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A SHORT HISTORY OF SLOVAK SOIL SCIENCE DEVELOPMENT

STRUČNÝ VÝVOJ HISTÓRIE SLOVENSKÉHO PÔDOZNALECTVA

PAVOL BIELEK, EMIL FULAJTÁR JUN., JAROSLAVA SOBOCKÁ, PAVEL JAMBOR
Výskumný ústav pôdoznalectva a ochrany pôdy, Bratislava

ABSTRACT

In this paper there are showed some significant milestones of historical soil science development in Slovakia with the aim to specify and supplement some new kinds of knowledge and literary sources. The oldest references about soil investigation in Slovakia lead to up 18th century to the era of Austrian Monarchy, latter are connected with political conditions dominating on this territory. In soil investigation there were reflected conditions of former Czech-Slovak Republic, the Second World War period, different conditions in socialism period till to recent time. The first land inventory and bonitation as well as first practical manuals referring soils are dating to 18th century. More systematic soil survey and mapping began at the end of 19th century, in 20-ties of 20th century first agricultural institutes were established, in 30 – 40-ties first specified monographies were still elaborated and issued. The most significant personalities of the Slovak soil science are presented including their share on soil survey, mapping and assessment development like H. HORUSITZKY, F. KYNTERA, O. KOŽUCH, F. HROŠŠO, and others. In 60-ties a new soils science research institute in Bratislava was found, which presents up to today most significant activities like general soil survey, bonitation as well as monitoring on the whole territory of Slovakia. Besides that a wide net of other specialized and university research working places with their own activities was developed.

KEYWORDS: soil science, history, agro-geological research, agro-pedology

ABSTRAKT

V príspevku sa poukazuje na niektoré významné medzníky vývoja pôdoznalectva ako vedy na Slovensku s cieľom upresniť a doplniť niektoré nové poznatky a literárne pramene. Najstaršie pramene výskumu pôd na Slovensku vedú do 18. storočia, do obdobia tereziánskych a jozefínskych reforiem, neskôr súvisia s politickými pomermi prevládajúcimi na jeho území. Vo výskume pôd sa odrážali pomery bývalej Československej republiky, obdobie druhej svetovej vojny, odlišné podmienky v socialistickej spoločnosti až po súčasnosť. Prvá inventarizácia pôdy a bonitácia ako aj prvé praktické odborné príručky o pôde pochádzajú z 18. stor. Systematickejší výskum a mapovanie pôd sa začalo koncom 19. stor., v 20-tych rokoch 20. stor. boli založené prvé poľnohospodárske ústavy, v 30 až 40-tych rokoch už boli vypracované a vydané prvé špecializované monografie. Spomenuté sú najdôležitejšie osobnosti slovenského pôdoznalectva a ich podiel na rozvoji pôdneho prieskumu, mapovania a hodnotenia pôd ako H. HORUSITZKY,

F. Kyntera, O. Kožuch, F. Hroššo, a ostatní. V 60-tych rokoch bol založený súčasný pôdoznalecký ustav v Bratislave, ktorého doterajšou najvýznamnejšou činnosťou bol pôdny prieskum, bonitácia pôd a komplexný monitoring na celom území Slovenska. Okrem neho sa rozvinula široká sieť ostatných špecializovaných a univerzitných výskumných pracovísk s vlastnými aktivitami.

Kľúčové slová: pôdoznalectvo, história, agro-geologický výskum, agro-pedológia

INTRODUCTION

Comparing to other natural sciences, soil science is a very young science. However, many practical problems required the attention and first investigation of soil began in many countries a long time ago. Each science is developing historically, primarily through series of practical recognitions in nature, experiments based on theory and experience of observations. Those were supported by analytical methods to practical use of findings, reflecting new needs or requirement of practice. Mainly agricultural land use is very narrowly connected with soil knowledge of soil science.

The agriculture had spread to recent Slovak territory from south-east in 6th millennium B.C. The first Neolithic farmers were moving from Balkan Peninsula along the Danube River, they penetrated to Carpathian Basin and settled in warm and fertile areas especially in loess hilly lands. Since that time the development of agriculture in Slovakia was continuous and archaeological evidences showed up that many flourishing civilisations occurred especially in south-western and south-eastern Slovakia. Only considerably later the agricultural settlement penetrated to intra-mountainous basins of Central Slovakia. This colonisation was attracted also by mining possibilities in mountainous areas. Important metallurgical centres with well organised export of arms occurred in basins of Liptov and Turiec already in bronze age (2nd millennium B.C.).

First written record on prosperous crop production referring to territory of Slovakia was provided in 6th century B.C. by Herodotos, Greek historian. He mentioned settlement Leukaristos (Lat. *Laugaricio*, Slov. Trenčín) occurring in the middle of agriculturally cultivated region.

Since 5th century B.C. Slovak territory was populated by Celtic tribes. Some indications shows, that Celtic farmers knew already the liming of acid soils, therefore the agricultural colonisation was spreading to less fertile areas and the population density in mountainous basins of Central Slovakia increased considerably. In 1st century B.C. the colonisation by Germanic Quadi tribes followed and soon after that the Romans occupied the left banks of the Danube and western Slovakia became exposed to intensive influences of Mediterranean civilisation. Romans and Quadi tribes were mutually competing and recent Slovak territory often used to be a battlefield. Romans brought to our territory vine growing with adequate care for land cultivation (terracing, trenching). Marcus Aurelius, the Roman Emperor and philosopher wrote on the territory of Slovakia his work "The talks to myself". Among the Roman authors especially Columella can be cited as early agricultural specialist with his impact on Slovak territory, who considered for good agricultural practice, crop rotation, bean (Vicia faba) as a crop, which improves soil fertility, as well as several forms of tillage.

In early Slavic period (6 – 10th century) the shifting agriculture was successively replaced by permanent farming and the crop rotation based on three year cycle (winter crop – spring crop – fallow) was introduced. This enabled the development of permanent settlement. The archaeological evidences show that many recent villages exist at the same place since 8 – 9th century. The change from shifting agriculture to permanent farming was the most important milestone since the introduction of agriculture.

After the period of chaos and decay in 10th century caused by invasion of Hungarian tribes and breakdown of Great Moravian Empire the consolidation followed in 11th century when Hungarian kingdom was established. The population growth occurs again in 12 – 13th century. This lead to first attempts to establish organised land management. This is indicated by royal decree from late 13th century on amelioration of the land along the Danube River. The construction of dams and drying of swamps continued since that time periodically.

In later period the shepherd colonization interfered significantly with agricultural settlement pushing in pasture land. Mining, forestry and charcoal production shifted forest border higher and formed conditions for wider farming land use and created conditions for extensive large-scale erosion.

EARLIEST PERIOD

The first attempt to evaluate the soil and its fertility occurred in the second half of 18th century. At that time Slovakia was part of Austrian Monarchy. The Austrian Empress, Maria Teresia initiated the inventory of all agricultural land and its ownership. This land registration had a great significance for owners and land users. Agricultural land was delineated according to 8-classes classification. This system served for administrative purposes even till second half of 20th century.

The first studies observing the soil from a scientific point of view occurred in Slovakia at the end of the 18th century. Samuel Tešedík (1732 – 1820) was an Evangelist preacher with Slovak ancestry. He established in 1780 an agricultural school in Sarvaš (city in south-east Hungary with considerable Slovak minority). It was the first secondary school of its kind in Europe. His activities were wide, i.e. he deserved in saline soils fertilization perhaps he can be considered as the first soil scientist. Matúš Pankl (1740 – 1798), professor of Royal Academy in Bratislava (Academia Istropolitana) published first manual on agriculture. He paid much attention to soil properties in his Handbook of Agriculture (several editions: 1790 in Lat. with Latin – Slovak – German – Hungarian dictionary, 1793, 1797, 1810 all three in Lat., 1964 in Slov.). He characterised the soil physical properties, explained the importance of soil texture and organic matter. He studied the organic matter mineralization and propagated a new manure approach.

At the same time Juraj Fándly (1750 – 1811) edited the Agricultural Encyclopaedia in 6 great volumes (Trnava, 1792), in which he also propagated the modern knowledge on soil properties and land management methods. The great advantage of this book, written in Slovak language, was that it could be understood by farmers and it was dedicated directly to them and the structure of the text was accommodated for this purpose.

