on a rotary shaker (180 rpm) at 28 ˚C for 24 h. All measurements have been performed in triplicate. Subsequently, the samples have been centrifuged (15 min at 5 000 rpm), and the supernatant has been decanted, extracted, and analyzed by HPLC. All measurements have been performed in triplicate.

7. Biodegradation of PCP

Biodegradation of PCP in soil in the presence of an inoculum of *C. testosteroni* has been carried out under laboratory conditions in real soil samples (Fluvisol, Chernozem, and Regosol) with and without the addition of OMC at initial PCP concentrations of 10 mg kg^{-1}, 50 mg kg^{-1}, and 100 mg kg^{-1}. For each concentration, three series of soil samples have been used. The experiments have been carried out for 7 d (first series), 17 d (second series), and 24 d (third series). Detailed procedure description is provided in our previous publication (Dercová et al., 1996).

8. Extraction of PCP from soil and HPLC analysis

In soil samples, steam distillation of PCP has been carried out after alkaline hydrolysis with NaOH. Samples have been transferred into a separation funnel and the pH adjusted to 3 – 5 and analyzed by HPLC. HPLC (LC-10AT VP, Shimadzu) conditions: the column WATREX 250 × 4 mm packed with Nucleosil 120-5 C18, mobile phase methanol : acetic acid : water (90:10:1), flow 0.73 ml min^{-1}, spectrophotometric detection.

9. Green spots experiments

Two variants of the experiments [(variant A – control variant, soil and plant, variant B – soil, plant and OMC (400 g OMC – 10 % of weight of each sample), both variants in 4 repetitions)], under control conditions, have been carried out to prove the effectiveness of OMC. Soil samples of Cambisol ad Fluvisol have been cropped with Spring Barley (*Hordeum vulgare*) to investigate plant uptake of Cd and Pb. The water solution has been applied according to the specified conditions. This experiment has lasted for 4 months.

RESULTS AND DISCUSSION

1. Sorption of PCP

We have attempted to combine the excellent sorption properties of both HAs and zeolite to develop procedure for soil decontamination based on the application of OMC to soil. Adsorption/desorption experiments involving PCP have been carried out with OMC prepared on the basis of the clay mineral (zeolite) and organic matter (HAs isolated from lignite) in three real completely characterized soil samples (Chernozem, Fluvisol, and Regosol). The characteristics of the selected soils are summarized in Table 1.

Table 1 Basic characteristics of the soils

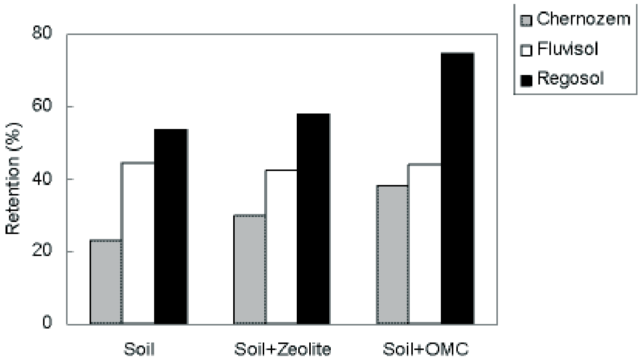
Soil type	pH ($CaCl_2$)	C_{org} (%)	Q^4_6	P (mg kg^{-1})	K (mg kg^{-1})	Nt (mg kg^{-1})
Gleyic Fluvisol	5.46	1.43	4.8	26	247	1 968
Calcaro-haplic Chernozem	7.77	1.16	3.8	168	230	1 531
Arenic Regosol	4.75	0.75	4.8	74	223	1 643

*** Q^4_6 –** a spectral parameter representing the ratio of optical density values measured in humic acid solution at 465 and 650 nm.

Higher amounts of HAs bound to zeolite enhance its potential to adsorb and retain PCP. Our previous study confirmed that OMC containing ca. 5 mg HA per g of zeolite possessed the best ability to retain PCP and represented an optimal economic solution from the point of view of the technological preparation (Barančíková et al., 2004; Pekař et al., 2004). Adsorption of PCP has been determined after stirring the flasks on a rotary shaker for 1 h (time adequate for reaching an equilibrium between the free and the bound amount of PCP). Desorption has been determined after 24 h and carried out under conditions of decreasing pH to a value of 2.5, which simulated the acid rains that release PCP from soil in real conditions.

Retention of PCP has been calculated by deducting the desorbed amount from the absorbed amount. Differences in adsorption and retention of PCP in the 3 types of soil have been described in our previous publication (Dercová et al., 2006). The best results, i.e. the highest adsorption and retention, have been obtained in soil with addition of OMC. This fact emphasizes the role of humic substances and their binding sites in this process. Soil with addition of pure zeolite showed values of PCP desorption comparable to or slightly higher than that observed with the pure soil. The results indicate that soils amended with OMC addition show better retention abilities than clay minerals or soil alone. Figure 1 illustrates the retention of PCP obtained in selected soils. The best results have been observed in soil with OMC.

Figure 1 Retention of PCP



2. Biodegradation of PCP

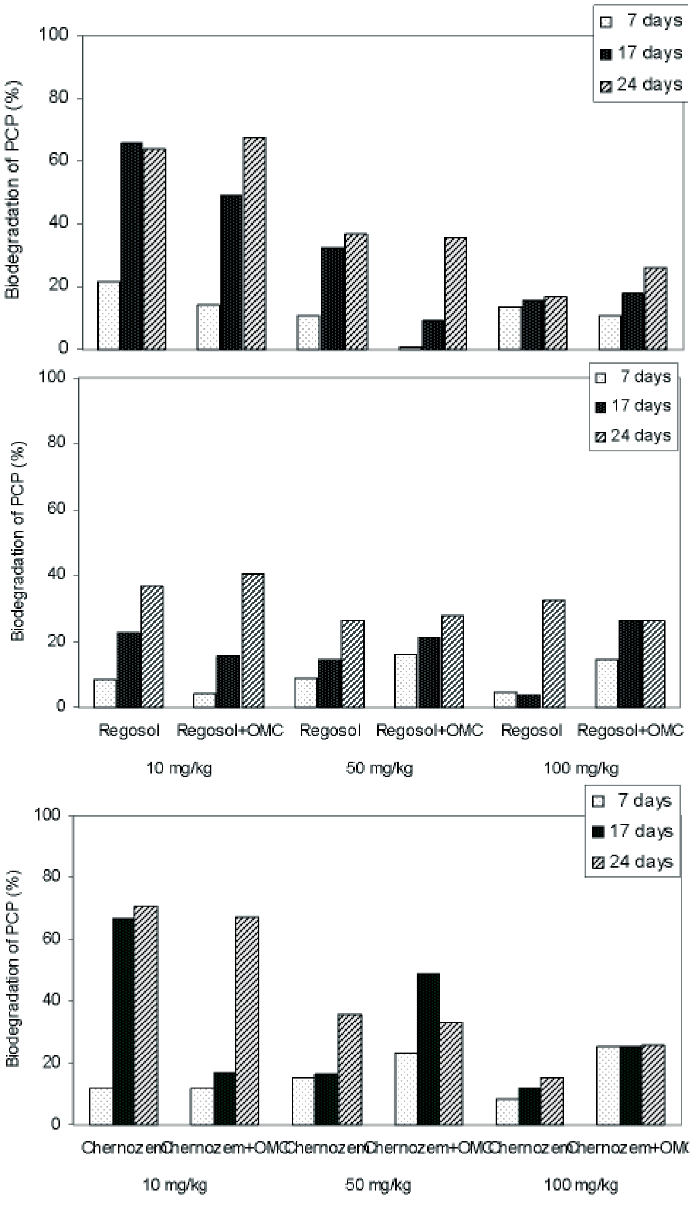
Subsequently, we have studied the effect of OMC as a possible sorbent for immobilizing PCP in soil during biodegradation. The aim has been to monitor sorption of PCP, its subsequent release due to microbial activity and simulated acid rains, and finally its degradation.

We have studied the biodegradation of PCP at initial concentrations of PCP 10, 50, and 100 mg kg^{-1} in sterile soil (50 g) with and without addition of OMC (5 % w/w). Soil samples have been bioaugmented with *C. testosteroni* (0.5 g kg^{-1}), which can use phenol as a sole carbon source. The soil samples have been analyzed after 7, 17, and 24 d. In a series of experiments with Fluvisol, Regosol, and Chernozem shown in Figure 2, biodegradation of PCP after 7 d has been significantly lower in the samples with OMC than in the soil without OMC.

This implies partial adsorption of PCP on OMC, which decreases its bioavailability. After 17 d, the degradation has increased markedly in both groups of samples, which suggests a release of PCP from the bound state. However, degradation has been still lower in the samples amended with OMC than in the soil with no OMC. After 24 d, the percentage of PCP degradation in the soil amended with OMC reached the same value as the PCP degradation in soil without OMC. This observation indicates that the binding is reversible and that a subsequent release of PCP for biodegradation occurs in the presence of microorganisms.

It is possible to state that the processes of sorption, sequential release, and degradation of PCP discussed above proceed similarly in all the tested soil types. The most pronounced effects of sorption and subsequent release have been observed at the lowest PCP concentration tested (10 mg kg^{-1}). At higher, more toxic concentrations of PCP (50 and 100 mg kg^{-1}), we have observed a partially protective and stimulating effect on biodegradation of PCP, probably primarily due to the HAs presence in the OMC. A positive effect of the HAs on increase of the microbial growth has also been observed by other authors (Feifičová et al., 2005).

Figure 2 Biodegradation of the PCP in the three different types of soil



According to our results, the HAs bound on zeolite appears to be a good trap for PCP with potential applications in remediation technology. One can assume that fast and effective adsorption and low desorption may serve as a remediation technology for reducing the PCP content in soil (by decreasing its bioavailability) and thus reduce its initial high toxicity. Lower concentrations of this toxic pollutant will probably not inhibit the survival and degradative ability of the bacterial strains present in the soil. The HAs and zeolite are of natural origin and so suitable for use in the environment. In this way, they supplement the natural ability of soil to reduce available contaminants.

3. Efficiency of the OMC concerning the mobility of HM

In our previous work, we have found, that organo-mineral complex containing ca 5 mg HA/g of zeolite possesses the best retention ability towards heavy metals (Cd, Cu) (Barančíková et al., 2004). In present study, we have attempted to assess the efficiency of this OMC in affecting the mobility of HM. The efficiency of OMC has been investigated under control conditions in two soil types, Fluvisol and Cambisol (Table 2), cropped with Spring Barley (*Hordeum vulgare*). The OMC has been used as additive to increase soil sorption capacity.

Table 2 Average values of soil parameters in the depth of 0 – 10 cm

Soil type	pH in $CaCl_2$	C_{ox}	Q_6^4	Total content of heavy metal in $mg.kg^{-1}$			
				Cd	Pb	Cu	Zn
Fluvisol	6.48	1.07	4.58	9.05	1 050	102	1 070
Cambisol	4.70	1.36	6.06	0.55	28	17	72

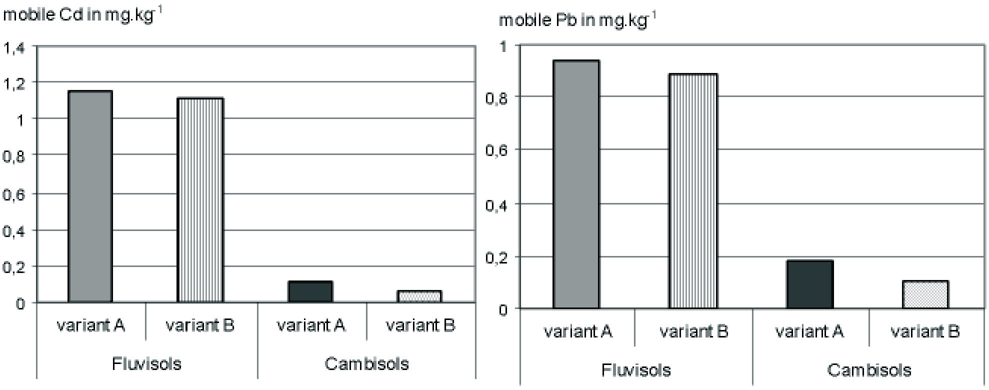
Table 3 Mobile content of Cd and Pb in soils and in grain of Spring Barley

Soil type		Mobile content in soil in $mg.kg^{-1}$		Content in grain of Spring Barley in $mg.kg^{-1}$
		Cd	Pb	Cd
Fluvisol	Variant A	1.150	0.942	0.165
	Variant B	1.110	0.885	0.120
Cambisol	Variant A	0.108	0.183	0.048
	Variant B	0.066	0.103	0.016

The preliminary results (Table 3, Figure 3) showe decreased content of Cd and Pb mobile forms in both soil types (post-harvest samples, variant B) upon application of the OMC in comparison to the untreated soil – variant A (in the case of Cd – Fluvisol 4,4 %, Cambisol 39 %, in the case of Pb – Fluvisol 6,3 %, Cambisol 44 %).

Decrease of the mobile forms of Cd in both investigated soil types has been also reflected in reduction of Cd content in Spring Barley (Table 3).

Figure 3 Concentration of the mobile forms of Cd and Pb in green spots experiments



CONCLUSIONS

Using of OMC is not a finale goal in soil decontamination; however, on the basis of the obtained data, it can be concluded that OMC has substantial efficiency in retention and biodegradation of the PCP and is able to reduce mobility of heavy metals.

The results can provide reasonable basis for a successful application of organo-mineral complex in *in situ* remediation technologies. 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 system protection of the investigated area in regard to the sustainable environment.

Acknowledgement

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MONITORING OF ARABLE SOILS IN THE GABČÍKOVO HYDROPOWER STRUCTURE AFFECTED AREA – EVALUATION OF RESULTS

MONITORING POĽNOHOSPODÁRSKYCH PÔD V OBLASTI VPLYVU VODNÉHO DIELA GABČÍKOVO – HODNOTENIE VÝSLEDKOV

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ABSTRACT

This paper evaluates results of the monitoring of arable soils in the Gabčíkovo hydropower structure area from its beginning in 1989 till 2005. The monitoring takes place in the built up net of stationary monitoring plots, which serve for soil and underground water samples collection. The main and evident impact of the Hydropower structure as well as its operation on arable soils is the improved soil water regime, more favourable soil water supply and consequential higher yields of planted crops. Others soil characteristics are influenced indirectly due to soil moisture.

KEYWORDS: soil water regime, soil water supply, soil moisture

ABSTRAKT

Predložený príspevok hodnotí výsledky monitoringu poľnohospodárskych pôd v oblasti vplyvu Vodného diela Gabčíkovo od jeho začiatku v roku 1989 do roku 2005. Monitorovanie poľnohospodárskych pôd prebieha na vybudovanej sieti stacionárnych monitorovacích plôch, ktoré slúžia na odber pôdnych vzoriek a vzoriek podzemnej vody. Ako hlavný a preukazný vplyv vodného diela a jeho prevádzky na poľnohospodárske pôdy je zlepšený vodný režim pôd, priaznivejšie zásoby pôdnej vody a s tým súvisiaca výška úrod pestovaných plodín. Ostatné pôdne vlastnosti sú ovplyvňované nepriemo prostredníctvom vlhkosti pôdy.

KĽÚĆOVÉ SLOVÁ: vodný režim pôd, zásoby pôdnej vody, vlhkosť pôdy

INTRODUCTION

Monitoring of arable soils has been carried out on stationary monitoring plots since 1989. From the viewpoint of timing, organization, and concept it includes three sequential stages (FULAJTÁR et al., 2003).

The first stage (June 1989 – October 1992) established the initial state of pre-dam soil conditions in the monitoring area. It recorded soil types and species of the monitored plots, soil moisture content development in the soil profile and soil water regime, basic physical and chemical properties of soils, the occurrence of salinization processes, and ground water chemical composition. Results of this stage serve as a baseline for comparison and evaluation of possible changes of these properties.

The second stage (1993 – 1997) recorded the first five years of influence of the Gabčíkovo project on the soil and hydrological conditions. The result of this stage showed that, when compared with the initial state, the project influenced the arable soils first of all through ground water levels, which mostly increased. In the surroundings of the Čunovo reservoir, it was 3 – 5 m, in the zone of the bypass canal 0,2 – 0,5 m, while in the zone of the tailrace canal the ground water level remained nearly unchanged. Increased level of ground water had positive influence on the soil moisture.

The third stage (after 1999) continues after a one-year break with a reduced number of monitoring plots. The original extent of the data collection was enlarged by monitoring of the crop-yield to soil moisture regime relation and of the electric conductivity of soil water and its mineralization. In 2002, we evaluated the influence of the Gabcíkovo hydropower structure in the whole monitoring period**.** The results, obtained during the 14 years, confirmed a positive influence of the project on the soil water, and subsequently on the crop yield and its limited dependence on precipitation. In the area of the Gabčíkovo depression and in the lower Žitný Ostrov Island, the results confirmed a generally slight to medium processes of salinization and alkalization.

MATHERIAL AND METHODS

Monitoring of arable soils is carried out on a network of stationary monitoring plots. In the first and second stage the network included 20 plots, while in the third stage the number of plots has been reduced to 12.

The monitoring plots are used for taking soil samples and samples of ground water, which are chemically analysed in relation to a possible rise and spreading of salt soils. Beside, regular profile measurements of soil moisture are carried out, precipitation that has fallen on the monitoring plot between two measurements of soil moisture is examined, as well as depth of ground water level and its electric conductivity. The vicinity of monitoring plots serves for the collection of crop yield.

The frequency of the data collection depends on the change dynamics of individual properties. Soil moisture, precipitation and depth of ground water level are measured in 10 – 14-day intervals during the vegetation season, in winter (November – February) once a month.

Soil moisture is evaluated according to its ecological classification, which expresses degrees (intervals) of soil moisture and the duration of individual intervals in connection with the basic hydro-limits. The used ecological classification includes intervals of the moisture given in Table 1 (Fulajtár et al., 1998).

Soil samples are taken once a year, samples of ground water twice a year (May, September). Electrical conductivity of ground water is measured in the field once a month.

Monitoring plots are distributed in the area so that they characterize soil and hydrologic conditions in the area of influence of individual parts of the Gabčíkovo hydropower structure: the Čunovo reservoir (2 plots), bypass canal (4 plots), tail-race canal (1 plot), area downstream from Sap (2 plots), and territory of the lower Žitný Ostrov Island as area with cumulative effect of changes in natural conditions (2 plots).

Table 1 Ecological classification of soil moisture

Moisture content	Moisture interval	Characteristics
Full saturation of soil water	Aquatic state	All soil pores are filled by water
Moisture between FS and FC	Uvidic interval	Soil is capillary saturated, part of the non-capillary pores is filled by air
Moisture between FC and PDA	Semiuvidic interval	Optimal moisture, soil contains sufficiently available water and air
Moisture between PDA and WP	Semiarid interval	Availability and mobility of soil water is low
Moisture lower than WP	Arid interval	Soil water is unavailable for plants

Explanations: FS – full saturation, FC – field capacity, PDA – point of decreased availability, WP – wilting point

RESULTS AND DISCUSSION

The main and verified influence of the hydropower structures and their effect on arable soils is the improved water regime, with the more favourable soil water supplies resulting in an increase of the crop yield. Other soil properties are influenced indirectly by the soil moisture, which has created improved conditions for the availability and use of nutrients, for the development of biological processes (like the activity of micro organisms), development of root systems, synthesis of biomass, etc.

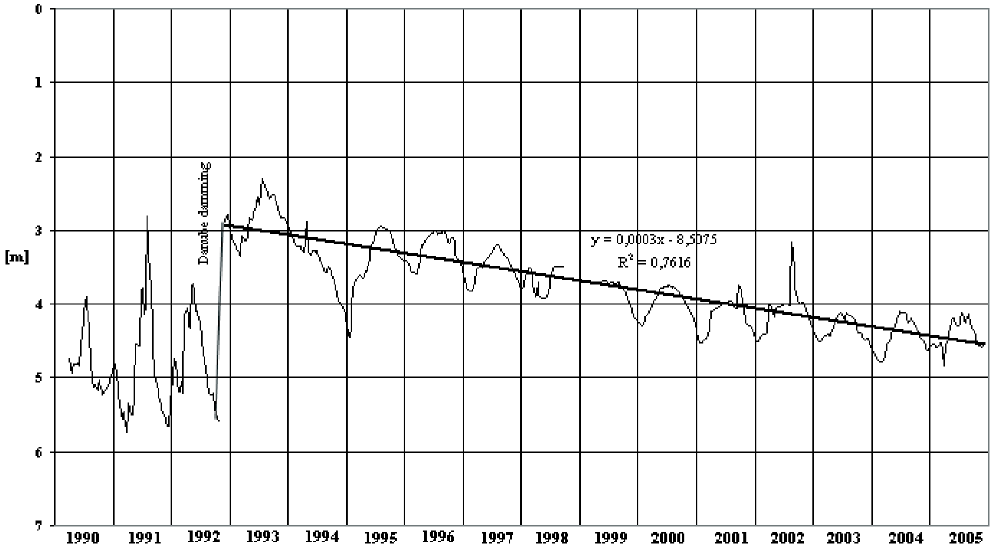
Water regime and supplies of soil water

The soil water regime expresses special and temporal stratification of soil water (soil moisture) in the unsaturated zone, i.e. between the soil surface and the ground water table during several subsequent years. In the area, the monitoring has already lasted for 17 years. This period included moist, humid, dry and extremely dry years, as well as more high and medium water states in the Danube. This allows generalization of results not only for the monitored area itself, but for other areas as well. Beyond, it can be used for a prognosis of the next development. The results show the soil water regime depends on the ground water level and its seasonal fluctuations, and on its contact with fine-grained surface sediments, which make possible capillary elevation of ground water into the soil profile. From this viewpoint, we distinguish between soils having a water regime without an influence of ground water and soils with regular or irregular influence of ground water (FULAJTÁR et al., 1998).

Soils without an influence of ground water have ground water in gravely sediments. It does not allow its capillary elevation. These soils occur locally, in the vicinity of the Čunovo reservoir and upstream part of the bypass canal. This situation is illustrated in Figure 1 (MP 3) (FULAJTÁR et al., 2006). Immediately after putting the project in operation, the ground water level elevated from the depth of 5.5 m to 2.8 – 2.3 m under the surface, but later it dropped to 4.5 m. However, it still remains continuously higher than in the pre-dam conditions.

The soil water regime remained principally unchanged in comparison with its initial state. Certain positive changes occurred in the depth of 3 – 4 m, where the new ground water level fluctuates. Moisture of this soil layer increased from its original values of 5 – 15 % up to 20 – 30 %. Above the ground water level, a short (0.5 m) capillary elevation occurs.

Figure 1 MP-3 ground water level



Dynamic changes of soil moisture regularly occur only in the surface fine-grained layer, with a thickness of 1 m. In autumn, winter and spring, the moisture of this layer reaches the semiuvidic interval (15 – 20 %). If such moisture also occurs in summer, it is usually caused by irrigation. In the vegetation season, the moisture of the surface layer regularly declines into the arid interval (<10 %). Deeper, in the profile below 1m, it is low and stable (5 – 15 %).

Soil water supply in the surface layer fluctuates in dependence on precipitation. In the cooler half-year they are mostly in semiuvidic interval, while in the vegetation season they decline to the semiarid to arid interval. In the subsoil (0.3 – 1.0 m) the soil water supply is in semiuvidic to semiarid interval.

Soils with an irregular or occasional influence of ground water on their water regime have ground water level at the boundary of gravely and fine-grained sediments. They occur especially in the area of the Čunovo reservoir and the upstream part of the bypass canal. This situation is described in Figure 2 (MP-1) (Fulajtár et al., 2006). After putting the hydraulic structures in operation, the ground water level elevated from the depth of 7 m to 2 m below the surface, and later it gradually decreased to an average of 3 m. The positive result of theses changes is the increased moisture from 5 – 10 % to 20 – 30 % in the layer of fluctuation of the ground water level, and the rise of a layer with stable moisture above 30 % at the depth of 1 – 2 m.

Dynamic changes of moisture occur only in the 1 m thick surface layer. Winter and spring precipitation saturates this layer to 15 – 25 %, while in the vegetation season its moisture decreases below 10 %, thus, it is in the semiarid interval.

Soil water supplies in the surface layer (0 – 0,30 m) decline in the vegetation season down to the arid interval, while in the subsoil (0.3 – 1.0 m) they are in the optimal semiuvidic interval.

Soils with a permanent influence of ground water on their water regime have the ground water permanently presented in fine-grained sediments, which makes possible its capillary elevation to a high layer of soil profile. This situation is described in Figure 3 (MP-9) (Fulajtár et al., 2006). Ground water level fluctuates at a depth of 1 – 2 m, where it saturates soil to a level of uvidic interval. The moisture of the 1 m thick surface layer is regularly high (30 – 40 %) and stable. Dynamic changes of the moisture occur only in the vegetation seasons, when the moisture in the topsoil decreases to semiarid interval as a consequence of evapotranspiration. These changes reach at maximum to the depth of 0.5 m.

Figure 2 MP-1 ground water level

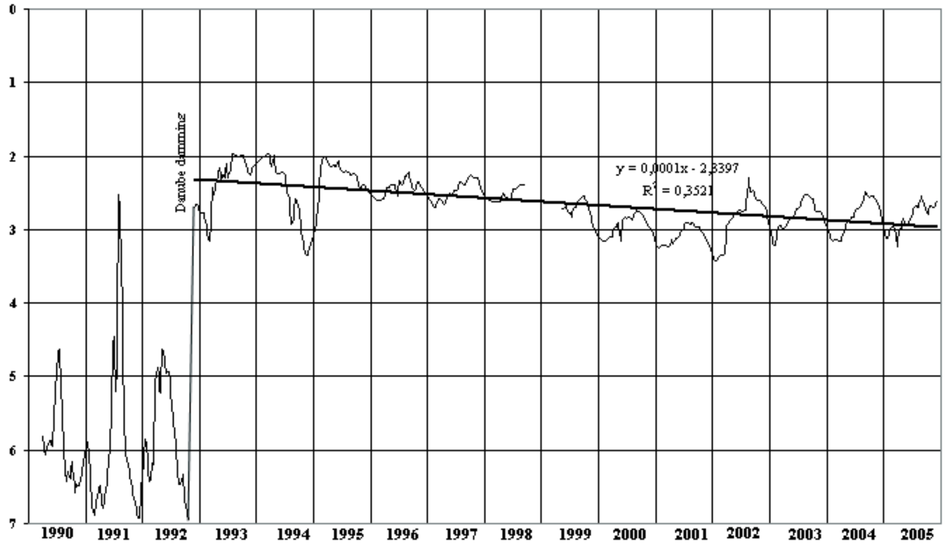
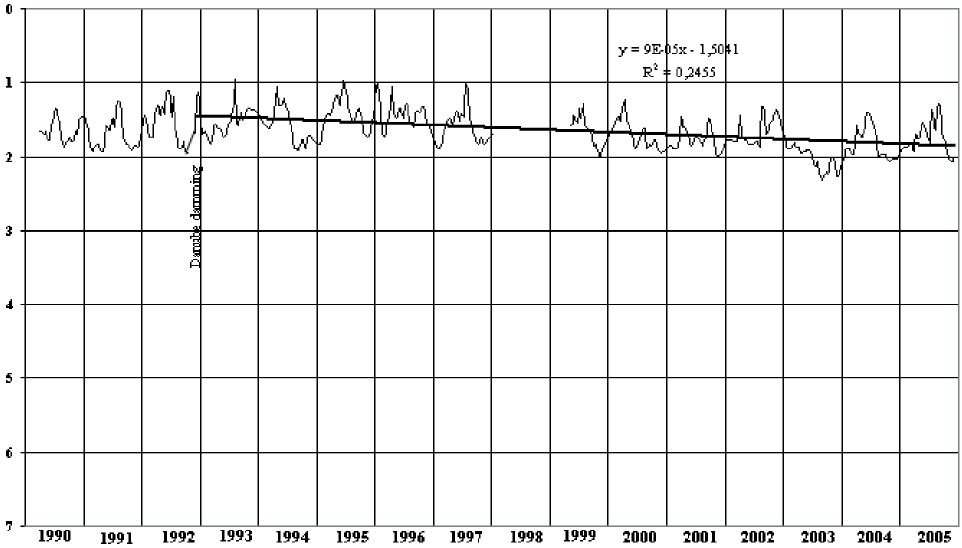


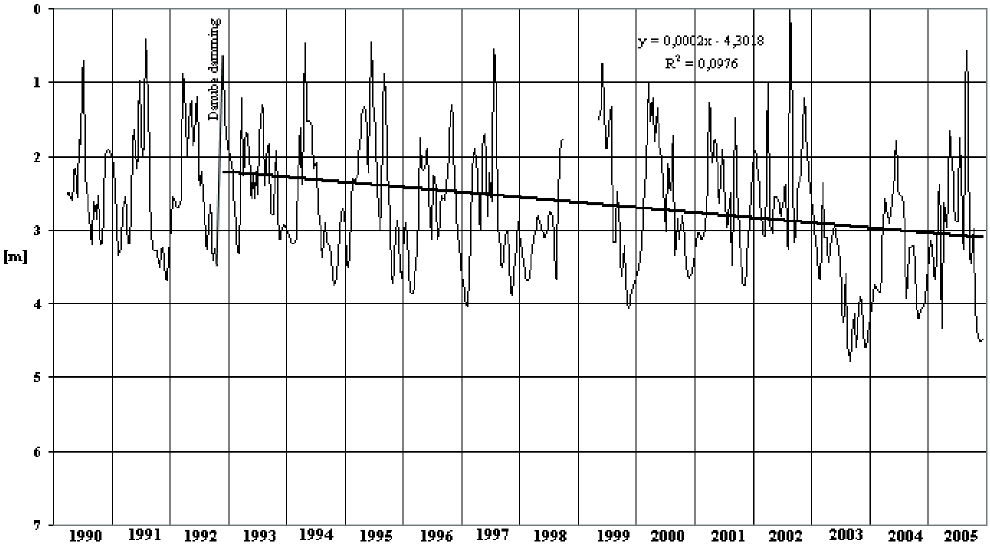
Figure 3 MP-9 ground water level



Soil water supplies in the topsoil (0 – 0,30 m) are predominantly in semiuvidic or, sporadically, in semiarid interval, while in the subsoil (0.3 – 1.0 m) they reach the level of uvidic interval.

Specific water regime occurs in soils in vicinity of tailrace canal, where ground water level depends on water level in the tailrace canal. It is manifested by frequent and extensive fluctuations of ground water level, changes of the moisture, and of soil water regime. This situation is described in Figure 4 (MP 10) (FULAJTÁR et al., 2006). The figure shows that ground water level fluctuates in depth of 0.4 – 4 m. During extraordinary flood waves (August 2002), ground water ascends to the soil surface and causes temporary waterlogging. On the contrary, in a period of long-lasting low discharges (summer and autumn 2003) it deeply drops.

Figure 4 MP-10 ground water level



In normal and more humid years, the ground water stays, in fine-grained and gravely sediments, for approximately 50 % of the time. The water regime in these soils is characterized by the presence of a continuous layer with high moisture (above 30 %) in the depth of 2.0 – 2.7 m. Above this layer, a continuous relatively dry layer with moisture of 5 – 20 % is situated at a depth of 1 – 2 m. This layer is occasionally broken by the ascendance of the ground water level and moisture increases to 30 – 35 %. Cause of the low moisture of this layer is the large content of sand reaching even 96 %. In periods when ground water drops below this layer, its moisture quickly decreases from uvidic to arid interval.

Soil surface layer (0 – 1 m) moisture prevailingly corresponds to field capacity, however in vegetation season in the topsoil layer, it uses to decrease to semiarid even arid interval. The subsoil layer moisture is in uvidic interval.

Soil water supply in the topsoil layer corresponds mostly to semiuvidic interval. In the vegetation season it decreases to semiarid, sporadically down to arid intervals. The subsoil moisture is almost always in uvidic interval, with an exception of the dry year 2001 (similarly also 2003), when it decreased to arid interval from May till August.

Crop yields in relation to soil water regime

The crop yields in the monitored area are influenced, besides precipitation, by the ground water and its capillary elevation into the soil profile. This aspect is illustrated in the monitored area by yields of wheat and maize, the main crops of this area, cultivated each year over an average of 32 % of monitoring plots. The basic agricultural practices, fertilization, and treatment in the course of the vegetation period are conventional, and more or less identical. Only the soil water regime differs between individual monitoring plots (Miklovič, 2002).

In individual soils with different influences of ground water on their water regime we obtained, in 1999 – 2005, the data given in Table 2 (Fulajtár et al., 2006).

Data from the table confirm that irregular or occasional influence of ground water on the soil water regime increases the wheat yield by 13.6 % and that of maize by 15.7 %. A permanent influence of ground water increases the wheat yield by 22.5 % and that of maize by 23.0 %.

Table 2 Average yields of main crops on soils with different influence of soil water

Soil group	Crop	Yield (t.ha^{-1})	%
Soils without influence of ground water	Wheat	4.03	100
	Maize	6.95	100
Soils with irregular influence of ground water	Wheat	4.58	113.6
	Maize	8.04	115.7
Soils with permanent influence of ground water	Wheat	4.94	122.5
	Maize	8.55	123

Development of salty soils

Medium to strongly mineralized ground waters, the water evaporation regime of soils, the coming warming of the climate, and the presence of salt in the area already in the pre-dam conditions, all create conditions for spreading of salt soils. The present results of monitoring confirm that some salinization and alkalization of soils occurs.

Salinization as a process of accumulating sodium salt is presented in the middle and lower part of monitored area. In surface horizons it is slight or initial, defined by a total content of salts of 0.10 – 0.17 %. In deeper profiles the salt content usually increases to 0.20 %, sporadically even to 0.30 %, which already represents a medium degree of salinization (FULAJTÁR, 2006).

Alkalization as a process of binding exchangeable sodium to soil is defined as a sodium content in soil above 5 %. Its low content (5 – 10 %) indicates slight alkalization, which runs predominantly in substrate and near-surface horizons during the whole monitoring period. In the last three years we observed an increased intensity of alkalization documented by the exchangeable sodium content exceeding 10 % in two localities, which is a change of slightly alkalized soils to alkalized soils (FULAJTÁR, 2006).

According to the chemical composition of soils and ground water, the risk of spreading salt soils is only in the lower Žitný ostrov – Island. In these areas, the soils have the highest content of exchangeable sodium (ESP above 10 %) and highest sodium adsorption ratio (SAR above 8 %) and the ground waters are highly mineralised (above 1 500 mg.l^{-1}) (FULAJTÁR, 2006).

CONCLUSIONS

Results of the monitoring confirm that the run of the Gabčíkovo hydropower structure as well as changed ground water regime has no negative effect on arable soils.

A positive effect of the hydraulic structures is the increase of the soil horizon moisture and its water regime, and the increase of total supplies of soil water in the unsaturated soil zone in the Čunovo reservoir area. The further positive effect is the stabilization of the moisture conditions and the soil water regime in the vicinity of the bypass canal. These conditions positively influence the height and stability of crop yields, and lower their dependence on precipitation. The devices of the Gabčíkovo hydraulic structures, together with the existing canal network, enable better regulation of water and moisture in the agriculturally exploited parts of the Žitný Ostrov Island.

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MIDDLE-SCALE MAPS COMPILATION USING ArcGIS DESKTOP AND THEIR APPLICATION IN ArcIMS

METÓDY TVORBY KPP MÁP STREDNEJ MIERKY V PROSTREDÍ ARCGIS DESKTOP A ICH APLIKÁCIA V ARCIMS

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ABSTRACT

A contribution provides basic information about soil cover from the General Survey of Agricultural Soils (KPP) and its consequential processing by GIS (ArcGIS Desktop) means. The goal of the paper is to show some methods of maps compilation for middle scales and methods of data preparation in ArcIMS. As a pilot projects have been chosen two regions: Šurany and Trebišov. Original KPP data occurring in analogue form have been converted into digital form in Soil Science and Conservation Research Institute, which is owner of all background data (reports, maps, tabs, etc.). These converted digital data were utilized for GIS application intending to compile middle-scale maps. This technology requires except to some knowledge in soil science also GIS skill and experience. Methodology of pedo-geographical regionalization has been used for digital map compilation as original KPP maps were mapped in the scale 1:5 000, or 1:10 000. New compiled digital maps have been generalized for scales 1:250 000 or 1:50 000 as soil associations.

Created maps have been displayed on map server in ArcIMS. Website map server provides users review of the basic soil maps by so-called html-reviewer, i.e. interactive maps are jointed with subsistent database. User can use various facilities of viewing by PC tools (enlarge of level, diminishing of level, switch on active level, switch on legend, information about soil types, soil texture, parent materials, etc.). Inherent advantage of map server is its use by the wide range of users who have got sufficient software and hardware equipment and Internet access, as well.