Initiation of soil science as serious science in modern sense in the territory of Slovakia was dated to second half of 19th century. Dionýz Štúr (1827 – 1893), one of the best Slovak geologists, becoming later the director of the Imperial Geological Institute in Vienna, published his study "The influence of soil on the spatial variability of vegetation" (1856 – 1858). This study, written in German became the first study of the soils from the point of view of natural sciences. It became well-known at international level.

In the last decades of the 19th century several specialised agricultural schools were established. The first one was opened in 1871 at Liptovský Hrádok. Later nine other agricultural schools were established, the last one in 1913. The agricultural school in Košice was transformed to an Agricultural Academy, the first agricultural high school in Slovakia. These agricultural schools served as background of the first institutional base for soil research. However, the attention was paid mainly to manure and only a little attention was paid to the soil research.

Important role played Gregor Friesenhof (1840 – 1913), rich landowner who belongs to founding members of Matica slovenská, the first Slovak scientific institution. He was interested in agro-meteorology and he initiated voluntary activities to educate farmers and to improve their life standard. He propagated cooperative farms, among farmers and despite he was of German-Russian origin in local journals he published papers about modernisation agriculture in Slovak language. His most successful achievement was the construction of new type of plough (plough of Nedanovce-Brodzany) and implementation of this new instrument to daily use among Slovak farmers.

Despite of all activities done at agricultural schools and by volunteers such as Gregor Friesenhof the development of soil research in last decades of the 19th century was limited because since 1867, when Hungary obtained autonomy within the Austrian Monarchy, all Slovak cultural institutions were exposed to political pressure. Matica slovenská as well as Slovak schools, except some four-class local schools were closed. This severe restriction affected also the agricultural schools. The lecturing in Slovak language was forbidden and replaced by Hungarian. This created a great limitation for the application of agricultural knowledge among Slovak speaking farmers.

In first decade of 20th century the agro-geological survey was organised by the Hungarian Royal Geological Institute at Budapest. This survey started only short time after the Russian geologist Vasilij Vasilievič Dokučajev (1946 – 1903) formulated his definition of soil and the theory of soil genesis and zonality. He perceived the soil science as an independent scientific discipline. The agro-geological survey was the first soil survey in Slovakia. Unfortunately it covered only part of the lowlands in West Slovakia. Leading personality was here Heinrich Horusitzky (1849 – 1929) – soil scientist and agro-geologist. The majority of the survey in this area he performed in 1902, 1903, 1905, 1908, 1909, 1912, and by Imrich Timko in 1904 and 1905. The soils were classified according to parent material and texture. Soil types were also mapped according to geological and hydro-geological soil parameters. The soil parameters studied were analyzed by their relationship to productivity potential as well as with respect to effective soil exploitation (sources of raw materials, rocks and water). Study works were edited and focused to rural country of Slovak regions Trnava, Senec, Šurany, Komárno, Štúrovo.

We must denote that Horusitzky was dominant personality in the group of Hungarian soil scientists, with active international contacts and participated also at organization of the first soil science conferences organized in first years of 20th century in Budapest and Prague. In his group were active also I. Timko, B. Inkey and Z. László. Both Horusitzky and Timko were of Slovak origin.

Another important soil scientist during the first decades of 20th century was Ján Lendvai-Lušňák (1881 – 1931). He studied humus, colloidal chemistry and soil capillarity. During the period of Austria-Hungary he lectured in several Hungarian universities. After establishment of Czech-Slovak Republic he was active within the State Research Institutes of Agriculture in Bratislava.

1918 – 1945

After the foundation of Czech-Slovak Republic in 1918, the soil science in Slovakia entered a period of fast development. Firstly, Slovak soil science was developing under rule of young generation of Czech soil scientists, as some pedologists active in Slovakia till 1919, emigrated to Hungary. The Czech soil scientists belonged to school of Josef Kopecký (1865 – 1967). In the state framework leading personality in Slovakia for several decades was Václav Novák (1888 – 1967).

In 1920 within the State Research Institutes of Agriculture (ŠVÚP) two institutes: for Agro-pedology and Bioclimatology (Bratislava, Košice) were established. They were first really scientific institutions for soil science with famous representants: František Kyntera (1897 – 1958 pedologist, agro-meteorologist), P. Kučera, and K. Kohout. The mentioned soil scientists came from Bohemia, where the scientific life was much more free than in Slovakia under the Hungarian rule. Soon the first modern scientific studies in Slovak language were published by F. Kyntera (1926, 1931), K. Kohout (1928) and some other studies about Slovak soils were written in Czech language (P. Kučera, 1935). F. Kyntera is the author of first Map of Soil Types in Slovakia. He lived in Bratislava for some years but after Czech-Slovak state abolishment he returned to Prague where he worked until his death.

The research was running in several branches of soil science, such as soil physics, hydro-pedology and soil chemistry. A great advance was achieved in soil classification and soil genesis. The principles of genetic soil classification developed in Russia and reworked for Central European conditions in Germany, were applied also to soils of Slovakia. Few local soil surveys were performed. During this time a new generation of Slovak soil scientists such as K. Nikitin, O. Kožuch and V. Pecho-Pečner was educated. K. Nikitin (1931) began with investigation of saline soils. Soon F. Kyntera (1937) wrote the monograph on saline soils. It was the first Slovak book in pedology. Viktor Pecho-Pečner (1899 – 1978) represents Slovakian soil activities in thirties of 20th century. He was employed in the ŠVÚP in Bratislava (in years 1938 – 1945 was director of this institute). He studied and worked mainly in soil chemistry (nutrient dynamics, pH, soil colloids).

The promising development of soil science continued also in the 40-ties, despite the war conditions. In 1939 the Regional Agro-pedological Institute in Košice was moved after the occupation of this city by the Hungarians to Spišská Nová Ves. The leading personality among young Slovakian soil specialist became Ondrej Kožuch (1896 – 1944). He implemented numerous investigations in several Slovakian regions – Spiš, Gemer, Liptov, Orava, Turiec, Horehronie – occurring mainly in central and northern parts of Slovakia. He planned and arranged detailed soil survey of all Slovakian farmland. His most important works:

- Soils of Slovakia and their Relationship to Cultivation of Agricultural Production (1943)
- Applied Soil Science (1944)
- Plant Nutrition from the Soil (1946, 1951, both editions after his death).

O. Kožuch was the most successful soil scientist of this period. Unfortunately, he was killed in the military action during the Slovak National Uprising which rose in summer 1944 against the occupation of Slovakia by German fascists.

1945 – 1960

The end of Second World War was a significant milestone is soil science development. Immediately after its end new research activities began and new generation of pedologists became active. František Hroššo, Jozef Mrakič and Bohuslav Maláč became leading personalities in this period. B. Maláč was the founder of the Department of geology and soil science at Agricultural University in Nitra. 1945 the "Geonomical Soil Survey" as a first large soil survey at national level started. In the period 1945 – 1948 within this survey the action "Liming Need on Soil of Czech-Slovak Republic" was carried out and focused to acid soils requiring liming. This survey covered mainly North and East Slovakia. Successively after that (1949 – 1951) a new soil survey was organised to complete the results of the former survey in those areas which were not covered. Thus the first national soil survey, although not very detailed, but first time covering the whole area of the country was completed.

However the further development of soil science was limited in 1950 by the administrative reorganisation of agricultural research. Both Regional Agro-pedological Institutes were closed and the soil research was split to several small working places, subordinated to various institutions such as the Academy of Sciences, the Central Testing Institute for Agriculture and the Agricultural and Forestry University in Košice. Some pedologists were facing serious obstacles in new political situation. Despite of these political troubles three fundamental books summarising the pedological knowledge in Slovakia were written in this period:

- F. Hroššo: Soil Science (1958)
- F. Hroššo: Soil Fertility and its Improvement (1961)
- B. Maláč: Main Soil Types of Slovakia (1962).

Another important publication was proceedings on Soil Erosion in Slovakia (Š. Bučko, 1958) providing an overview of the result of erosion research, among which the Map of Gully Erosion of Slovakia at a scale of 1:500 000 by Š. Bučko and V. Mazúrová was most valuable.