KEYWORDS: KPP maps, GIS, ArcGIS Desktop, map server, ArcIMS, regionalization, region, soil type

ABSTRACT

Príspevok poskytuje stručný pohľad na základné informácie o pôdnom kryte z Komplexného prieskumu poľnohospodárskych pôd (KPP) a ich následné použitie v prostredí Geografických informačných systémov (ArcGIS Desktop). Údaje pôvodne v analógovej forme z KPP sa konvertujú do digitálnej podoby vo Výskumnom ústave pôdoznalectva a ochrany pôdy, ktorý je vlastníkom všetkých podkladov z KPP (správy, mapy a pod.). Konkrétne prezentuje prácu z digitálnou formou databázy v Geografických informačných systémoch (GIS). Opisuje tvorbu pôdnych máp v ArcGIS Desktop, a to v strednej mierke, ktorá si vyžaduje určité znalosti z oblasti pôdoznalectva a GIS. Cieľom príspevku je poukázať na metódy tvorby KPP máp v strednej mierke a metódy prípravy pre použitie daných máp spolu s databázou v prostredí ArcIMS. Pri konštrukcii máp strednej mierky je použitá metodika regionalizácie, kedže pôvodné mapy KPP boli zostavované vo velkej mierke 1:5 000. Digitálne mapy KPP boli generalizované pre strednú mierka, ktorá je aplikovaná ako mapový server v prostredí ArcIMS v rozsahu 1:250 000 až 1:50 000.

Mapový server poskytuje užívateľovi prezeranie vlastností pôdy pomocou html. prehliadača, resp. interaktívnych máp spolu s prislúchajúcou databázou. Užívateľ využíva rôzne možnosti prehliadania máp s pomocou rôznych nástrojov (zväčšenie vrtsvy, zmenšenie vrstvy, prepnutie na aktívnu vrstvu, prepnutie na legendu, informácie o pôdnom type, pôdnom druhu, pôdnom substráte a pod.). Neodmysliteľnou výhodou mapového servera je v podstate jeho použitie širokou škálou užívateľov, ktorí majú dostatočné softvérové a hardvérové vybavenie a prístup k internetu.

Kľúčové slová: mapy KPP, ArcGIS Desktop, mapový server, ArcIMS, regionalizácia, región, pôdny typ

INTRODUCTION

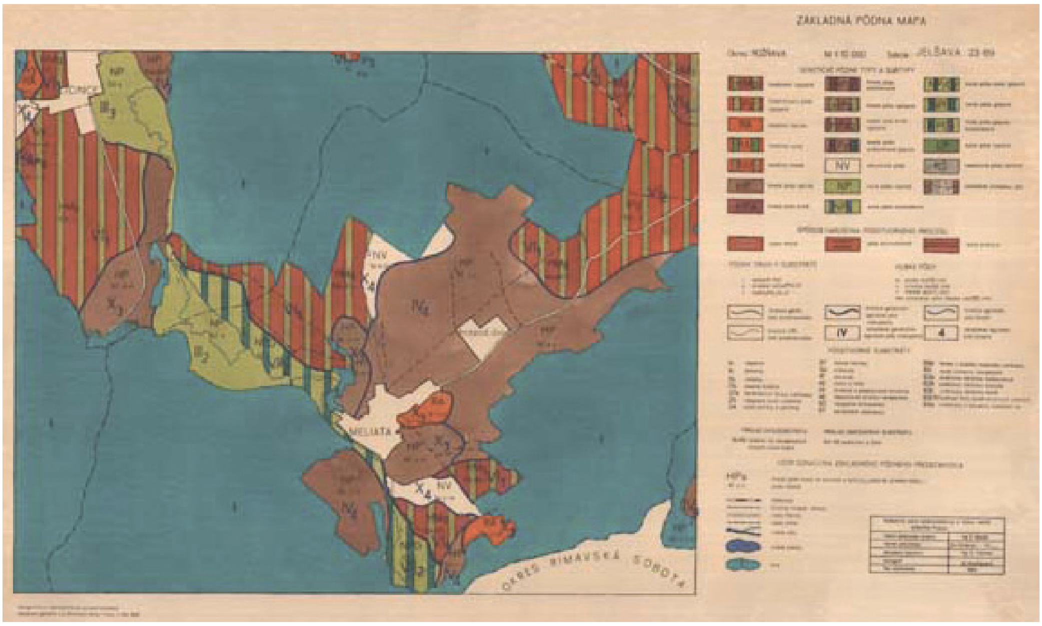
Soil presents a very specific and multi-functional natural body with many ecological and social-economical functions, mainly as medium of environment for plants and human. However, this resource is veriy restricted and destructible. Its heterogeneousness in time and space demands some specific approaches in graphic expression in maps or other partial visualizations (i.e. connected with relief) according to Čurlík et al. (1997), Čurlík, Šurina (1998). Respecting this approach there was necessary to create a multi-functional soil data-knowledge system, which defines soil segments, soil properties and their mutual relations as continuity structure of the soil cover (Skalský et al., 2005). Soil-data-knowledge system can provide integral information image about soil cover in Slovakia for wide range of users as soil scientists, agronomists, students, soil managers etc. Output of this work is a map server of Soil Science and Conservation Research Institute on the base of ArcIMS with the title Soil Portal.

MATERIAL AND METHODS

As the main source for maps` compilation, analogue maps created during the General Survey of Agricultural Soils (KPP) realized in the years 1961 – 1970 have been used. Maps in the scale of 1:5 000, or 1:10 000 can act as great information base about soil cover, however, their compilation for lesser scales requires methods of regionalization and soil association creation without lose of basic information. As the pilot projects have been chose regions of Šurany and Trebišov. Our aim is to extent map production for all territory of Slovakia (except to forest soils).

The General Survey of Agricultural Soils represents a soil survey of two coordinated tasks: agricultural soil mapping to gain basic information about the agricultural soil genetic-agronomic properties, and permanent agrochemical ploughing horizon testing in 5-years cycles. These activities were made for overall soil fertilization and production increasing. An example of agricultural soils mapping can be presented a basic soil map in analogue form in the scale of 1:10 000 (Figure 1).

Figure 1 Basic soil map in analogue form in the scale of 1:10 000



Analogue maps have been converted into digital form for the ArcGIS working. Digitalization of the KPP maps have been made in Soil Science and Conservation Institute Bratislava (more details in SKALSKÝ, 2005; SKALSKÝ et al., 2005). Digitalized maps are permanently completed by database describing basic soil information incl. laboratory analyses. Cartographic works are done in ArcGIS Desktop software of the ESRI (2001). ArcGIS Desktop presents a set of integrated software applications of ArcCatalog, ArcMap, ArcToolbox, ModelBuilder and ArcGlobe. Their common application is able to simply perform many tasks in the GIS at all required levels: map compilation, geographical analyses, control of spacious data, their visualization and working. For our purposes (map compilation in the middle scales), we have used applications of ArcMap, ArcCatalog and ArcToolbox.

A methodology of physical-geographical regionalization incl. soil association compilation has been used for new soil areas compilation respecting the scale of 1:50 000. It consists of unification and delineation of individual areas on the pedotope level. Areas have been identified on the bases of some relatively spatial unity (similarity) according to some dominating soil feature. This feature is called as regionalization criterion. "Purity" of delineated soil areas has to be more than 80 % (MIČIAN, 1977). Region can be determined as output of regionalization. It is defined as a part of territory on Earth's surface, which is delineated on the base of certain criterion.

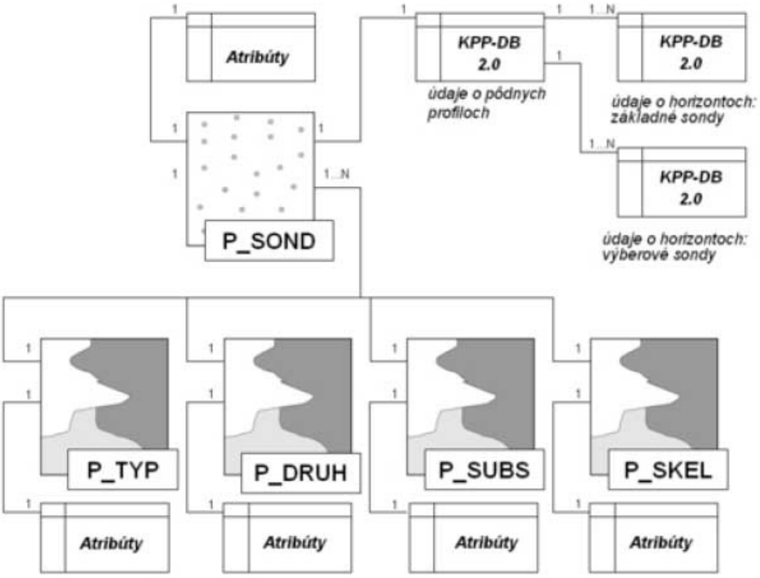
A basic soil type has been chosen as a dominating regionalisation criterion for combination (synthesis) of soil areas. Also categories of soil texture, kind of parent material and categories of stoniness has been taken into consideration. Soil associations have represented areas with dominating soil type completed by secondary and sporadic soil units. Dominating soil unit represents areas with more than 60 %, secondary soil units are areas of 60 – 10 % and sporadic soil units must be very specific to be mapped and represents less than 10 %.

RESULTS AND DISCUSSION

Database formation

Database model of KPP outputs represents a geo-referenced database of agricultural soil of Slovakia 1.0 (GDPPS 1.0) in format <.mdb> (Skalský, 2005; Skalský et al., 2005) – see Figure 2. The basic database includes ID – identification number of region, SHAPE AREA – area size in square meters, and SHAPE LENGTH – line length, polygon circumference in meters. These database values cannot be modified nor deleted. For compilation of maps in the middle scale there is a need to create correction and update of spatial and attribute extent GDPPS 1.0 using up-to-date data about soil cover in landscape.

Figure 2 Database structure GDPPS (Skalský, 2005)



In the first step an update of the soil type extent attribute has been carried out according to the table comparing Genetic-agronomic Soil Classification (Němeček et al., 1967) with the Morphogenetic Soil Classification System of Slovakia, later as MSCS 2000 (Kolektív, 2000). This comparison respected valid standards for soil description and classification. In such way the Geo-referenced database of agricultural soils of Slovakia 2.0 (GDPPS 2.0) has been created according to the MSCS 2000. It fills contemporary demands on topicality of soil attribute extent.

Consecutively, also correction and update of parent material and textural categories attribute extent has been implemented respecting the MSCS 2000. The GDPPS 2.0 (Personal Geodatabase) is constituted in ArcCatalog program as Feature Dataset (in given case su_smvpod) in coordinate system S-JTSK (S-JTSK_Krovak_East_North) containing areas, or polygons (.shp formát) and indicate soil type (su_smptyp), soil texture (su_smdruh), parental material (su_smpsubstrat), and in some regions stoniness (soil units containing increased amount of stones).

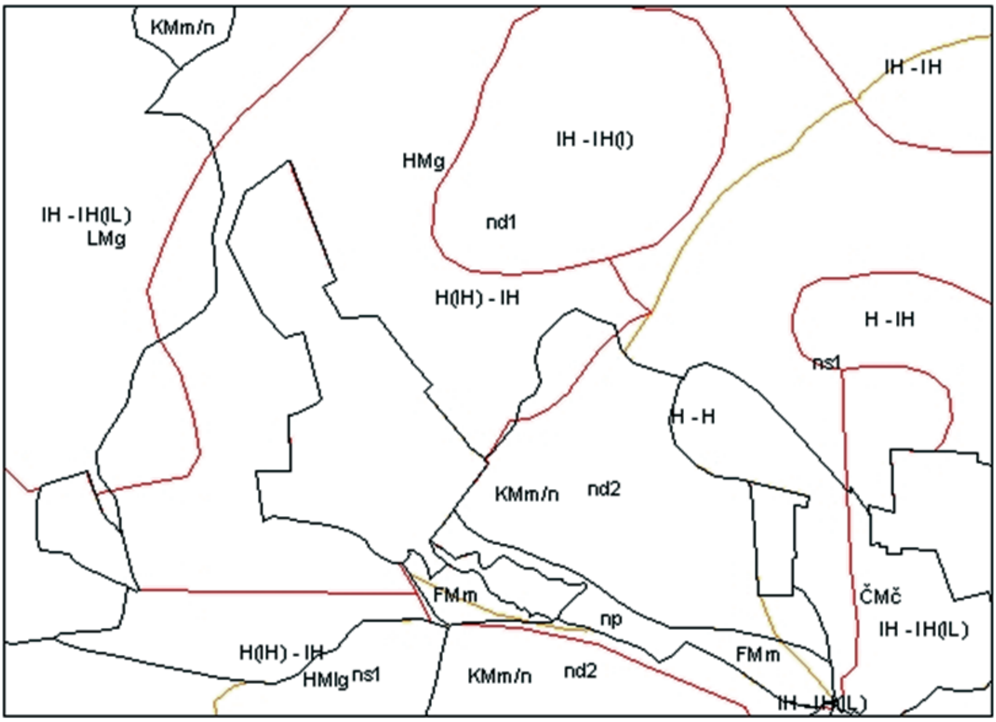
Map digitalization and compilation

Digitalization output represents shape form <.shp> of spatial taxonomic soil units, or soil types, respectively, and then shape forms of: parent materials, textural categories (for topsoil and subsoil) and stoniness (for topsoil and subsoil). In given case shape form represents class of polygons – regions, or set of simple elements with polygon geometry.

Feature Dataset represents classes of topologic elements forming equal spatial references (GEODATABÁZA, 2001). Denomination su_smptyp means: su – area indication of mapped region, in our case region Šurany, smptyp – middle scale of soil type. Original shape formats of GDPPS 1.0 (soil type, parent material, and texture) have been exported into prepared geo-referenced database GDPPS 2.0.

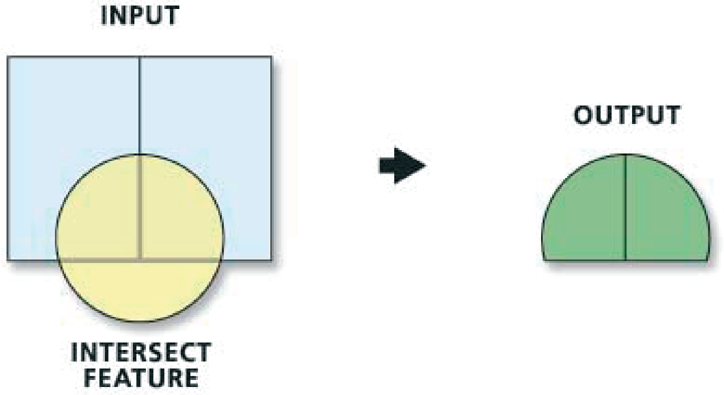
Minimalization of the maps from the large scale (1:10 000) into the middle scale (1:50 000) requires some tools for simplification of individual polygons in intention to preserve special content of maps. Therefore, in the second step there has been a need to delineate conjunct areas. Specifically, there have been individually delineated overlapping and digitalized boundary lines for soil type (black line), parent material (red line) and soil texture (yellow line) (Figure 3).

Figure 3 Overlaying digitalized polygons of soil type, soil texture and parent material



For computer regionalization we have selected appropriate tool in the ArcGIS – ArcToolbox after special discussion and testing of various ArcGIS means. We have decided for application of analytical tool: "Overlay" (overlapping of areas) and "Intersect" (intersecting and crossing of areas) illustrated in the Figure 4.

Figure 4 Application of analytical tool Intersect (polygons overlying)



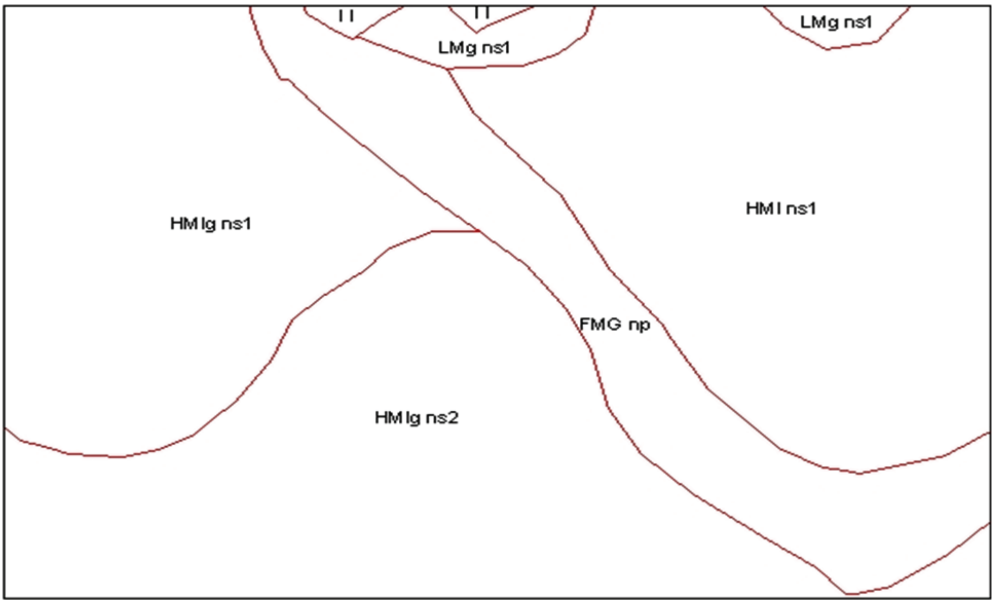
ArcGIS Geoprocessing Operations – Intersect

As the first conjunction areas have been compiled areas for soil type and parent material (Figure 5). An inevitable tool of this step has been checked-up of planar topology running under program ArcCatalog. The program shapes systems of line and planar elements as a continual layer that comprises of non-overlapping polygons. Planar topology does not allow any element to cross through other element without intersecting. By such system we can define only one polygon for each spatial point covering space. At planar topology we have used tool "Must Not Overlap" (polygons must not be overlapped) and tool "Must Not Have Gaps" (polygons must not have gaps). By location of overlapped or redundant mistakes we have removed them. We have compared compiled areas (non-classified) with areas of soil types and parental materials. On the base of this comparison we have assigned to each area subsistent attributes.

The further step has been to overlap newly created areas (soil type and parent material) by the areas of soil textural categories. Even in this procedure there has been a need to do the same steps as in the previous case: topology ⟶ location ⟶ mistakes removing. By polygons overlapping we have obtained resultant areas representing dominant soil type characteristic by the soil texture and parent material. In the most cases, the areas have had the same soil type, but not the identical soil texture and soil material. In the final map of the middle scale we have used synthesis as method of the polygons unification.

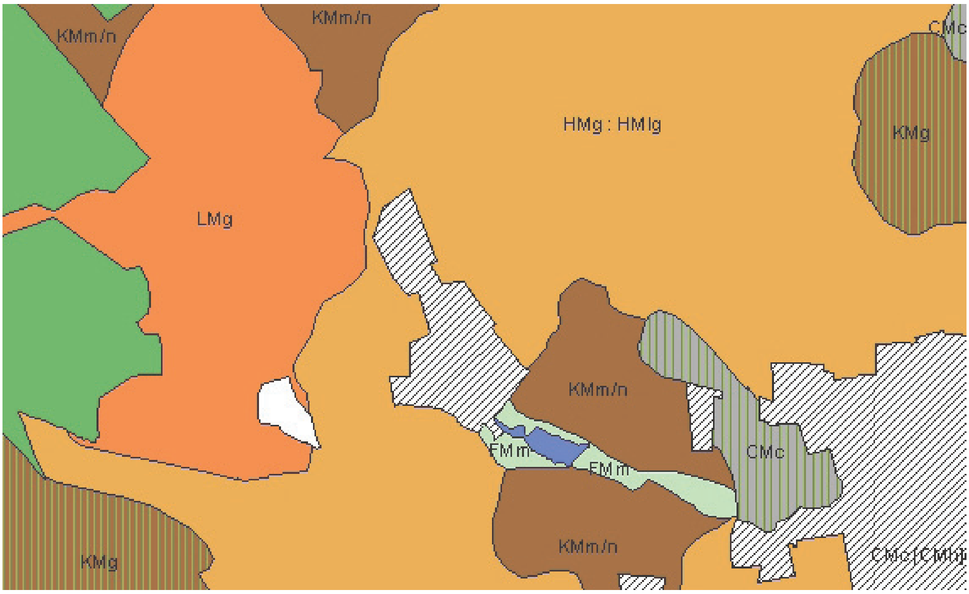
By the tool "Merge" we have grouped areas with similar soil types, completed by database of parent material or soil textural categories, which have not corresponded. Resultant areas of the same soil types include two, or three different parent materials or textural classes. Their features are classified as secondary units. At a minimum extent they have classified as sporadic. Dominating soil unit is characterized by more than 50 % area from total polygon extent. Secondary unit is represented by less than 50 % from the total polygon extent, sporadic units less than 10 %.

Figure 5 Conjunction areas of the soil type and parent material



Pedo-geographical synthesis has been accomplished at a large number of slightly differentiated soil subtypes. It has been done by the mapping of soil units into the soil associations or complexes. Prevailing soil type has been mapped as dominant, other soil types or subtypes have been presented as secondary or sporadic. Compiled map has got relatively high intensity of spatial attributes preserving technical processing and legibility. Such new constructed middle-scale maps can hold maximum information and precision near to large scale maps as it showed in the Figure 6.

Figure 6 Resultant digitalized soil map in the scale of 1:50 000

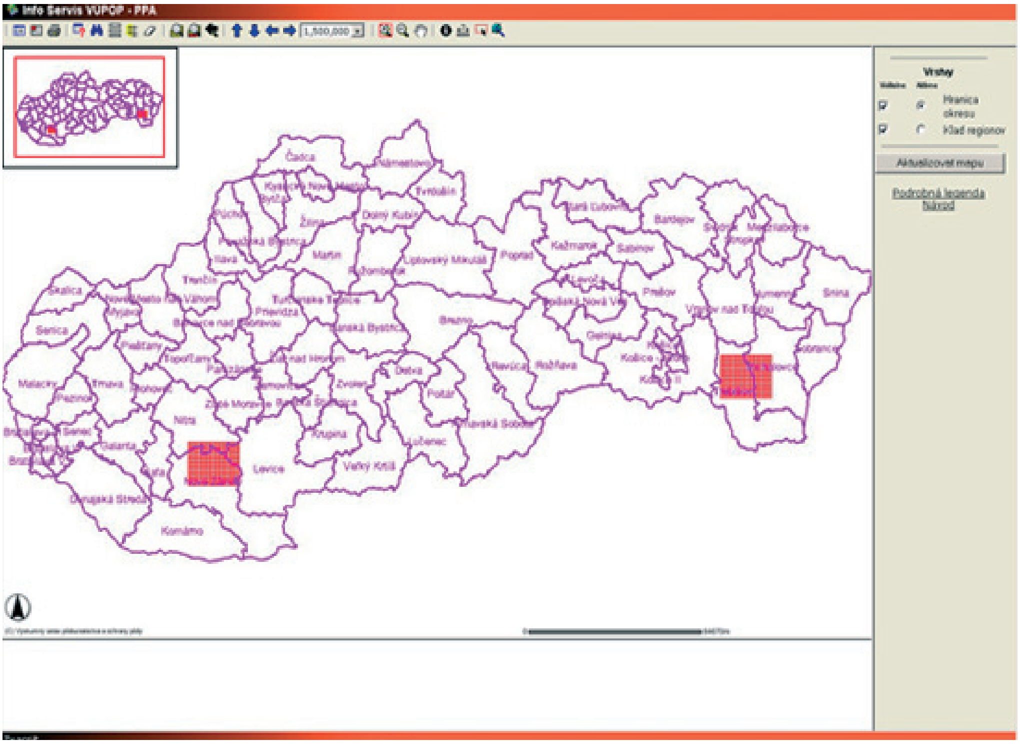


Map information server creation

Arrangement of map information server about soil cover of Slovakia involves knowledge from soil science, keeping many rules from informatics or geographical information systems (GIS). Soil information server can fulfill increased claims of practice in the frame of information technical society. The GIS tools present advanced technology used for various purposes (i.e. digital model relief formation, thematic map construction, modelling of global phenomena, prediction of future processing, simulation of different disasters, etc.).

In our case, the GIS tools are used as spatial and attribute data about soil cover of Slovakia, their interaction referring soil types and subtype, parent material, soil texture. Many of these properties can be used by potential users (farmers, environmentalists, and agricultural managers). Map information server on the ArcIMS base can provide not only information, but also facilitates various application and operations in the GIS media, which promotes its wide spectral using.

Figure 7 Map in the Internet reviewer ArcIMS showing middle-scale mapped section (Šurany, Trebišov)



For information server there has been inevitable to adapt map legend into axl. format. This format can be read and presented by the program ArcIMS. Modification of database, as well as legend programming into the format axl. has been carried out in the text editor ArcPad. User can use various facilities of viewing by PC tools (enlarge of level, diminishing of level, switch on active level, switch on legend, information about soil types, soil texture, parent materials, etc.).

The ArcIMS (html reviewer) presents an Internet GIS technology of ESRI firm, which allows central presentation and providing of maps, data and on-line service in intranet or Internet media. Using of ArcIMS system develops availability of large amount of data for users and public. Users can combine these data with others, which allow practically disseminate geographical data in a large scale. This server except to newly regionalized maps provides also applicable legends and other database (extent, signature, code, characteristics, etc.).

At present, soil map server ArcIMS for maps of middle scale can act as pilot project for modelled territory: region Šurany and region Trebišov (Figure 7). Information is available on website of the Soil Science and Conservation Research Institute (http://www.podnemapy.sk), which is a part of so-called Soil Portal at the website www.vupu.sk. Inherent advantage of map server is its use by wide range of users who have got sufficient software and hardware equipment and internet access, as well. Application involves user name and password which can be obtained by e-mail claim.

CONCLUSIONS

Methodology of digital maps construction involves several procedures to be included in the ArcGIS Desktop. It can facilitate automated construction of middle scale maps from large scales ones. Map compilation is based on more objective principles than in manual mapping survey. Soil maps containing quantum information about soils and their properties can serve for many purposes of interested soil scientists, environmentalists, agronomists, agricultural managers, etc. Moreover, precision and accuracy of constructed maps is not negligible.

Pedo-geographical principles have been selected for soil unit regionalization with dominating criterion soil type. However, other soil properties have been taken into consideration as parent material and soil texture. For creation of maps huge soil database has been necessary to review and adapt. Geo-referenced database has been the base for our application. Application has been made according to the latest soil classification system of Slovakia. Similar technology can be used also for other maps compilation to gain satisfactory and adequate basic information about soils.

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SOME FEATURES OF SOILS FORMING IN (SEMI)HYDROMORPHIC CONDITIONS

NIEKTORÉ ČRTY PÔD FORMUJÚCICH SA V (SEMI)HYDROMORFNÝCH PODMIENKACH

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ABSTRACT

Soil forming process running in hydromorphic conditions has a significant position in the landscape quality. These conditions can be permanent (wetland) or temporal, resp. interrupted during a year (wet and dry season). Result of the given conditions is creation of hydromorphic phenomenas described in this contribution. Basic soil parameters have been determined on selected sites (pH/KCl, H_2O, $CaCl_2$, C_{ox}, N_t, fractional composition of humus – HA, FA, Q^4_6, as well as labile carbon content – C_L). In addition, also iron in dithionite (Fe_d) and oxalate (Fe_o) extracts has been determined. On the basis of obtained results creation of (semi) hydromorphic phenomenas refers to:

- heterogeneity of soil cover
- reconstruction of genesis of soil and landscape
- qualitative change of soils during their development
- part of soil profile can be older than originally presupposed
- soil with paleohydromorphism phenomenas occurrence can relatively well and long time keep their soil properties

KEYWORDS: hydromorphism, paleohydromorphism, soil genesis, relict and recent soil forming process

ABSTRAKT

Pôdotvorný proces prebiehajúci v hydromorfných podmienkach má výrazné postavenie pri hodnotení kvality krajiny. Tieto podmienky môžu byť trvalého charakteru alebo dočasného, príp. sa môžu počas roka striedať (mokré a suché obdobie). Výsledkom takýchto podmienok je postupná tvorba fenoménov hydromorfizmu, ktoré sú popisované v uvedenom príspevku. Na vybraných lokalitách boli zisťované nasledovné parametre: (pH/KCl, H_2O, $CaCl_2$, C_{ox}, N_t, frakčné zloženie humusu – HK, FK, Q^4_6, C_L). Taktiež bolo stanovené železo v dithionitovom (Fe_d) a oxalátovom extrakte (Fe_o). Na základe dosiahnutých výsledkov tvorba (semi) hydromorfných fenoménov sa spája s:

- heterogenitou pôdneho krytu
- rekonštrukciou genézy pôdy a krajiny
- kvalitatívnymi zmenami pôd počas ich vývoja
- konštatovaním, že časť pôdneho profilu môže byť staršia ako sa pôvodne predpokladalo

– konštatovaním, že pôdy s výskytom fenoménov paleohydromorfizmu si relatívne dobre a dlhodobo udržujú svoje pôvodné vlastnosti

KĽÚČOVÉ SLOVÁ: hydromorfizmus, paleohydromorfizmus, genéza pôdy, reliktný a recentný pôdotvorný proces

INTRODUCTION

Evaluation of the soil forming processes running under hydromorphic conditions is rather complicated, because these can be influenced by surface or groundwater level during historical or recent period. In addition, given conditions can be changed during genesis of soil. Such development is in relation to changed structure and composition of the soil profile, as well.

Finally, result of the soil forming process running under hydromorphic conditions is creation of specific phenomenas, which can occur in surface layer of soil profile and/or in its lower part. It often causes significant variability of soil properties. It is well known that genesis of soil is in correlation to landscape development. Soil properties created in historical periods can be more or less preserved for a long period. It means that relict features can be often completed with recent features. Thus, the term-recent or relict soil must be related to the concrete locality and soil taxonomy, because various soil types during their genesis reflect changed interactions of soil forming factors variously. In addition, occurrence of dark-coloured humus horizons is reflection of historical hydromorphic phase in the soil cover development where in recent conditions accumulation of the humus is not a characteristic (predominant) soil forming process.

Beyond, change of groundwater level has caused development of soil with changed automorphic, semihydromorphic and hydromorphic conditions, as well.

Figure 1 Occurrence of relict and recent soils in Turčianska kotlina (depression)

MATERIAL AND METHODS

Some important parameters of (semi)hydromorphism conditions have been measured on six selected sites of dark-coloured soils with mollic humus horizon of Slovakia: pH/H_2O, $CaCl_2$, KCl, Cox, Nt, HA, FA, C_L (labile carbon) as well as oxides of iron (Fe_o, Fe_d). On the basis of given parameters the following important characteristics of (paleo) hydromorphism regarding soil forming process and genesis have been obtained. The basic parameters have been determined according to mandatory analytical procedures for soil (FIALA et al., 1999).

RESULTS AND DISCUSSION

There are selected six soil profiles affected more or less by hydromorphic soil forming process and different in comparison with surrounding soils. Basic parameters are given in the following Table 1.

Table 1 Basic parameters of dark-coloured arable soils in non-chernozem conditions of Slovakia

N	Locality	Soil (MKSP 2000)	Soil (WRB-98)	Depth in cm	pH/KCl	Cox (%)	Nt (%)	C/N
1	Badín	ČAa	Mollic Fluvisols	0 – 10 35 – 45	6.30 6.50	2.10 1.75	0.23 0.17	9.13 1.29
2	Príbovce	ČAac	Calcaric Mollic Fluvisols	0 – 10 35 – 45	7.12 7.16	3.41 2.66	0.42 0.37	8.12 7.19
3	Dúbrava	ČAa	Mollic Fluvisols	0 – 10 35 – 45	5.57 4.25	2.57 1.21	0.30 0.15	8.56 8.06
4	Kežmarok	ČAa	Mollic Fluvisols	0 – 10 35 – 45	5.39 5.54	2.26 0.63	0.21 0.08	1.76 7.87
5	Spišská Belá	ČAa	Mollic Fluvisols	0 – 10 35 – 45	6.28 6.21	2.16 1.45	0.20 0.15	10.80 9.66
6	Petrova Ves	ČMa	Haplic Chernozems	0 – 10 35 – 45	6.70 7.37	1.16 0.64	0.15 –	7.73 –

There are soils, which occur in acid to slightly acid as well as to neutral environment. Except Badin locality, these soils are infuenced by water flow with high underground water level. Content of organic carbon is about 2.27 %, a higher value in comparison with similar soils in automorphic conditions of chernozem region (1.60 – 2.00 %) – KOBZA et al. (2002). Total nitrogen content is represented with higher values 0.15 – 0.42 % in contrast to similar soils in chernozem region (0.17 – 0.21 %). C:N ratio is about 7 – 11, also a higher value in contrast to dark-coloured soils in chernozem region (7 – 8).

On the basis of the obtained results (Table 2) it may be said that qualitative humus is characteristic for these soils (HA : FA > 1). Aside of this, also labile carbon content is one of the most important characteristics of humus. In the following Table 3, there is given a comparison of labile carbon content between dark-coloured soil in chernozem region (Voderady at Trnava) and dark-coloured soil in non-chernozem region (Spišská Belá).

Table 2 Humus fractional composition of dark-coloured arable soils in non-chernozem conditions of Slovakia

N	Locality	Soil (MKSP 2000)	Soil (WRB-98)	Depth in cm	HA (%)	FA (%)	HA/FA	Q^4_6
1	Badín	ČAa	Mollic Fluvisols	0 – 10	19.74	10.16	1.94	4.00
2	Príbovce	ČAa^c	Calcaric Mollic Fluvisols	0 – 10	22.43	14.25	1.57	3.56
3	Dúbrava	ČAa	Mollic Fluvisols	0 – 10	16.95	22.44	0.75	4.40
4	Kežmarok	ČAa	Mollic Fluvisols	0 – 10	20.06	10.16	1.97	3.94
5	Spišská Belá	ČAa	Mollic Fluvisols	0 – 10	22.57	13.14	1.72	3.74
6	Petrova Ves	ČMa	Haplic Chernozems	0 – 10	23.99	15.24	1.57	4.07

HA – humic acids, FA – fulvoacids, Q^4_6 – colour quotient

Table 3 Qualitative composition of humus in different conditions of hydromorphism (depth 0 – 10 cm)

Locality	Soil (MKSP 2000)	Soil (WRB-98)	pH in H_2O	pH in $CaCl_2$	C_t (%)	C_L (g.kg^{-1})	Share of C_L from C_t (%)	C_{NL} (g.kg^{-1})	L (C_L/C_{NL})	N_{pot} (mg.kg^{-1})	C_L:N_{pot}
Voderady	ČMa^c	Haplic Chernozems	7.54	7.12	1.75	2.03	11.60	15.47	0.13	147	13.80
Sp. Belá	ČAa	Mollic Fluvisols	6.75	6.31	2.51	4.23	16.80	20.87	0.20	109	38.80

C_t – total carbon, C_L – labile carbon, L – index of lability, N_{pot} – potentially mineralisable nitrogen

In comparison of the soils with different genesis, higher content of labile carbon has been determined on soils influenced by hydromorphism during their development and at present time they occur in more or less automorphic conditions. Also share of labile carbon from carbon total content is on these soils (16.80 %). C_L: N_{pot} ratio is significantly higher (38.80) on the described soils, what is in relation to the lower quality of humus in contrast to automorphic soils. This ratio seems to be a better parameter for evaluation of humus quality opposite C:N ratio (ZAUJEC, KOBZA, 2002).

It is well known that in the group of hydromorphic soils are classified also soils where hydromorphic soils forming process is not only influenced by underground water but also by surface water, as well. This process can be more or less interrupted. Under influence of oxido-reductional processes, the creation of motley mosaic of rusty and grey mottles can be often visible. However, only few studies exist on genesis of rusty and grey mottles and tongues from hydromorphism point of view. Finally, their difference is often homogenized during preparation of soil samples for chemical procedures. Therefore, we have tried to separate rusty and grey mottles and tongues in which iron forms (oxalate – Fe_o and dithionite – Fe_d) have been determined. Obtained results are given in the following Table 4.

Table 4 Free iron in the rusty and grey leaks in E/B horizon of Planosol

Leaks	pH value and free iron forms							
	pH/H_2O	pH/KCl	Fe_o (%)	Fe_d (%)	Fe_d – Fe_o	Fe_o/Fe_d	Fe_o:clay . 100	Fe_d:clay . 100
Rusty	5.20	5.00	0.98	4.73	3.75	0.21	8.48	40.95
Grey	6.20	6.10	0.66	3.02	2.36	0.22	7.17	32.83

Different distribution of iron forms refers to soil forming process influenced by rainfall water flow and its penetration into the deeper part of the soil profile.

At expressive texturally differentiated soils (d ≥ 2.0) the Fe_o content has increased in surface horizon indicating more expressive hydromorphism (KOBZA, 1991). The single pseudogleying process has proceed differentiatelly and irregulary in relation to different distribution of iron forms – so called pedogene Fe-oxides in rusty (0.98 % Fe_o and 4.73 % Fe_d), and grey (0.66 % Fe_o and 3.02 % Fe_d) in the leaks of Planosol.

In addition, Fe_o:Fe_d ratio is characteristic for the degree of iron migration and hydromorphism (KOREŇ, 1984). During more intensive hydromorphism Fe_o:Fe_d ratio decreases and on the contrary, crystalline forms of iron (Fe_d – Fe_o) increases. It is demostrated especially on old soil-sedimentary deposits and their phenomenas, in which soil regimes are not relevant to (sub) recent conditions.

CONCLUSIONS

Some features and phenomenas of soil forming process running under hydromorphic conditions are described in this contribution. Well, process of hydromorphism in reality is more complicated. On the basis of obtained results this soil forming process is often connected with creation of hydromorphic phenomenas. This creation has a significance to evaluation of heterogeneity of soil cover relating to genesis of soils and landscape. Finally, some soils with existence of paleohydromorphic phenomenas (with occurrence of crystalline forms of Fe (Fe_d – Fe_o)) seem to be older in contrast to surrounding soils.