MODERN PERIOD

The new political regime emerging after Second World War under the political influence of Soviet Union resulted in new type of agriculture and fundamental changes in political and public relations to soil. The agriculture in Slovakia was collectivised and large scale co-operative and state farms were established. National self-sufficiency in food production became one of the main political aims. At the highest political levels the ideas about the needs to increase the soil potential exploitation and the increase of the agricultural production were adopted. At the end of 50-ties the responsible political forces start to understand, that the decision to close the agricultural institutes in 1950 was wrong. It became obvious that the soil research scattered to several institutions cannot deliver the required results.

The perceiving of the need resulted in founding specialised scientific institution for soil science in Slovakia – the Laboratory of Soil Science in Bratislava in 1960. Later this institute worked under the name Research Institute of Soil Science and Plant Nutrition (RISSPN). Founder of the institute was Juraj Hraško. During next decades this institute underwent several transformations but although working under different names such as Soil Fertility Research Centre (SFRC) in second half of 80-ties, Soil

Fertility Research Institute (SFRI) in 90-ties and recently Soil Science and Conservation Research Institute (SSCRI), throughout the times it has been a leading research body specialised to soil science.

Since the foundation of RISSPN as a solid institutional basis for the development of soil science new generation of pedologists have been educated. It was much more numerous compare to earlier times. This allowed much better specialisation and many researchers (especially J. Hraško, Z. Bedrna, M. Džatko, E. Fulajtár, B. Juráni, F. Zrubec, V. Linkeš, C. Juráň, P. Bielek, B. Šurina, P. Jambor, J. Čurlík, J. Karniš, etc.) became a leading personalities each of them in different field.

Since 60-ties the soil science is developing also at several universities. At Comenius University soil geography was studied in 60-ties (L. Mičian). In 90-ties the Department of Soil Science was established here by group of researchers from SFRI under the leadership of B. Juráni. At Agricultural University in Nitra the agricultural aspects of soils were studied under the leadership of S. Sotáková, K. Holobradý, J. Hanes, A. Zaujec and their successors. At Forestry University in Zvolen the forest soils, their genesis and soil erosion were studied by R. Šály, D. Zachar, P. Midriak, E. Bublinec and many other. All Slovak soil science research institutions work in mutual cooperation. For better exchange of information Slovak Soil Science Society (Societas pedologica slovaca) was established in 1992. It provides a communication forum for a whole pedological community in Slovakia.

Slovak pedologists were working in close cooperation with main specialists in Czech Republic such as V. Kosil, J. Pelíšek, J. Němeček, R.Vaculík, A. Prax, J. Janeček J. Kozák, P. Novák, and others. Close cooperation was maintained also with Russian soil science also thank to the personal contacts of several Slovak soil scientists who studied at Russian universities. At the end of 60-ties they had intensive relations with soil science in Netherlands and several researchers from RISSPN studied in Netherlands. Later in 70-ties and 80-ties the international cooperation was again limited to eastern countries. Since the beginning of 90-ties the research became much more diversified and the intensive cooperation especially with European countries and USA began.

MAJOR ACHIEVEMENTS

The most important activity which was performed by Research Institute of Soil Science and Plant Nutrition in peroid 1960 – 1970 was the General Soil Survey of Agricultural Soils. During this relatively long period of survey detailed information about the agricultural soils of Slovakia was obtained. The density of sampling was 1 site per 16 ha of agricultural land. More than 10 000 map sheets at a scale of 1:5 000 and analytical data from 18 000 soil profiles are available until today to provide information about agricultural soils of Slovakia. The archive of soil samples is also an important heritage of this soil survey. As a result of this soil survey, Slovakia (as well as Czech Republic) was at the beginning of 70-ties one of the countries in the world with the most precise information about soils resource and thanks to next survey activities it is the truth up to now.

Soil maps with general characterisations and proposals for soil amelioration and land management changes were offered to each co-operative and state farm as an implementation of actual information to the agricultural practice. The soil survey data provided important and helpful information to improve the decision making activities in agriculture and to achieve higher standards and yield in agriculture practice.

Later the soil survey of forest land was performed by research groups working in forest pedology in Zvolen, although in much less detail compare to General Soil Survey at agricultural land. Finally the data on both the agricultural and forest soil survey were compiled together on a general Soil Map of ČSFR at the scale 1:500 000 (1973). Afterwards several regional soil maps were published. The latest approximation of Soil Map of Slovakia at a scale 1:400 000 was published in 1993.

Based on the data of the general soil survey many other new important interpretations were made, published and implemented in practice. Already before the finalisation of this survey numerous studies on soil genesis were published. The new knowledge was summarised in a new general book (Bedrna, Hraško, Sotáková, 1968).

In the 70-ties the preparation of theoretical principles for evaluation of soil production potential was the new important task that came up. On the base of the General Soil Survey results, land evaluation maps at a scale of 1:5 000 were produced. Leader persons were M. Džatko and V. Linkeš. The principles of subsidization and taxes in agriculture were deduced and the price of soil was determined on the base of the "pedo-ecological units", the elementary mapping units of the land management maps. With the help of these maps the land use is planned, the crop rotation approaches are recommended; the rates of fertilisers are advised for individual parcels and crops.

The soil survey results were systematically complemented with other information about the Slovak soils. One of the most important innovations was the construction of a data base about soil pollution. The survey of soil pollution in Slovakia has shown "hot spot" regions of contamination. About 30 – 40 000 ha of agricultural land are over the limit of contamination (1.2 – 1.6% of the total agricultural soils). Polluted soils are continuously monitored and investigated with the aim to solve the problems.

Very fruitful results in Agrochemical Soil Testing are progressing. This started in 1955 and is still carried out. Available forms of nutrients, pH and need for liming is determined for the topsoil of each soil parcel. The results are evaluated in 5-years (3-years respectively) cycles. Based on the results of the Agrochemical Soil Testing the individual fertilisation plans have been elaborated for farmers (individual, co-operative, state).

Since the beginning of 80-ties in Soil Science and Conservation Institute Bratislava the Geographical Information System about the agricultural soils was created. It includes a huge amount of data and graphical interpretations (maps) about the soil cover. The system is computerised and actively working.

In 90-ties several new challenging tasks emerged. First of all it was Partial Soil Monitoring, which is running already more than 10 years and provides basic information on the development of all important soil properties under changing environmental conditions. It comprises 288 permanent monitoring sites where many relevant soil parameters are determined. Simultaneously, other specific monitoring systems are performed. Among very important results of soil research should be included the works by P. Bielek that were concentrated to soil biology and nitrogen dynamics in soil.

Next new task was the monitoring of influence of Gabčíkovo Hydro-work at Danube on the soil properties, especially the soil water regime, soil physical status and eventual salinization. Another new task was preparation of the Soil Geochemical Atlas with the maps of the distribution of selected elements in soils of Slovakia.

Important task of SSCRI apart of the research is to deal with many commercial activities related to land evaluation and land inventories. Services are provided to Ministry of Agriculture, cooperative farms and small land owners.

The institute initiated the innovation of national soil classification and new classification was successfully introduced in cooperation of all relevant soil science working places and at the platform of Slovak Soil Science Society. This institute is also responsible in research of soil science development, environment conservation as well as in advisory service for agricultural practice using latest technology and innovation tools. It is involved in several international research projects and is presenting as an excellent centre for soil science in Europe. Many scientific books, papers and applied handbooks and brochures were published especially since second half of 90-ties, when SSCRI established own edition centre.

Valuable results were provided also at other soil research organisations, or in cooperation between these institutions and SSCRI. L. Mičian from the Department of Physical Geography of the Comenius University, together with Z. Bedrna from RISSPN made in 60-ties a major contribution to understanding the geographical distribution of soils. They introduced the concept of piedmont zonality explaining the distribution of soils at Slovak Lowlands. The Department of Pedology at Comenius University is lecturing modern aspects of soil science and educating new generation of soil scientists.

The results of some researchers from Slovak universities were published internationally. Probably the most successful was the book on soil erosion by D. Zachar based on the long lasting research done at Forestry University in Zvolen. This book had two Slovak editions (1960, 1970) and one English edition by Elsevier (1980). Many other authors published their studies in international journals and thus contributed to overall development of soil science at international level.