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THE EUROPEAN APPROACH TO AGRICULTURE MULTIFUNCTIONALITY ASSESSMENT (MEA-Scope) AND AGRICULTURAL DATA REQUIREMENTS

EURÓPSKY PRÍSTUP K HODNOTENIU ASPEKTOV MULTIFUNKČNOSTI POĽNOHOSPODÁRSTVA (6 RÁMCOVÝ PROGRAM MEA-SCOPE) A POŽIADAVKY NA ÚDAJE O POĽNOHOSPODÁRSKEJ VÝROBE

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ABSTRACT

The MEA-Scope approach to multifunctionality of European agriculture is based on the fact that agricultural production provides both commodity and non-commodity outputs (agriculture operates commodity and non-commodity functions as well) according to society demands and demands for sustainable development. As well, important seems to be the fact that agriculture has multifunctional impact that comprises range of agricultural benefits in environmental and socio-economic fields.

In submitted article the problem (the aspects) of agricultural multifunctionality in European agricultural sector context is discussed and presented both at the theoretical level (the conceptual base of MEA – Scope project, three micro-economic models – AgriPoliS, MODAM and FASSET) and at the regional level (the specific conditions of agricultural sector in seven selected regions). The paper provides a view on data related to agricultural production at regional and farm level that are required for micro-economic models integrated in MEA – Scope In this paper several aspects of collecting and pre-preprocessing regional data (Piešťany region) related to agricultural production in accordance with individual models requirements (AgriPoliS, MODAM and FASSET) are presented as well.

KEYWORDS: multifunctionality of agriculture, MEA-Scope, micro-economic models, AgriPoliS, MODAM, FASSET, agricultural data

ABSTRAKT

Multifunkčnosť poľnohospodárstva, ako reálna a významná črta poľnohospodárskej výroby v európskom priestore, sa prejavuje priamou produkciou poľnohospodárskych produktov (komodít) na jednej strane, ako aj produkciou nepoľnohospodárskych výstupov ako výsledku dopytu a požiadaviek spoločnosti a požiadaviek na trvalo udržateľný rozvoj na strane druhej. Okrem produkcie sa multifunkčnosť poľnohospodárstva výrazne prejavuje v dopade poľnohospodárskej výroby, a to ako v environmentálnej, tak aj sociálnej oblasti.

Predložený príspevok sa venuje problematike hodnotenia aspektov multifunkčnosti európskeho poľnohospodárstva a poľnohospodárskej výroby, a to ako na teoretickej úrovni (v rámci

EU projektu 6. rámcového programu – Model európskeho poľnohospodárstva – MeaScope), tak aj na úrovni regionálnej (v rámci vybraných európskych regiónov, vrátane regiónu Piešťany v SR). Príspevok je zároveň zameraný na analýzu vstupných údajov týkajúcich sa poľnohodspodárskej výroby pre potreby mikro-ekonomických modelov integrovaných v projekte MEA a na analýzu dostupnosti a vhodnosti existujúcich údajových báz pre potreby spracovania vstupných údajov a iných zdrojov, resp. možností ich získania (expertné znalosti, dotazníky a pod.), ktoré boli aplikované v procese zberu a pred-prípravy týchto údajov.

Kľúčové slová: multifunkčné poľnohospodárstvo, MEA–Scope projekt, mikro-ekonomické modely, AgriPoliS, MODAM, FASSET; údaje o poľnohospodárstve

INTRODUCTION

Common Agriculture policy (CAP) represents one from the first European policies and is classified as most important, integrated and complicated. Through its beginning and progress, CAP has overcome several reforms and the urgent question regarding the environment assessment and landscape suitable development is still more and more important. Set of indicators, including economical, environmental and social characteristic produce efficient tools for assessment of multifunctional agricultural concept (Cassini et al., 2005a).

The project "Micro-economic instruments for impact assessment of multifunctional agriculture to implement the Model of European Agriculture: project (MEA-Scope)" approach is based on the idea of multifunctionality in agriculture according to which the agriculture represents the producer of agricultural goods primary and producer of diverse outputs as landscape and environmental benefits, food security, rural employment or cultural heritage as well. The agricultural multifunctionality resides in fact that agriculture produces commodity and non-commodity outputs at the same time (Cassini et al., 2005b, Damgaard et al., 2005).

The 6th Framework Programmne (EU) project MEA – Scope (http://www.mea-scope.org/) responds to the need of multifunctionality impact assessment. A key objective of MEA – Scope is to develop a tool that allows interactions between multifuncionality in agriculture and policy instruments at farm and regional level to be simulated (Piorr, Müller 2004). The Mea-Scope project is applied to one exemplary farming system (beef production) for seven European landscapes among the EU member states – besides Slovakia, there is Hungary (Borsodi Mezöseg region), Poland (Turew landscape area), Denmark (River Gudenå Area), Germany (Rhin-Havelländisches Luch region), France (Combrailles region) and Italy (Mugello area). As a representative region for the Slovakia in the MEA – Scope project Piešťany region (NUTS4 unit) has been selected. Piešťany region represents the landscape (agroecosystem type) characterized by intensive agriculture on hilly lowland with pastures with increased landscape diversity as selected positive externality and with nitrate leaching in vulnerable area as selected negative externality.

Soil Science and Conversation Research Institute (SSCRI) takes part in the MEA-Scope project in position of regional partner that is responsible for pre – processing of data related to regional specific knowledge about agricultural production systems and their interactions with environmental and socio-economic settings in regional conditions (Piešťany region) (Hutár et al., 2005; Nováková et al., 2005). SSCRI operates in the project work at the field oriented to Multifunctionality Impact Assessment (at Farm and Landscape level).

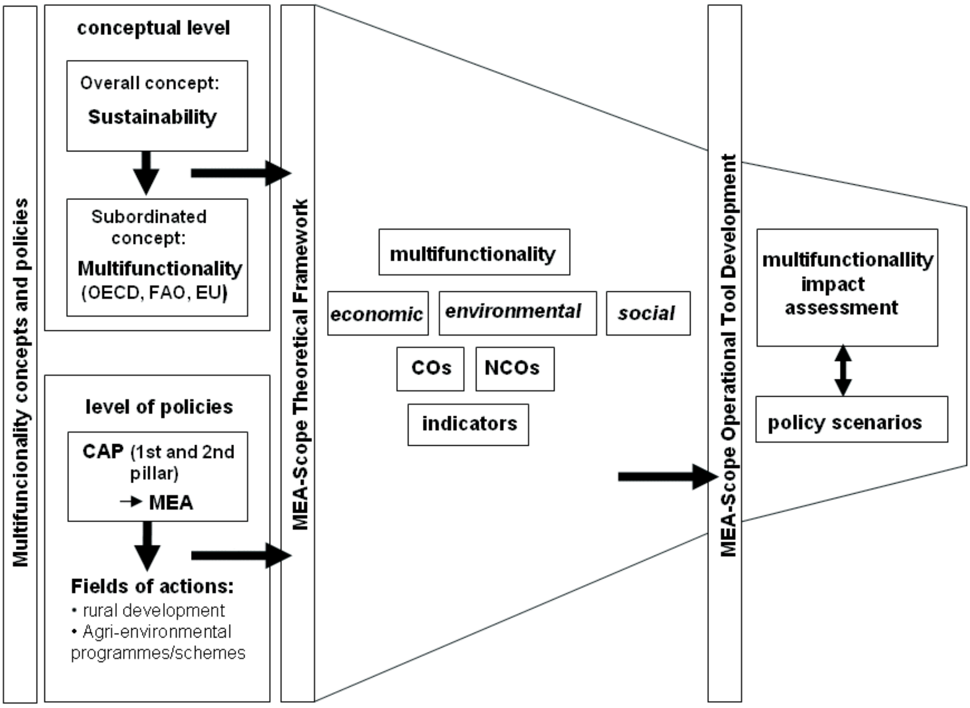
Submitted paper deals with the problem of multifunctionality in European agriculture and development of quantitative tool oriented to multifunctionality impact assessment in the condition of different CAP reforms (MEA-Scope). The paper provides a view on data related to agricultural production at regional and farm level that are required for micro-economic models integrated in MEA-Scope. Besides, paper several aspects of collecting and pre-preprocessing regional data (Piešťany region) related to agricultural production in accordance with individual models requirements (AgriPoliS, MODAM and FASSET) are presented as well.

STATE-OF-THE-ART OF THE MEA-SCOPE PROJECT (OVERVIEW OF MEA-SCOPE OBJECTIVES AND THEORETICAL PRINCIPLES)

MEA-Scope objectives

MEA-Scope project aims at developing integrated (both theoretical and functional) framework for the assessment of multifunctionality impacts of the CAP reform options (Figure 1).

Figure 1 Scheme of making the multifunctionality concept (in MEA-Scope) operational (according to PIORR, MÜLLER 2004)



This general MEA-Scope objective is elaborated in detail objectives:

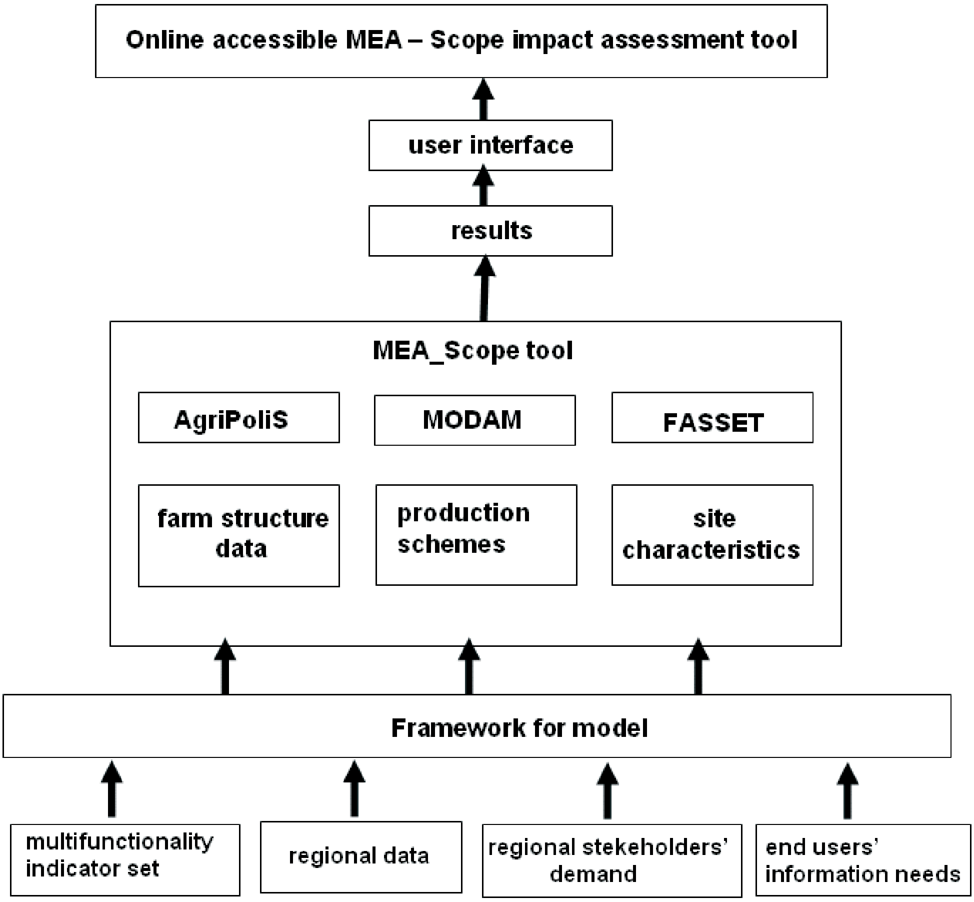
- development of the multifunctionality concept for European agriculture;
- development of the quantitative tool for assessment of multifunctionality impacts of the CAP reform options;
- answering policy-relevant questions for the implementation of the multifunctionality concept;
- demonstration of the operability of integrating assessment framework;
- generation (derivation) of the scientific knowledge on specific questions regarding multifunctionality of agriculture, particularly wit the respect to spatial scale and regional differences.

Micro-economic modelling of agricultural decision-making

The approach applied in the MEA-Scope (as it has been mentioned above) is to link three independent existing simulation models (AgriPoliS, MODAM and FASSET – Figure 2) with the aim to express and capture different environmental, economic, social aspects of multifuntionality and land – use at a different scale (Damgaard et al., 2006).

Each of the models has beenoriginally developed to cover different complementary aspects relevant in the multifunctionality impact assessment.

Figure 2 Process of MEA-Scope tool development (according to Piorr, Müller 2004)



AgriPoliS (Agricultural Policy Simulator) has been developed (at Institute of Agricultural Development in Central and Eastern Europe – IAMO) as the policy evaluation tool oriented to investigate structural change in regional agricultural structure (change in model of regional agricultural structure) in agriculture changes effect (Damgaard et al., 2004; Damgaard et al., 2005).

MODAM (Multi-Objective Decision support tool for Agroecosystem Management) has been developed (Centre for Agricultural Landscape and Land Use Research – ZALF) as the policy evaluation tool oriented to investigate policy effect on the farmers decision behaviour and related (corresponding) environmental effect (Damgaard et al., 2004; Damgaard et al, 2005).

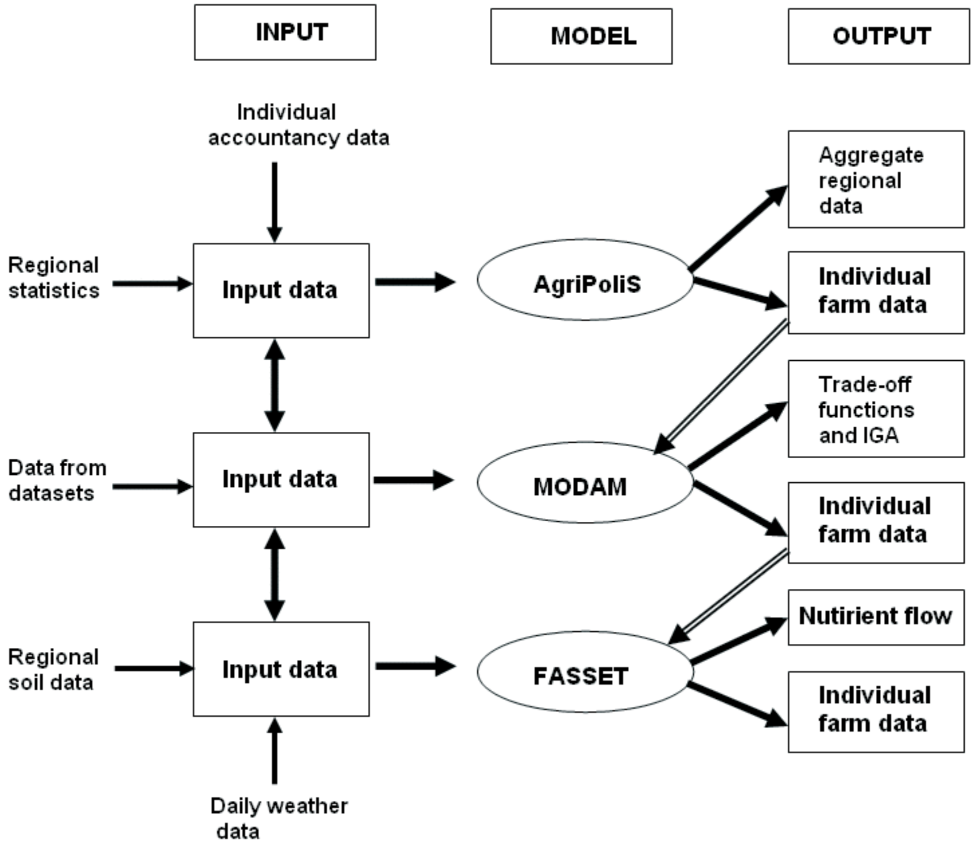
MODAM represents hierarchical, bio-economic modeling system, which has been developed to analyze relations between economic and ecological objectives in agricultural land use.

FASSET (Farm ASSEssment Tool) has been developed (at Danish Institute of Agricultural Sciences – DIAS) as dynamic, deterministic model oriented to simulate relations between agricultural production, economics and pollution (nutrient flows, nitrate leaching, emission or absorption of greenhouse gases) at farm and field level and on daily bases (DAMGAARD et al., 2004; DAMGAARD et al., 2005).

The process of three models linking (Figure 3) allows to extent the possibilities and capabilities to model multifunctional aspects of agricultural systems in two directions:

- to combine the individual capabilities of each model and obtain more complex model from spatial, analytical and temporal aspects point of view;
- to cover a wide range of multifunctionality indicators (WAARTS, Y., 2005) – as the indicators of beef production and its multifunctional impacts – which are simulated in respective models and to analyze results with regard to these.

Figure 3 The process of models linking (according to PIORR, MÜLLER 2004)



SELECTED ASPECTS OF AGRICULTURAL MULTIFUNTIONALITY IMPACT ASSESSMENT IN MEA-SCOPE

The Aspect of Agricultural Production (Agricultural Structure) Modelling at the Regional Level

Agricultural structure of the individual region is considered as a system (agro-ecosystem) consisting of number of autonomous farms, environment (landscape) in which the farms are located, the markets for factor inputs (labour, capital, quota, etc.) and outputs (products) and the actions and interactions of farms in the region or landscape (relations in agro-ecosystem).

In the MEA-Scope, AgriPoliS aims to understand the regional structure in agricultural production and create its model; to analyze land market and farm structure. The model represents the real observed farming system structure in a base year (Δt = 1 financial year) in the closest approximation as it is possible.

This task requires to describe region's key structural indicators and to collect relevant data related to agricultural structure and region production activities at regional and farm level.

Data Related to Agricultural Structure

Data at the regional level (regional dataset) describe the main structural characteristics of the region and the main productions which can be found in region. The structural indicators have been modified and specified on the base of regional particularities. Data at the farm level (individual level dataset) describe a sample of farms and their characteristics in region considered as "typical" for case study area. Data related to 15 selected farms (with the utilized agricultural land area higher then 1 ha) have been pre-processed for Piešťany region.

Required data at regional level are represented by following inputs: *general characteristics* (number of farms, utilized agricultural area, livestock structure in region – number of beef cattle, dairy cows, other cows, ewes, other sheep, breeding sows, pigs for fattening, other representative livestock branches); *structural characteristics* (number of individual farms, partnership, other organizational forms of farms); *total utilized agricultural area* of all farms belonging to *farm organization category; area* (grassland, arable land in region), *number of farms specialized in* field crops, milk, grazing, granivores or mixed – crop and livestock; *total utilized agricultural area* according to *farm specialization* categories; number of *farms according to size farm categories; total number of selected livestock group* (pigs for fattenings, sows, dairy cows) for all farms *according to livestock size (heads) categories.*

Farm Structure Census (FSC) database (under Statistical Office of SR maintenance) and LPIS (under SSCRI maintenance) have been utilized as the data sources needed for required regional dataset pre-processing. Farms with the area of agricultural utilized area below 1 ha have been eliminated from the databases. Consequently, FSC data have been compared, complemented and moderately modified with actual LPIS data (in several cases as number of farms, area, agricultural land structure, etc.).

Required data at farm level are represented by following inputs**:** *general information on the farm* (organizational form of the holding, type of farming, organic or conventional farming, irrigated area, altitude zone, structural funds area, area with environmental restrictions); *data about farm structure and yield* (farm economic size, total labour input, labour input, unpaid labour input, total utilized agricultural area – UAA, UAA in owner-occupation, rented UAA, UAA structure – arable land, grassland, cereals, vineyards, permanent crops, set aside; livestock structure – male cattle, dairy cows, other cows, ewes, breeding sows, pigs for fattening, etc.); *costs* (total farming overheads, machinery and building current costs, energy, contract work, other direct inputs, depreciation, wages paid, rent paid, etc.); *subsidies* (total subsidies – excluding investments, total subsidies on crop, compensatory payments/area payments, total subsidies on livestock, environmental subsidies, LFA subsidies); *balance sheet* (total assets, total fixed assets, agricultural land, land, permanent crops and quotas, buildings, machinery, total liabilities); *income* (total output, gross farm income, family farm income, farm net value added) and f*inancial indicators* (net worth, change in net worth, gross investments, net investments).

The Farm Accountancy Data Network (FADN) database (in the maintenance of the Institute for Agrarian and Foodstuff Economic in Slovakia) as the "main" data source has been recommended to obtain data at farm level. As these data are not accessible in Slovakia, FSC dataset has been utilized as data source. There is a limiting factor – FSC does not contain all data items monitored in FADN and thus not all of required data (especially data related to balance sheet, income and financial indicators) have been obtained and provided to AgriPoliS modelers. The missing data have been refilled later, with the modelers help and their access to FADN database on the base of international cooperation with FADN data providers.

Data related to region production activities

AgriPoliS requires data related to regional production activities in aggregated form. These data inputs allow AgriPoliS to simulate dynamic side of agricultural production (the investing in farming activities) and they are related to one financial year.

Required data are represented by following inputs: *plant production activities* (gross margin, total variable costs, total labour demand, variable costs bounded during the production period, revenue, premium – all indicators recounted per individual crops); *livestock production activities* (the same indicators per individual livestock categories), *animal stables* (investment costs, useful life, capacity, work time for one entity (animal) per year); *set of investments* (for machinery categories in respect to farm area and for livestock categories in respect of livestock number on individual farms); *additional activities*, *annual maintenance cost; land rent; capital* (short-term and long-term borrowed capital, short-term equity capital); *cost and revenue* (derived for 1 ha of wheat, 1 ha of intensive grassland, 1 pig and 1 dairy cow); *crop rotation, average labour hours per year*.

A part of required data (related to the set of investments) for Piešťany region has been substituted by accessible data from Nitra region (data accessible to AgroPoliS modelers from another project). The leaving part of required data has been provided and derived by MODAM database (especially the economic coefficients of production activities) in aggregated form.

The Aspect of the Agricultural Production Modelling at the Farm Level (The Farms and their Production Techniques in Economical and Ecological Environment)

MODAM utilization in the MEA-Scope aims to evaluate the agricultural production from the economic and ecological point of view at farm level. The basic MODAM principle resides in simulation of representative farming systems in the study region expressed by hierarchical modules with detail descriptions of farms production practices (in plant and livestock branch as well), economic and ecologic evaluation of production alternatives (costs, farm machinery, energy consumption, etc.) with the aim to generate linear programming farm models for integrated economic-ecological production analysis under the different conditions (policies).

Data Related to Region – Specific Production Activities – Detailed Description

In generally, the farm agriculture production has to be characterized with standardized or surveyed crop and livestock practices, farm-specific information on capacities, site-specific information (soil quality, soil production potencial, etc.) and scenario-specific information (subsidies, premiums, etc.). For crop and fodder production required detail data on different cropping practices have been collected. Crop production practices are represented with individual operations as tillage, sowing, fertiliser, pesticide or other protection matter application, weeding, irrigation or harvesting. Description of these operations *work-steps* (number and frequency of work step practices); *timing* (year of step carrying out, year of harvest/cash return, time span); *machinery* (technical equipment, used machinery); *inputs and outputs* (number and amount of input/output transported to the field, application of different matter – pesticides, etc., labour, type of product yield) has been carried for all planted crops. For livestock production, detailed data on animal husbandry system have been collected. Livestock production practices have been aggregated into production units as milk production, production of pork, chicken, horses, sheep and other according the regional particularities. Data related to *herd size* (actual number of animals, technical size of stables – capacity); *animal housing system* (feeding system, manure system, milking system); *grazing period*; *labour*; *replacement system* (calves, heifers and bulls); *feeding needs* (energy, protein, roughage, etc.) and *yield class* (breeding, fattening) describe the animal husbandry system. General data have been collected at the level of livestock branches (for example dairy cattle, fattening pigs, etc.) and detail data relate to animal groups (for example dairy cows, heifers, piglet breeding, etc.).

As it has been not possible to collect relevant data from existing agricultural data sources, the questionnaires has been prepared (according to MODAM requirements) and consequently applied in the interview form on selected farms in Piešťany region. The typical farms selection, both for crop and livestock production description, has been based on fixed criterions – the production orientation (farm type according to FADN classification), organic or conventional production, production level (high, low, medium) and different site conditions (soil type, climate and altitude). In Piešťany region three representative farms have been polled. Initially our effort has been to apply questionnaires on more farms. Some problems have occurred in the communication with the farms' deputies related to their busyness or no-kindliness to participate in the MEA-Scope project.

Data Related to Environmental Impact Assessment (EIA)

The environmental impact assessment module is included in the MODAM. This module deals with *abiotic sub-modules* (risk of nitrate leaching to ground water, risk of nutrient entries into surface waters, risk of pesticide entries to ground water and surface waters, ground water recharge potential and risk of water erosion) and *biotic sub-modules* (impact on the habitat potential for skylarks, field hares, amphibians, hover flies or for wild flora species). At present, there are several additional assessment modules under consideration (green house emissions, wind erosion, soil organic matter content, etc.). Implementation of assessment modules in the MEA-Scope at regional level (Piešťany region) required detailed data related to *production practices* (operations / work-steps specification, timing, type of machinery used, type and quantification of inputs); *site characteristics* (soil type/fertility, biotope/habitat type, site-specific sensitivities) and *indicator-related information* (time-dependent sensitivities as breeding, migration period, habitat requirements, sensitivity to operations such as risk to be disturbed or killed, sensitivity to inputs like toxic effect of pesticides).

Amount of required data (related to production practices) for Piešťany region has been provided and derived by the MODAM database. Site-specific data on Piešťany region (for example DEM, land-cover, land-use, soil characteristic, soil production potential, LPIS – the farms with agricultural production, etc.) have been obtained from national GIS databases, pre-processed according to the MEA-Scope requirements and provided to modelers. The rest of required data (indicator-related data) has been collected especially on the base of existing literature knowledge and expert knowledge.

The Aspect of Agricultural Production Modelling at Farm and Field Level – The Simulation of Production and Individual Processess (Matter Flows)

As data required by FASSET are available from the MODAM (MODAM outputs) or from other publicly available datasets (daily weather data from MARS weather databases and detailed data related to soil properties from JRC soil datasets) there have been no requirements on regional or farm scaled data to be pre-processed and provided for Piešťany region.

CONCLUSIONS

The key objective of the MEA-Scope is to develop a tool that allows interactions between multifuncionality in agriculture and policy instruments (CAP reforms) at farm and regional level to be simulated. The MEA-Scope approach resides on linking of three existing independent simulation models (AgriPoliS, MODAM and FASSET) originally developed to cover different complementary aspects relevant in the multifunctionality impact assessment. The "new" model aims to express different environmental, economic, social aspects of agriculture multifunctionality and land – used at a different scale.

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CROP YIELD FORECASTING IN 2005 – THE ESTIMATES AND THE REALITY COMPARISON

ODHAD ÚROD POĽNOHOSPODÁRSKYCH PLODÍN V R. 2005 – POROVNANIE VÝSLEDKOV ODHADU A REÁLNE DOSIAHNUTÝCH ÚROD

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ABSTRACT

Several institutes in Slovakia carry out the crop yield and production forecasting during the vegetation period, possibly immediately before the crop harvest. This fact represents a response on increased interest and demand on the results of crop yield estimates from the side of Ministry of Agriculture SR and individual farmers as well. The crop yield estimates based on various methods also offer the possibility to monitor estimates level and retrospectively compare them to achieved crop yield. The estimates accuracy is significant and important crop yield estimating parameter, which determines the estimates reliability and their serious utilization in large measure.

As the comparison of the crop yield estimates carried out by the Soil Science and Conservation Research Institute in 2005 and real reached crop yield values refers to relatively marked differences. The submitted article attends to refer and partially explain the results of accuracy analysis related to 2005 campaign crop yield estimates. The variances (value defined in t/ha, % respectively) between the winter wheat, spring barley, oil seed rape, grain maize, sugar beet, sunflower and potatoes estimates (calculated in July and October 2005) and their real achieved crop yield in 2005 agricultural season (published by Statistical Office of SR) were determined.

Keywords: crop yield estimates, remotes sensing, NDVI, DMP, biophysical model, WOFOST, TAGP, TWSO, estimates accuracy, estimates reliability

ABSTRAKT

Priebežný odhad úrod a produkcie poľnohospodárskych plodín počas vegetačného obdobia, prípadne v jeho záverečnej fáze – tesne pred žatvou, realizuje v rámci Slovenskej republiky viacero inštitúcií. Snaha o čo najpresnejšie predpovedanie očakávanej úrody je výsledkom zvyšujúceho sa záujmu o výsledky týchto analýz, a to ako zo strany Ministerstva pôdohospodárstva SR, tak aj zo strany jednotlivých poľnohospodárskych subjektov či jednotlivých poľnohospodárov (farmárov). Výsledky viacerých odhadov úrod, vychádzajúcich z použitia rozdielnych metód, poskytujú priestor pre sledovanie a vzájomné porovnávanie úrovne stanovených odhadov a zároveň umožňujú spätné porovnanie a kontrolu výsledkov priebežných odhadov s reálne dosiahnutými úrodami poľnohospodárskych plodín. Presnosť odhadov úrod predstavuje základný ukazovateľ dôveryhodnosti, hodnovernosti odhadov úrod a do veľkej miery určuje možnosti ich následného využitia v praxi.

Predkladaný príspevok sa venuje stanoveniu presnosti odhadov úrod hlavných poľnohospodárskych plodín (pšenica ozimná, jačmeň jarný, repka olejná ozimná, kukurica na zrno, cukrová repa technická, slnečnica ročná a zemiaky) realizovaných v roku 2005 Výskumným ústavom pôdoznalectva a ochrany pôdy v porovnaní s definitívnymi výsledkami úrody plodín (publikovanými Štatistickým úradom SR).

Kľúčové slová: odhad úrod, diaľkový prieskum zeme, NDVI, DMP, biofyzikálny model, WOFOST, TAGP, TWSO, hodnovernosť odhadov, presnosť odhadov

INTRODUCTION

Several institutes in Slovakia carry out the crop yield and production estimates during the vegetation period, possibly immediately before the crop harvest. The yield estimates provided by Statistical Office of Slovak Republic (SO SR) are based on the mathematical and statistical methods application. Research Institute of Plant Production forecasts the crop yield on the base of field research results (observations on selected plots oriented to determine the plant count, number of plant grain or their weight on the area of 1 square meter) and consequent recount.

Based on methodology introduced by JRC (Genovese, Bettio 2004; Lazar, Genovese 2004; Micale, Genovese 2004; Royer, Genovese, 2004 and JRC projects – MARS-Monitoring Agriculture with Remote Sensing (http://agrifish.jrc.it) and MCYFS-Mars Crop Yield Forecasting System (http://agrifish.jrc.it/marsstat/Crop_Yield_-Forecasting/cgms.htm)), the Crop Yield and Production Forecasting System at Soil Science and Conservation Research Institute (SSCRI) has been created.

The objective of the Crop Yield Forecasting System at the SSCRI is to provide the most likely, precise, accurate, scientific and independent yield forecasts for the main crops. The system consists of:

- trend analysis of really achieved crop yield data (from 1997 to 2004) on NUTS 4 level (counties);
- regression analysis of derived and simulated vegetation indicators and real achieved crop yield in historical series, and yield forecast (on NUTS 4 level);
- crop yield forecasting based on regression analysis on vegetation indicators data and real achieved crop yield in historical series and on derived or simulated vegetation indicators in actual agricultural season (on NUTS 4 level);
- crop yield estimates data aggregation - recount NUTS 2 data on NUTS 3 and NUTS 0 units level.

The process of crop yield forecasting at the SSCRI is based on the results of:

1. crop yield estimation based on Remote Sensing methods utilization (low resolution satellite systems as a data source) and statistical analysis of derived vegetation indicator (Scholtz, 2005; Scholtz, Nováková, 2004);
2. crop yield estimation based on WOFOST agro-meteorological model utilization and statistical analysis of simulated vegetation indicators (Nováková, 2005; Scholtz, Nováková 2004).

In 2005, for the first time the crop yield forecasting was carried out by application of both above mentioned methods on the level of NUTS 4 (counties administrative units) (Sviček et al., 2005a, b). The NUTS 4 represents official, spatial and statistical units for crop yield register. This fact enabled crop yield estimates to be compared to the real achieved crop yields in 2005 as well. In this way, the estimates accuracy and reliability was specified, although on the base of one year results.

MATERIAL AND METHODS

Vegetation Indicators

As it was mentioned, the crop yield and production forecasting system at SSCRI is based on two different methods utilization presented by two methods for selected vegetation indicators determination. Derived or simulated vegetation indicators present the base and core data for consequent analysis.

The Remote Sensing methods utilization is based on Normalized Difference Vegetation Index (NDVI) derivation and its consequent analysis. The NDVI represents vegetation stage and growth indicator, specifically a measure of the amount and vigor of vegetation at the ground surface. The NDVI value relates to the level of photosynthesis activity (amount of chlorophyll as indicator) in the observed vegetation (for detail see Royer et al., 2004).

In the 2005 as NDVI data source satellite images from Advanced Very High Resolution Radiometer (AVHRR) sensor of National Oceanic and Atmospheric Administration (NOAA) satellites system were used. These satellites represent group of Low Resolution (LR) satellites characterized by large field of view (wide width scenes) and they scan the whole Earth's surface every day. Disadvantage of these satellites is a low spatial resolution – the pixel size is 1 km^2 (Royer et al., 2004). As the plant development is not so dynamic and daily acquired data represent redundant data, the maximum value composite (MVC) derived for decades is used.

Biophysical and agrometeorological modelling is based on the idea of crop phenological development, growth and production formation from its emergence till maturity, which notably depends on the crop genetic and physiological properties and environmental conditions. At the SSCRI, in the process of crop yield forecasting the WOFOST model was used as well. Weather data, rainfall data and phenological data (obtained from Slovak Hydrometeorological Institute) from 69 weather station localised across the Slovakia, soil data prepared on the base of data from Digital Database of Selected Soil Profiles of General Agricultural Soil Survey of Slovakia, and crop data – WOFOST default European crop files were used to simulate crop (biomass) growth (for WOFOST data requirements and WOFOST theory (see Boogaard at al., 1998; Supit, Goot, 2003). Two vegetation indicators were simulated and used for consequent analysis: TAGP (Total Above Ground Production) and TWSO (Total Dry Weight of Storage Organs).

Crop yield estimates accuracy in 2005

The estimates accuracy was defined as a variance between the crop yield prediction determined by the Remote Sensing Methods utilization (forecast based on NDVI data) or the WOFOST simulations (TAGP or TWSO vegetation indicators) in 2005 and real (official) crop yield data in 2005 (published by Statistical Office of SR). The variances (value defined in t/ha and in %) for the winter wheat, spring barley, oil seed rape, grain maize, sugar beet, sunflower and potatoes estimates were calculated.

RESULTS AND DICSUSION

The comparison of estimated crop yields achieved by SSCRI and real crop yield values refers to relatively variable differences (Tables 1 – 7). These tables present results of the last estimates carried out during the agricultural season in 2005 (the last of three crop yield estimates for winter wheat, spring barley and oil seed rape was carried out in July 2005; the last of three crop yield estimates for grain maize, sugar beet, sunflower and potatoes was carried out in October 2005).

The comparison of the crop yield estimates derived by the Remote Sensing and WOFOST

The presented tables (the crop yield estimates) refer to acceptable differences between the crop yield estimates derived by the Remote Sensing and WOFOST (from 0 % to 7.37 %, namely 0 % in the case of grain maize yield estimates; 1.31 % in the case of sugar beet; 2.44 % in the case of oil seed rape; 2.87 % in the case of potatoes; 4.1 % in the case of sunflower; 5.76 % in the case of winter wheat and 7.37 % in the case of spring barley crop yield prediction). The relatively low differences prove the fact that both methods reflect the same trend in the biomass stage and development as a crop yield and production indicator. As well, the presented results support Remote Sensing methods and WOFOST utilization in the SSCRI System of Crop Yield Forecasting.

The variances between the crop yield estimates derived by the Remote Sensing and WOFOST (Tables 1 – 7) follow mainly from different methods for vegetations indicators derivation (or simulation). The NDVI as the vegetation indicator derived from the images (Remote Sensing) reflects the vegetation stage as its immediate response on actual weather conditions. TAGP and TWSO vegetation indicators, which are simulated by the WOFOST represent vegetation stage simulated retrospectively with a time delay (time span) caused by weather data pre-processing. Besides, the NDVI represents vegetation indicator that relates biomass as a whole. Meanwhile TAGP and TWSO vegetation indicators are simulated for individual crops. Both methods disadvantages include the problem of not reflecting the extreme situation in vegetation development, as well as for example crop freezing and ground frost appearance at the beginning of a vegetation period or the crop damage by hailstorms.

The Comparison Between the Crop Yield Estimates and Real Crop Yields in 2005

The results of the comparison between the crops yield estimates and real crop yields in 2005 (presented in Tables 1 – 7) enabled crops to be characterized and consequently grouped into several groups with different estimates accuracy:

a) The cereals (winter wheat – Table 1 and spring barley – Table 2) and potatoes (Table 7) are characterized with the most accurate estimates in 2005. The differences between the yield estimates and the real crop yields are lower than 10 % (they range between 0.6 % in the case of spring barley and 8.5 % in the winter wheat case) at the level of the NUTS 0. Lower differences were noticed for the estimates derived by the WOFOST utilization. The differences between the yield estimates and the real crop yields at the NUTS 3 level demonstrate more considerable fluctuation trend. The differences often range from 0 to 10 %, less 15 %; in the case of potatoes they range from 10 to 22 % (the extreme noticed value 31 %).

b) The sunflower (Table 6) and rape oil seed (Table 3) are characterized with the relatively accurate estimates in 2005. The differences between the yield estimates and the real crop yields frequently fluctuate around 10 % at the level of the NUTS 0 and lower differences were noticed for the estimates derived by the Remote Sensing methods utilization. At the NUTS 3 level, the differences between yield estimates and reached crop yields in 2005 are characterized with relatively high variances (frequently over 15 – 20 %).

c) The sugar beet (Table 5) and grain maize (Table 4) yield estimates in the comparison with the real crop yields at the NUTS 0 level show the highest differences – nearly 20 %. The same fact is valid for differences between crop yield estimates and really reached crop yields at the NUTS 3 level.