Figure 1 An example of Heinrich Horusitzky publication in German language

ERLÄUTERUNGEN
GEOLOGISCHEN SPEZIALKARTE DER LÄNDER DER UNGARISCHEN KRONE.
HERAUSGEGEBEN VON DER KGL. UNGAR. GEOLOGISCHEN REICHSANSTALT.

VÁGSELLYE, NAGYSURÁNY, SZENC UND TALLÓS.

Erläuterung zu den agrogeologisch kolorierten Blättern Zone 13 Kol. XVIII. und Zone 13 Kol. XVII. im Masstabe (1:75.000.)

Geologisch und pedologisch aufgenommen in den Jahren [illegible] und erläutert von:

HEINRICH HORUSITZKY.

Übertragung aus dem ungarischen Original.

BUDAPEST.
BUCHDRUCKEREI DES FRANKLIN-VEREINS.
1915.

CONCLUSION

Most accounts of the history of soil science have focused upon development in Russia, America and Europe as a whole, but much less are known about the growth of the subject in small countries like Slovakia. Some broad phases can be distinguished:

- 1st – a pioneering phase (before 1918) characterized by isolated initiatives,
- 2nd – a development phases divided in two periods 1918 – 1945 and 1945 – 1960 when soil studies expanded rapidly in the context of agricultural and forest development,
- 3rd – modern consolidation phase (after 1960) when soil scientists largely enforced soil science development.

REFERENCES

BEDRNA, Z., HRAŠKO, J., SOTÁKOVÁ, S., 1968: Poľnohospodárske pôdoznalectvo. Bratislava, SVPL, 362 s.

BIELEK, P., FULAJTÁR E. JUN., 1998: Soil science in Slovakia, History, and Perspectives, Pedologie – Themata 4, BSSS, RUG, Gent, 7p.

BUČKO, Š., 1958: Vodná erózia na Slovensku, SAV.

BUČKO, Š., MAZÚROVÁ V., 1958: Výmoľová erózia na Slovensku. In: Vodná erózia na Slovensku, SAV.

DEMO, M., 2001: Dejiny poľnohospodárstva na Slovensku. SPU Nitra, VÚPOP Bratislava, 662 s. ISBN 80-7137-894-1.

FÁNDLY, J., 1792: Pilní domajší a poľní hospodár. Trnava.

FÁNDLY, J., 1990: Pilní domajší a poľní hospodár. Bratislava, Tatran. ISBN 80-222-0237-1.

HORUSITZKY, H.: Agrogeologische Verhaltnisse der Umgebung von Nagy-Surany. Budapest, Jber. Ung. geol. Anst. für 1900, 1902.

HORUSITZKY, H.: Agrogeologische Verhaltnisse der Umgebung von Komjat und Totmegyer. Budapest, Jber. Ung. geol. Anst. für 1901, 1903.

HORUSITZKY, H.: Die Umgebung von Tornocz und Urmenyi im Komitat Nyitra. Budapest, Jber. Ung. geol. Anst. fur 1903, 1905.

HORUSITZKY, H.: Geologische und bodenkundliche Beschreibung des westlichen Teiles des ungarischen kleinen Alfold. Budapest, Jber. Ung. geol. Anst. fur 1906, 1908.

HORUSITZKY, H.: Die geologische Verhaltnisse der sudlichen Teiles der Kleinen Karpathen. Budapest, Jber. Ung. geol. Anst. fur 1907, 1909.

HORUSITZKY, H., 1912: Die agrogeologischen Verhaltnisse der Umgebung von Szered--Czeste und Felsodios, E. J.

HROŠŠO, F., 1958: Pôdoznalectvo, Bratislava, SVPL.

HROŠŠO, F., 1961: Úrodnosť pôdy a jej zvyšovanie. Bratislava, SVPL.

KYNTERA, F., 1926: Pôdy Hodžovej kolónie pri Komárne. Bratislava.

KYNTERA, F., 1931: Pôdoznalecké preskúmanie pozemkov obce Lekene, okres Tornala, Praha.

KYNTERA F., 1937: Soľné pôdy, ich vlastnosti a zlepšovanie so zvláštnym zreteľom na soľné pôdy Slovenska. Praha.

KOHOUT, K., 1928: Pôdoznalecké preskúmanie pozemkov štátnej vyššej hospodárskej školy v Košiciach. Košice.

KOŽUCH, O., 1943: Pôdne pomery na Slovensku a ich vzťah na zveľadenie poľnohospodárskej produkcie. Bratislava.

KOŽUCH, O., 1944: Praktické pôdoznalectvo. Liptovský Mikuláš, Tranoscius.

KOŽUCH, O., 1951: Výživa rastlín z pôdy. Bratislava, Oráč, 106 s.

KUČERA, P., 1935: Půdy horni části Zemplinske vrchoviny, Praha.

MALÁČ, B., 1962: Hlavné pôdne typy Slovenska. Bratislava, SVPL.

NIKITIN, K., 1931: Prírodné podmienky pre vznik soľných pod na Slovensku, Bratislava.

PANKL, M., 1790: Compedium oeconomia ruralis. Regia academia Posoniensi, Budae.

PANKL, M., BERNOLÁK, A., 1964: Náuka o poľnohospodárstve. Bratislava, Osveta, 24 s.

ŠTÚR, D.,1856 – 1858: Űber den Einfluss des Bodens auf die Vertheilung der Pflanzen. Imperial Academy of Sciences, Vienna.

TIMKO, I., 1904: Agrogeologische Verhaltnisse in der Umgebung der Gemeiden, Kezsegfalva, Nemesoica, Aranyos, Marcelhaz, Martos, Comitat Komarom. Jber. Ung. geol. Anst. für 1902, Budapest.

TIMKO, I., 1905: Die agrogeologischen Verhaltnisse in zentralen Teil der Insel Csalokon zwischen Nyarasd, Vajka und Kulcsod. Jber. Ung. geol. Anst. für 1903, Budapest.
ZACHAR, D., 1960: Erózia pôdy. Bratislava, SAV, 308 s.

METAGEOGRAPHIC INFORMATION AND META-INFORMATION SYSTEM

METAGEOGRAFICKÉ INFORMÁCIE A META-INFORMAČNÝ SYSTÉM

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ABSTRACT

This paper deals with problems about meaning of metadata in information society at this time, describes the character and utility of metadata, which are very important and unavoidable to create the Geographical Information System.

The chapter about information system of agriculture department, refered to the structure, character and the basic attributes of individual informational systems, MIS, IGIS, unavoidable to created the information society. The metadata standardization describes the basic important standards for metadata (CSD GM, ISO 19115, CEN ENV 12657), characterization of present norms. This chapter is assessing the present situation of standardization, which is necessary not only at present time, but also in the future.

At the end, the paper deals and describes the character and structure of digital database within the framework of Information System Soil – Soil – Science and Conservation Research Institute (ISP-VUPOP), delineated the ideational model of integrative information system, which is using the generalize information from the partial of digital database. The database included specific data purposefully aimed to particular domain of research of soil units.

KEYWORDS: Metadata (metainformation), GIS – geographical information system, geographic data, geographic dataset, MIS (metainformation system), IS (information system), IGIS (integrative geographical information system), KPP-digital database of selected soil profiles of Complex Slovak Agricultural Soils Survey, PEU – digital database of pedo-ecological units

ABSTRAKT

Predkladaný príspevok sa zaoberá problematikou významu metageografických údajov v súčasnej spoločnosti, ktorá sa vyznačuje aktuálnou potrebou informatizácie v dôsledku narastajúceho objemu dopytu informácií, poukazuje na charakter a využiteľnosť metainformácií na ich dôležitosť a nevyhnutnosť pri tvorbe Geografických informačných systémov.

Príspevok sa venuje problematike informačných systémov v rezorte pôdohospodárstva, zobrazuje štruktúru, charakter i základné atribúty jednotlivých informačných systémov, MIS, IGIS, nevyhnutných pre budovanie informačnej spoločnosti.

Poukazuje na dôležitosť štandardizácie metaúdajov nielen na lokálnej, regionálnej úrovni, ale aj na nadnárodných úrovniach, popisuje základné dôležité informácie o štandardoch pre metainformácie (CSD GM, ISO 19115, CEN ENV 12657), zaoberá sa charakteristikou súčasných noriem, týkajúcich sa metaúdajov, hodnotí súčasný stav štandardizácie a kladie dôraz na jej potrebu nielen v sučasnom období, ale hlavne v blízkej budúcnosti.