Table 1 Comparisons of winter wheat yield estimates and really reached yield in 2005

Region	WINTER WHEAT						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	4.36	4.22	-0.14	-3.2	3.99	-0.37	-8.5
BA kraj	4.10	4.20	0.10	2.4	3.83	-0.27	-6.6
TT kraj	4.73	4.73	0.00	0.0	4.45	-0.28	-5.9
TN kraj	4.41	4.09	-0.32	-7.3	4.11	-0.30	-6.8
NI kraj	4.85	4.61	-0.24	-4.9	4.37	-0.48	-9.9
ZA kraj	3.36	3.51	0.15	4.5	3.45	0.09	2.7
BB kraj	3.70	3.52	-0.18	-4.9	3.17	-0.53	-14.3
PO kraj	3.18	3.07	-0.11	-3.5	3.08	-0.10	-3.1
KE kraj	3.99	3.79	-0.20	-5.0	3.39	-0.60	-15.0

Table 2 Comparisons of spring barley yield estimates and really reached yield in 2005

Region	SPRING BARLEY						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	**3.62**	**3.64**	**0.02**	**0.6**	**3.39**	**-0.23**	**-6.4**
BA kraj	3.44	3.53	0.09	2.6	3.22	-0.22	-6.4
TT kraj	4.29	4.22	-0.07	-1.6	3.92	-0.37	-8.6
TN kraj	3.50	3.69	0.19	5.4	3.62	0.12	3.4
NI kraj	4.22	4.06	-0.16	-3.8	3.86	-0.36	-8.5
ZA kraj	2.40	2.88	0.48	20.0	2.98	0.58	24.2
BB kraj	2.48	2.83	0.35	14.1	2.34	-0.14	-5.6
PO kraj	2.49	2.76	0.27	10.8	2.62	0.13	5.2
KE kraj	2.62	2.96	0.34	13.0	2.55	-0.07	-2.7

Table 3 Comparisons of oil seed rape yield estimates and really reached yield in 2005

Region	OIL SEED RAPE						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	**2.27**	**2.00**	**-0.27**	**-11.9**	**2.05**	**-0.22**	**-9.7**
BA kraj	*	1.99	**	**	1.86	**	**
TT kraj	*	2.15	**	**	2.22	**	**
TN kraj	2.57	2.20	-0.37	-14.4	2.19	-0.38	-14.8
NI kraj	2.33	2.12	-0.21	-9.0	2.13	-0.20	-8.6
ZA kraj	2.35	1.82	-0.53	-22.6	2.10	-0.25	-10.6
BB kraj	2.06	1.73	-0.33	-16.0	1.83	-0.23	-11.2
PO kraj	1.92	1.93	0.01	0.5	1.90	-0.02	-1.0
KE kraj	2.30	1.99	-0.31	-13.5	1.89	-0.41	-17.8

Note: ***** – data are not available; ****** – it is not possible to derive data

Table 4 Comparisons of grain maize yield estimates and really reached yield in 2005

Region	GRAIN MAIZE						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	**6.97**	**5.71**	**-1.26**	**-18.1**	**5.71**	**-1.26**	**-18.1**
BA kraj	6.24	5.11	-1.13	-18.1	4.58	-1.66	-26.6
TT kraj	7.35	5.89	-1.46	-19.9	5.84	-1.51	-20.5
TN kraj	6.60	5.57	-1.03	-15.6	5.15	-1.45	-21.9
NI kraj	7.65	6.22	-1.43	-18.7	6.38	-1.27	-16.6
ZA kraj	5.06	3.98	-1.08	-21.3	**	**	**
BB kraj	5.49	4.42	-1.07	-19.5	4.10	-1.39	-25.3
PO kraj	3.94	5.10	1.16	29.4	5.40	1.46	37.1
KE kraj	4.56	4.46	-0.10	-2.2	4.75	0.19	4.2

Note: ***** – data are not available; ****** – it is not possible to derive data

Table 5 Comparisons of sugar beet yield estimates and really reached yield in 2005

Region	SUGAR BEET						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	**52.16**	**41.50**	**-10.66**	**- 20.4**	**42.05**	**-10.11**	**-19.4**
BA kraj	57.49	41.45	-16.04	-27.9	39.84	-17.65	-30.7
TT kraj	50.28	41.98	-8.30	-16.5	41.97	-8.31	-16.5
TN kraj	50.91	43.79	-7.12	-14.0	42.78	-8.13	-16.0
NI kraj	54.36	41.49	-12.87	-23.7	43.10	-11.26	-20.7
ZA kraj	*	**	**	**	*	**	**
BB kraj	47.94	29.79	-18.15	-37.9	32.18	-15.76	-32.9
PO kraj	*	**	**	**	*	**	**
KE kraj	*	30.46	**	**	32.95	**	**

Note: ***** – data are not available; ****** – it is not possible to derive data

Table 6 Comparisons of sunflower yield estimates and really reached yield in 2005

Region	SUNFLOWER						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	2.14	1.87	-0.27	-12.6	1.95	**-0.19**	**-8.9**
BA kraj	2.33	1.97	-0.36	-15.5	1.74	-0.59	-25.3
TT kraj	2.51	2.09	-0.42	-16.7	2.27	-0.24	-9.6
TN kraj	2.12	2.19	0.07	3.3	2.09	-0.03	-1.4
NI kraj	2.37	1.92	-0.45	-19.0	2.19	-0.18	-7.6
ZA kraj	1.52	**	**	**	**	**	**
BB kraj	1.71	1.37	-0.34	-19.9	1.29	-0.42	-24.6
PO kraj	1.39	1.42	0.03	2.2	2.25	0.86	61.9
KE kraj	1.39	1.70	0.31	22.3	1.29	-0.10	-7.2

Note: ***** – data are not available; ****** – it is not possible to derive data

Table 7 Comparisons of potatoes yield estimates and really reached yield in 2005

Region	POTATOES						
	Yield (2005) (t/ha)	WOFOST			REMOTE SENSING		
		Yield estimate	difference		Yield estimate	difference	
			t/ha	%		t/ha	%
SR	**15.77**	**15.93**	**0.16**	**1.0**	**16.40**	**0.63**	**4.0**
BA kraj	27.72	21.82	-5.90	-21.3	22.74	-4.98	-18.0
TT kraj	26.15	17.82	-8.33	-31.9	20.83	-5.32	-20.3
TN kraj	16.01	16.90	0.89	5.6	17.67	1.66	10.4
NI kraj	19.66	17.77	-1.89	-9.6	17.90	-1.76	-9.0
ZA kraj	14.29	16.69	2.40	16.8	16.49	2.20	15.4
BB kraj	13.65	14.37	0.72	5.3	15.44	1.79	13.1
PO kraj	12.44	15.13	2.69	21.6	14.52	2.08	16.7
KE kraj	14.02	12.98	-1.04	-7.4	14.64	0.62	4.4

Presented differences between predicted crop yields and really reached crop yields in 2005 (Tables 1 – 7) are mainly caused by the utilized methods limitations and input data limitations as well.

The limitations of the methods utilized in the crop yield forecasting – the process of forecasting represent only selected technique utilization for reality simulation. Results differences (in comparison to reality) are simulation's undesirable side effect. In order to reduce the results differences, it is important to make an effort to completely calibrate the WOFOST model at the conditions of Slovakia, to deal with input data accessibility, consistence and adequate spatial resolution as well.

Input data limitations, namely statistical data inconsistence related to planted area and real crop yields at NUTS 4 level (which presents the base data for the crop yield estimations and for the process of data aggregation and up-scaling to NUTS 3 and NUTS 0 level as well), represent important problem. The most problematic are the NUTS 4 data related to planted area in counties where selected crops are planted on relatively small area. These data utilization would cause estimates garbles and considerable generalizations.

CONCLUSIONS

The comparison between the crop yield estimates and the real crop yields in 2005 refers to following conclusions:

The cereals and potatoes are characterized with the most accurate estimates. The differences between the yield estimates and the real crop yields were lower than 10 % (0.6 % spring barley and 8.5 % winter wheat) at the NUTS 0 level; the differences at the NUTS 3 level noticed fluctuation trend (0 – 10 %, fewer 15 %; in the case of potatoes 10 – 22 %, the extreme difference 31 %).

The sunflower and rape oil seed are characterized with the relatively accurate estimates in 2005. The differences between the yield estimates and really reached crop yields fluctuated around the 10 % at the level of the NUTS 0; at the NUTS 3 level relatively high variances (frequently over 15 – 20 %) were marked.

The sugar beet and grain maize are characterized with the highest differences between the yield estimates and the real crop yields at the NUTS 0 level (nearly 20 %). The same trend (high differences) was marked between the crop yield estimates and the real crop yields at the NUTS 3 level.

As presented results are based on the observations regarding only to one agricultural season (2005) and considering the annual weather variability (differences between the vegetation seasons from the weather character point of view), it is necessary to verify derived conclusions (with the results of several years at least) in order to test their long-term accuracy and reliability. Besides very important is to deal with known limitations of methods and data utilized in the Crop Yield Forecasting System at the SSCRI with the aim to reduce estimates garbles and considerable generalizations if possible.

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SOIL SCIENCE AND CONSERVATION RESEARCH INSTITUTE (SSCRI) ACTIVITIES IN THE FIELD OF PRECISION FARMING

AKTIVITY VÝSKUMNÉHO ÚSTAVU PÔDOZNALECTVA A OCHRANY PÔDY (VÚPOP) V RÁMCI PROBLEMATIKY PRESNÉHO POĽNOHOSPODÁRSTVA

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ABSTRACT

The complex and local variable approach to the various agricultural activities represents the basic principle of Precision Farming techniques implementation and application into the common agricultural practices.

As agricultural activities are conditioned markedly by local (site specific) soil properties and local (site specific) soil variability, the requirement on detailed geo-referenced soil and landscape data as the essential input for the precise agriculture management has to be solved. The field of soil sampling and laboratory measurements related to soil properties determination represents traditional method in soil research. Their utilization is supplemented with methods based on remote sensing techniques (vegetation indexes, digital elevation models) or based on a non-destructive determining of soil and crop properties using electro-magnetic waves (soil electrical conductivity, chlorophyll contents) together with parallel GPS utilization. On the other hand, Precision Farming as a scientific and practical field includes amounts of problems related to agriculture production (plant production, animal production and their management), to information technologies (technologies for data collection, interpolation and visualization of data, etc.), as well as to statistical and geo-statistical assessment (spatial variability, spatial analyses, etc.).

Soil Science and Conservation Research Institute (SSCRI), as an institution responsible for the complex soil research in the Slovak Republic, accesses the problematic of the Precision Farming from the soils properties point of view. In 2005 SCCRI started with the Precision Farming issues in corporation with Agrodivízia Selice, Ltd. on the base of previous activities in this field. The activities related to relevant data collection (soil and landscape data from existing sources, field measurement), data pre-processing and data statistical or geo-statistical analyses with the aim to understand and formulate interactions between the crop production ability (crop yield) and environmental character (site specific landscape conditions).

KEYWORDS: Precision Farming, site-specific soil conditions, within-field variability, Remotes Sensing, GPS, NDVI, DEM, soil conductivity, crop yield, multiply regression

ABSTRAKT

Komplexný a priestorovo variabilný prístup k jednotlivým aktivitám poľnohospodárskej výroby predstavuje základný princíp precízneho (presného) hospodárenia na pôde, resp. základný princíp implementácie a aplikovania technológií precízneho hospodárenia na pôde do poľnohospodárskej praxe. Z dôvodu výraznej podmienenosti poľnohospodárskych aktivít lokálnou variabilitou pôd a variabilitou ich vlastností, sa do popredia dostáva požiadavka na získavanie detailných, priestorovo lokalizovaných údajov o pôde a krajine, ako základných, vstupných údajov pre potreby presného poľnohospodárstva. Odoberanie pôdnych vzoriek (v teréne) spolu s následnými laboratórnymi rozbormi pôdy, predstavuje tradičné a spoľahlivé metódy stanovenia pôdnych vlastnosti. V súčasnosti sú tieto časovo aj finančne náročné metódy doplňované metódami založenými na nedeštrukčnom stanovení pôdnych a rastlinných vlastností – elektromagnetickým žiarením (elektický odpor pôdy, stanovenie obsahu chlorofylu) a pomocou metód DPZ (vegetačné indexy, digitálny model terénu). Precízne hospodárenie, ako vedný odbor do výraznej miery prepojený s poľnohospodárslou praxou, však zahŕňa riešenie problémov ako z oblasti poľnohospodárskej výroby, z oblasti informačných technológií, ako aj z oblasti štatistického a geoštatistického spracovávania údajov.

Výskumný Ústav Pôdoznalectva a Ochrany Pôdy (VÚPOP), ako inštitúcia zodpovedná za komplexný pôdny výskum v Slovenskej Republike, pristupuje k problematike presného poľnohospodárstva z hľadiska vlastností pôdy a z hľadiska variability vlastností pôdy. Problematike precízneho hospodárenia sa VUPOP venuje od roku 2005 (spolupráca s poľnohospodárskym subjektom Agrodivízia Selice, s.r.o.. Aktivity VUPOP v rámci tejto spolupráce boli (a sú) zamerané na zber relevantných údajov o pôde a krajine (z existujúcich databáz a pôdnym prieskumom), na prípravu a prvotné spracovanie týchto údajov (základné analýzy údajov) a na ich štatistickú a geoštatistickú analýzu, s cieľom postihnúť, vysvetliť a vyjadriť vzťah medzi produkčnou schopnosťou pôdy (reprezentovanú dosiahnutou úrodou) a ostatnými pôdnymi parametrami, či inými, relevantnými parametrami krajiny.

KĽÚČOVÉ SLOVÁ: presné poľnohospodárstvo, lokálna priestorová variabilita pôd, variabilita v rámci parcely, diaľkový prieskum Zeme, GPS, DMR, konduktivita pôdy, úroda plodín, viacnásobná regresia

INTRODUCTION

Precision Farming represents the “response” on demand of new, more effective methods and technologies utilization in agriculture. The Precision Farming is based on application of local variable (site specific) farming systems operating on detail, spatial and site specific knowledge related to soil properties and environment. The aim of the Precision Farming is to enhance the agricultural production efficiency by decreasing the costs (inputs) with considerable environmental aspect.

SSCRI started with the activities in the field of Precision Farming in 2005. The activities in 2006 are realized on the base of contract with Ministry of Agriculture in Slovak Republic (MoA SR): Models elaboration and application of the Precise Farming combining GIS, Remote Sensing and field quantification.

In the submitted paper, an example of co-operation between SSCRI and agricultural subject – AgroDivízia Selice, Ltd. in the field of Precision Farming is discussed. The co-operation is focused on explanation of interactions between the crop production ability (crop yield) and environment characters (site specific conditions expressed with soil and landscape properties). Several work-steps as data acquiring (data collection from existing data sources or field measurement with GPS utilization), data pre-processing, geo-statistical and statistical analyses in

GIS, satellite images interpretation and others, were necessary to realize with the aim to explain the relations in the system of soil-crop-landscape (especially the relation of crop yield – soil or landscape parameters).

MATERIAL AND METHODS

Agrodivízia Selice, Ltd. represents an agricultural subject which farms in a region with the highest production level – Podunajská nížina lowland (the farm is located near the Šaľa town). The region is characterized with a warm and moderately dry climate. The farm lies at the river Váh left side (river flat and terraces form the relief conditions point of view) and Haplic Fluvisoils and Molic Fluvisoils (according to WRB98 nomenclature) represent dominant soil types. The farm has been transformed to a limited liability company with an agricultural production specialization in wheat, barley, grain maize and alfalfa production. Agrodivízia Selice, Ltd. makes an effort to apply precision farming methods on the whole utilized agricultural area, but the research (co-operation with SSCRI) focused only on selected parcels (4 parcels with area of 750 ha – Žihárec 0001/1, Šaľa 0902/1, Palárikovo 9001/1 and Jatov 9901/3, Figure 1) and several analyses were realized only on one parcel (Žihárec 0001/1 with area of 131 ha).

Data required for analyses were obtained from the following data owners and data – sources:

- SSCRI – soil related databases: LPIS (Land Parcel Identification System), PEU (Soil-ecological Units Database) and KPP (General Soil Survey of Agricultural Soil of Slovakia);
- SSCRI – satellite images appropriate for the vegetation indexes as NDVI (Normalized Difference Vegetation Index) and MSAVI2 (second Modified Soil Adjusted Vegetation Index) interpretation;
- SSCRI – field measurements carried out in 2005 - mechanical resistance of soil and actual soil humidity in 4 horizons (SVIČEK et al., 2005a,b);
- Agrodivízia Selice, Ltd. – soil electrical conductivity measured in 2005, at depth of 0.3m and 0-0.9m in soil horizons;
- Agrodivízia Selice, Ltd. – crop yield of spring barley and winter wheat collected by 2 harvesters (John Deere) fully equipped with the mapping system (including GPS) in 2005;
- Agrodivízia Selice, Ltd. – contents of soil nutrients (P, Mg, K and Ca), measured in 2005.

At first, collected data were analyzed from the accessibility, correctness, completeness or spatial resolution point of view and then pre-processed. After the basic control data were statistically analyzed with the aim to determine their interdependence and to specify measure of interdependence between individual parameters (correlations, regression analysis). Based on the results of the previous statistical analyses, regression equations (with crop yield as dependent variable and other parameters as independent variables) for each crop were derived separately. Finally, the site specific model for yield calculation based on the experimental data was constructed (by application the equations) (SVIČEK et al., 2005a, b).

RESULTS AND DISSCUSION

Data, their analyses and pre-processing

Data obtained from the SSCRI databases

As the LPIS (Land Parcel Identification System) exactly defines parcels identification and the parcels borders, it also represents the basic (essential) data layer for the Precision Farming (Figure 1). There is also an additional information linked to individual parcels – for example information on parcel area, Less Favorite Areas, Nitrate Directive, etc. (www.podnemapy.sk).

The soil data (data related to the soil properties) are accessible in several databases maintained by the SSCRI. The Soil-Ecological Units database (PEU) was built in 70-ties and is continuously actualized. The Soil-Ecological Units are characteristic by a numerical code, in which the information related to climatic region, soil type, slope, exposition, soil stoniness, soil depth and soil texture is coded (Linkeš et al., 1996; Džatko, 2002). Soil – Ecological Units Database is represented in form of digital georeferenced polygons (in S-JTSK coordinate system). The PEU utilization in the Precision Farming is limited because of data low spatial resolution and low representativeness (average soil data that represent polygons) (Figure 2a).

The database of General Soil Survey of Agricultural Soil of Slovakia contains the data related to the soil profiles properties (morphological, physical and chemical properties). Data as soil texture – clay contents and pH in topsoil and subsoil were used for geo-statistical analyses. The 34 soil profiles are localized on the selected parcels (Figure 2b). Data were interpolated by spline and kriging methods and visualized in a form of georeferenced spatial variability maps.

Figure 1 Localization and identification of selected parcels farmed by Agrodivízia Selice, Ltd.

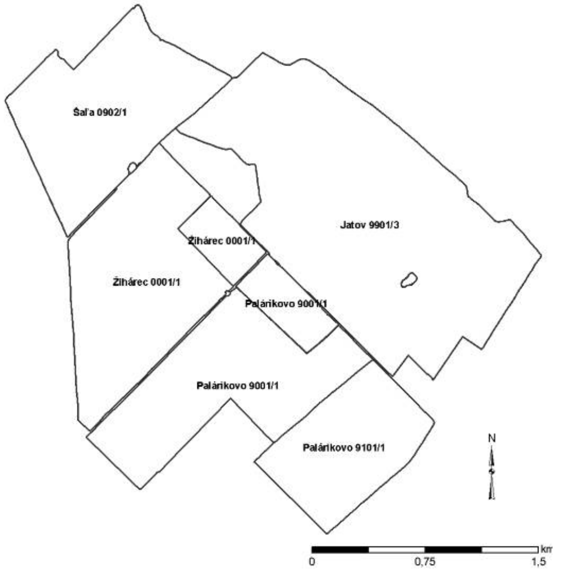
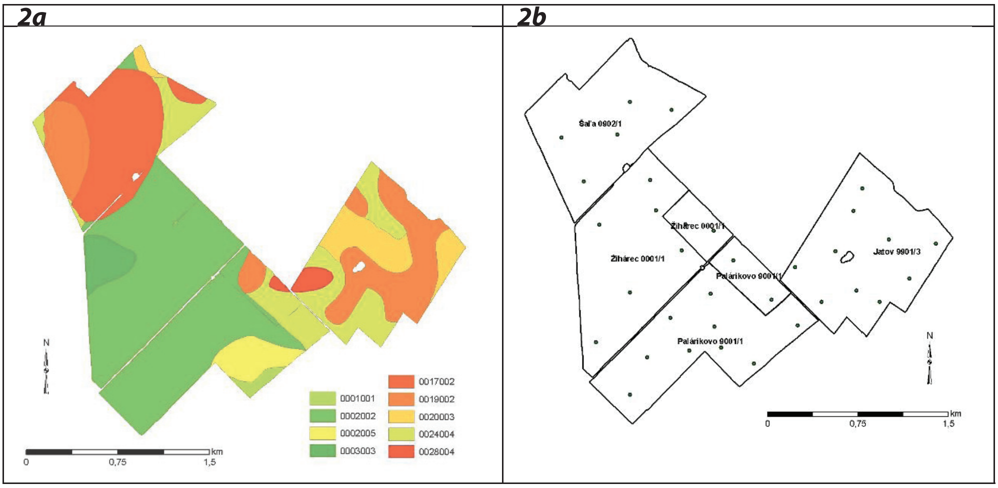


Figure 2 Map of Soil – Ecological Units (2a) and localization of Complex Soil Survey soil profiles (2b)



The field measurement of soil mechanical resistance (by pushing the cone of penetrologger probe into the soil) is used to detect compacted layers in soils (Zrubec, 1998). The measurement was realized on the base of soil conductivity zones on 86 places only at the parcel Žihárec 0001/1. Measured soil mechanical resistance was statistically processed as medians and averages from 10 measurements after elimination of extreme values (outliers). Consequently, the processed data were corrected by gravimetrically measured actual humidity. Soil mechanical resistance and also the data related to soil humidity were interpolated by the kriging method and visualized into the maps of georeferenced spatial variability (Figure 3a and 3b).

Figure 3 Spatial variability of soil mechanical resistance in the depth of 30 cm (3a) Soil humidity in the depth of 20 – 30 cm (3b)

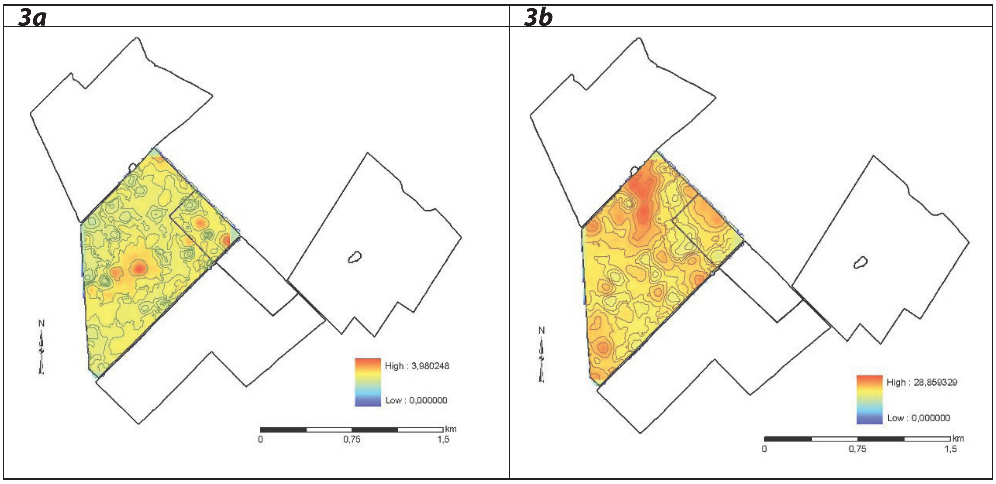
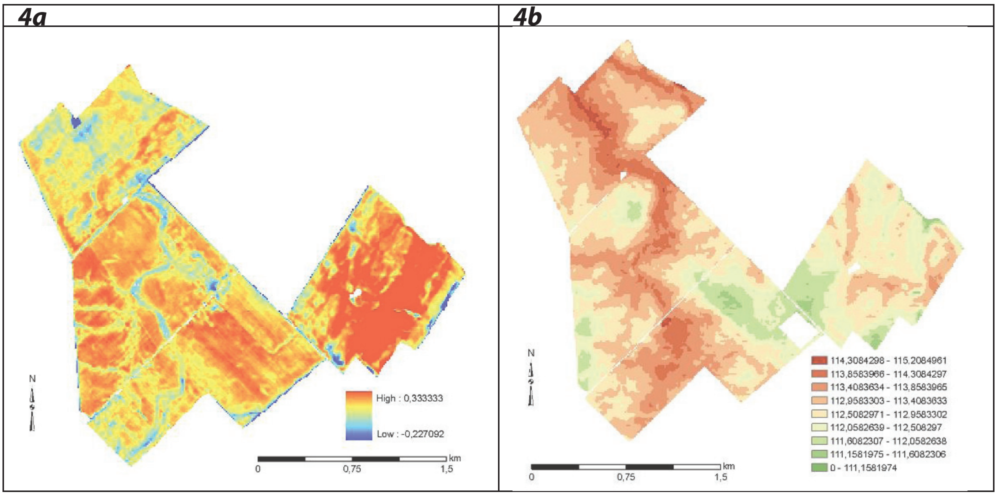


Figure 4 Map of NDVI from 17.06.2005 (4a) a DEM (4b)



From the Remote Sensing sources, the satellite images from several satellite systems were used. The vegetation indexes were interpreted from the obtained satellite images (Table 1). Vegetation indexes express the amount and vitality of vegetation on the Earth. The most frequently used is the Normalized Difference Vegetation Index (NDVI) (Figure 4a). The second used vegetation index was second Modified Soil Adjusted Vegetation Index (MSAI2). This index eliminates the soil background scattering (for more details see ROYER, GENOVESE, 2004; SANDHOLT et al., 2005; SCHOLTZ, 2005).

The important data layer for the Precision Farming is Digital Elevation Model (DEM). DEM represents appropriate input layer for statistical analyses (spatial resolution of 5 m – Figure 4b). Its importance resides in a possibility to analyze expectation and prediction of behavior and intensity of various landscape processes coherent to the relief character. Conditions of the soil and vegetation cover can be reconstructed with knowledge of the relief character as well.

Table 1 Summary of available satellite images

Date	Satellite	Resolution	Spectral channels	Date	Satellite	Resolution	Spectral channels
4.5.2002	Landsat 7	15 m	8	15.4.2004	Landsat 5	30 m	7
21.6.2002	Landsat 7	15 m	8	22.4.2004	SPOT 5	10 m	4
4.8.2002	IRS-1D	25 m	4	8.6.2004	SPOT 4	20 m	4
				21.7.2004	SPOT 2	20 m	3
21.3.2003	IRS-1C	25 m	5	4.8.2004	SPOT 5	3 m	PAN
6.5.2003	IRS-1D	25 m	4	5.8.2004	Landsat 5	30 m	7
7.5.2003	Landsat 7	15 m	8	9.8.2004	SPOT 5	3 m	PAN
6.6.2003	IRS-1C	25 m	4				
30.6.2003	IRS-1C	25 m	5	2.4.2005	Landsat 5	30 m	7
30.6.2003	SPOT 5	2.5 m	PAN	20.5.2005	Landsat 5	30 m	7
				17.6.2005	SPOT 5	10 m	4
				1.8.2005	IRS-P6	25 m	4

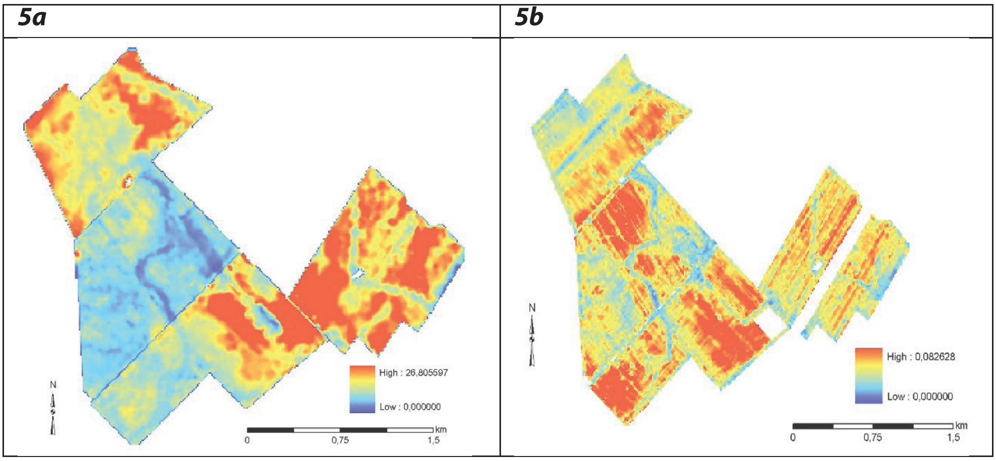
Data obtained from Agrodivízia Selice, Ltd.

Soil conductivity is the soil ability to conduct electrical current. The conductivity represents a "complex" soil parameter. Its value depends on amount of physical and chemical soil properties important from the soil production potential point of view (for example contents of soil organic matter, soil salinity, soil humidity, bulk density, temperature, etc.) (Šařec et al., 2002). Data were collected by the system dragged by tractor (VERIS principle) with the conductivity measuring at depth of 0.3 m and 0.9 m (in autumn 2004 and spring 2005). The soil conductivity data layer was represented by georeferenced points (in WGS-84 coordinate system) on 4 selected parcels. In the preprocessing, the data were converted into S-JTSK coordinate system and the kriging method was used to interpolate and visualize data (Figure 5a).

Real crop yield data (spring barley and winter wheat in 2005) were collected by 2 harvesters (John Deere) fully equipped with the mapping system (including GPS). The crop yield data layer was represented by georeferenced points (in WGS-84 coordinate system) on 4 selected parcels. In the preprocessing, the data were converted into S-JTSK coordinate system and kriging method was used for data interpolation and visualization (Figure 5b).

Soil sampling for pH and soil nutrients (P, K, Ca and Mg) determination was realized by a hydraulic sampler at 0 – 0.3 m depth according to zones created on the base of measured soil conductivity (in July 2005). One soil sample (consisting of 16 samples) was collected per zone. The soil analyzes for selected parameters were carried out by an accredited laboratory using Mehlich III method. Nutrient contents and pH data layers were represented by 28 georeferenced points (in WGS-84 coordinate system) on 1 selected parcel (Žihárec 0001/1). Data were converted into S-JTSK coordinate system in the preprocessing faze and visualized using kriging interpolation method.

Figure 5 Spatial variability of soil electrical conductivity in the depth of 30 cm (5a) and spatial variability of the wheat and barley yield (5b)


5a **5b**

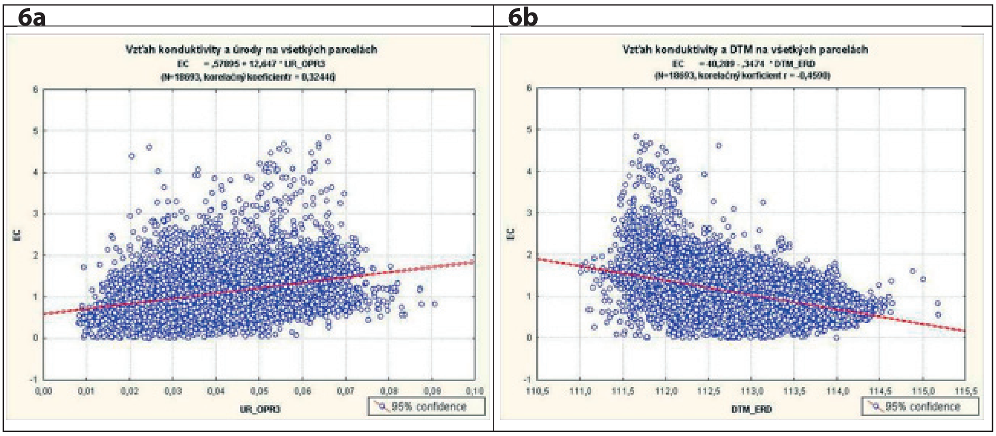
Statistical And Geostatistical Analyses

Data basic statistical analyses (deviation, minimum, maximum, outliers, average, median, modus, etc.) were carried out before the data preprocessing. The data analysis was necessary to get general overview of the data with the aim to prepare data for processing (elimination of outliers) and to select appropriate methods for data interpolation.

It is possible to visualize on the base of data absolute values (measured values) or on the base of the normalized data. The data normalization is appropriate process for the data "clear" spatial variability visualization and it is used mainly in cases when data are collected in different conditions (for example drought respectively wetness have big influence on measured data). In this case, the normalization base on the median was used for the crop yield and electric conductivity data visualization. The Figure 5a shows the results of data spatial variability interpolation (electric conductivity in the depth of 30 cm, and spring barley and winter wheat yield normalized to the parcel and crop median).

Correlation represents the rate of dependence between two or more variables. In the case of the data from Agrodivízia Selice, Ltd., the correlations between all parameters were specified at the farm level, as well at the parcel and crop level (Figure 6a, 6b).

Figure 6 The graphical representation of selected parameters correlation



The correlation coefficient could not be determined in the case of comparison on "non-comparable" data layers (for example yield and soil type or soil texture categories, where the yield is measured each 0.8 m and the soil texture represents the average value from area). In these cases, the „box-graphs" were used to graphically visualize and evaluate dependence between intervals of the parameters. Based on the graphs interpretations, we concluded that there is considerable variability in the dependence between the yield and the soil parameters (obtained from the soil-ecological unit database).

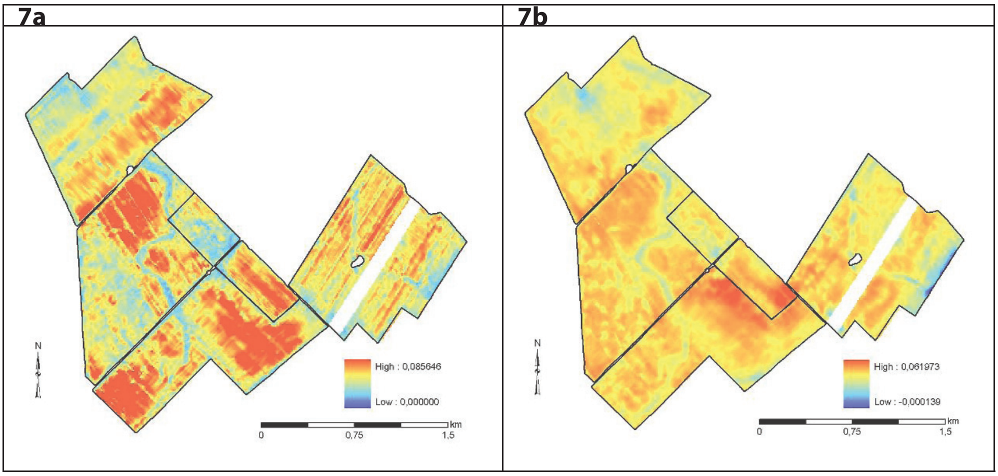
Based on the results, it is clear that the there are significant relations between several parameters minimally at the farm level, as well as at parcel (field) level. However, there is also assumption that specified relations will be significant even at other locations (farms, parcels) in different conditions (it should be verified by a further research).

The method of multiply regression enables to quantify interrelations between a lot of variables at the farm, respectively at a parcel level. On the base of the multiply regression results, it is evident that relations and the rate of dependence above mentioned parameters is noticeable spatial variable. The correlation coefficients of equal parameters as well as the structure of relations (different pairs of parameters have greater correlation coefficient) differ not only between the different parcels, but also between parcels with the same crop as well. Multiple regressions were applied on several parameters in all the parcels and at more input parameters on the selected parcel (Žihárec 0001/1) on which the soil analyses for pH and soil nutrient, measurements of mechanical resistance and soil humidity were carried out.

After the determination of crop yield as dependence variable (independence variables – the rest input parameters) the usage of multiply regression method allows to specify the regression equation – the linear relation between yield and other parameters. The regression equations were determined for all the parcels (individually), for each crop (spring barley and winter wheat) and for the whole Agrodivízia Selice, Ltd. farm (for 4 selected parcels). Then, the crop yield models were created (on the base of regression equations application) and they were consequently tested on several parcels (Figure 7).

The results of the data of statistical and geostatistical analyses test (verification) possibilities, methods and accuracy specified for a model of production conditions and crop yield within the field spatial variability. It is necessary to focus on the input data quality with the aim to improve credibility of generated and visualized models. At the same time it is also necessary to deal with the various methods utilization in data processing (we have used only one of the available methods for model creation from experimental data – the method of multiply linear regression).