V závere sa zameriava na charakter a štruktúru digitálnych databáz v rámci ISP-VUPOP, načrtáva konceptuálny model integrovaného informačného systému využívajúceho generalizované informácie z čiastkových digitálnych databáz obsahujúcich špecifické informácie (údaje) cieľavedome orientované na konkrétnu oblasť výskumu pôdnej jednotky.

Kľúčové slová: GIS (Geografické informačné systémy),geografické dáta, geografický súbor dát, MIS (metainformačný systém), IS (informačný systém), IGIS (integrovaný geografický informačný sytém), KPP-digitálna databáza výberových sond KPP, PEU-DB, – digitálna databáza pôdno-ekologických jednotiek

INTRODUCTION

The present time is typical with actual demand of informatization society and equally increasing capacity like accessible and also new and unknown data from all the areas of the life of society.The classification and finding information is more ambitious and responsible task for people, firms, institutions or states.

The boom in informatization brought changes and progress in informational technologies and in terms of them – progress of geoinformational technologies. The people find here the suitable dataset for solutions to selected problems.

This trend is shown in exploitation technologies of geographical information systems.This systems are implements, which are often using in process of management, deciding or research of the landscape, regions.

The selection information is the most important stage in „building“ GIS. Geographical information consist of 2 forms:

- spatial form
- attribute form

which are mutually associated (connected) and typologicly configurationed.

Geographical information system is effective, functional and qualitative when is using the quality data. How to find out the quality data? Through metadata and metadata systems.

RESULTS AND DISCUSSION

The results are divided into several individual levels:

- metadata and metadata systems
- the structure of IS, IGIS for department of agriculture and basic attributes
- importance of metadata (metainformations)
- standardization of metadata
- metadata for the digital soil database

Metadata and Metadata Systems

We use a several definitions of metadata, which are separated in to the stage of complexity. The most frequencently definition of metadata is the definition, that the metadata or metainformation are actual information about information, or the metadata describe the content, quality, condition and other characteristics of data.

If the metadata (metainformation) are used in the context of utilization digital data, present so-called "background", data about quality, contents, conditions about their researching from another institutions. If the maps are analogy, metadata are often used in the part of caption. (Hart, D., Philips, H., 1998).

Each institution can create its own structure of metadata (metainformation) systems. The metadata for information systems are different in the individual firms, industries or environmental information system. Metadata are used in the systems, which keeping and declassified information. Metainformation promote a lot of functions in internet:

- identified function
- selection
- documentation
- searching

This data has another functions and has pivotally task of integrations and interoperability among the systems, which is working with various formats and application protocols. Metadata are processing of 2 forms:

- dataset
- metadata information system

(summary of metadata = catalogue of metadata = catalogue of data sources)

They often opened up in text forms *txt, or *htm and *html. We must say, that the metadata are created by organizations, which their provided. Data are provided for individual institutions and their geoapplications (http://www.iszp.sk/metasys/koncept.htm). According to already mentioned, we have in mind the Information system of agriculture department.

The Structure of Information System for Department of Agriculture and Basic Attributes

The necessary condition for effective management of agriculture department is the voluminous information system with defined internal structure and content, also with defined internal and external mutual relations.

This department was created by existing data and naturally separated into the parts. Metainformation system includes for example these data (geographical data, i.e. BPEJ, maps data, database data-ATIS, data about grants, table data).

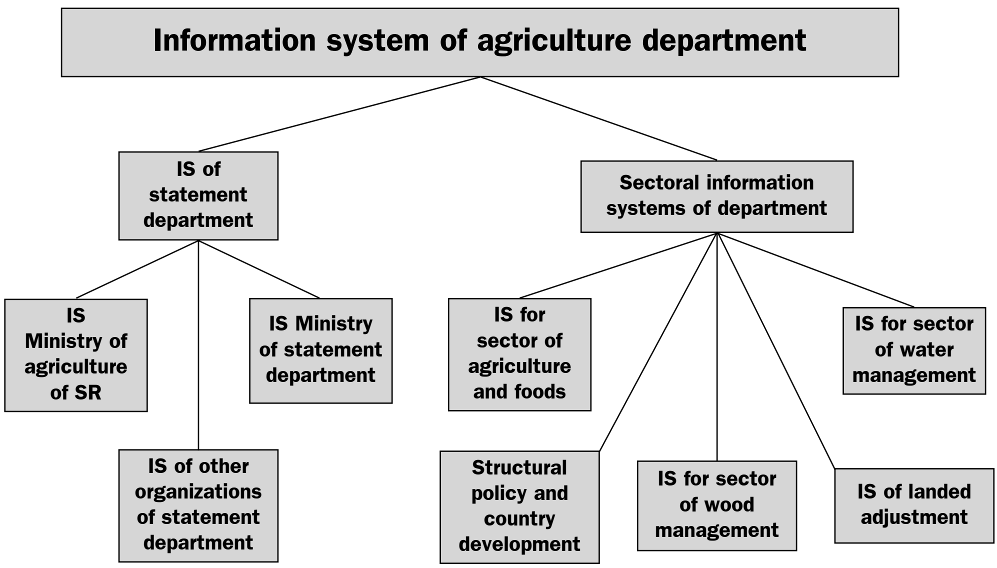
The information system is capable for anytime and anybody, find out where and in which quality the desiderative data are and which conditions are important to obtain them. MIS department of agriculture was paced by means of the analysis of information resources department of agriculture in 1999. System was oriented to the all information resourses of department, so the system does not include detailed processing of geographical information about the areas.

The basic defects of IS were:

- absence of the common integration IS of department
- imperfectly created communication and information infracture of department
- absence of integration elements and implement systems
- the fragmentation and existence of cca 230 relatively idependent information resources
- the fragmentation of authorization and insufficient coordination of tasks among the individual organization units of department
- not coordinate financing of tasks

The results and conclusions of analyse were point of departure for elaboration of strategy, conception and program of informatization of department (LEVČÍKOVA., 2002). The system must take note of the present time european standards for metadata or metainformation. The structure of information system for department of agriculture can see on Figure 1.

Figure 1 The structure of the information system for department of agriculture



The basic attributes of metainformation system:

1) information about individual under systems of department of information system
2) information about individual subject, which are have a stake on create of department informatics
3) information about existence and localization of individual data source
4) information about possibility to have a access to get the data source

The department of agriculture governed with the spatial activities over the basic natural component of land (soil, forest, water). The department is the biggest producer, but also user of spatial data. The tasks, which are connected with using the implements of photogrammetry, GIS, represented the strategic item of tasks,connected with creation of internal and multinational integrative conditions. So, the result is that is necessary to create the integration modul, so-called Integrational Information System of Agriculture Department.

The data structure of IGIS:

- the central data store
  (physically and logically integrated data from the sectoral GIS)
- the system of partial geographic data sources
  (represented the data sourceses from department and out of department sources)

The organizations, who realize GIS in the sphere of department are:

- Soil Science and Conservation Research Institute
- Water Research Institute
- Slovak Land Fund
- Forestproject, Zvolen
- Waterworks and Sewerage Enterprises

Importance of Metadata

Metadata information systems are created, because the data for building GIS are the most expensive and non transparent (80% of total financial costs, Kuranda, 1999).

The using not quality data should be very dangerous for inception of the financial losses and obtain the unavailable untrue information in the process of evaluation flood threat, to create models for simulation of geomorphology processes in the regions or of the models, which create the regional development and planning country (regions).

Advantages of creating metadata files and metadata systems presents:

1) combing of data, for example by Internet (browsing)
2) transformations, meanig – download
3) documentation of data

Existing dataset of spatial data and geodata are the results of creating the metadata systems. This data are opened up to users. So, for come up reasons, if the GIS is build up, in the structure of data model about object, oftentimes are appearing in the item-metadata grade (MITÁŠOVÁ I., HÁJEK M., 1999).

Metadata standardization

The question about standardization is more and more actuall in this time. The quantum of data standards, structures of matadata and generally disunited of approach to the management, the processing and changing of geographic digited data, of course, was started to create the united of standard.