Figure 7 Comparison of measured (7a) and modeled (7b) crop yield on selected parcels



CONCLUSIONS

The SSCRI activities in the field of the Precision Farming (the corporation with the Agrodivízia Selice, Ltd.) mainly focused on analyses of available data utilization for the Precision Farming purposes, as well as on analyses related to possibilities of specifying and formulating relations between selected parameters and analyses of data processing possibilities in the case when relations and their rates are know. On the base of the above mentioned analyses results, carried out on Agrodivizia Selice, Ltd., it is possible to note (or to consider) and to summarize that:

- the main factor that determines within-field variability of a crop yield and crop production is the elevation, actually the groundwater depth (confirmed assumption);
- there exist relevant relations between selected parameters (soil conductivity, NDVI, configuration of the terrain – DEM) and crop yield;
- on the base of specified and quantified relations and through statistical and geostatistical methods utilization on input soil and landscape data, it is possible to create a model of reality (the model of real crop yield);
- the specified relations are valid minimally at selected farm and parcels level but with a high assumption of universal validity (in modified form) in different conditions (this consideration has to be analyzed in the future).

Besides, there are several considerations related to the input data quality and results for the Precision Farming:

- the satellite images with 10 m and more spatial resolution seem to be the most appropriate primary source for mapping of crop yield and crop production of within-field spatial variability (advantage – multispectral satellite images cover large areas near-realtime – about 100 eventually 1 000 km^2, disadvantage- the price);
- utilization of the systems for soil electrical conductivity mapping, eventually the systems for crop yield mapping implemented on harvesters seem to be the most appropriate for detailed identification of productive zones inside the parcels;
- there is a problem to unambiguously consider and explain a dominant factor (or parameter) that determines crop yield of within-field spatial variability inside the production zones – this would be determined only in the field (on the base of terrain conditions, field and consequently laboratory measurement);
- It is possible to carry out soil sampling not only in the regular grid but also on the base of production zones (intelligent raster) (advantage – the georeferenced data allow precise localization on the parcels and precise survey with adequate GPS equipment)
- it is possible to prepare application maps for requested variable technologies (for example seeding or fertilization, etc.) on the base of data analyses and data processing with the aim to find the way for more effective crop production and ecological production as well.

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MULTISCALE EUROPEAN SOIL INFORMATION SYSTEM I. – PROJECT BACKGROUND AND BASIC PRINCIPLES

VIACÚROVŇOVÝ INFORMAČNÝ SYSTÉM O PÔDACH EURÓPY I. – VÝCHODISKÁ A ZÁKLADNÉ PRINCÍPY

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ABSTRACT

In 2005 – 2006 period Soil Science and Conservation Research Institute, Bratislava participated as the national expert in project for pilot application of methodology to develop Multi-scale European Soil Information System (MEUSIS-SK : MEUSIS in Slovakia). In presented article, project background and basic principles are described to make one more insight in to problems of soil information in Europe, as well as the need for new harmonised soil information system is defined. General definition of the Multi-scale European Soil Information System and some related political issues (activities and important documents) are addressed in the first part of the article. In the second one, state-of-the-art in the area of soil information across the Europe is briefly described. Main problems of applicability and quality of available information on soil are identified both at European and national level. In the last part of the article, basic methodological principles of Multi-scale European Soil Information System are described and some important methodological and technical aspects of the system are introduced.

Keywords: multi-scale soil information system, spatial data harmonisation, soil data, soil information

ABSTRAKT

V období rokov 2005 – 2006 sa Výskumný ústav pôdoznalectva a ochrany pôdy Bratislava zúčastnil ako národný expert riešenia projektu zameraného na pilotnú aplikáciu metodiky pre tvorbu Viac úrovňového informačného systému o pôdach Európy (MEUSIS-SK : MEUSIS in Slovakia). Predkladaný príspevok je zameraný na popis východísk a základných princípov projektu, jeho účelom je priniesť základné informácie o problematike informácií o pôde v rámci Európy a zároveň zdôvodniť potrebu nového harmonizovaného informačného systému. V prvej časti príspevku je uvedená všeobecná definícia Viac úrovňového informačného systému o pôdach Európy, tiež sú identifikované dôležité politické dokumenty a aktivity, ktoré majú vzťah k jeho budovaniu. V ďalšej časti príspevku je pozornosť venovaná súčasnému stavu v oblasti pôdnych informácií. Identifikované sú hlavné problémy využiteľnosti a kvality dostupných informácií o pôde a to tak na európskej, ako aj na národnej úrovni. V poslednej časti príspevku sa pozornosť zameriava na základné metodologické princípy Viac úrovňového informačného systému o pôdach Európy, predstavené sú niektoré dôležité metodické a technické aspekty budovania informačného systému.

Kľúčové slová: viac úrovňový informačný systém o pôde, harmonizácia priestorových údajov, údaje o pôde, informácie o pôde

INTRODUCTION

The Multiscale European Soil Information System (MEUSIS) development is the pilot activity recently started in the field of harmonization of soil (geo)information across the Europe. The MEUSIS development activity is running under the responsibility of Institute of Environment and Sustainability of Joint Research Centre, Ispra, Italy (IES JRC) mostly within the scope of the action for Monitoring the State of European Soils (Action 2132 – MOSES).

The MEUSIS is supposed to enhance availability and usability of the soil information within wide range of research or policy-making oriented environmental projects and activities not only across the European Union (EU) space but also within the larger region defined by the rest of the Europe and Mediterranean. More particularly, the MEUSIS aims in the field of data (soil information) harmonisation can be summarised as (Panagos et al., 2006): (i) to accelerate the progress of harmonisation of soil information, (ii) to facilitate the update of existing soil information, (iii) to provide enough reliable information to assess soil conditions at different levels of detail, (iv) to provide a structure so that coherent and complementary data, available at a nested set of geographical scales, can fit together, (v) to be integrated (MEUSIS) into more comprehensive and multilayer monitoring and reporting principles (see bellow).

As from political point of view, the need for harmonized soil information (in the frame of wider defined environmental information) is declared in several documents. Probably the most important one is the Infrastructure for Spatial Information in Europe (INSPIRE) directive proposal adopted by the Commission in 2004 (SEC(2004)980). Another higher-level political action having forced MEUSIS development in the recent years is the identification of the thematic data (information) needs within the Global Monitoring for Environment and Security in Europe initiative (GMES). Particularly, the European soils data (information) needs identified in the GMES documents are in more details defined in the European Thematic Strategy for Soil Protection (which consits of several documents, for more information see STS).

SOIL INFORMATION FOR EUROPE – STATE OF THE ART

European soil information system (EUSIS)

At present day, the most important European-level source of the soil information is the European Soil Information System (EUSIS) maintained by the IES JRC. The main data elements of EUSIS are (Montanrella et al., 2005): (i) Soil Geographical Database of Europe at scale 1:1 000 000 (SGDBE), (ii) Soil Profile Analytical Database of Europe (SPADE), (iii) Pedotransfer Rules Database (PTRB) and also (iv) Georeferenced Soil Database for Europe at scale 1:250 000 is available for application in several pilot regions of Europe (Italy, Odra river basin).

The most important EUSIS source for deriving soil related geo-information is SDGBE. The digital database was created on the basis of the 1:1 000 000 scale FAO soil map of Europe in early 90'ies of the 20th century (for more details see e.g. Le Bas et al., 1998; Montanrella et al., 2005). In present day, version of SGDBE data on soil cover is organised in the geo-referenced database using vector spatial representation for modelling regions of soil mapping units (SMU) delineated on the original soil map. Content of each SMU is in the SGDBE described via information on presence and (area) share of soil typological units (STU) within the defined delineated region (SMU). Each STU is in the database further described by the non-spatial attribute data on: (i) soil classification and parent material (using WRB classification, Collective, 1998), (ii) some basic to the soil profile or topsoil/subsoil related soil properties, (iii) soil-landscape conditions and (iv) soil management (for more details see Lambert et al., 2002). Using PTRB database, originally developed as the support tool for SGDB, the list of STU related attributes in SGDBE can be extended (for more details see e.g. Montanrella et al., 2005).

Broad demand for the soil data (information) in the form more usable for non-soil science community (pure soil/soil cover parameters rather than information presented in soil classification or soil mapping terms) as well as the demand for more usable spatial soil data/information representation (regularly shaped spatial elements rather than by natural borders defined soil bodies) has resulted in development of raster version of the ESDB (ESDB v2 1 X 1 km Raster Library (Documentation)). In the raster version of ESDB in total 73 basic and pedo- or taxotransfer rules (PTRB database) derived soil parameters are available in single raster layers form covering the whole spatial extent of the ESDB.

Although the above mentioned raster approximations of the ESDB have been recently successfully applied in several environmental oriented projects (e.g. Jones et al., 2005; Kirkby et al., 2004; Balkovič et al., 2005), some problems and limitations still restrict the broad application of the ESDB as the basic source of soil information across the Europe within the frame of INSPIRE, GMES and STS requirements:

- for many purposes, ESDB/ESDB approximations does not match the minimum requirements for spatial and attribute detail of information, i.e. ESDBN data application is appropriate for EU25 spatial resolution level, but it is not applicable for further "hot spots" more detailed analysis (regional or national spatial resolution level),
- although several refinements and corrections have taken place in recent years, there are still many inconsistencies in the data (both spatial and attribute) having arisen from integration not in all aspects consistent national data used for original European coverage compilation (differences soil classification used, soil mapping units definition, etc.),
- although the data can be in ESDB/ESDB approximations represented as parameter values (via PTRDB derived qualitative or semi-quantitative data), the estimations are mostly based only on soil genetic, soil parent material and soil textural unit information available in original soil map (the estimations can or can be not supported by statistically derived data from SPADE database), i.e. parameter values estimations for STU or STU derived regular spatial element are very broad and general not fully representing the real variability (real values) of soil parameters mostly when more detailed spatial resolution is considered (the same situation is also for the ESDB based data interpretations),
- there are no directly measured or observed data on main soil STS identified threads to soils available in the ESDB (data on erosion, decline in soil organic matter, soil contamination, soil sealing, soil compaction, decline in soil biodiversity, salinisation and floods and landslides), as well as no appropriate regional (or local) scale knowledge on the soil landscape relationships regarding the above mentioned threads are up to use, i.e. when needed, the data on soil threads have to be estimated from existing broad primary soil data and only very general soil-landscape knowledge,
- regarding the soil data as the subset of wider defined group of environmental data, application of vector representation based ESDB data or its approximations is not very appropriate if it is an input into the geographical-overlay-based spatial analysis together with spatial

data from other sources (e.g. land cover, physiographic or hydrological data) as this can yield in many artificial spatial elements in results (problem of not fully exact spatial consistency among the available geographical data in vector data representation), i.e. there is considerable spatial inconsistency in different-source geographical data at European level and immediate (or ad hoc) application of such data in complex environmental analysis without previous data treatment is not possible.

National soil data sources for Europe

Besides the general soil information system for Europe (EUSIS), various national soil (soil-landscape, soil threads) data organised within more-or-less complex soil (soil-landscape) databases or national soil information systems are actually available across the Europe (for more information see e.g. Bullock et al., 2005). At the national level, also knowledge on soil-landscape relationships is available (published knowledge, integrated knowledge in the form of soil-landscape data interpretation rules, etc.) which can be employed together with the data in regional and/or national level environmental analysis (e.g. regarding the STS issues). Broad and immediate application of national soil (soil-landscape) data in regional or national scale environmental analysis regarding the European space (as some "complement" to the EUSIS data based analysis or interpretations) is, however, restricted by several problems which can be summarised as:

- there are many differences among the national soil surveys in (i) data availability (area fully or partly covered by appropriate soil data, general or specific-purpose soil data, etc.), (ii) data quality (scale of spatial data, attribute for description, attribute detail and precision, etc.) and (iii) level of data integration within soil databases or soil information system (digital or analogue data, the way of the data spatial representation, integrated or non-integrated knowledge on soil-landscape relationships, etc.),
- "national deviations" occur in (iv) methodologies of soil survey and soil classification, (v) soil sampling strategies and analytical methodologies having applied in collecting the national soil data, as well as (vi) the way how the obtained knowledge on soil/soil cover is represented (soil maps and survey reports compilation, auxiliary data/knowledge support, etc.) can be different from one national survey to another,
- national data holders or providers are not too compliant to share their (pure) data for analysis or interpretations carried out by third persons (e.g. interpretations carried out only by reputable national or international institutions teams without direct participation of data holders or providers representatives in research team).

MEUSIS – THE WAY FOR HARMONIZATION SOIL INFORMATION

MEUSIS has been designed to overcome most of the above mentioned problems related to soil data compilation and application both on European and national level (the problems like data availability, appropriateness, reliability, consistency, availability, etc.). There can be probably three basic assumptions making MEUSIS able to fulfil its aims in field of enhancing the availability and quality of soil information across the Europe identified:

- MEUSIS should be multi-scale, i.e. different spatial resolution level information should be available in the MEUSIS so that it can be employed in various analysis or interpretations addressing global, European, national or regional scales,
- most detailed and appropriate data (knowledge) being available (national soil data and soil data related knowledge) should be used as the basis for the MEUSIS compilation,

- in the MEUSIS only information on soil is reported instead of real soil data provision, i.e. national data have to be pre-processed (interpreted) by national data holders or providers (experts) prior to integration (reported) into the MEUSIS database.

With regard to the above mentioned assumptions, the spatial reference grids and data exchange format having developed for the MEUSIS purposes in recent years as well as the meta-information system (not fully developed so far) can be identified as the general spatial and data/information harmonization tools for the MEUSIS database compilation and subsequent application.

Spatial reference grid for soil information reporting

To provide the solid base for the spatial integration of MEUSIS data into the higher-level environmental information systems as well as to avoid most of the disadvantages of vector spatial representation of soil data, all MEUSIS information on soils is coupled to predefined geographical grid of regular spatial elements (pixels) referred to as spatial reference grid. Following the INSPIRE principles (INSPIRE, SEC(2004)980), harmonised hierarchical geographic grid (covering whole Europe) with a common point of origin using the ETRS89 Lamberth Azimuthal Equal Area geographic co-ordinate reference system (ETRS-LAEA) has been selected as the spatial reference grid for the MEUSIS.

So far, four geographical reference grids have been proposed on different spatial resolution levels and consequently tested (c.f. MEUSIS (Multiscale European Soil Information System) - Alpine grid, MEUSIS-SK: MEUSIS in Slovakia): (i) 100 X 100 km grid to represent the highest resolution level (further referred to as 100k), (ii) 10 X 10 km resolution grid (further referred to as 10k), (iii) 5 X 5 km resolution grid (further referred to as 5k) and at the lowest spatial resolution level 1 X 1 km grid (further referred to as 1k). 100k, 10k, 5k and 1k reference grids are spatially arranged in the way so that each pixel of higher hierarchical level can be represented by the set of pixels coming from lower hierarchical levels (e.g. 10k grid can be spatially represented by the set of four 5k or one hundred 1k pixels, similarly one 5k grid pixel can be represented by the set of twenty five 1k grid pixels). Constructed in this way, the MEUSIS 100k, 10k, 5k and 1k reference grids constitute a system of spatially nested hierarchical grids.

Each of the 100k, 10k, 5k or 1k grid cell is in the geographical database identified by via unique identification number (alphanumerical string). Identification number is derived in accordance with proposed coding system for European geographical reference grids (Wirthmann et al., 2003). The pixel code is derived on the basis of the pixel's lower left corner x and y co-ordinate values using first two, first three or first four numbers of x and y co-ordinate value (ETRS-LAEA) for 100k, 10k or 1k grids, respectively. The numbers for x and y co-ordinate are separated by symbol "_" (e.g. 1234_1234 for the 1k grid pixel). Identification number for 5k grid pixel is derived from identification number of 10k grid pixel the 5k grid pixel is located within (by the further specification of the 10k grid pixel quadrant the 5k grid cell is placed in: NW – northwest, NE – northeast, SW – southwest, SE – southeast, e.g. 123_123NE).

Data exchange format for soil information reporting

Data exchange format use is the way how to represent a "semantic" content of the MEUSIS data. In the process of harmonization of the soil information the MEUSIS data exchange format is a mediator standing between the data and harmonised information. From more technical point-of-view the data exchange format represents an internal-structured relational database which is coupled to the MEUSIS geo-referenced data (spatial reference grids). Relation of the data exchange format data to the exact spatial reference (pixel) is in the MEUSIS database carried out by the unique identification number of each 100k, 10k, 5k or 1k grid pixel. Within the MEUSIS database each spatial hierarchical level (100k, 10k, 5k or 1k) is described by the separate set of data tables (the set of tables constitute the data exchange format), i.e. reference grid on the defined spatial resolution level together with the data exchange format data related represent a self-standing element of MEUSIS database.

Beside the spatial hierarchy defined by spatial reference grids, also another kind of hierarchy can be identified within the MEUSIS database. This information level hierarchy represents the level of attribute detail used for the pixel description. In the data exchange format it is implemented via separate sets of attribute fields organised within the data tables.

The lowest information level attribute data (further referred to as Set1) are in the data exchange format used for general description of the pixel (pixel as a whole). Regarding the soil information Set1 data has in the data exchange format mostly supporting and meta-information function. In the pilot project for Slovakia (MEUSIS-SK: MEUSIS in Slovakia), for example, following set of description attributes was used in data exchange format for Set1 data: identification number of pixel (as the database key), urban area (%) within the pixel, rock and bare rock deposits area (%) within the pixel, water bodies area (%) within the pixel, total soil (both agricultural and forest soil) area (%) within the pixel, estimated confidence level of pixel description, soil data availability for the pixel description, scale of the main source used for the pixel description, number of total documented observations within the pixel and total number of documented soil profiles within the pixel.

Second information level attribute data (further referred to as Set2) are in the data exchange format used for more specific (soil cover related) information on the pixel as a whole. Set2 data are set up to describe the quantitative parameters of soils (mean most frequent or summarised values) presented within the pixel. In the pilot project for Slovakia (MEUSIS-SK: MEUSIS in Slovakia), for example, total organic carbon stocks (in 0 – 30 and 0 – 200 cm depths) were selected as the Set2 description attributes. In the similar manner, however, also another e.g. STS required parameters can be reported in MEUSIS database (soil erosion, soil contamination, etc.).

At the third, the highest information level (further referred to as Set3), the interpreted data on dominant soil units presented within the pixel are to be reported (STU for MEUSIS are defined in the same way as it is done for STU in SGDBE database). Furthermore, the STU description attributes in the SGDBE are used also for Set3 data (Lambert et al., 2002) so that clear relation can be created among the MEUSIS information and existing SGDBE data. Set3 information level, besides it brings very detailed information on STU within the pixel, makes one able to infer the soil (soil parameters values) or soil landscape spatial arrangement within the pixel (i.e. to create a "sub-pixel" spatial information). Regarding the above mentioned, any of the MEUSIS spatial elements (pixesl) represents an artificial shaped soil mapping unit (SMU) within the data on constituent STU are reported (c.f. ESDB data structure described in Lambert et al., 2002). In the pilot project for Slovakia (MEUSIS-SK: MEUSIS in Slovakia), for example, besides all the STU description attributes from the SGDBE (Lambert et al., 2002), some other mostly the STS requirements based attribute fields were used for further Set3 level description: dominant and secondary topsoil/subsoil organic carbon stocks and holorganic carbon stocks (t/ha), dominant and secondary soil loss (t/ha/year), dominant and secondary salinisation (dS/m), dominant and secondary soil alkalinity, topsoil and subsoil contamination and topsoil and subsoil soil compaction.

Another important constituent of the data exchange format is the set of attribute domains. The attribute domains represent a powerful more specific tool for attribute harmonisation of soil data. Attribute domains are in data exchange format set for all the Set1, Set2 and Set3 attribute fields and by the aid of the attribute values, which can be used for description, are defined. Although there are no exact guides for input data interpretation defined in the MEUSIS (the best available data and knowledge should be applied to obtain harmonised information), attribute domains clearly defines how the interpretation results should look like.

Meta-information system for soil information reporting

Even though the meta-information strategy for the MEUSIS have not been finally developed yet, it is obvious that the meta-information is an important option for the whole system function. In the meta-information system detailed information on used data as well as information on interpretation methodologies applied should be reported. Important function of meta-information system is also providing the information on used analytical methodologies for soil chemical and physical parameters (or the way how the values were transformed if the analyses are not in accordance with international standards). In the pilot project for Slovakia (MEUSIS-SK: MEUSIS in Slovakia), for example, the detailed meta-information regarding all the above mentioned issues was submitted in plain text (non-structured) form. In the coming future the efforts connected to MEUSIS meta-information system development, however, should be oriented on creation of the proposal for general, structured and formalised meta-information system as the essential support tool for via MEUSIS spatial reference grid and the data exchange format reporting harmonised information.

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MULTISCALE EUROPEAN SOIL INFORMATION SYSTEM II. – PILOT PROJECT FOR SLOVAKIA

VIACÚROVŇOVÝ INFORMAČNÝ SYSTÉM O PÔDACH EURÓPY II. – PILOTNÝ PROJEKT RIEŠENÝ PRE SLOVENSKO

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ABSTRACT

In the 2005 – 2006 period, Soil Science and Conservation Research Institute, Bratislava participated as the national expert in project for pilot application of methodology for Multi-scale European Soil Information System (MEUSIS-SK: MEUSIS in Slovakia). In the presented article, all important national data sources appropriate for the Multi-scale European Soil Information System purposes are identified and briefly described. Interpretation methodology for the national data flow into a common reference format is reported and meta-information system for harmonised data is described. General conclusions are given regarding the common reference format application within the national conditions of Slovakia. Several more specific national data related conclusions are formulated in which the availability, overall quality and appropriateness of national data are addressed.

Keywords: Soil Information System of Slovakia, multi-scale soil information system, data harmonisation, soil data, soil information

ABSTRAKT

V období rokov 2005 – 2006 sa Výskumný ústav pôdoznalectva a ochrany pôdy Bratislava zúčastnil ako národný expert riešenia projektu zameraného na pilotnú aplikáciu metodiky pre tvorbu Viac úrovňového informačného systému o pôdach Európy (MEUSIS-SK : MEUSIS in Slovakia). V predkladanom príspevku sú identifikované a stručne popísané národné zdroje údajov o pôde, ktoré môžu byť využiteľné pre účely jeho tvorby. Prezentovaná je stručná informácia o vytvorenom metodickom postupe pre transformáciu údajov pre potreby ich publikácie vo forme spoločného referenčného formátu pre výmenu informácii o pôde. Stručne popísaný je aj metainformačný systém, ktorý bol vyvinutý ako doplnok výslednej údajovej bázy. V záverečnom zhrnutí sú uvedené niektoré postrehy aplikácie spoločného referenčného formátu pre údaje o pôde v konkrétnych podmienkach Slovenska. Zhrnutá a hodnotená je aj dostupnosť údajov, ich celková kvalita a vhodnosť pre dané účely.

Kľúčové slová: informačný system o pôde Slovenska, viac úrovňový informačný systém o pôde, harmonizácia údajov, údaje o pôde, informácie o pôde

INTRODUCTION

The Multiscale European Soil Information System (MEUSIS) development is the pilot activity recently started in the field of harmonization of soil (geo)information across the Europe. The rational, political and historical background as well as basic technical description of the MEUSIS is given in the paper of Skalský, Filippi (2006), so now we concern more specific problems related to the pilot project for the national data flow to the MEUSIS. In 2005 – 2006, based on a contract between Institute of Environment and Sustainability of Joint Research Centre, Ispra, Italy (IES JRC) and the Soil Science and Conservation Research Institute (SSCRI), MEUSIS data harmonization approach was tested in pilot application using Slovak soil national data.

The tasks to be performed by the SSCRI within the pilot project were set up as follows: (i) to identify appropriate data sources for interpretation, (ii) to set up, test and apply the interpretation methodologies for the source data transformation into the MEUSIS reference format and (iii) to provide the structured meta-information as a complementary part of information on the soils provided. All issues related to the national data processing and providing the harmonised information discussed in this paper are in more details described in the MEUSIS pilot project final technical report (Skalský et al., 2006). The results of the project are also published on the official IES web-page (MEUSIS-SK : MEUSIS in Slovakia).

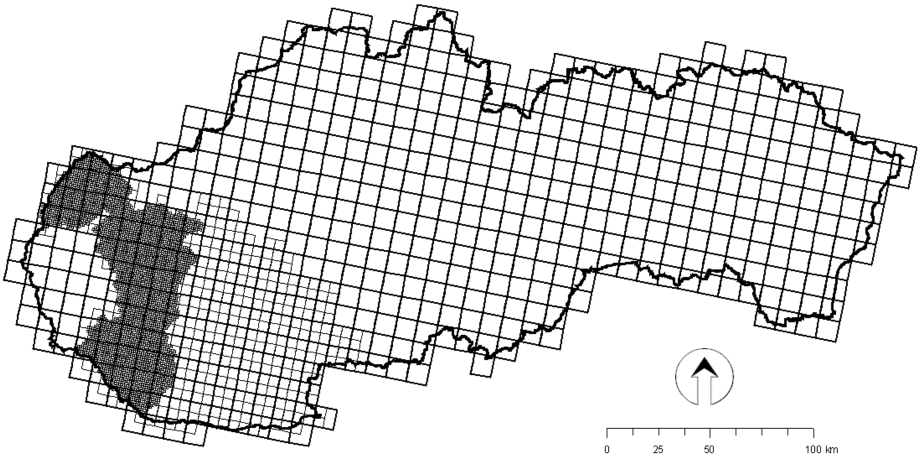
Brief overview on MEUSIS approach

In the MEUSIS, all geographical information is supposed to be represented within a general frame defined by the grid of regular spatial elements (pixels). Individual pixel represents semantically independent spatial element to which structured non-spatial information is coupled. To represent different spatial resolution details, three spatial resolution levels of geographical information were defined for the MEUSIS. Geographical reference grids of different spatial resolution: 10 km^2 resolution grid (10k), the 5 km^2 resolution grid (5k) and the 1 km^2 resolution grid (1k) were defined. Each pixel of the 10k, 5k and 1k grid is described by the sets of data on three information levels. At the highest level (Set1), the pixel is described as a whole by general data (partly, the Set1 data has meta-information function). Ar the second level (Set2), the pixel is described as a whole by specific and quantitative soil cover/landscape related data (the data are derived from the lower level soil cover and landscape information). Finally,at the third, the most detailed, level (Set3), a pixel is described by the data on soil cover constituents (soil units) presented within its area. More detailed information on the reference grid (10k, 5k and 1k) and the data exchange format (Set1, Set2 and Set3) can be found in the above mentioned publication of the authors Skalský, Filippi (2006).

MEUSIS pilot project areas for Slovakia

For the MEUSIS pilot for Slovakia, three pilot areas were selected (Figure 1) so that they represent all levels of geographical information details. Each pixel of the pilot area for the 10k resolution (pilot area L1), 5k resolution (pilot area L2) and 1k resolution (pilot area L3) were supposed to be described by all sets of data (Set1, Set2 and Set3).

Figure 1 MEUSIS pilot project areas for Slovakia



MATERIAL AND METHODS

Source data

Available national data sources for the pilot areas description are represented by (i) primary georeferenced data (spatial information on the delineated soil bodies), (ii) secondary geo-referenced data, as a source of additional information on the primary geo-referenced data, and (iii) geo-referenced soil profile data mostly used for morphological and analytical information on the primary geo-referenced data defined soil bodies. Brief and general overview of the data sources and some application and operation aspects of the bellow presented data sources, as well as an overview of its approximations is given by Bielek et al. (2005).

(i) primary geo-referenced data

Digital Soil Map of Slovakia in scale of 1:400 000 (PM400) is a digitized version of the recently issued soil map assembled by Hraško et al. (1993). The thematic content of PM400 is based on an earlier published soil map in the scale of 1:500 000 (Hraško et al. 1980; Mazúr, Jákal 1982). Kobza (1999) updated and completed the existing PM400 legend with the some further description of the PM400 soil associations.

Digital geo-referenced database of soil-ecological units (PEU-DB) is digitized version of the specific oriented set of soil cover maps in the scale of 1:5 000. The thematic content of the original 1:5 000 maps is represented by semantically complex and spatially homogenous soil-landscape units (soil-ecological units – PEU), for more details see Linkeš et al. (1988), Linkeš et al. (1996).

Set of digital regional maps of geo-factors of landscape – soils in the scale of 1:50 000 (GFZP) is a partial result of widely defined regional geological and geochemical survey project. The GFZP soil survey and GFZP soil maps are available for selected regions of Slovakia and procedures applied for the map construction follow the national soil survey methodologies (Čurlík et al., 1998; Čurlík, Šurina 1998).

Geo-referenced Database of Agricultural Soils of Slovakia (GDPPS) is the digital representation of selected aspects (data and data relations) of General Soil Survey of Agricultural Soils of Slovakia (KPP), Němeček et al. (1967), Hraško, Bedrna (1970). In the GDPPS, only local (non-generalized) data on geographical distribution in 1:10 000 scales of soils and related soil profiles morphological and analytical data (basic and selected soil profiles) are stored (more information in Skalský, 2005).

(ii) secondary geo-referenced data inputs

Digital geo-referenced database of production blocks (LPIS) is a part of more wider defined Land parcel identification system. The LPIS was originally devoted to serve as a basic geographical information support for the Control and Administrative System in Agriculture (IACS) for Slovakia. Besides this purpose, the LPIS geographical database is supposed to be a multi-functional database with related thematic environmental data on landscape (the specific registers/datasets can be related to LPIS spatial elements).

Digital geo-referenced database of soil-ecological regions (PER-DB) is a partial result of long-term soil ecological and soil production-economical research in Slovakia. Soil-ecological delineation and additional ecological and productive assessment for the PER-DB creation followed the methodology developed and described by Džatko (2002).

(iii) geo-referenced soil profile data

Digital database of selected soil profiles of KPP (KPP-DB) represents a digital database of KPP soil profile data. The KPP-DB is the result of a previous version of the KPP selected soil profile database updated and reprocessed (Skalský, Balkovič 2002). In the KPP-DB, every general soil profile (soil classification, soil profile stratification) and soil profile morphological properties (morphological and analytical data on soil horizons) are described.

Digital database of soil profiles of GFZP (GF-DB) stores the soil classification and analytical data on the soil profiles which were used for the field examination of the GFZP delineated soil combinations and for collection of data on soil contamination (more in Čurlík et al., 1998). In soil samples the content of obligatory set of risk elements is analyzed using common analytical methodologies (Čurlík, Šefčík 1999) and the basic soil parameters are analyzed using the national soil analytical procedures methodology (Fiala et al., 1999).

Digital database of soil profiles of geochemical atlas of Slovakia (GChA) contains data on analytical results of samples collected during the national project "Geochemical atlas of soils of Slovakia". Genetic sampling scheme was used to collect samples from topsoil and parent material. In detail, soil sampling methodology, samples preparation methods and analytical methods used are described by Čurlík, Šefčík (1999).

Digital database of soil monitoring of Slovakia (CMSP) represents digital data archive of the "Partial monitoring system-Soil" as a part of the Complex Environment Monitoring of Slovakia. A set of 312 representative monitoring sites is localized in agricultural land and sampled in 5-years frequency (three monitoring cycles in 1993, 1998, 2003 years have finished so far). Mandatory analytical methodology (Fiala et al., 1999) is applied to obtain analytical data. Parameters analyzed for CMSP are listed and described by Kobza (1995).

General data processing and interpretation methods

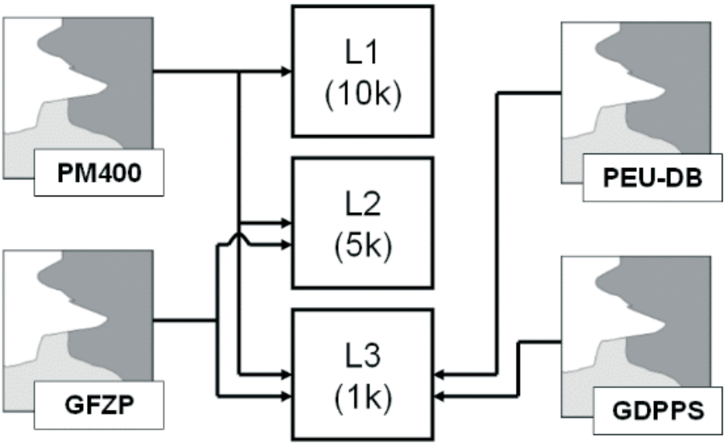
The techniques applied in the national data pre-processing and interpretation procedures for the MEUSIS purposes can be identified and briefly described as following: (i) database tools, operations performed by the means of the standard and self-developed SQL and Visual Basic scripts in MS Access® database environment applied for input data treatment and input data querying, pre-processing of data inputs for expert analyses and non-spatial analyses performing, calculating attribute values in the interpretation domain tables and the interpretation domain tables completion, the MEUSIS reference format tables and metadata tables storage and maintenance completion, (ii) GIS tools, geographical analysis and data processing by means of standard editing, geo-processing and analytical tools in ESRI ArcGIS® GIS environment applied for input data treatment and pre-processing, input data spatial analyses and querying for further expert or non-spatial analyses, raster-based operations and analysis on elevation and land use data (raster algebra, reclassification, raster-based zonal statistics) for the geographical attributes and (iii) expert tools, various procedures applied for statistical and data aggregation procedures for analytical data pre-processing, expert knowledge, expert experience and published data based methods (expert matrices, expert evaluations) for various parameters and attribute values estimation and classification methods for national and reference soil classification comparison.

RESULTS AND DISCUSSION

General scheme for the input data allocation within the pilot areas

To provide appropriate soil cover information on the MEUSIS reference grid pixels from national soil data sources, an allocation scheme for primary geo-referenced input data allocation within the L1, L2 and L3 pilot area reference grids (10k, 5k, 1k) had to be set. Complementary, some basic and specific allocation rules were defined in accordance with the MEUSIS requirements for the most accurate pixel description. By the aid of the rules, a way how to carry out the most detailed information on both agricultural and forest soils is defined, as well as data overlapping conflicts solutions are given (more details on the rules can be found in publication of Skalský et al. (2006). The input data allocation scheme as it was set up for primary geo-referenced data allocation is given in figure (Figure 2).

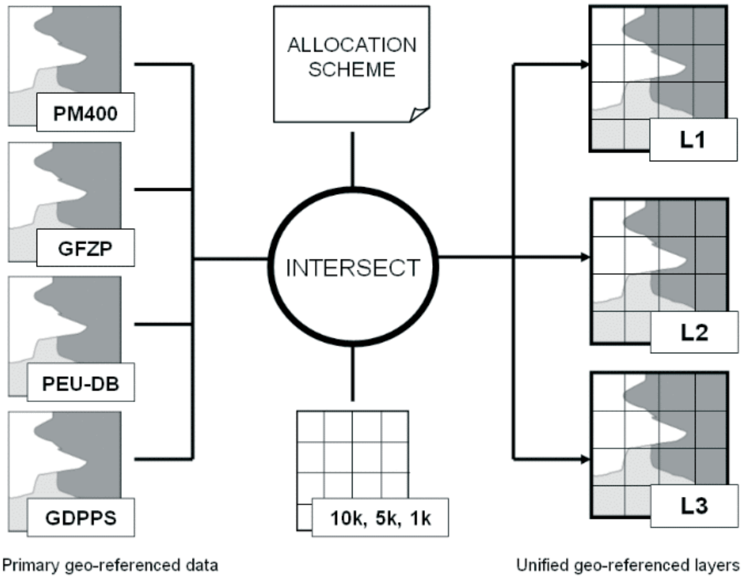
Figure 2 Input data allocation scheme for unified geo-referenced input data layers



Primary geo-referenced data pre-processing

In order to obtain geographically unified geo-referenced input data layers for the data interpretation, primary geo-referenced data layers were intersected in the GIS with the 10k, 5k and 1k MEUSIS reference grid layers (after data allocation). The geographically unified geo-referenced input data layers were created separately for each the MEUSIS L1, L2 and L3 pilot area (Figure 3).

Figure 3 Primary geo-referenced data geographical unification



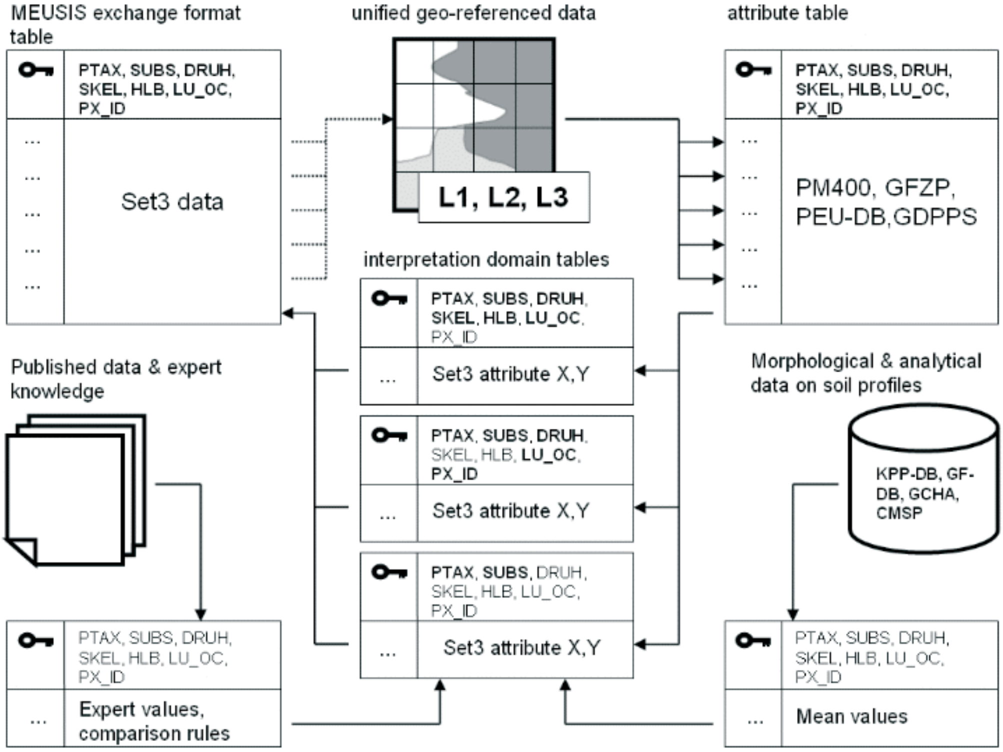
In order to provide the unified attribute base for the data interpretation, common attribute structure was defined for each of the unified geo-referenced layer (L1, L2 and L3). Geo-referenced input data layers (for L1, L2 and L3 pilot areas) unified in the geographical and attribute space were used in all the Set2 and Set3 data interpretations afterwards as a primary soil and landscape data on MEUSIS pixels (instead of the non-treated original datasets: PM400, PEU-DB, GFZP and GDPPS).