Standards for metadata:

- CSDGM
- ISO 19115
- CEN ENV 12657
- ANZLIC Metadata Guildlines

Metadata system which is the component of GIS, is standardized.

The process of standardization predicate in:

- specify the tematic structure of metadata
- specify the content (the selection attributtes of data)

Standards harmonize the basic task, like perspicuous and precise "resource" in economic, industrial or geographic sphere.We can see the development of activities in state, european and world dimension (LUKÁČ Š., 1998).

The endeavour about unification means of the metadata standardization in European countries is pursuing a longer time. Standards are using in the countries, which belonging to the EU. The standardization was considered and still is in the countries of East and Central Europe for participial task at the entering to EU.

The commission, who is interesting in, of course, on the international level is the Comitee Europeen de Normalisation (CEN), which was created the prolusory norms-CEN- prEN 287009-Geographic Information-Metadata.(www.cenorm.be).

The members of CEN are the national normalization organization of:

Austria, Belgium, Cyprus, Czech republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

The functional metageographic information system on the public level can be:

- metainformation system created by Czech association for geoinformation, so--called "Metainformation Database System" (MIDAS), (http://www.cagi.cz)
- metainformation system created by the Netherlands-NCGI (National clering house for Geoinformation), (http://www.ncgi.nl)
- metainformation system created by Portugal – SNIG (National System for Geographic information), (snig.cnig.pt/snig/englis/index.html)

The metainformation system created by Belgium on the region level is the SPIDI (Spatial Information Directory), (http://193.58.158.196/metadata)

The digital soil database

KPP-database,
PEU-database,
The digital database of geochemical atlas,
Database of partial monitoring system

Digital database KPP is proposed for storing and managing data form the Complex Survey of Agricultural Soils of Slovakia. The results of soil survey, which were collected in 1961 – 1970, were stored in form of operating soil maps and additional profile ducumentation. Many field workers have participated this survey during nearly the decade period, without whose efforts this database, which represented a unique source of information, should not be finished.

Database structure:

The proposal of the new data field structure of KPP results from requirements for rationalization of data using as well as from requirements for logical consistence of data in KPP database.

All soil profile data were divided in two datasets:

1) dataset of general information
2) dataset of profile information (tables for horizons)

1) It accounts information about soil profile as whole and it is created by one table. Individual fields of table of general information can be divided into several separate groups.
   - information about profile identification
   - information about profile location
   - information about natural conditions
   - pedological information
2) This dataset provides information about basic pedological properties of individual soil profiles.Pedological characteristics are presented for individual genetic horizons. A number of table fields for the concrete record depends on number of recognized horizons in the concrete pedon. This dataset is divided into free individual tables as follows:
   - table of morphologic properties
   - table of physical propersties
   - table of chemical properties

We must say, that all records in individual tables of both datasets are connected by a primary key, it is the identification number of soil profile, and possible mistake in querying for the concrete record is excluded therefore. We can see the tabular preview of current fields of KPP database in Appendix 1. We must observe that the topological coordinates of individual soil profiles were adopted from operating maps of KPP, which were based on the Official State Maps-scale 1:5 000, 1:10 000, (Šurina et Juráni, 1997).

PEU-database

PEU-database together with digital database of Monitoring on Agricultural Soils of Slovak Republic are the frequent resourses of using data about soils in Slovakia for the government and other institutions, which are interesting in, especially the department of Life Environment.

PEU-DB, currently it is in an use as the background for polygons data processing. Consedering the absence of relevant digital database, PEU-DB provides the layer of the soil units expansion in agricultural land. This database comprises the data on the distribution of purposeful map soil units. Due to its basic objective, PEU-DB utilizes data originated from the cartographical database of the BIS system.(Bonitation Information System, Džatko et al., 1976, 1996, Ilavská et al, 1998).

PEU-DB database is the property and under the management of SSCRI.

Items of the relational PEU-DB database, (Demo et al, 1998):

- the basic characterization of the polygons (area, perimeter of the soilecological units)
- the background attributes (climate conditions, slope gradient, slope spatial distribution, exposure)
- data of the soil attributes (depth, coarse material content, texture, granularity)

- data of the soils classification (soil-created substratum, the main soils units)

Geochemical Atlas Of Soil Database – GchA-DB

Geochemical Atlas represents the specific objectively developed database on the soil cover of Slovakia. We must say, that the database was created as an outcome of the state supported complex program "Geological Factors of Life Environment".

GchA database consists of in total 5 168 records about analytic properties for upper A horizon and substructural C horizon.

The database items for individual records consists of:

- geographic localization of soil profile
- soil unit
- granulated faction
- content of carbon
- content of individual risk elements

Digital database of Monitoring on Agriculture soil of Slovakia-ČMSP

It is thought to be the essential objective database on soil cover properties of agricultural land in Slovakia. It is the subsystem of the Partial Monitoring System of Slovak Soils that takes a part in the Complex Environmental Monitoring of Slovak Republic. The basic aim of the monitoring lies in observing the temporal change of soil properties.

The database contains records about 333 monitoring sites disseminated in agricultural land across Slovak Republic.We must observe, that monitoring database is the property of Ministry of Life Environment and, of course, under the management of SSCRI.

The database consists of:

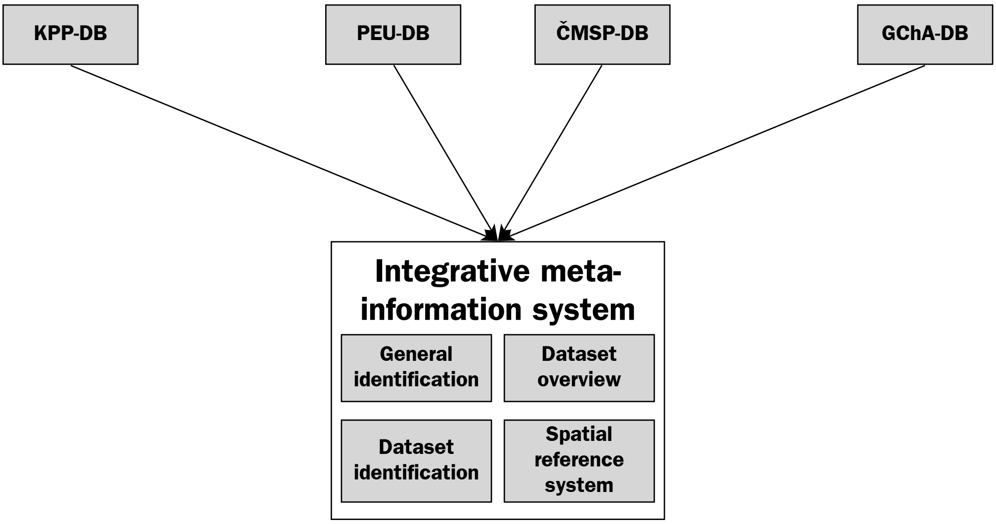
- bloc of generally data (identification, topographic localization)
- bloc of soil science data (morphologic, physical and chemical properties of soil)
- bloc of data about hygienic condition of soil (risk elements concentration)

We must say, that the integrative information system is not existing yet in the ISP--VUPOP, which could be included all partial digital databases(KPP-DB, digital database of selected soil profiles of Complex Slovak Agricultural Soils Survey, PEU-DB, digital database of pedo-ecological units, ČMSP-DB, digital database of Monitoring on Agricultural soils of The Slovak Republic, GchA-DB, Geochemical Atlas of Soils Database), which are often used alone, without orientation on complex and integrative solutions. It is obvious the absence of the integrations elements, it is necessary to "strongly" define the internal and external associations among the individual subjects.

It is necessary to create the integrative information system, because the data in the individual digital databases are specific oriented and the common system, which could be synthesized in the individual systems, is not existing.

The idea of the structure of the integrative information system is described in Figure 2.

Figure 2 The idea of the structure of the integrative meta-information system



CONCLUSIONS

The tempo of the creation of information system by GIS tools, the topicality of geodataset and metadata and the form of distribution, in present time, is still unsatisfactory for demands of practice.

The metadata and metadata structures are actually and important within the meaning of creation the integrative information systems. The question of standardization has connection with integration of efforts and joining of Slovakia to European Union. It is important to understand the data in the regional geodatabases within the meaning of not uniform system of standardization norms.