Soil data interpretation system

The specific data interpretation system (Figure 4) was developed as a specific informatics tool mostly for the Set3 data interpretation support. Rational management of input and output data and data-related knowledge within the data interpretation process, rational management of experts being included in the interpretation process and reduction of the high-powered expert work (i.e. reducing the number of data records to be expert interpreted) were the main reasons which conditioned the interpretation system development.

In the data interpretation system (i) input data being interpreted (unified geo-referenced data for the L1, L2 and L3 pilot areas), (ii) input of pre-processed geo-referenced profile data (statistically aggregated morphological and analytical data), (iii) input of published and expert derived information (expert derived or estimated soil parameters), (iv) specifically defined attribute domains (relational classes for exchange data table and input data table attributes) and (v) interpreted output data (MEUSIS exchange format tables) were defined as the key constituents.

Figure 4 Diagram of the data interpretation system for input data



Expert interpretation methodologies and interpretation results

Detailed description of the expert interpretations methodologies developed and applied for the input data interpretation within the frame of the MEUSIS pilot project for Slovakia would go beyond the scope of this paper, though, only a very brief identification of interpretation methods and data sources addressed are given in the following text. However, detailed description of the developed methodologies, can be found in the MEUSIS pilot project for Slovakia final technical report (Skalský et al., 2006). Interpretation methodologies, which were developed for the L1, L2 and L3 pilot areas to provide harmonized Set1, Set2 and Set3 information are as following (in description the MEUSIS exchange format attribute group is identified first, as the second, data sources addressed in the methodology are given in brackets):

- Set1 data interpretation methodologies: (i) land use information on pixel (PEU-DB, LPIS), (ii) metadata on soil cover description (PM400, PEU-DB, GFZP, GDPPS, KPP-DB, GF-DB, GCha and CMSP),
- Set2 data interpretation methodologies: (iii) average soil organic carbon stock within the pixel (relevant Set3 data attribute fields for organic carbon, see Skalský, Filippi (2006),
- Set3 data interpretation methodologies: (iv) soil typological unit identification and area (PM400, PEU-DB, GF-ZP and GDPPS), (v) soil and soil parent material classification (PM400, PEU-DB, GF-ZP and GDPPS), (vi) soil typological unit relief parameters (PM400, PEU-DB, GF-ZP and GDPPS together with digital elevation data), (vii) land use interpretation (PM400, PEU-DB, GF-ZP and GDPPS together with pre-processed PEU-DB and LPIS data), (viii) limitation for agricultural use (PM400, PEU-DB, GF-ZP and GDPPS), (ix) soil depth (PM400, PEU-DB, GF-ZP

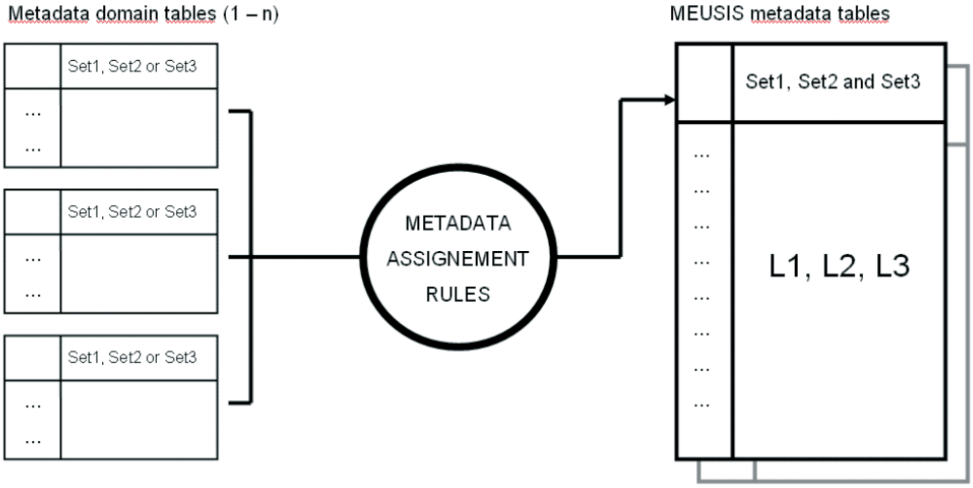
and GDPPS together with KPP-DB), (x) soil texture (PM400, PEU-DB, GF-ZP and GDPPS), (xi) organic carbon stocks estimation (PM400, PEU-DB, GF-ZP and GDPPS together with KPP-DB, GF-DB, GChA and CMSP), (xii) soil erosion (PM400, PEU-DB, GF-ZP and GDPPS together with digital elevation data and LPIS), (xiii) soil salinity and alcalinity (PM400, PEU-DB, GF-Z and GDPPS), (xiv) soil contamination (GF-DB, GChA, CMSP), (xv) soil depth and water movement limitation (PM400, PEU-DB, GF-ZP and GDPPS) and (xvi) soil water regime (PM400, PEU-DB, GF-ZP and GDPPS).

Interpreted data were used for the completion of the MEUSIS exchange format tables. The MEUSIS database created covers selected pilot areas in Slovakia and fulfilled all the technical requirements given by the MEUSIS methodology. Harmonized data on the soil cover of Slovakia are implemented in the MS Access® database environment. In total, 509 pixels and 1 332 soil units, 475 pixels and 992 soil units and 4 409 pixels and 8 952 soil units were included in the database for description of the L1, L2 and L3 MEUSIS pilot area, respectively.

Meta-information system for the MEUSIS pilot project

In order to provide metadata for all the Set1, Set2 and Set3 data interpreted for the L1, L2 and L3 pilot areas, a simple metadata organization scheme was designed and implemented (Figure 5). Metadata descriptions (plain text) for individual Set1, Set2 or Set3 table attribute fields or group of fields were organized within the metadata domain tables. In the plain text description, all important information on attribute value origin, the way of input data interpretation, input data sources identification, etc. were given. For each the metadata domain table was created and assignment rules were defined in order to provide the link between the metadata domains and the Set1, Set2 or Set3 data tables. For all the attribute fields contained in the Set1, Set2 or Set3 metadata tables metadata descriptions were set as numerical (i.e. numerical codes are used instead of plain text descriptions).

Figure 5 Metadata organization scheme for the MEUSIS pilot data for Slovakia



CONCLUSIONS

The MEUSIS pilot project for Slovakia should be perceived as an important step towards the final methodology establishment for the national data flow into the harmonised soil information format. Regardless of the above mentioned international (or European) issues, at the national level MEUSIS pilot project for Slovakia also opened a floor for a rigorous examination of national data and knowledge on soil cover ability to be passed into the MEUSIS common reference format (both spatial and attribute integration is considered). Based on the results of the project and regarding the general MEUSIS methodology and national data and knowledge available we can assume following general conclusions:

- MEUSIS approach seems to be feasible way of the national soil cover data integration at European level (at least in conditions of Slovakia) and to report them for various purposes,
- MEUSIS is a dynamic and open platform, thus, data of various origin and quality can be integrated within its data structure and harmonised information can be reported being supported by related meta-information,
- after its final establishment as the tool for exchange of information on soil cover within the Europe, MEUSIS can also serve as the general frame for the soil data organisation set up at the national level.

In addition to above mentioned, with regard to the national soil data and related soil-landscape knowledge, several more specific conclusions can be assumed:

- appropriate soil cover data are available for all the territory of Slovakia for lower spatial resolution levels (10k, 5k), for higher resolution level (1k), however, soil data availability is restricted only to the area of agricultural soil (data on forest soils are not available in the digital form so far, as well as there are also some differences in attribute precision and details when compared with detailed soil data on agricultural soils),
- all the crucial soil data sources available for the Slovakia (PM400, GFZP, GF-DB, GChA, CMSP, PEU-DB, KPP-DB and GDPPS) contain spatial and attribute data organized in the way applicable for their interpretation into the MEUSIS required harmonised data format,
- operability of the crucial data sources is, however, slightly restricted as there is no common data structure or data integration baseline set for the various sources data organisation in the databases,
- spatial and attribute data consistency within the single soil datasets is of different quality, as well as the data cross-consistency within the different data sources is not fully satisfactory and this has to be always taken into consideration when various-source soil data are processed together,
- not well examined methodologies or formalised soil-data-related knowledge for the interpretation of reliable information on some important soil characteristics, e.g. soil threads related properties of soil are not up to use now (validated methodologies for soil contamination, soil erosion, soil compaction and soil organic matter estimation, etc.) and it is not possible to make any immediate (or ad-hoc) high confidential estimation, neither at the detailed resolution level (1k), nor at the general ones (10k, 5k) with significant additional effort.

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ENVIRONMENTAL RISK ASSESSMENT RESULTING FROM SOILS OF THE CITY OF BRATISLAVA

ENVIRONMENTÁLNE OHROZENIE VYPLÝVAJÚCE Z PÔD MESTA BRATISLAVY

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ABSTRACT

One of the inevitable assumptions to secure environment control in cities is mapping of polluted and by other degradation affected soils. This tool facilitates indication and detection of the areas, which represent environmental and health hazard for urban population. On the case of the city of Bratislava the contribution demonstrates methodical procedure of environmental risk assessment resulting from soil. It is based on differentiation and delineation of pedo-urban ecosystems (incl. urban pedotope consideration) and processing of several information sources including proper soil survey, sampling and analysis of surface contamination. The basis for urban soil contamination is represented by creation of two-type pedo-urban ecosystem categorization: (1) ecosystem categorization respecting real and potential soil contamination, (2) ecosystem categorization regarding areas potentially endangered by environmental risks resulting from soil. As a mapping outcome map of environmental risks resulting from soils in the scale of 1:25,000 is presented. Considerable part of the urban soil quality indication is application of legislation measures for urban soil protection. However, these are absent in Slovakia.

Keywords: environmental risk, urban soils, city of Bratislava

ABSTRAKT

Jedným z nevyhnutných predpokladov zabezpečiť kontrolu životného prostredia je mapovanie znečistených a rôznou degradáciou postihnutých pôd. Tento nástroj umožní indikáciu a odhalenie území, ktoré predstavujú environmentálne a zdraviu nebezpečné ohrozenie mestskej populácie. Príspevok na príklade mesta Bratislavy demonštruje metodický postup hodnotenia environmentálneho ohrozenia vyplývajúceho z pôdy. Je založený na diferenciácii a vyhraničení pedo-urbánnych ekosystémov (vrátane výskumu urbánnych pedotopov) a spracovaní viacero informačných zdrojov vrátane vlastného pôdneho prieskumu, odberu vzoriek a analýzy povrchovej kontaminácie. Pre hodnotenie kontaminácie urbánneho prostredia boli vytvorené dve kategorizácie: (1) kategorizácia ekosystémov predstavujúca reálnu i potenciálnu kontamináciu pôd, (2) kategorizácia ekosystémov označujúca územia potenciálne ohrozené environmentálnym ohrozením vyplývajúcim z pôdy. Ako mapový výstup je znázornená mapa environmentálneho ohrozenia z pôdy v mierke 1:25 000. Významnou súčasťou hodnotenia kvality urbánnych pôd sú možnosti aplikácie legislatívnych opatrení, ktoré však z hľadiska ochrany urbánnych pôd chýbajú.

Kľúčové slová: environmentálne ohrozenie. urbánne pôdy, mesto Bratislava

INTRODUCTION

Generally, urban soils as an important part of the urban ecosystem can be polluted by noxious elements input into soil. It can be result of various sources immediately connected with urbanized-industrial and traffic activities of cities and mega-polis. There is often a soil pollution distributed by point sources as chemical plants, refineries, petrol pump stations, etc. Less known and measured are diffused sources of pollution accumulated in urban soils (e.g. emission from traffic, heating processes in housing, building material, uncontrolled deposit of ash, slag and waste, as well as trans-boundary contamination). A very joyless fact is that in many cities a lack of information about concentration and distribution of noxious substances in soils prevails. This status is a consequence of ignorance of systematic urban soils research that is not integrated into management planning and control of city environment.

To obtain such information reveals problem of urban soil heterogeneity and their substrata, various soil contamination, problem of diversity of urban areas, altered soil function, etc. (Norra et al., 2001). Most of the urban soils are young of age, mostly artificially created soil profiles as a result of building and industrial activities with artefacts presence as an evidence of recent history of the site.

For environmental risk assessment in cities high density of sampling is required. We have proposed method – procedure restricting time-consuming sampling and laboratory analyses that provides effective tool for relatively fast and economic quality of urban soils evaluation.

MATERIALS AND METODS

Methodology is demonstrated on the case of Bratislava (capital of Slovak Republic) with extent of 367.6 km^2, 450,000 inhabitants (Sobocká, 2004; Sobocká et al., 2004). In the city, there are several pollution sources located, mainly chemical industry, technical glasswork, building industry, incineration plant, etc. Quantitative and qualitative data (amount and kind of discharged emission, chemical compounds of air, waste stock-pile, and evidence of old environmental loads) have been kindly provided by Bratislava city authorities (Atelier of Environment).

Main Information Sources

As the main information sources have been used:

1. Database of recognition and detailed soil survey of pedo-urban ecosystems of Bratislava city with respecting spatial diversity of urbanized territory and highlighting areas with the highest soil environmental significance.
2. Soil description field book: urban pedotope description, characteristics and classification of 13 selected representative soil profiles following these properties: texture (USDA triangle), pH in H_2O, pH in $CaCl_2$, $CaCO_3$ content [%], Cox content [%], humus content [%], Nt content [mg.kg^{-1}], P content [mg.kg^{-1}], in some cases heavy metals analyses (Cd, As, Pb, Ni, Cr, Hg,) and organic pollutants analyses (PAH, PBC, NEL). Soil profiles have been classified according to the Morphogenetic Soil classification system of Slovakia (Kolektív, 2000) incl. signature of diagnostic horizons.
3. Sampling and analyses of surface soil contamination on risk elements (heavy metals: Cd, As, Pb, Ni, Cr, Hg) from 20 potentially most loaded urban locations in the city (Burghardt, 1994; Madrid et al., 2004). Analyses have been tested by valid manual for soil analyses (Fiala et al., 1999), heavy metals by Aqua Regia extraction, Hg by total analysis. Results of risk elements (heavy metals, PAH, PCB a NEL) have been evaluated according to risk elements limited criteria (No. 220/2004 Code).

4. Database stored in the Atelier for Environment City of Bratislava: sources of air pollution, registered waste stock-piles, old environmental load situation, etc.
5. Database of Soil Science and Conservation Research Institute. Soil map of the Bratislava city has been compiled on the base of these sources: basic soil maps of the county Bratislava, in the scale of 1:50,000 from the General Soil Survey of Agricultural Soils (GSSAS), maps of texture, skeleton and moisture, maps of parent substrate, own soil survey in cities, mainly in non-mapped areas.

Procedure of the environmental risk assessment map compilation

Process of delineation of areas really or potentially endangered by environmental risk resulting from soil includes several items:

1. Delineation of pedo-urban ecosystem regarded in relation to soil quality (e.g. industrial areas, commercial-housing areas, residential wards, traffic infrastructure, public green places, parks, recreation areas, child playing grounds, kindergarten, schoolyards…)
2. Compilation of pedo-urban ecosystems of the city Bratislava in the scale of 1:25,000; as a background orthophotos maps scanned in July 2002 in the scale of 1:5,000 have been used and digitalized in Arc Map.
3. Soil quality definition following available analytical results of urban pedotopes (see main information sources) combined by their relation to the individual functions of urban ecosystems, i.e. demands of soil quality according to site use of various groups of urban population.
4. Creation of two types special pedo-urban ecosystem categorization: (1) pedo-urban ecosystem categorization based on the real and potential soil contamination, (2) categorization of pedo-urban ecosystem potentially endangered by the environmental hazard resulting from soils.
5. Compilation and printing Map of environmental risks resulting from soil (city Bratislava, scale 1:25,000).

RESULTS AND DISCUSSION

As a very important step has been considered delineation of individual pedo-urban ecosystems from ortho photo maps scanned and provided by the firm EUROSENCE in July 2002. Urban soils-sealing complexes have been reviewed in relation to required quality of soils. E.g. special attention has been paid to urban areas used by child and youth urban population, where very severe limits are given (Bundes-Bodenschutzgesetz, 1998).

Representative soil profiles have been selected, described and sampled with basic and special pedological characteristics. Sampling of surface dust contamination has been carried out from 20 selected sites, affected prevailingly by contamination from traffic where we have assumed impact on soil from the traffic emission (residential areas, historical centre, playing grounds, market centre, pumping stations, sites near chemical plants).

Map of the pedo-urban ecosystem of Bratislava was compiled on the base of some resources: basic topographic maps of the city Bratislava in the scale of 1:10,000 (20 sheets), ortho-photo maps, aerially sensing in July 2002. The legend of the Map of urban ecosystems of the city Bratislava, 1:25,000 is specific, created according to the relation to urban soils.

In the next step we have proposed two-type categorization reflecting delineated pedo-urban ecosystems and measured quality of urban soil.

Very important role has been assigned to measurement of surface contamination respecting spatial distribution of local point source of pollution. By interpretation of the analytical results (Table 1) exceeded values of Cd 7 times, Pb 4 times and Zn 13 times (Agricultural Soil Protection Low No. 220/2005 Code) have been detected.

Table 1 The Analytical values of heavy metals (As, Cd, Cr, Pb, Zn, and Hg) from surface contamination sampling (colored values represent exceeded limits)

Sample	As mg.kg^{-1}	Cd mg.kg^{-1}	Cr mg.kg^{-1}	Pb mg.kg^{-1}	Zn mg.kg^{-1}	Hg mg.kg^{-1}
BAK-01	3.95	0.24	32.45	120.34	342.69	0.0653
BAk-03	7.90	0.82	59.30	31.95	162.45	0.1662
BAk-03a	6.70	0.53	38.45	67.11	205.82	0.0597
BAk-03b	5.40	0.45	36.90	51.28	109.53	0.1389
BAk-04	6.50	0.20	30.70	61.23	171.39	0.1001
BAk-06	4.38	0.67	16.25	23.58	101.77	0.0400
BAk-07	1.58	0.23	39.85	68.95	257.80	0.0439
BAk-08	6.73	0.80	35.75	38.50	184.10	0.1814
BAk-09	3.73	0.72	41.30	49.77	444.45	0.0440
BAk-10	5.03	0.75	49.00	79.09	237.78	0.0375
BAk-11	6.63	1.19	38.45	34.21	133.60	0.1883
BAk-12	5.88	0.42	30.70	22.69	152.70	0.0414
BAk-13	5.98	0.28	21.15	23.11	111.72	0.1435
BAk-14	3.78	0.34	28.80	20.75	91.57	0.0166
BAk-15	6.68	0.28	24.90	102.64	53.39	0.0628
BAk-16	10.35	1.20	28.65	112.69	453.27	0.3450
BAk-17	6.60	0.24	28.75	15.74	87.76	0.0745
BAk-18	3.40	0.88	44.00	33.32	204.28	0.0512
BAk-19	4.98	0.95	43.55	62.39	293.36	0.0703
BAk-20	4.45	0.39	30.60	22.49	134.85	0.0327

We have submitted some environmental load of the city by a special analysis on organic pollutants. As an example, we have introduced stock-pile of chemical waste an old environmental load with historically recorded storage. Soils have been severely contaminated by the organic pollutants influencing ground water level and surroundings. Limit values have multiplex exceeded (Table 2), e.g. polycyclic aromatic hydrocarbons (PAH) (max. 38.8 mg.kg^{-1}, limit PAH = 1.00), polychlorinated biphenyls (max. 2.1125 mg.kg^{-1}, limit PCB = 0.05) as well as oil minerals (max. 860 mg.kg^{-1}, limit NEL = 0.10).

In this case, there is a very difficult to find appropriate answer how to manage such contaminated and healthy-dangerous area. Area is permanently monitored, mainly ground water level which is polluted into the depth of 40 m and affects surroundings like neighboring garden allotments, arable land and some dwellings. This event provokes many questions related to accurate and right use of this site without any risk to be exposed to effects of non-healthy environment.

Table 2 Analytical values of chemical stock-pile Vrakuňa

Sample (cm)	Content 1 PAU (mg.kg^{-1})	Content 2 PAU (mg.kg^{-1})	PBC (mg.kg^{-1})	NEL (mg.kg^{-1})
BA 8 (2 – 8)	38.8	38.8	0.0150	130
BA 8 (12 – 18)	8.0	8.0	2.1125	860
BA 8 (35 – 45)	21.1	20.8	under detection	110
BA 8 (75 – 85)	3.3	3.3	under detection	100
BA 8 (105 – 115)	3.3	3.3	under detection	290

Note: content 1 PAU – sum of 16 compounds, content 2 PAU – sum of 12 compounds

Categorization of pedo-urban ecosystems and their environmental risks

Two categorized groups of pedo-urban ecosystems with differentiation of their environmental risk from soil have been created.

I. Categorization following real and potential soil contamination (presence of heavy metals, organic pollutants, intensity rate tends down).

1a chemical and other similar industry, incineration work of domestic waste, stock-piles, old environmental loads (Slovnaft, O.L.O, Istrochem, Technical Glasswork).

1b highway communication, railway lines, haven, airport and other traffic areas.

Characteristics:

The category 1a represents risk areas, i.e. soils of these areas are strongly contaminated or deteriorated by other anthropic impact degraders. They alone represent potential sources of soil contamination for surrounding areas and soils. The contamination sources are mainly substances with cancerous effect (Cd, Ni, benzene, 1.3-butadiene, and ethylene-oxide), solid inorganic substances (Pb), inorganic gaseous substances (NH_3, HCl) and organic gaseous substances (naphthalene, vinyl benzene, ethanolamine, ethyl benzene, chlorine-benzene, etc.).

Pedo-ecosystems 1b primarily represent the busiest cross roads and highways communications loaded by exhausted emission, which affects quality of adjacent soils. There are mainly inorganic substances (Pb, Zn, Cd), with measured concentration exceeding tolerance limit. Also airport and Danube haven, they both are included in this category. They are sources of benzene and oil minerals and other organic-inorganic pollutants.

2a trade-commercial and other small production systems including commercial-housing areas with sealing of more than 60 %.

2b residential areas with less than 60 % sealing (housing development, villa district, etc.).

Characteristics:

Delineated areas are disturbed by anthropic activities in lesser rate than in the above mentioned category. However, there is an objective assumption that these urban ecosystems represent potential sources of environment contamination for soil. It is due to a high production of heterogeneous garbage and waste, small industrial works production, hospitals, and shopping centers characterized by high energetic consumption and traffic emission as well.

II. Categorization potentially threatened by environmental risks resulting from soil (raising requirement on soil quality)

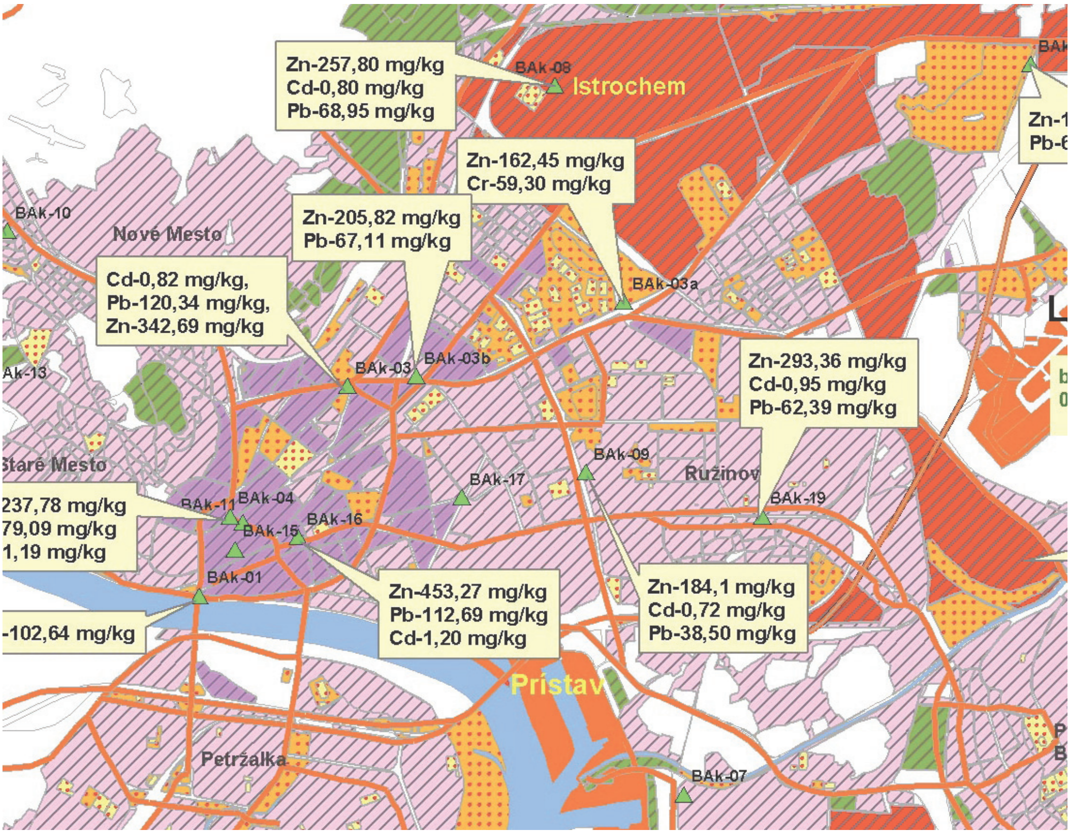
A main risk areas regarding soil quality: kindergarten, playing grounds, public playing sandboxes, sport grounds, schoolyards used by urban children population till 15 years. There is possible contamination from traffic emissions (Pb, Zn, Cd, As, Hg), industrial sources (organic pollutants), trans-boundary contamination (SO_2, NO_x), and noxious substrata prevailingly of anthropogenic origin. Here is recognized that the immediate contact with the soil considerably interacts the most sensitive children's health.

B risky areas regarding soil quality: sport stadiums and grounds, ornament gardens and parks, cemeteries and crematories, recreation areas and water pools used prevailingly by adult urban population. There is possible contamination from the traffic emissions and industrial works (Pb, Zn, Cd, As, Hg, organic pollutants), trans-boundary contamination (SO_2, NO_x), and substrata of poor quality.

- **C** specifically risky areas: garden allotments and settlements, vineyards, orchards. There is a possible contamination of surface horizons by inorganic elements from traffic emissions (Pb, Zn, Cd, As, Hg) from exceeded application of fertilizers (N, P, K, S), manure, slurries from sewage plant, pesticide application (persistent chlorine-phenol, aldrins, DDT, hexachlorobenzols etc.) as well as from soil liming (As, Pb).
- **D** areas potentially slightly threatened by environmental risk related to soil: arable land, meadows and pastures, urban and suburban forests, natural reservation areas. There is possible contamination from the traffic emissions (Pb, Zn, Cd, As, Hg) and other adjacent harmful sources. Well-managed arable land can eliminate risk contaminants by its buffer activity. Also green areas of forest and forest-parks represent very precious biotopes with significant barrier and sanitary functions.

By delineation of individual areas we have created the whole image of real and potential environmental risk on the territory of Bratislava city. We have defined the most sensitive areas vulnerable to risk related to soil. Figure 1 shows illustrative cut from the map with legend described according to above mentioned categorization. Moreover, monitoring sites net was suggested in relation to observe, analyze and assess tends of urban soil behavior, mainly observation of risk elements concentration in the most sensitive and environmentally threatened sites.

Figure 1 Illustrative cut-out of the Map of environmental risks in relation to soil (city of Bratislava, scale 1:25,000)



Present legislation measures interfering urban soil protection

There is a need to point out that legislation of Slovak Republic for soil protection and conservation is specified only for agricultural soils, i.e. soil quality limits are valid only for agricultural soils. The urban soils are not included here. Several documents deal with quality of soils:

- Methodical instructions MSPNM a SKZP No. 130/1992 contain limits for status assessment of earth and groundwater contamination in the categories A, B, C (Dutch limits).
- Resolution of MP SR č. 531/1994-540 on the most acceptable values of noxious substances in soils (only agricultural soils).
- Law 220/2004 on protection and use of agricultural soils.
- Law 205/2004 on gathering, keeping and propagation of information about environment.
- Law 245/203 on integrated prevention and control of contaminated environment.

It means that in Slovakia is a lack of legislative measures protecting urban soil in contrast to some countries in which urban soils are evaluated as environmentally endangered and require legal conservation measures. As an example can serve, urban soil protection (BUNDES-BODENSCHUTZGESETZ, 1998) in North Rhine-Vestfalen in Germany with different approach for risk elements and substances limits in soils. This law differentiates individual limits for playing grounds and sandboxes, housing areas, park and recreation zones as well as industrial sector.

CONCLUSIONS

From this point of view this study might be intervened as a certain starting point for consideration of development and implementation of legislative frame for urban soils protection. This paper provides evidence about human health endangerment. One of the inevitable assumptions of the legal concept elaboration has to be considered the preservation of differentiated principles of pedo-urban ecosystems concerning importance of urban soils in the aspect of health and environmental risk of urban population.

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SOIL EROSION ASSESSMENT AT THE CONCRETE CATCHMENT USING GIS TECHNOLOGY

VYUŽITIE GIS TECHNOLÓGIE NA ZHODNOTENIE PÔDNEJ ERÓZIE V KONKRÉTNOM POVODÍ

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ABSTRACT

The main objective of this study is evaluation of agricultural soils affected by water erosion as well as intensity of erosion assessment (soil matter loss) at the Neresnica river-basin (14 147 ha) using Geographical Information System (GIS). In the GIS, it is possible to combine available data of main erosive factors on purpose to generate a map of potential or actual soil erosion (sensitivity and risk of soil erosion). Empirical model of Universal Soil Loss Equation (USLE) modified for soil erosion assessment at local scale has been used in the GIS technology. Rainfall-runoff erosivity, soil erodibility, potential of relief and cover management digital data layers have been created on this purpose (conservation practice factor has been not considered in this study). Digital GIS layers have been derived from primary data of various sources (e.g. soil database of Soil Science and Conservation Research Institute) or from already existing digital layers of Slovakia (R-factor).

On the basis of achieved results it may be said that approximately 37.5 % of farmland in monitored locality is potentially affected by soil erosion processes of various intensity (from low to extremely high). Extension of agricultural soils affected by potential soil erosion is dominantly controlled by relief (it represents undulated hillyland in this example). Area of actually affected soil by the soil erosion is expressively lower (only 1.4 % of farmland) in monitored locality. Relatively large area of agricultural soils is located at submountainous parts of the study region where relatively steep slopes (not available for cropping of usual agricultural crops) predominate. In general, these areas of agricultural soils are well protected by covering of permanent grass which has a very good anti-erosive effect.

KEYWORDS: soil erosion, USLE, GIS

ABSTRAKT

Hlavným cieľom predkladaného príspevku je zhodnotenie záujmovej lokality z pohľadu zastúpenia vodnou eróziou ovplyvnených poľnohospodárskych pôd a stanovenia intenzity vplyvu erózie (strata pôdnej hmoty) na pôdy v predmetnej lokalite (povodie Neresnice s rozlohou 14 147 ha) využitím Geografického informačného systému (GIS). GIS poskytuje možnosti kombinovať prístupné dáta týkajúce sa eróznych faktorov za účelom generovať mapy potenciálnej a aktuálnej pôdnej erózie (senzitivita a náchylnosť pôdy na eróziu). V prostredí GIS sme použili empirický model Všeobecnej rovnice straty pôdnej hmoty (USLE) modifikovaný pre zhodnotenie pôdnej erózie v lokálnej mierke. Pre tento účel boli vygenerované digitálne vrstvy eróznych faktorov (faktor eróznej účinnosti dažďa, faktor erodovateľnosti pôdy, faktor dĺžky a sklonu svahu, faktor ochranného vplyvu vegetačného krytu), ktoré sme zohľadnili pri tvorbe záverečných máp náchylnosti poľnohospodárskych pôd na eróziu (potenciálna, aktuálna). Pri odvodzovaní digitálnych vrstiev jednotlivých eróznych faktorov v lokálnej mierke sme využili primárne údaje (databáza VÚPOP), alebo už existujúce digitálne vrstvy Slovenska (vrstva R faktora).

Na základe dosiahnutých výsledkov môžeme konštatovať, že približne 37,5 % výmery poľnohospodárskej pôdy záujmovej lokality je potenciálne ovplyvnené pôdnou eróziou rôznej intenzity (kategórie erodovanosti od nízkej až po extrémnu). Rozšírenie poľnohospodárskych pôd ohrozených potenciálnou pôdnou eróziou je vo veľkej miere funkciou reliéfu záujmového územia (v tomto prípade sa jedná o členitý pahorkatinový reliéf). Výmera poľnohospodárskej pôdy aktuálne ohrozenej eróziou je v tomto prípade výrazne nižšia (iba 1,4 % výmery PPF). Pomerne veľká časť záujmového územia je lokalizovaná v jeho podhorských častiach, v ktorých prevládajú relatívne strmé svahy nevhodné pre pestovanie bežných poľnohospodárskych plodín. Poľnohospodárska pôda nachádzajúca sa v týchto častiach regiónu sa využíva ako trvalé trávne porasty, ktoré majú veľmi dobrý antierózny účinok.

Kľúčové slová: pôdna erózia, USLE, GIS

INTRODUCTION

Soil erosion belongs to the most serious environmental problems regarding to agricultural and natural environment (degradation of soil and water quality, contamination, clog up water reservoirs, eutrophication etc.). Erosion includes processes by which earth materials are entrained and transported across a given surface. It is a result of different factors influence and interactions (rainfall, soil erodibility, slope length, steepness, cropping management). Erosion control is based on the information about quantitative and qualitative evaluation of soil erosion on a specific site and so it requires knowledge of terrain information, soils, cropping system and management practices, as well.

Erosion of soil is a significant problem of agricultural soils in Slovakia due to the mountainous character of this territory. A great deal of arable soils is located on the relatively steep slopes. Erosion is a natural process but it has been frequently accelerated by absence of thinking in human activities during the last decades. The farmers working on the soils situated on the erosive sensitive areas should use appropriate erosion control to decrease undesirable effect of soil erosion.

Obtained knowledge on vulnerability of agricultural soils concerning erosion processes in concrete area can be helpful for the farmers to apply appropriate erosion control measures to combat soil erosion. Erosion control is understood as a system of measures suitable for prevention and reduction of soil loss and preserving of soil fertility.

Evaluation of areal distribution by water erosion affected agricultural soils as well as intensity of erosion assessment (soil matter loss) at the monitored locality (Neresnica river-basin) using the GIS has been the main objective of this study. Geographical Information System is becoming appropriate and popular tool in the estimation and prediction of intensity of soil erosion because with the GIS the main factors influencing soil erosion can be visualized (Bergholz, 2003).

MATERIAL AND METHODS

The GIS allows to work with positions, areas, shapes and topology of objects. It is suitable to implement a lot of attributes for connecting and combining, generation of new attributes, analysing, modelling and creation of various forms of outputs (e.g. graphs, maps, 3D models etc.). Program ArcGis is one of the numerous GIS program packs suitable for the displaying and analysing geographical data. We are using ArcGis to connect geographical data from various sources, formats and cartographical images to only one surrounding. Creation of outputs (in our example maps of studied locality) is divided into two main steps:

- analysis and excerption of obtained results
- digital processing of data for the map outputs

In the GIS, it is possible to combine available data of main erosive factors on purpose to generate a map of potential or actual soil erosion (sensitivity and risk of soil erosion). Extensive data identify agricultural soil affected by soil erosion (on the example of Neresnica river-basin) have been used from databases of the Soil Science and Conservation Research Institute (land evaluated pedo-ecological units database, remote sensing images database, R-factor database).

Empirical model of Universal Soil Loss Equation (USLE) modified for the soil erosion assessment at a local scale has been used in GIS technology.

Potential soil erosion expresses the susceptibility of bare soil to erosion (if soil is without any protective vegetation cover). This way it provides information on the worst possible situation that might occur (Šúri et al., 2002). Rainfall-runoff erosivity, soil erodibility, hillslope length and steepness digital data layers of monitored locality have been created on this purpose.

Actual soil erosion expresses a contemporary vulnerability of soil by the processes of water erosion taking into account (besides rainfall-runoff erosivity, soil erodibility, hillyslope length and steepness) cover management (present vegetation cover) and support conservation practices (erosion control measures).

USLE (Wischmeier, Smith, 1978) is a method for soil loss estimation from the lands influenced by an overland flow. The USLE model is a set of mathematical equations that estimate average annual soil loss from studied localities in concrete (climatic, hydrologic, pedologic, topographic) conditions. It helps us to estimate soil loss from a hillyslope caused by the impact of raindrop and overland flow (interrill erosion) and rill erosion. The USLE is calculated as:

$$A = R \,.\, K \,.\, LS \,.\, C \,.\, P$$

where: A – average annual soil loss in tons per hectare and year
R – rainfall-runoff erosivity factor
K – soil erodibility factor
LS – hillyslope length and steepnes factor
C – cover-management factor
P – conservation practice factor

R-factor (erosivity of rainfall) – is understood as a multiplication of total rain kinetic energy and its maximum 30-minute intensity. The R-factor is an expression of the rainfall and runoff erosivity at a particular location. The values of this factor (for the individual parts of Slovakia) have been calculated from the measurements of ombrographic stations (Mališek, 1992).

K-factor (erodibility of soil) – represents both susceptibility of soil to erosion and the rate of runoff. The values of K-factor are the function of organic-matter content, particle-size distribution, structure and permeability of the soil. K-factor has been computed directly from the code of Land Evaluated Pedo-ecological Units (7 numerous code) to every of main soil units (3rd and 4th position in a code) (Ilavská et al., 2005).

LS-factor (potential of relief) – is an expression of the effect of topography (relief) on the rates of soil loss at a particular site. Slope length factor represents the ratio of soil loss from the field slope length to that from a 22.1 m length on the same soil type and gradient. Slope steepness factor represents the ratio of soil loss from the field gradient to that from a 9 percent slope under otherwise identical condition. Calculation of the LS-factor (effect of slope factor) is made by the flow accumulation layer, which estimates a slope length (Moore, Burch, 1986).

C-factor (cover management) – expresses effect of crop rotation and management practice on erosion processes initiation and course.

P-factor (erosion control measures) – expresses ratio between the soil loss of the investigated land (tillage along contour) and the soil loss on standard plot tilled up-and-down the slope.

RESULTS AND DISCUSSION

Study area

Monitored locality (Neresnica river-basin) is localised on a hilly relief of the middle part of Slovakia (micro region of Pliešovská kotlina hilly basin, middle part of the Zvolen district). The whole area of this small basin is 14 147 ha (farmland: 5 860 ha). This part of the country is characterized by heterogeneous relief, which was predominantly formed during intensive volcanic activity (Paleozoic era), tectonic development and erosive activity of water streams. Neresnica is the main water stream of studied area and a majority of small water streams (creeks) runs to this river. Average altitude is 544 m o.s. (the lowest point is in 325 m o.s. and the point with highest altitude is 905 m o.s.). The values of slope steepnes are going from 0 to 35.5° and predominant slope steepnes is more than 12° (0 – 3°: 20 %, 3 – 7°: 22 %, 7 – 12°: 24 %, more than 12°: 34 % of monitored locality area). Average annual precipitation value is influenced above all by real altitude. At the lowest areas of basin is an average annual precipitation value approximately 665 mm and with higher altitude the precipitation value is going up (more than 900 mm). Loamy soils predominate on the whole studied area especially Eutric Cambisols, Eutric Cambisols (shallow), Stagni-Dystric Cambisols, Dystric Planososls, and Albi-Stagnic Luvisols (according to WRB, 1998).

GIS technique

The technique of GIS for the evaluation of areal distribution by water erosion affected agricultural soils, as well as intensity of water erosion assessment at Neresnica river-basin has been used in this study. We have used empirical model of Universal Soil Loss Equation (USLE) in the GIS technique to generate maps of potential and actual average annual soil loss at the monitored locality. Rainfall-runoff erosivity, soil erodibility, potential of relief and cover management digital data layers have been created on this purpose (conservation practice factor has been not considered in this study). Digital GIS layers have been derived from primary data of various sources (e.g. databases of Soil Science and Conservation Research Institute, Bratislava) or from already existing digital layers of Slovakia (R-factor).

Rainfall erosivity digital layer (R-factor) of monitored locality has been created from the R-factor of Slovakia revised map (digital layer) done by Styk, Pálka (2005). R-factor map has been created by combination of R-factor computed values from measurements of individual ombrographic stations, digital elevation model, digital layers of climatic regions and average annual precipitation in Slovakia (Figure 1).

Soil erodibility digital layer (K-factor) created directly from the database (digital layer) of Land Evaluated Pedo-ecological Units (7 numerous code). K-factor has been computed from the 3rd and 4th position from this code. It is the position for every main soil units (soil types and subtypes) in this code. Numerical values of K-factor have been calculated for every individual soil type and subtype (Figure 2).

Figure 1 R-factor (erosivity of rain)

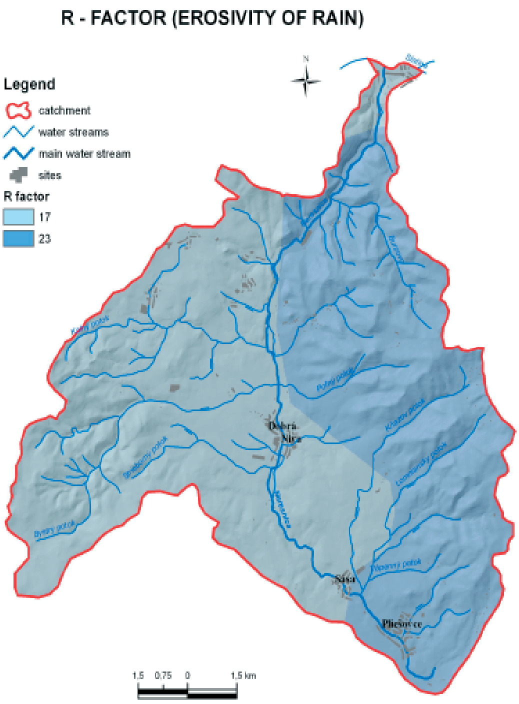
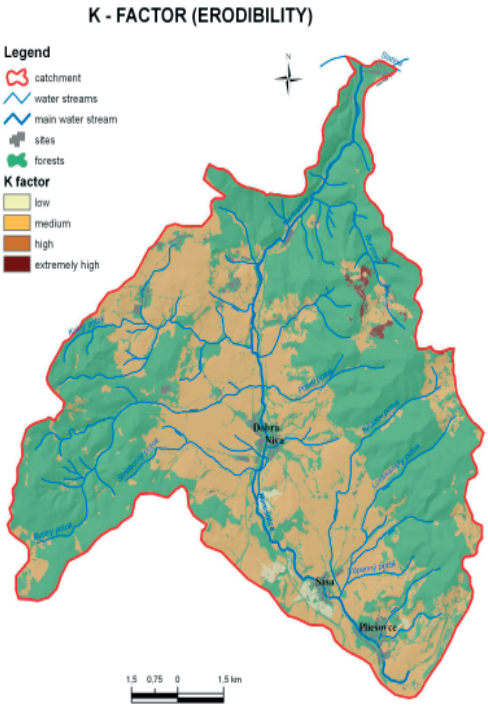


Figure 2 K-factor (soil erodibility)



Technique used in this study requires computing the LS-factor (potential of relief) at the monitored locality by flow accumulation layer, which estimates a slope length. Flow accumulation can be calculated from DEM (digital elevation model) using the hydrologic extension. The present study modelling used a raster, based on an approach where a square cell of 5 meters is chosen (5 meters grid resolution). The equation for estimating LS-factor based on flow accumulation and slope steepness (Moore, Burch, 1986) is following (Figure 3):

$$LS = (\text{Flow Accumulation} * \text{Cell Size}/22.13)^{0.4} * (\sin \text{slope}/0.0896)^{1.3}$$

Cover management (C-factor) is used to reflect of cropping and management practices on erosion rates. Cover-management factor at the studied locality has been interpreted from satellite images (remote sensing method). Real land cover (vegetation) has been identified by interpretation of these images under Arc View Programme on the basis of various colour reflectance of individual plants (Figure 4). These images have been obtained from the Landsat satellite during summertime 2005. The studied area arable land is predominantly covered by winter cereals, ensilage maize, summer cereals, potatoes and forage crops.

Conservation practice factor (P-factor) has been not considered in this study.

Figure 3 LS-factor (influence of relief)

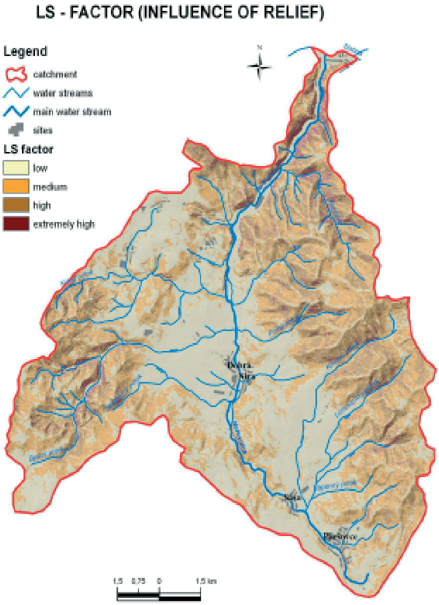
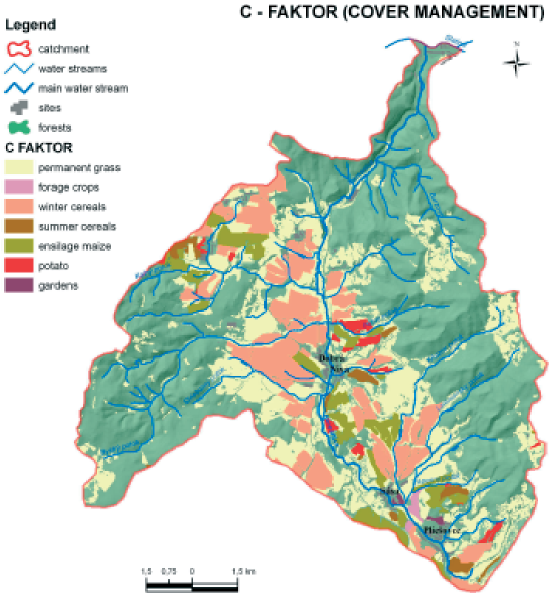


Figure 4 C-factor (cover management)



Area at risk of soil erosion

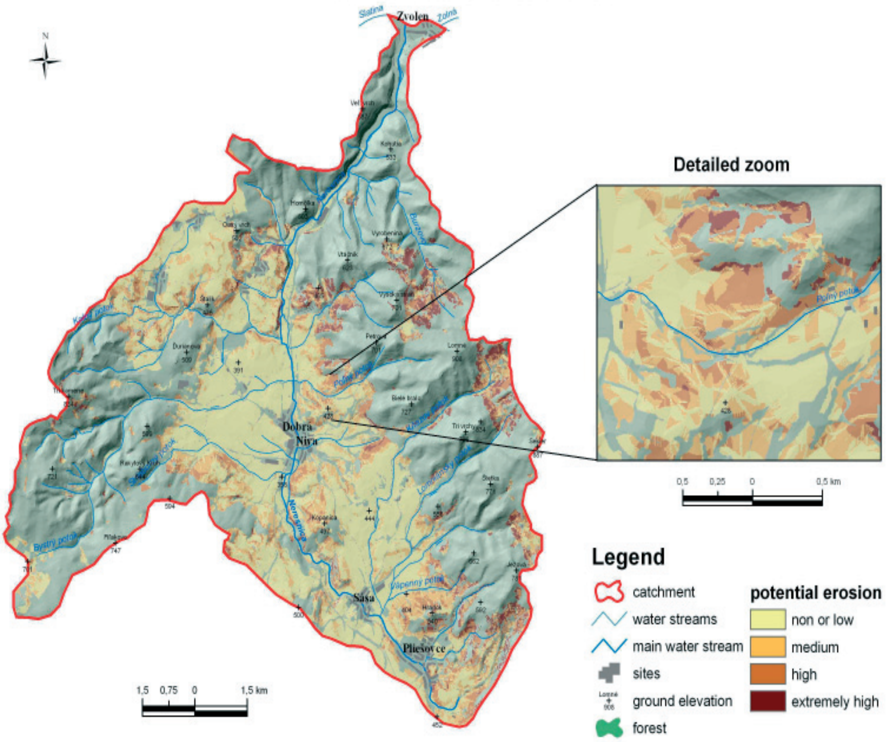
The results of this study demonstrate the possibility of identifying the areas at risk of soil erosion by using available data in the GIS. We can see (Table 1, Figure 5,6) the extent (ha or % of farmland) of individual erosivity categories (actual and potential erosion) in studied locality. The data layers of actual and potential soil threat to water erosion on Neresnica river-basin (situated on a hilly relief of middle part of Slovakia) are the products of the USLE equation in the GIS technique. The values derived from these layers represent average annual soil loss in tones per hectare (Table 1).

Table 1 The extent of individual erosivity categories in the studied locality

Erosivity categories	Potential soil erosion		Actual soil erosion	
	Area in ha	% of farmland	Area in ha	% of farmland
None or low	3 662.5	62.5	5 776.3	98.6
Medium	1 122.6	19.1	75.3	1.3
High	742.3	12.7	8.1	0.1
Extremely high	332.6	5.7	0.3	0.0
Σ	5 860.0	100	5 860.0	100
Catchment area	14 147.0		14 147.0	

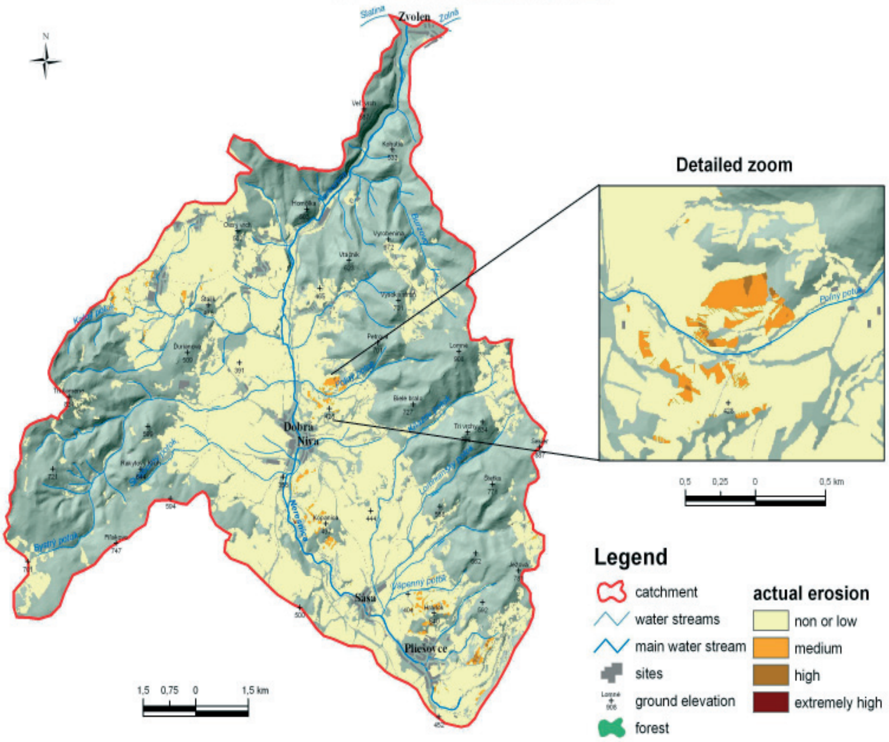
Relief dominantly controls extension of the water erosion of potentially influenced soils and from this point of view 37.5 % of farmland in monitored locality is endangered by soil erosion processes of various intensity (from low to extremely high) (Figure 5). Soil, climate, and lithological local conditions (except relief) play also a significant role in distribution of potential soil erosion affected soils. Medium heavy (loamy) soils with medium humus content are predominant for this region. These soils are considerably less susceptible to negative influences of soil erosion processes.

Figure 5 Potential vulnerability of agricultural soils by water erosion in the catchment (basin)



Relatively large area of agricultural soil is located at sub mountainous parts of the study locality, where relatively steep slopes (not available for usual agricultural crops) predominate. In general, these areas of agricultural soils are well protected by a permanent grass, which has a very good anti-erosive effect. From this point of view, although the agricultural soils have relatively high potential to erosion, actual vulnerability by the soil erosion is expressively lower (1.4 % of farmland) in the monitored area (Figure 6). We can see a decrease of the farmland in potential vulnerability in the categories of medium, high and extremely high erosion from the 19.1, 12.7 % and 5.7 % to 1.3 %, 0.1 %, as well as 0 % in the farmland in actual vulnerability (Table 1).

Figure 6 Actual vulnerability of agricultural soils by water erosion in the catchment (basin)



CONCLUSIONS

The monitored territory belongs to the part of the country characterized by a heterogeneous relief (volcanic and tectonic development of this area). Extension of the agricultural soils affected by the potential soil erosion is dominantly controlled by the relief (it represents undulated hillylands in this example). On the basis of the achieved results, it may be said that approximately 37.5 % of farmland in the monitored locality is potentially endangered by the soil erosion processes of various intensity (from medium to extremely high).

The actual soil erosion refers to the present vulnerability when taking into account contemporary cover management (land cover). Although the agricultural soils have a relatively high potential to erosion vulnerability in the regions associated with sub mountainous areas, actual vulnerability by the soil erosion is expressively lower (1.4 % of farmland) in the monitored area. These areas of agricultural soils are in general well protected by the permanent grass, which has a very good anti-erosive effect.

The study of the monitored locality (Neresnica river catchment) demonstrates the suitability of using the GIS technique to locate areas with risk of soil erosion. Empirical model of the Universal Soil Loss Equation (USLE) modified for soil erosion assessment at a local scale has been used in the GIS technique. Information (graphic outputs) on vulnerability of agricultural soils (areal distribution) to erosion processes in the concrete area (in this example small basin) can be helpful for farmers (agricultural practice) to apply appropriate erosion control measures to combat soil erosion in concrete conditions. In general, erosion control is a system of measures for mitigation of erosive factors influence in such a way that soil erosion is reduced to a tolerable limit.

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LAND USE/COVER SURVEY IN SLOVAK REPUBLIC IN 2006

PRIESKUM VYUŽITIA KRAJINNY A KRAJINNEJ POKRÝVKY NA SLOVENSKU V ROKU 2006

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ABSTRACT

The present paper gives an overview of the survey of LUCAS points in Slovakia. The Land Use/Cover Area frame Statistical survey was designed to collect agricultural, environmental data and photographs by field observation of a specific geographically referenced point.

LUCAS 2006 survey in the Slovak Republic was carried out by a Soil Science and Conservation Research Institute (SSCRI). The survey of 3 392 points was organized from the 21st of March till 16th of July. The measurements were carried out by 7teams (in pairs). All points had to be visited, measured with GPS and documented. Documentation included, besides the land use and land cover identification, also photo documentation of 5 – 6 photographs.

The controls of surveyors were organised in May by two supervisors who controlled 5 % of the surveyed points.

Important part of the project was the data transfer to Eurostat on weekly basis with a week progress report and transfer of photo documentation biweekly.

The result of the project is georeferenced information about the land use and land cover with photo documentation of each point. These results in combination with products of other approaches of agro-environmental variables enable further analyses.

KEYWORDS: Land use/cover area frame statistical survey (LUCAS), land use/cover nomenclature

ABSTRAKT

Predkladaná práca pojednáva o vykonaní prieskumu LUCAS (štatistický rámcový prieskum využitia krajiny a krajinnej pokrývky) na území Slovenskej republiky. Cieľom projektu LUCAS bol zber poľnohospodárskych a environmentálnych údajov prostredníctvom pozemného pozorovania s použitím GPS prístrojov a fotografovania špecifických georeferencovaných bodov.

Prieskum LUCAS 2006 na území Slovenskej republiky vykonal Výskumný ústav pôdoznalectva a ochrany pôdy. Zber údajov na 3 392 stanoviskách bol organizovaný od 21. marca 2006 do 16. júna 2006. Zber údajov zabezpečilo 7 prieskumníckych dvojíc. Všetky body bolo potrebné navštíviť v teréne a prostredníctvom GPS prístroja zamerať a zdokumentovať. K dokumentácii, okrem určenia využitia krajiny a krajinnej pokrývky na základe danej nomenklatúry s opisom cesty na bod, sa prikladali aj fotografie v počte 5 až 6.

Vnútorná kontrola prieskumníkov sa uskutočnila v máji, kontrolovaných bolo 5 % bodov, ktoré boli navšívené kontrolórmi.

Dôležitou súčasťou projektu bol týždenný presun informácií Eurostatu s priloženou správou o stave projektu a časového harmonogramu a dvojtýždňové dodanie fotodokumentácie.

Výstupom projektu sú polohovo lokalizované informácie o využití krajiny a krajinnej pokrývky s fotodokumentáciou každého bodu, ktoré v kombinácii s inými metódami zberu agro-environmentálneho charakteru umožnia ďalšie analýzy.

KĽÚČOVÉ SLOVÁ: štatistický rámcový prieskum využitia krajiny a krajinnej pokrývky (LUCAS), nomenklatúra využitia krajiny a krajinnej pokrývky

INTRODUCTION

In order to test the integration of land use and land cover data at European level through harmonisation of nomenclatures and collection methods, the LUCAS *"Land Use/Cover Area frame statistical Survey"* pilot project was launched by the Eurostat in 2001, in close collaboration with the Directorate General for Agriculture and with the technical support of the Joint Research Centre ISPRA.

Area frame surveys are common approaches to gather land cover and land use data. In contrast to mapping approaches, area frame sampling is a statistical method. Based on the visual observation of sample geo-referenced points, area estimates are computed and used as a valid generalisation without studying the entire area under investigation. The approach has also an important advantage of not involving/disturbing land owners and farmers.

LUCAS was implemented in 2001 in 13 EU Member states, in 2002 in United Kingdom, Ireland, Estonia, Hungary and Slovenia.

The survey was carried out again in 2003 in all the EU Member States (15) plus Hungary allowing to evaluate the change detection (2001 – 2003).

Building on the conclusions of the LUCAS 2001 and 2003 surveys and on the experiments of the JRC Ispra in Greece in 2004, a new methodology was designed for the forecasted 2006 survey and tested in a pre-pilot survey in 2005 in Latvia, Lithuania and Poland.

The LUCAS 2006 survey was organized in 11 Member States (FR, CZ, SK, HU, PL, ES, IT, BE, LU, DE, NL) (http://forum.europa.eu.int/irc/dsis/landstat/info/data/index.htm).

MATERIALS AND METHODS

Survey methodology as well as the nomenclature was given by the Eurostat. The technical documentation had the following structure:

- Doc A: Sample selection
  - A-1. Selection of Base and Master sample, and photo-interpretation,
  - A-2. Selection of the field sample
- Doc B: Technical guidelines (for the field operators)
  - B-1. Preparation of the field work, technical requirements
  - B-2. Guidelines for reports
- Doc C: Instructions for the surveyors
  - C-1. Instructions for the surveyors
  - C-2. Field form
  - C-3. Nomenclature

Doc D: Data entry and transmission, including software (for the field operators)

D-1. Data entry

D-2: Data transmission

Every document given to the surveyors had to be translated (Doc. C and D-1).

Sample selection (by Eurostat)

The LUCAS master sample was defined as intersection of points of a 2 km-grid covering the territory of the EU. It consists of around 1,000,000 geo-referenced points.

Each point of the master sample was photo-interpreted in order to stratify the master sample into 7 strata (Table 1). For photo-interpretation, the most recent orthophotos were used.

From the stratified master sample, a sub-sample of points (around 250.000 points for 23 EU Members) was extracted in order to be classified by the field visit according to the full land nomenclature (EUROSTAT, 2005).

Slovak Republic

Master sample: 12.262 points

Results of the photo-interpretation and size of the field sample by strata:

Table 1 Number of points in a field sample

Stratum name	Number of points in strata	Sampling rate	Number of points in field sample
1 – Arable land	3.704	50 %	1.852
2 – Permanent crops	110	50 %	55
3 – Grassland	1.659	50 %	830
4 – Wood/Shrubland	5.995	10 %	600
5 – Low, rare vegetation	70	10 %	7
6 – Artificial land	367	10 %	37
7 – Water	106	10 %	11
Total	12.011	28.23 %	3.392

Methodology

The surveyors had to get as close to the point as possible by car. To get to the point topographic map was used together with the orthophoto. The exact location of the point was identified by a large scale orthophoto and GPS. On the whole, the orthophoto had to be taken as a reference.

After they reached the point (or got as close as they could), they measured the exact location by the GPS. At the point, they had to fill in the field form with the required information concerning the date and time of the observation, exact coordinates, distance of the observation, land use land cover (primary, sometimes secondary as well), direction of the observation, way to the point, some special circumstances if some occurred. The surveyors had obligation to document their observation by means of several photos. They had to take a photo of the point, a photo of the crop/cover (Land cover classes B1x- B4x and Exx) and four landscape photos as well. Each point was documented according to the above mentioned. More about the methodology can be found in the LUCAS 2006 Technical reference documentation.

The point, where the land use/ cover had to be observed, corresponds to a circle with a 1.5 m radius (or 3 m diameter), so the point represents an area of about 7 m^2. In most cases, the point falls in a unique area and the above mentioned definition can be easily applied. In some cases the point fell into a boundary of two plots or was located on a linear feature <3 m wide (small hedge, small track, roadside verge). In these cases a special rule "Look to the North" had to be applied. In exceptional cases when the border between two plots or the linear feature was in the North-South direction "Look to the East" rule was applied. Then land use/ cover was observed north or east of the point.

Some land cover classes require observation of a larger area, i.e. a reference larger than the point "area" 7 m^2, for example the wooded areas, the grassland with or without trees etc. Also, when the land cover is not homogeneous, for example when it is composed of trees or shrubs interspersed with grassland, the scale of observation has to be changed to classify it. In these cases a systematic observation of the "environment" of the point (Extended Window of Observation) within a radius of 20 meters of distance (or 40 m diameter) from the point had to be adopted (this represents an area of 0,13 hectares). Systematically, the window of observation had to be extended whenever the land cover at the point was identified as permanent crop (B7, B8, except nurseries B84), grassland (E), shrub land (D) or woodland (C) (Eurostat, 2006).

Materials and equipment given to the surveyors:

- topographical maps with LUCAS points of the team, scale 1:100 000 (A3)
- orthophoto for each of the points and its coordinates, scale 1:20 000 and 1:5 000 (A4)
- field documents
- translated reference documentation: C-1, C-2, C-3, D-1
- additional documentation: Overview, Brief instructions – equipment, back-up and data transmission, Internal quality control
- Route Atlas of Slovak Republic 1:100 000
- clipboard, pen, folders for maps and orthophotos
- CDs for the back-up and to send photos to the central office
- authorization document
- Garmin GPSMAP 60CSx + batteries
- Panasonic Lumix DMC-LS1 digital camera + SD memory card 256MB + batteries
- quick battery charger
- notebook Asus A6U – B060H
- compass
- point indicators – plate, stick

Eurostat provided "LUCAS Data-entry tool' to enter the data and carry out data checks. This tool was developed in JAVA. The version provided by the Eurostat was in English. The tabular files had to be translated in order to allow efficient use. The software was available to each surveyor to enter the data in electronic form shortly after the field survey, on a daily basis.

RESULTS AND DISCUSSION

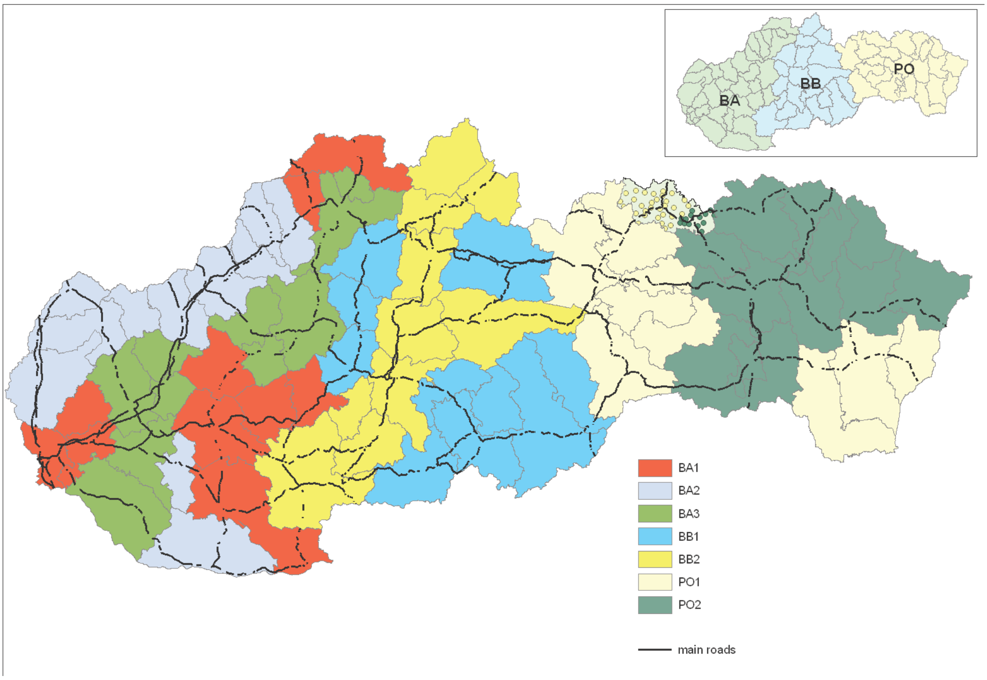
The whole LUCAS team consisted of 21 people divided into managerial team and seven surveyors` teams with additional back-up members. The surveyors were from three regional departments of the Institute: Bratislava (3 teams), Banská Bystrica (2 teams) and Prešov (2 teams).

The preparatory works included check and control of the transformation of the given coordinates, preparation of the ground documents, translation of the reference documentation, selection of the equipment (GPS, digital camera, notebooks), preparation of the materials and documentation for training of the surveyors.

The other important part of the preparatory work was the distribution of the points, which included the division of the points equally among the surveyors. The points were divided according to the districts of Slovakia and regional departments of the Institute.

One of the criteria was to give each of the surveyors' team equal number of points on arable land and in woodland (according to the stratification given by Eurostat) and the other one was the communication network not to complicate the transfer. Result of the distribution of the points per surveyors` team is visible on the Figure 1.

Figure 1 Distribution of the points according to regional districts and road network



The number of points per team is presented in the following table (Table 2).

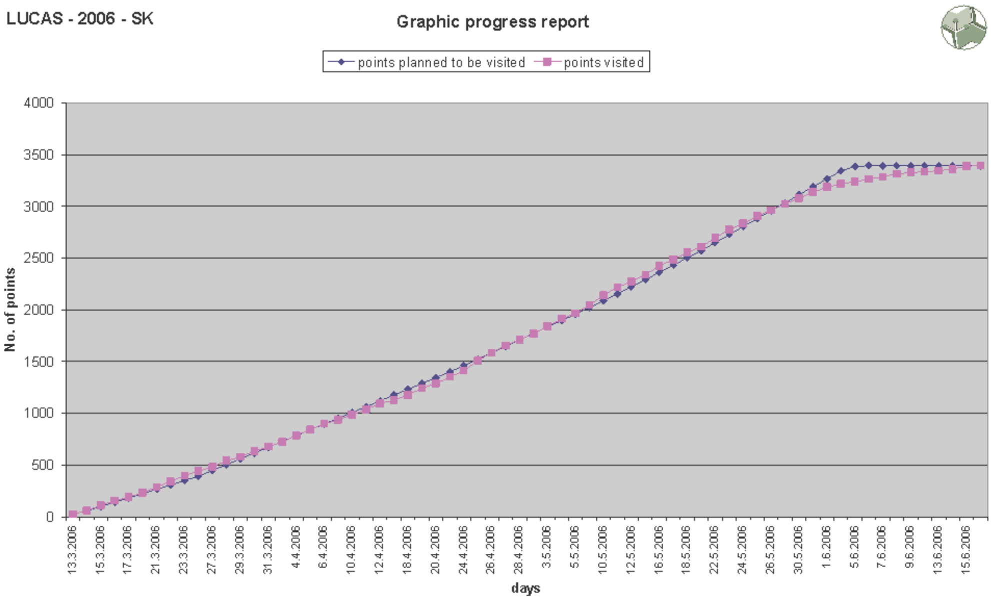
Table 2 Division of points per surveyors` team

Team/ stratum	1, 2	3,4,5,6,7	Sum
BA1	344	135	**479**
BA2	308	180	**488**
BA3	333	143	**476**
BB1	212	265	**477**
BB2	217	266	**483**
PO1	246	249	**495**
PO2	247	247	**494**

The field visits began very early, on 13th of March 2006 – according to the plan the grasslands, woodlands/shrublands and permanent crops had to be visited first. The weather conditions were tough, the snow cover caused difficulties to reach the points and recognize the land use/cover (Szőcsová, 2006).

The progress of the field visits copied the plan; in the first few weeks the average number of points was very low due to their accessibility and the weather conditions. At the end, the minimum number of points to be visited per day was set to 11. This was not reached only in cases of some technical problem issues. The end of the field measurements was postponed one week, instead of planned 9th of June the survey finished on the 16th of June. The graphical progress of the survey is given in Figure 2.

Figure 2 Graphical progress of the survey



Some details about the performance of the survey are given in Table 3. The average number of the points per day had increasing character from 6 at the beginning to 11 at the end giving mean of 9 points/ a day. The average was slightly lower whenever the weather conditioned worsened. The most critical situation was in the 5th week 10 – 14th of April due to heavy rains and floods.

The average survey time per point had also decreasing characteristic. The first weeks, the measurements took longer because of the snow cover and difficult access to the points in the forest and on the grassland. Later, the time needed for the observation was around 15 minutes or less because access to the points was easier. The longest survey time was registered in the cases of points in the forest, grassland (long walking distances) and in the arable land after heavy rains when the field roads were inaccessible. The shortest survey time was registered in the cases of arable land when the observations were done from the distance in case of exact identification of the point.

The upper mentioned averages show statistics of the evaluated points per day. Points which were visited but not documented (case of summer crops, inaccessible points due to snow, floods) were not count; therefore, according to these strict rules the average is lower than it could be in a case of all the points visited.

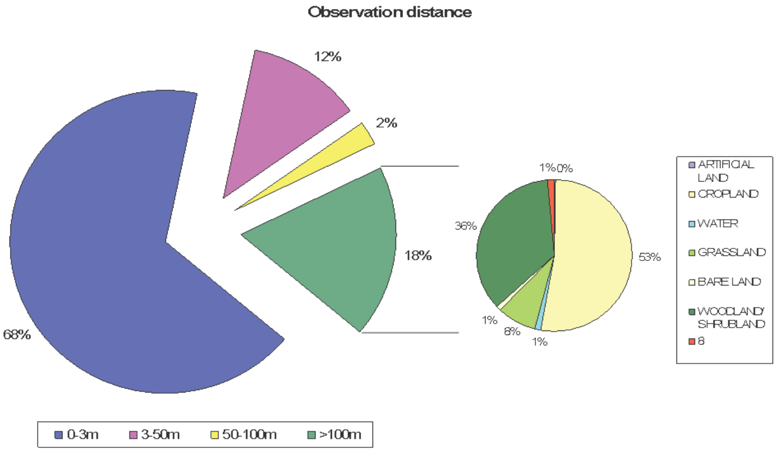
Table 3 Performance of the survey

Team	Date started	Date finished	No of days in the field	Average No of points/day	Average time/point
BA1	13.3.2006	16.6.2006	51	9	20 min
BA2	13.3.2006	8.6.2006	56	9	14 min
BA3	13.3.2006	9.6.2006	56	9	13 min
BB1	13.3.2006	6.6.2006	58	8	18 min
BB2	13.3.2006	1.6.2006	55	9	19 min
PO1	15.3.2006	9.6.2006	54	9	19 min
PO2	13.3.2006	13.6.2006	54	9	21 min
TOTAL	13.3.2006	16.6.2006	67	9	18 min

Number of photo-interpreted points is represented by 9 %. Those points were not accessible and had to be interpreted in the terrain on the orthophotomap. In the most cases, those points were located in a forest where entry by car was prohibited, the forest was impenetrable and the GPS signal weak.

The accessibility can be also expressed by the distance of the observation; 67 % of the points were observed on the point (0 – 3 m) and 18 % from a distance more than 100 m (Figure 3), where 36 % was represented by a woodland/ shrubland and 53 % of these observations are pertained to cropland. Some of the points were located in large fields (50 – 100 ha or more), distance to the point was 100 – 400 m or more. The fields were hard to cross due to the height of plants but the point could be located and exactly defined – the observation from distance in these cases was allowed. These points were checked on satellite images as well obtained for another project by the Institute.

Figure 3 Observation distance of the visited points



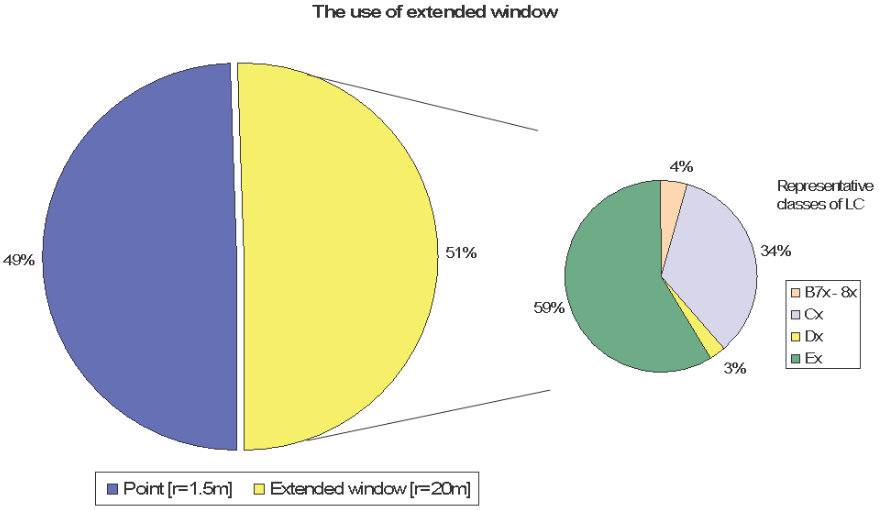
Extended window (EW) was applied in case of homogeneous land cover like the woodland or grassland to define the land cover correctly. The statistics of usage can be found in the table below (Table 4, Figure 4).