The digital databases are the main source of the spatial data about the soils structure across the Slovakia, they are created the basic spatial-attributeed component of GIS about agricultural soils in Slovakia. The global character of PEU-DB data, is possible in the spatial information about the character of unpedological object, especially in association with georelief (Minár J., Machová Z., 2001).

PEU- database together with digital database of Monitoring on Agricultural Soils of Slovak Republic are the frequent resourses of using data about soils in Slovakia for the government and other institutions, which are interesting in, especially the department of Life Environment.

KPP-DB belongs among basic databases of agricultural soils nowadays and it creates one of the basic spatial and atributte foundation of Geographic Information System of Slovak Agricultural Soils. This database is the forward-looking database with huge information potencial and it can be used in mathematical-statistical processing in GIS applications. Database was also used for "the map building of some basic and derived soil properties in small scales" (Bielek et al., 2002).

Knowledgeability and manipulations with geodata and using of metadata elements or standards for geodata interchange it could be necessary for organizations and institutions.

Appendix 1 Structure and field description of KPP-DB

GENERAL DATA SET			
general data table			
data_ form	**field name**	**field description**	**notes/data origin**
N	ics	identification profile number	generated number (explicit identificator - primary key)
W	cs	profile number	alphanumeric profile signature assigned according to field forms and operating map CSS
W	rok_odberu	year of sampling	assigned according to field forms CSS
W	obec	town or village	assigned according to administrative regionalization
W	ku	cadastre	assigned according to administrative regionalization
W	sekcia	map section	map section of official state map 1:5 000
N	c_mapy	map number	map number of official state map 1:5 000
N	x	x - coordinate	coordinates read from operating maps of CSS (based on official state map 1:5 000)
N	y	y - coordinate	coordinates read from operating maps of CSS (based on official state map 1:5 000)
N	nadm_v	altitude (meters)	altitude read from operating maps of CSS (based on official state map 1:5 000)
W	lok_mezo	landscape position	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	lok_mikro	mikrorelief	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	sklon_sv	slope gradient (in °)	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	expoz_sv	slope aspect	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	agrokl_obl	agroclimatic region	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	agrokl_pod	agroclimatic subregion	assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982
W	kultura	land use	land use in five categories assigned according LINKEŠ V., ŠIMONYOVÁ S., 1982

GENERAL DATA SET				
general data table				
data_ form		**field name**	**field description**	**notes/data origin**
N		pocet_h	number of horizons	assigned according to field forms CSS
W	*)	skup_00	soil group	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	typ_00	soil type	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	subtyp_00	soil subtype	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	var_00	soil variety	generated, based on database querring using analytical data for 1. horizon
W	*)	forma_00	soil form	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	kod_00	soil unit - code	generated, based on database querring in accord with MSCS 2000
W	*)	subs00_s	substrate group	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	subs00_kat	substrate category	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	subs00_c	substrate - code	generated, based on comparation of used classification of original database and MSCS 2000
W	*)	zrn_tr_00	soil texture (after triangle)	generated from analytical data in accord with MSCS 2000, assigned according to topsoil horizon
W	*)	zrn_tr_c00	soil texture (after triangle) - code	generated from analytical data in accord with MSCS 2000, assigned according to topsoil horizon
W		zrn_tr	soil texture (after triangle)	generated from analytical data in accord with USDA
W		zrn_no	soil texture (after Novak)	assigned according to field forms CSS
W		skelet	coarse fragments content	assigned according to field forms CSS

PROFILE DATA SET				
Table of morphological properties				
data_ form		**field name**	**field description**	**notes/data origin**
N		ics	identification profile number	generated number (explicit identificator – primary key)
W		ozn_h	horizon signature	alphanumeric code of horizon signature
N		hlbka_h	horizon depth	depth of genetic horizon – bottom, in cm
W		prech_h	horizon transition	generated, based on database querying in accord with horizon signature (according Linkeš 1984)
W		vlh_h	water state	assigned according to field forms CSS
W		farba_h	color – hue	generated by automatic procedure from relevant fields of original database – horizon signature (according Linkeš 1984)
W		farba_k_h	color – value	generated by automatic procedure from relevant fields of original database – horizon signature (according Linkeš 1984)
N		skvrn_h	color – chroma	assigned according to field forms CSS – in %
W		strukt_h	soil structure	generated by automatic procedure from relevant fields of original database – horizon signature, texture (according Linkeš 1984)
W		knzis_h	consistency/plasticity	assigned according to field forms CSS
W	*)	zrn_00_h	soil texture (after triangle)	generated, based on database querying in accord with MSCS 2000
W	*)	zrn_c_h	soil texture (after triangle) - code	generated, based on database querying in accord with MSCS 2000
W		zrn_tr_h	soil texture (after triangle)	generated, based on database querying in accord with USDA
W		zrn_no_h	soil texture (after Novak)	assigned according to field forms CSS
W		novo_h	neoformations	assigned according to field forms CSS
W		skel_h	coarse fragments content	assigned according to field forms CSS – in %
W		v_t_sk_h	coarse fragmets shape and size	assigned according to field forms CSS

data_ form		field name	field description	notes/data origin
PROFILE DATA SET				
Table of morphological properties				
W		petr_k_h	coarse fragments petrology	assigned according to field forms CSS
W		preko_h	roots quantity	assigned according to field forms CSS
Table of basic chemical properties				
N		ics	identification profile number	generated number (explicit identificator – primary key)
N		ph_h2o_h	pH/H_2O	assigned according to field forms CSS
N		ph_kcl_h	pH/KCl	assigned according to field forms CSS
N		caco3_h	carbonate content	assigned according to field forms CSS, in %
N		caco3_h	carbonate content	assigned according to field forms CSS, in %
N		S_h	cation exchange capacity	assigned according to field forms CSS, in (mval.kg^{-1})
N		T_h	amount of exchangeable bases	assigned according to field forms CSS, in (mval.kg^{-1})
N		V_h	base saturation	assigned according to field forms CSS, in %
N		humus_h	humus content	assigned according to field forms CSS, in % of oxidable carbon (Cox).1.724
N		p_fosf_h	available phosphorous	assigned according to field forms CSS, in mg.kg^{-1} P_2O_5
N		p_dras_h	available potassium	assigned according to field forms CSS, in mg.kg^{-1} K_2O
Table of basic physical properties				
N		ics	identification profile number	generated number (explicit identificator – primary key)
N		celk_il_h	fraction under 0.01 mm	assigned according to field forms CSS – in %
N		fyz_il_h	fraction pod 0.001 mm	assigned according to field forms CSS – in %

PROFILE DATA SET				
Table of morphological properties				
data_ form		**field name**	**field description**	**notes/data origin**
N		j_prach_h	fraction 0.001 – 0.01 mm	assigned according to field forms CSS – in %
N		h_prach_h	fraction 0.01 – 0.05 mm	assigned according to field forms CSS – in %
N		j_pies_h	fraction 0.05 – 0.25 mm	assigned according to field forms CSS – in %
N		piesok_h	fraction 0.25 – 2.0 mm	assigned according to field forms CSS – in %
N	*)	j_pr00_h	fraction 0.002 – 0.01 mm	in %, data range according to texture triangle of MSCS 2000
N	*)	il_00_h	fraction under 0.002 mm	in %, data range according to texture triangle of MSCS 2000, generated by automatic procedure from fraction < 0.001 mm
N	*)	pr_00_h	fraction 0.002 – 0.05 mm	in %, data range according to texture triangle of MSCS 2000
N	*)	pie_00_h	fraction 0.05 – 2.0 mm	in %, data range according to texture triangle of MSCS 2000
N	*)	gcm3_h	bulk density	in ($g.cm^{-3}$), generated by automatic procedure from relevant fields of KPP-DB

Notes: 1. *Symbol *) in prefix of field_name field highlights completed items to KPP-DB (as part of original database update).* 2. *In data_form field is used W – for text string and N – for number.* 3. *Symbol _h in field_name field suffix (in profile data set) is in KPP-DB replaced by number (of genetic horizon (in range 1 – 5), final number of items is then multiple of number of described horizons.*

List of abbreviations:
CSS – *Complex survey of agricultural soils of Slovakia*
MKSP 2000 – *Morfogenetic soil classification system of Slovakia - basal reference soil taxonomy*
USDA – *Field Book for Describing and Sampling Soils (used in USA)*

REFERENCES

Bielek, P., Ilavská, B., Džatko, M., Lazúr, R., Skalský, R., Rybár, O., Vilček, J., Torma, S., Houšková, B., Granec, M., 2002: Nové hodnotenie pôd Slovenskej republiky, In: Zb. konfer. Prvé pôdoznalecké dni v SR,Račkova dolina, VUPU, Bratislava, p. 405 – 406.