In the case of grassland, woodland and permanent crops, there was a need to extent the observation window to describe the land cover correctly. In decision making the ortophotomaps were very helpful due to the visible crown density and the possible coverage estimation. It was problematic to assess the point if it was in a forest or other tree area or grassland with some shrubs or shrubland.

Table 4 Usage of the extended window

ALL	Extended window	Percentage	Class	Number	Percentage [EW]	Percentage [ALL]
3 392	1 718	50.6 %	B7x-B8x	77	4.5 %	2.3 %
			Cx	586	34.1 %	17.3 %
			Dx	50	2.9 %	1.5 %
			Ex	1 005	58.5 %	29.6 %

Figure 4 Use of the extended window and representatives of land cover classes



The European version of the land cover nomenclature contains 58 classes, which are indicated by the combination of a letter of the category and two digits. From the 51 categories identifiable in Slovak Republic only 46 were used in the LUCAS survey (Annex 1).

The identification of the land cover categories was generally correct. Problems in identification were connected with similar categories like Common wheat and Triticale or Grassland with sparse tree/shrub cover and Shrubland without tree cover. The crops in the very early vegetative state, not identifiable by seeds or any other features, were observed later. Land cover map of the Slovakia as the result of the survey can be found in the Annex 2.

The European version of the land use nomenclature defines 33 classes, which are indicated by the combination of the letter "U" and two or three digits. The national nomenclature stayed unchanged, but instead of 33 categories only 22 classes were used (Annex 3).

Problems in identification were connected mainly with used or unused land (grasslands and some fields) vs. fallow land, because fallow land is not a part of the agricultural policy in Slovakia. The measurements were sent every day to the central office where they were controlled, mainly on the completeness and rightness of the collected data. Additional control, before sending the data to Eurostat, was done with the photographs to avoid/lessen the errors of misinterpretation or wrong decision making.

Some revisions were done in the beginning of the survey due to blurred pictures of landscape, point or a crop. Another reason was an unidentifiable crop or a snow cover. Those measurements were not sent or reported to Eurostat. Quality check of the surveyed points was done in the proposed Access database LUCAS Quality Check.mdb together with the photo documentation. Example of the check is in the Figure 5.

Figure 5 Quality checks of the surveyed points

CTRY	POINT_ID	TYPE OF OBSERVATIO	SURVEY TYPE	OBSERVED	DISTANCE	DIRECTION	CHECK REM
SK	50842854	Field survey	Survey	The point is observed	>100m	On the point	

LC1 B32 Rape and turnip seeds CHECK LC1
LC2 8 Not relevant CHECK LC2
RADIUS 1.5m
LU1 U111 Agriculture (excluding fallow land and kitchen garde CHECK LU1
LU2 8 Not relevant CHECK LU2

CHECK ○ Ok ○ NOk ○ Doubt ○ TBR

SURVEYOR 62200 Vzdialenost 247.72799 CIRCUM
DATE 10/05 ☐ CHECK

WAY Bod bol pozorovaný zo vzdialenosti cca 240 m, lebo kvitnúci repkový porast bol vysoký a hustý.

PHOTO POINT Taken
PHOTO CROP Taken
NORTH Taken
EAST Taken
SOUTH Taken
WEST Taken

Besides this control action, the supervisors controlled 5% of the measurements in the terrain on the screen. According to the guidelines, the supervisors had to navigate themselves to the same location as the surveyors and had to control the decision made by surveyors. They had 2 sets of coordinates in the GPS: 1. surveyors location, 2. LUCAS point.

The criteria of control point selection were one or more of the following:

- snow cover – weak plants on the photo documentation, early vegetation stage
- long observation distance
- doubtful land cover/use coding

As the result of the control (Table 5) -12 % of the points were recoded. Some changes were the result of the crop change, some of misinterpretation or wrong decision in the case of doubtful land cover.

The errors in land cover are nearly unique except of 6 cases when B11 and B13 were not identified correctly, others are the results of bad decision making regarding the forage mixtures.

In the land use identification the main problem was whether the field was or was not used, and after the heavy rains some of them were wrongly coded as wetlands (SZŐCSOVÁ et al., 2006).

Table 5 Aggregated table

Class	Controlled points	Number of differences	Differences (%)
A	0	0	0.00
B1	69	10	5.75
B2	0	0	0.00
B3	22	1	0.57
B4	0	0	0.00
B5	12	4	2.30
B7	3	0	0.00
B8	8	1	0.57
C	10	1	0.57
D	1	0	0.00
E	49	4	2.30
F	0	0	0.00
G	0	0	0.00
Total	**174**	**21**	**12.07**

CONCLUSIONS

The upper presented demonstrates the workflow and the results of the LUCAS survey in Slovak Republic. The meaning of the land cover and land use at the first sight is evident but in the practise we often face the problem of mixing these two different concepts. The LUCAS survey effectively draws the attention to understand that for example airport is not a land cover but a type of use of an artificial land.

There are other positive conclusions of the survey. After the visit of 3 392 points in the terrain and proper documentation together with photo documentation of the point, crop and the landscape of four cardinal directions can be combined with the results of other approaches and agro environmental variables.

Results from the Area Frame Surveys can be used at a range of geographical levels, in support of environmental research and education, environmental profiling, planning and reporting. Compared to exhaustive mapping approaches, sample surveys provide rapid results, thus, enabling periodic (annual or seasonal) surveys. In addition, accuracy estimates are possible, which judge reliability and efficiency. Each year field observations at the same location provide accurate data particularly for the detection of land cover and land use changes.

The LUCAS image archive provides an accessible visual source of information on the state and changes of the landscapes. Due to its geographical extension, the landscape images can be easily understandable tool in interpreting and communicating land use/land cover change indicators.

Some of the points were observed with the use of the 'Look to the North/East' rule – have to consider it in the case of using the data for other purposes or combination with remote sensing.

Acknowledgement

I would like to thank to all my colleagues who supported the successful realisation of this survey in Slovak Republic, especially to the surveyors who collected the data in all weather condition.

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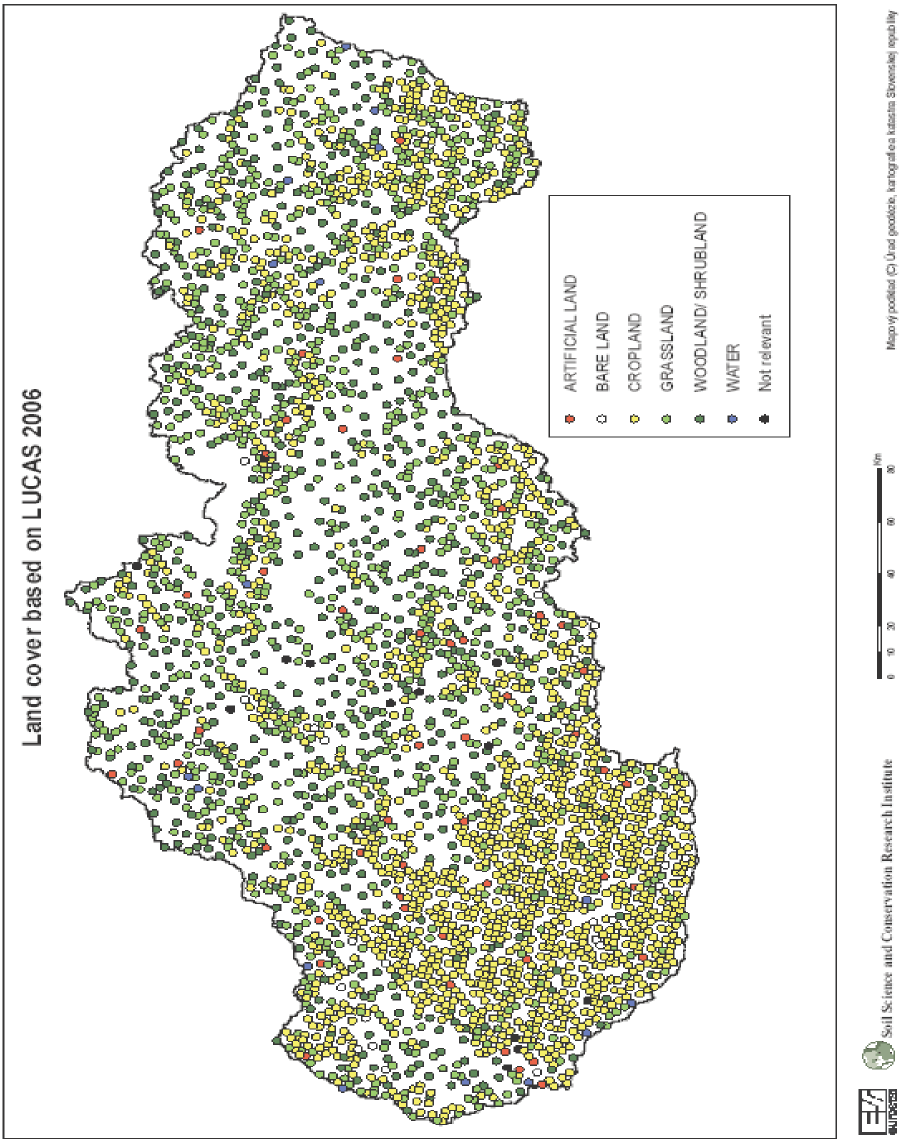
HTTP://forum.europa.eu.int/irc/dsis/landstat/info/data/index.htm

Annex 1 LUCAS 2006 – Slovak Republic – Land cover classes

A	ARTIFICIAL LAND	53	A1	Built-Up Areas	19	A11	Buildings with 1 to 3 floors	17
						A13	Greenhouses	2
			A2	Artificial Non Built-Up Areas	34	A21	Non built-up area features	6
						A22	Non built-up linear features	28
B	CROPLAND	1 630	B1	Cereals	1 021	B11	Common wheat	455
						B13	Barley	246
						B14	Rye	18
						B15	Oats	36
						B16	Maize	260
						B18	Triticale	4
						B19	Other cereals	2
			B2	Root Crops	58	B21	Potatoes	25
						B22	Sugar beet	33
			B3	Non Permanent Industrial Crops	325	B31	Sunflower	117
						B32	Rape and turnip seeds	180
						B33	Soya	19
						B35	Other fibre and oleaginous crops	9
			B4	Dry Pulses, Vegetables And Flowers	33	B41	Dry pulses	17
						B42	Tomatoes	1
						B43	Other fresh vegetables	11
						B44	Floriculture and ornamental plants	1
						B45	Strawberries	3
			B5	Fodder Crops	114	B51	Clovers	11
						B52	Lucerne	51
						B53	Other leguminous, mixes of leguminous and others for fodder	52
			B7	Permanent Crops	45	B71	Apple fruit	23
						B72	Pear fruit	1
						B73	Cherry fruit	2
						B74	Nuts trees	1
						B75	Other fruit trees and berries	18
			B8	Other Permanent Crops	34	B82	Vineyards	32
						B83	Nurseries	2
C	WOODLAND	586	C1	Forest Area	526	C11	Broadleaved forest	272
						C12	Coniferous forest	134
						C13	Mixed forest	120
			C2	Other Wooded Area	60	C21	Other broadleaved tree area	42
						C22	Other coniferous tree area	8
						C23	Other mixed tree area	10
D	SHRUBLAND	50	D0	Shrubland	50	D01	Shrubland with sparse tree cover	20
						D02	Shrubland without tree cover	30
E	GRASSLAND	1 005	E0	Grassland	1005	E01	Grassland with sparse tree/shrub cover	204
						E02	Grassland without tree/shrub cover	801
F	BARE LAND	38	F0	Bare Land	38	F00	Bare land	38
G	WATER	16	G0	Water	16	G01	Inland water bodies	10
						G02	Inland running water	6
8	Not relevant	14	8	Not Relevant	14	8	Not relevant	14

Annex 2 LUCAS 2006 – Slovak Republic – Land cover map



Annex 3 LUCAS 2006 – Slovak Republic – Land use classes

Agriculture	2 313	U11	U111	Agriculture (excluding fallow land and kitchen garden)	2 236
			U112	Fallow land	41
			U113	Kitchen garden	36
Fishing	5	U13	U13	Fishing	5
Forestry	537	U12	U12	Forestry	537
Minig, Quarrying	2	U14	U14	Mining, quarrying	2
Energy Production	6	U21	U21	Energy production	6
Industry, Manufacturing	1	U22	U223	Coal, oil and metal processing	1
Transport, Communication, Storage, Protective Works	43	U31	U311	Railways	5
			U312	Roads	27
			U313	Water transport	3
			U318	Protection infrastructure	8
Contstruction	3	U33	U33	Construction	3
Commerce, Finance, Business	4	U34	U34	Commerce, finance, business	4
Community Services	35	U35	U35	Community services	35
Recreation, Leisure, Sport	16	U36	U361	Amenities, museums, leisure	8
			U362	Sport	4
			U363	Holiday camps	4
Residential	59	U37	U37	Residential	59
Water, Waste Treatment	4	U32	U321	Water supply and teatment	4
Unused	328	U40	U40	Unused	328
Wetland	22	U50	U50	Wetland	22
Not Relevant	14	8	8	Not relevant	14

SELECTION OF GCPS FOR HR AND VHR SATELLITE IMAGES IN THE FRAMEWORK OF CONTROL WITH REMOTE SENSING

VÝBER VLÍCOVACÍCH BODOV PRE SATELITNÉ OBRAZOVÉ ZÁZNAMY S VYSOKÝM A VEĽMI VYSOKÝM ROZLÍŠENÍM PRE KONTROLU DOTÁCIÍ POMOCOU DPZ

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ABSTRACT

The paper is dealing with the problem of the specification and appropriateness of potential and available features for GCPs to fulfill the requirements defined by the European Commission (EC) in the framework of control with remote sensing in the area-based subsidies.

Ground control points (GCPs) are the key inputs of the geometric correction process of satellite data. The quality requirements of the GCPs depend on the spatial resolution of the geometric corrected image. The most appropriate option for high resolution (HR) images is the collection of GCPs from large scale orthophotos. For VHR imagery, where in general the target specification is <2.5 m RMSE1d, only the GCPs with a specification of <0.8 m RMSE are suitable.

KEYWORDS: orthorectification, high and very high resolution satellite images (HR, VHR), ground control point (GCP), Control with Remote Sensing (CwRS), CAP (Common Agricultural Policy), SPOT, IRS, Landsat, IKONOS2, Quickbird-2

ABSTRAKT

Článok je venovaný problematike určenia a vhodnosti potenciálnych a dostupných prvkov pre vlícovacie body pre splnenie požiadavok definovaných Európskou komisiou pre účely kontroly dotácií metódami diaľkového prieskumu Zeme.

Vlícovacie body sú kľúčovým vstupným údajom pre korektné geometrické korekcie satelitných obrazových záznamov. Požiadavka na kvalitu vlícovacích bodov závisí od priestorového rozlíšenia spracovávaného obrazového záznamu. Ako najvhodnejším zdrojom pre zber vlícovacích bodov pre satelitné obrazové záznamy s vysokým rozlíšením sa javia digitálne ortofotomapy veľkej mierky. Pre satelitné obrazové záznamy s veľmi vysokým rozlíšením, kde vo všeobecnosti výsledná stredná polohová chyba (m_{xy}) musí byť menšia ako 2,5 m, vyhovujú len vlícovacie body so strednou polohovou chybou menšou ako 80 cm.

KĽÚČOVÉ SLOVÁ: diferenciálne prekreslenie obrazu, satelitný obrazový záznam s vysokým a veľmi vysokým rozlíšením, vlícovacie body, kontrola diaľkovým prieskumom Zeme (DPZ), spoločná poľnohospodárska politika, SPOT, IRS, Landsat, IKONOS2, Quickbird-2

INTRODUCTION

Since 1993, the European Commission DG Agriculture has promoted the use of „Control with Remote Sensing" (CwRS) as appropriate control system within the Common Agricultural Policy (CAP) to prevent agricultural subsidy irregularities (Astrand et al., 2004). Since 1999, the MARS (Monitoring Agriculture with Remote Sensing) project at the JRC (Joint Research Centre) centralizes the satellite image acquisition and provides the member states (MS) with high and very high resolution satellite images (HR, VHR).

The satellite data are extraordinary concerning their spectral and spatial resolution in comparison with aerial photographs and are more cost and time effective than on-the-spot controls. The accomplishment of the CwRS is based on the rightness of data processing like the orthorectification. The newcomer satellites have greater and greater spatial resolution and that is why they need more accurate ground truth and input data to process them correctly.

Soil Science and Conservation Research Institute (SSCRI) has experienced the CwRS since 2001. The 2003 pilot project was in the frame of pilot projects in EU Candidate Countries coordinated by the JRC. In 2003, the JRC also solved a pilot project of using VHR images in CwRS. In the years 2004 – 2006 (3 campaigns) the CwRS in Slovakia was in full action.

In the CwRS a set of High Resolution (HR) multispectral images as SPOT, Landsat and IRS (mainly 3 or 4 per campaign) are used for precise identification of crop grow. On the opposite the Very High Resolution (VHR) images from IKONOS2, QuickBird-2, EROS-A1 and SPOT 5 Supermode satellites are used for precise measurements of cultivated areas.

The selection and collection of the GCPs for the HR and VHR images differs. This paper will deal with the appropriateness and differentness of ground control point (GCP) selection for the HR and HR images as one of the key inputs of orthorectification process.

MATERIALS AND METHODS

Satellite systems generally used for the purposes of CwRS

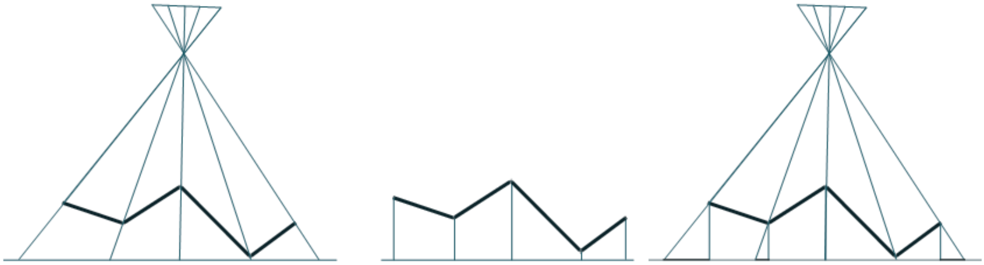
Classification based on resolution:

- High Resolution (HR) – pixel size 3 m – 30 m. Satellites: Landsat, IRS, SPOT.
- Very High Resolution (VHR) – pixel size 3 m and less. Satellites: QuickBird-2, IKONOS2, EROS-1A, SPOT 5 Supermode.

Orthorectification

Orthorectification is a process of digital transformation of the satellite image from central projection to the orthogonal cartographic projection (Figure 1) with elimination of distortion due to sensor lens system, inclination of satellite and terrain elevation (European Commission, 2006).

Figure 1 Comparison of the central and orthogonal projection



There is a need to use input data of appropriate quality to get the best results of orthorectification (European Commission, 2006):

- satellite images suitable for orthorectification. It is necessary to use satellite images without geometric pre-processing.

Table 1 Types of satellite image products applicable 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

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

Table 2 Precision of the 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 defines that the quality of GCPs should be three times better than the final product) but also their good arrangement is important.

MATERIALS

Satellite images provided by the JRC during the campaigns of 2004 – 2006:

Table 3 Satellite images of 3 years (2004, 2005, 2006) for the CwRS

Site		Acquisition window	Platform	Acquisition date	Pixel size
2004	**PODU**	SPRING1	SPOT 5	22. 4. 2004	10 m
		SPRING2	SPOT 4	8. 6. 2004	20 m
		SUMMER1/ **VHR**	**SPOT 5 PAN**	**4. 8. 2004**	**2.8 m**
			SPOT 5 PAN	**9. 8. 2004**	**2.8 m**
		SUMMER2	SPOT 2	21. 7. 2004	20 m
	VRAN	SPRING1	SPOT 2	15. 4. 2004	20 m
		SPRING2	SPOT 4	14. 6. 2004	20 m
		SUMMER1/ **VHR**	**IKONOS 2**	**8. 6. 2004**	**1 m**
			IKONOS 2	**8. 6. 2004**	**1 m**
			EROS-A1	**15. 6. 2004**	**2 m**
			EROS-A1	**5. 7. 2004**	**2.1 m**
		SUMMER2	SPOT 5	19. 7. 2004	10 m
2005	**LEVI**	AUTUMN	SPOT4	17. 1. 2005	20 m
		SPRING1	SPOT5	15. 4. 2005	10 m
		SPRING2	SPOT5	21. 5. 2005	10 m
		VHR	**IKONOS 2**	**20. 5. 2005**	**1 m**
			IKONOS 2	**23. 5. 2005**	**1 m**
		SUMMER1	SPOT5	17. 6. 2005	10 m
			SPOT5PAN	17. 6. 2005	3 m

Site		Acquisition window	Platform	Acquisition date	Pixel size
2005	**RIMA**	AUTUMN	SPOT4	17. 1. 2005	20 m
		SPRING1	SPOT4	22. 4. 2005	20 m
		SPRING2	SPOT5	21. 5. 2005	10 m
			SPOT5PAN	21. 5. 2005	3 m
		VHR	**QuickBird2**	**22. 5. 2005**	**0.6 m**
			QuickBird2	**14. 6. 2005**	**0.6 m**
		SUMMER1	SPOT5	21. 6. 2005	10 m
	TREB	AUTUMN	IRS-P6 LISS-III	30. 3. 2005	23 m
		SPRING1	SPOT4	27. 4. 2005	20 m
		SPRING2	SPOT5PAN	23. 5. 2005	3 m
		VHR	**IKONOS 2**	**14. 5. 2005**	**1 m**
			IKONOS 2	**14. 5. 2005**	**1 m**
		SUMMER1	SPOT5	16. 6. 2005	10 m
2006	**KOMA**	SPRING1	SPOT4	20. 3. 2006	20 m
		SPRING2	SPOT2	18. 5. 2006	20 m
		VHR	**Quickbird2**	**12. 6. 2006**	**0.6 m**
		SUMMER1	Landsat5	10. 7. 2006	30 m
		SUMMER2	SPOT5	16. 8. 2006	10 m
	TOPO	SPRING1	SPOT2	6. 4. 2006	20 m
		SPRING2	SPOT2	12. 6. 2006	20 m
		VHR	**Quickbird2**	**12. 6. 2006**	**0,6 m**
		SUMMER1	SPOT4	17. 7. 2006	20 m
		SUMMER2	SPOT4	18. 8. 2006	20 m
	SOBR	SPRING1	SPOT5	9. 4. 2006	10 m
		SPRING2	SPOT5	15. 5. 2006	10 m
		VHR	**Quickbird2**	**22. 6. 2006**	**0.6 m**
			Quickbird2	**3. 7. 2006**	**0.6 m**
		SUMMER1	SPOT2	10. 7. 2006	20 m
		SUMMER2	IRS-P6 LISS-III	18. 8. 2006	23 m
	KEZM	SPRING1	**no acquisition**		
		SPRING2	SPOT2	19. 6. 2006	20 m
		VHR	**IKONS2**	**19. 6. 2006**	**1 m**
			IKONS2	**19. 6. 2006**	**1 m**
		SUMMER1	SPOT4	18. 7. 2006	20 m
		SUMMER2	SPOT5	17. 8. 2006	10 m

Digital Elevation Models (DEMs) used for the orthocorrection of the HR and VHR images were either procured externally – based on photogrammetric methods (HR images in year 2004, VHR all campaigns) (Sviček et al., 2004) or produced internally – based on contour lines (HR images in 2005, 2006) (Sviček et al., 2005).

Ground control points (GCPs) are considered to be "well defined" points in the context of the resolution of the images. They are gathered from two sources (European Commission, 2005b):

- digital orthophotos – for the HR images,
- ground survey by Global Positioning System (GPS) using static phase measurement and postprocessing – for the VHR images.

Selection of the GCPs requires practise, precision and good distribution. Well-defined points are represented by easily visible and exactly identifiable features on the ground (VHR) or on the digital orthophotos (HR) and on satellite image as well.

RESULTS AND DISCUSSION

European Commission defines geometric accuracy of orthorectified images based on absolute Root Mean Square Error (RMSE) on check points (European Commission, 2005a).

Table 4 Maximum allowed 1D RMSE

Data type	RMSE
IKONOS2	2.5 m
QUICKBIRD2	2.5 m
SPOT 5 Pan Supermode	5 m
SPOT 5 multispectral	15 m
SPOT 2, 4 multispectral	30 m
IRS – P6	34.5 m
Landsat 5	45 m

These 1-dimensional RMSE values are applied separately for the *X* and *Y* direction. Root Mean Square Error on the GCP residuals has to be better then 0.5 of the tolerance for geometric accuracy in Table 4. The values in this table represent approximately 1.5 of the pixel size of the images. Along with the above mentioned, the results of the orthorectification should be under 0.75 (approximately) of the pixel size.

Ground control points for HR satellite images

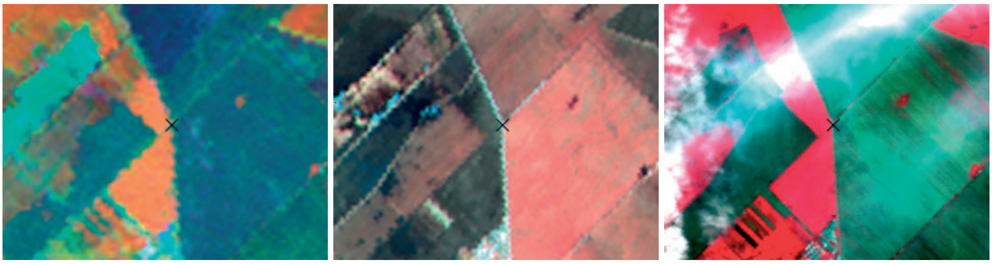
According to the above mentioned GCPs, the HR images have to fulfill the requirements concerning the residuals on the selected points which should not exceed the following values:

Table 5 Maximum allowed thresholds of HR images

Data type	Threshold
SPOT 5 multispectral	7.5 m
SPOT 2, 4 multispectral	15 m
IRS – P6	17 m
LANDSAT5	22.5 m

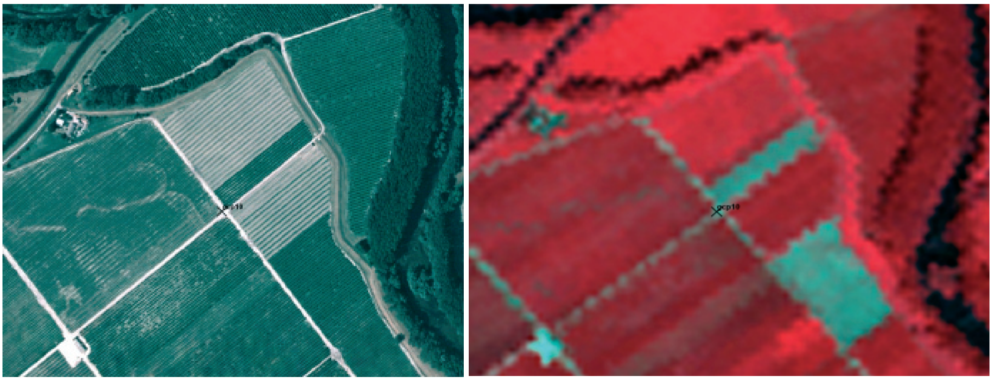
Representatives of the GCPs for the HR satellite images differ on the images according to their resolution. The better the resolution the more precise should be the identification as well.

Figure 2 GCP on different HR images (Landsat5, SPOT4, SPOT5)



Well-defined points on the HR images due to the type of the country as well are those that are visible and identifiable on the master image like the 1 m pixel size orthophoto. The most common representatives are road junctions, the best are the right-angled but the visibility depends more on the surrounding land cover (Figure 3). Among the visible features are the rivers or canals but those are not appropriate representatives of the GCPs as well as bridges and other features not located on the ground. Generally, the most important role belongs to the vegetation cover and the season of the acquisition of the multispectral image.

Figure 3 HR image and the master image (orthophoto, SPOT2)



Distribution of the GCPs on the image should be one in each cell of a 4x4 grid to cover the whole area. The points should be placed near the corners/edges of the image and should be dependent on the character of the country as well.

Ground control points for VHR satellite images

Thresholds concerning the VHR image are given in the table below.

Table 6 Maximum allowed thresholds of the VHR images

Data type	Threshold
IKONOS2	1.25 m
QUICKBIRD2	1.25 m
SPOT 5 Pan Supermode	4.5 m

Ground control points for the SPOT 5 Pan Supermode are also measured on the digital orthophotomaps as described above.

For the IKONOS2 or Quickbird-2 images another source of measurement has to be used to fulfill the requirements on accuracy – geodetic static phase carrier GPS measurement with post processing. More about this methodology gives the work of Scholtz, Szőcsová (2005).

Selection and the preparatory works need more time and effort. The points must be selected strictly and very precisely, and a special documentation has to be done before and after the measurement. After three years and several VHR images orthorectified (not only for the purposes of CwRS), some examples and recommendations will be given from the work done.

The recommendation is to locate 4 points as near as possible to each image corner and an additional one in the centre.

Year 2004

In this campaign easily findable and identifiable features were selected like crossings or access paths to houses. The orientation in the unknown country might be difficult and time-consuming. More effective is to look for features near main roads. After this experience, it can be confirmed that crossings are very precisely identifiable features, but dangerous (Figure 4). Danger means a possible noise during the measurement; fast moving cars cause vibrations and instability of the station.

Figure 4 Examples of crossings as potential GCPs (ground photo vs. IKONOS2)

Year 2005

After the experiences from the previous campaign with the crossings, the decision and the preparatory works were focused mainly on paths, entrances, which are also clearly identifiable.

Figure 5 Examples of paths and entrances as potential GCPs (ground photo vs. QuickBird-2.)

Year 2006

The selection focused on features easily visible, recognisable mainly in the build-up area with the criteria not to disturb the residents. The most appropriate are the concrete pavements in the cemeteries, which simplify the orientation in the unknown area and save time. Some examples are given in the following figure.

Figure 6 Examples of features in cemeteries as potential ground control points (ground photo vs. QuickBird-2)

In some cases the character of the country does not enable to select features which could be identified precisely. Some examples are given below (Figure 7). The use of doubtful features causes higher discrepancies which has a negative effect on the final result.

Figure 7 Examples of doubtful features (ground photo vs. QuickBird-2 PAN)

The success in the orthorectification results achieved comes also from the cautiously selected GCPs as described above. Results of orthorectification fulfill the criteria set by the EC. Beyond, the geometric accuracy of orthorectification mainly reached less than 0.5 pixel size of the image.

Table 7 Results of orthorectification on different satellite images in campaigns 2004 – 2006

Year	Site	Scene	Number of GCPs	Source of GCP	RMSE_{GCPX} [m]	RMSE_{GCPY} [m]	RMSE_{GCPXY} [m]
2004	PODU	04-04-22_SPOT5	20	d. orthophotomap	4.75	4.00	6.21
		04-06-08_SPOT4	20	d. orthophotomap	5.49	5.96	8.10
		04-07-21_SPOT2	20	d. orthophotomap	6.81	7.34	10.01
		04-08-04_SPOT5	16	d. orthophotomap	1.50	1.51	2.93
		04-08-09_SPOT5	16	d. orthophotomap	1.43	1.46	2.92
	VRAN	04-04-15_SPOT2	17	d. orthophotomap	5.00	6.92	8.54
		04-06-14_SPOT4	16	d. orthophotomap	3.27	4.36	5.45
		04-06-08_IKONOS0-PAN	**6**	**GPS**	**0.49**	**0.59**	**0.76**
		04-06-08_IKONOS0-MS	6	d. orthophotomap	1.00	1.24	1.59
		04-06-08_IKONOS1-PAN	6	GPS	**0.59**	**0.20**	**0.62**
		04-06-08_IKONOS1-MS	6	d. orthophotomap	1.15	1.36	1.78
		04-07-19_SPOT5	16	d. orthophotomap	3.97	3.61	5.37

Year	Site	Scene	Number of GCPs	Source of GCP	RMSE$_{GCPX}$ [m]	RMSE$_{GCPY}$ [m]	RMSE$_{GCPXY}$ [m]
2005	LEVI	05-01-17a_SPOT4	16	d. orthophotomaps	14.57	8.62	16.93
		05-04-15_SPOT5	16	d. orthophotomaps	3.96	4.34	5.87
		05-05-20_IKONOS2	**6**	**GPS**	**0.43**	**0.13**	**0.44**
		05-05-21a_SPOT5	16	d. orthophotomaps	4.18	3.39	5.38
		05-05-23_IKONOS2	**6**	**GPS**	**0.27**	**0.34**	**0.43**
		05-06-17_SPOT5	16	d. orthophotomaps	3.08	2.32	3.85
		05-06-17_SPOT5PAN	16	d. orthophotomaps	1.16	1.21	1.67
	RIMA	05-01-17b_SPOT4	16	d. orthophotomaps	7.83	8.54	11.59
		05-04-22_SPOT4	16	d. orthophotomaps	5.63	5.59	7.94
		05-05-21b_SPOT5	16	d. orthophotomaps	3.65	3.62	5.14
		05-05-21_SPOT5PAN	16	d. orthophotomaps	1.25	1.49	1.95
		05-05-22_Qb2	8	GPS	**0.40**	**0.41**	**0.57**
		05-06-14_Qb2	**6**	**GPS**	**0.28**	**0.05**	**0.28**
		05-06-21_SPOT5	16	d. orthophotomaps	3.02	2.72	4.07
	TREB	05-04-27_SPOT4	16	d. orthophotomaps	6.00	5.78	8.33
		05-05-14a_IKONOS2	**6**	**GPS**	**0.31**	**0.36**	**0.48**
		05-05-14b_IKONOS2	**6**	**GPS**	**0.48**	**0.29**	**0.56**
		05-05-23_SPOT5PAN	16	d. orthophotomaps	1.11	0.84	1.39
		05-06-16_SPOT5	16	d. orthophotomaps	3.20	2.77	4.23
2006	KOMA	06-03-20_SPOT4	16	d. orthophotomaps	4.85	4.81	6.83
		06-05-18_SPOT2	16	d. orthophotomaps	6.48	4.79	8.06
		06-06-12b_QB2	**5**	**GPS**	**0.22**	**0.16**	**0.27**
		06-07-10_ls5	16	d. orthophotomaps	9.72	7.19	12.09
		06-08-16_SPOT5	16	d. orthophotomaps	2.88	2.25	3.65
	TOPO	06-04-07_SPOT2	16	d. orthophotomaps	6.27	2.54	6.76
		06-06-12_SPOT2	16	d. orthophotomaps	2.71	2.27	3.54
		06-06-12a_QB2	**5**	**GPS**	**0.47**	**0.33**	**0.57**
		06-07-17_spot4	16	d. orthophotomaps	8.42	5.65	10.14
		06-08-18_SPOT4	16	d. orthophotomaps	5.95	4.19	7.28
	SOBR	06-04-09_SPOT5	16	d. orthophotomaps	2.77	1.86	3.34
		06-05-15_SPOT5	16	d. orthophotomaps	2.97	3.54	4.62
		06-06-22_Qb2	**5**	**GPS**	**0.59**	**0.26**	**0.65**
		06-07-03_Qb2	5	GPS	1.32	0.87	1.58
		06-07-10_SPOT2	16	d. orthophotomaps	8.00	6.60	10.37
		06-08-18_IRS-P6	16	d. orthophotomaps	10.75	7.25	12.97
	KEZM	06-06-19_SPOT2	16	d. orthophotomaps	6.32	4.10	7.54
		06-06-19a_IKONOS	6	GPS	**0.54**	**0.14**	**0.57**
		06-06-19b_IKONOS	**6**	**GPS**	**0.49**	**0.08**	**0.5**
		06-07-18_SPOT4	16	d. orthophotomaps	6.57	5.62	8.65
		06-08-17_SPOT5	16	d. orthophotomaps	5.00	3.70	6.22

CONCLUSIONS

To achieve good results in orthorectification, all input data and their gathering has to fulfill certain requirements. The theories are mostly dealing with the use of appropriate models which describe the transformation between object coordinates and coordinates of the satellite image, the accurateness of the DEM or methods of the creation of the DEM. Actually, this affects the most of the results of the orthorectification. Practise brings improvements and the attention is drawn to sub processes as well in order to achieve better results.

Ground control points are considered to be "well defined" points in the context of the resolution of the images. It is recommended to use right-angled road junctions in case of high resolution images located one in each cell of a 4x4 grid which are measured on a large scale orthophotomap. In case of very high resolution images the selection is stricter. The representatives measured on the ground by the very precise GPS are edges of paths in the cemeteries, entrances or fences. The point should be localised as near as possible to the edges of the image and one additional in the centre.

The results achieved in the orthorectification are very satisfying and are far below the thresholds defined by the European Commission in the Technical Recommendations. Each campaign/year brings some changes (new satellites launched, new technical recommendations), which represents challenge for further testing and deepening of knowledge.

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