Demo M., a kol., 1998.: Usporiadanie a využívanie pôdy v pôľnohospodárskej krajine. Nitra, 302 s.

Džatko M., Abrahám J., Bedrna Z., Linkeš V., Stašík V., 1976: Charakteristika pôdno-ekologických jednotiek SSR.MPVž, Bratislava.

Džatko M, Linkeš V., Pestún V., 1996: Príručka pre používanie máp bonitovaných pôdno-ekologických jednotiek. VUPU, Bratislava

Hart, D., Philips, H., 1998: NSGIC Metadata Primer, [Homepage of NSGIC Metadata/ Primer/, Standards for Digital Geospatial Metadata, FGDC, Reston, Virginia

Kuranda, J., 1999: Metainformacni systemy a geoinformace, GeoInfo, vol. 5/99, pp: 24 – 27, Computer Press.

Ilavská, B., et al., 1998: The Soil Geographic Information system Buiding up at SFRI. In: Proceedings of SFRI, vol. 21, SFRI, Bratislava, p. 55 – 63.

Levčíková A., 2002: Integrovaný informačný systém v rezorte pôdohospodárstva SR.In:Vojenský informačný systém o území a prax, (Zborník referátov), Banská Bystrica.

Linkeš V., Šimonyová S., 1982: Príprava a kontrola dát z pedologických sond pre informačný systém o pôde. Záverečná správa (S 11-529-119-02/03), VUVR, Bratislava.

Linkeš V., 1984: Realizácia jednoduchej varianty informačného systému o pôde SSR. Záverečná správa (S 11-529-119-02/E07, VUVR, Bratilava.

Lukáč Š., 1998.: Aktuálny stav právnych a technických predpisov v odvetví geodézie, kartografie a katastri nehnuteľnosti In: Geoinformatika v službách armády SR, pp. 179 – 194.

Minár J., Machová Z., 2001: Podklady o georeliéfe. In: Minár et al.: Geoekologický (komplexný fyzickogeografický) výskum a mapovanie vo veľkých mierkach. Geografické spektrum 3, 2001, Prif UK, Bratislava, p. 52 – 54.

Mitášová I., Hájek M., 1999.: Mapy a vytváranie výstupov z geoinformatických systémov, kartografické listy 7/1999, s. 63 – 70.

Šurina B., Juráni B., 1997: Mapovanie pôd a pôdne mapy na Slovensku. In: Kartografické listy No. 5, p. 99 – 104.

STUFF, 2000: Morfogenetický klasifikačný systém pôd Slovenska – bazálna referenčná taxonómia. Societas Pedologica Slovaca, VUPOP, Bratislava

STUFF, 1996: Field Book for Describing and Sampling Soils, USDA-NRCS, Lincoln, Nebraska

STN P ENV 12657., 1998: Geografická informácia, Opis dát, Metadáta.

http://topu.army.sk/zbornik02/13_Levcikova.pdf

http://www.cenorm.be

http://www.eurogeographics.org

http://www.opengis.org/techno/spect.html

http://www.fgdc.gov/publications/documents/metadata/workbook.pdf

http://www.fgdc.er.usgs.gov/metadata/whatsnew/fgdciso.html

http://www.gisdevelopment.net/news/2001/mar/nps001.htm

http://www.cagi.cz

http://www.en.eun.org/eun.org2/eun/en/training/sub_area_frame.cfm?sa=134

http://www.ifla.org/documents/libraries/cataloging/metadata/astmd18.pdf

http://www.fgdc.gov/metadata/metadata.html
http://www.anzlic.org.au/infrastructure_metadata.html
http://www.iszp.sk/metasys/koncept.htm
http://www.lic.wisc.edu/metadata/metaprim.htm

PILOT PROJECTS ON CONTROL WITH REMOTE SENSING IN ACCESSION COUNTRIES IN THE FRAME OF JRC SUPPORT TO IACS SET UP

Pilótne Projekty kontroly pomocou Diaľkového prieskumu zeme v kandidátskych krajinách EU v rámci podpory JRC pri realizácii Intergrovaného administratívneho kontrolného systému (IACS)

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ABSTRACT

The Soil Science and Conservation Research Institute (SSCRI), Bratislava is a focal point of Remote Sensing methods use in the Agriculture Department of Slovak Republic. One of the tasks is the "Control of the conditions fulfilment for the subsidies fixed to agricultural area by use the Remote Sensing methods" (in the text only control by Remote Sensing).

The Control by Remote Sensing is one of five focal components of the Integrated Administrative and Control System (IACS). This subsidy control method is one of the check methods officially respected by European Union (EU) focused to authorized subsidies fixed to farmland, based on EU directives concerning Common Agriculture Policy (CAP) – Decree N. 3508/92 article 4 and 8.4 cited – national administrative can use Remote Sensing methods when controlling areas and uses of the parcels. Further is Decree N. 2419/01 – article 23 (before Decree N. 3887/92).

This form of subsidy control is momentally preferred control method in most EU member countries. On average is in the member countries checked 10% application forms, of it more than one half just by this method. Its key advantage is temporal control efficacy of agricultural objects high quantity in short temporal horizon needed by the control principles. Therefore the control by Remote Sensing is considered for a filter on-the-spot control.

The control by help of Remote Sensing consists of several consecutive steps in strict time stages. The results have been used as documents of the controls required by CAP directives.

The control of given territory RO MPSR Nové Zámky was executed in cooperation with the Point Research Institute – Research Centre of European Commission (JRC), Ispra (Italy) within the Pilot Projects CwRS (control by Remote Sensing) in 9 candidate countries. This research center is responsible for the control methodology and external inspection of the procedure. The JRC secured methodological course of the VÚPOP workers in March 2003, and in June 2003 was organized working meeting of candidate countries teamworks. The JRC control of the results sent in comprehensive structured report (term October 30th, 2003) and digital data of Earth Remote Sensing used at the control, as it has been currently done in the countries participating at this programme.

The control results showed, in acute IACS operation when using Remote Sensing methodology, for authorized control of subsidy on area and crop, from total number 39 observed subjects 6 subjects was accepted, 12 subjects showed small discrepancies, and 12 subjects was not accepted. In the level of user's parcels it was 47.68% within technical tolerance, 20.69% was declared smaller area than detected cultivated area and at remaining 31.64% the area declared was bigger than detected cultivated area – overdeclaration.

Main reason, why such high parcel number was out of the tolerance, was not satisfactory new system knowledge (LPIS/IACS) from the side of agricultural subjects representatives. This was caused mainly by use of physical field blocks instead of cadastral parcels, which farmers most met bill now, this was the reason of unproper declared areas.

The results as well as elaborated data were sent to the JRC. They evaluated the project positively, whereby JRD made also the control of the project quality. The results were also presented at 9th CwRS at Köln, Germany.

European Commission recommended for next year to control 20% of application forms for present candidate countries. The method used showed to be objective and temporally and finantially high effective.

KEYWORDS: Control with Remote Sensing, control site, applications, satellite images, orthophotomaps, LPIS (Land Parcel Identification System)

ABSTRAKT

VÚPOP (Výskumný ústav pôdoznalectva a ochrany pôdy) je národným centrom (focal point) využívania metód DPZ (diaľkový prieskum Zeme) v rezorte pôdohospodárstva SR. Jednou z úloh je „Kontrola plnenia podmienok pre získanie dotácií viazaných na poľnohospodársku plochu využitím metód diaľkového prieskumu Zeme" (ďalej len kontrola pomocou DPZ).

Kontrola pomocou DPZ je jedným z piatich kľúčových komponentov systému IACS. Táto metóda kontroly dotácií je jednou z Európskou Úniou (EU) oficiálne uznávaných metód kontroly oprávnenosti poberania dotácií viazaných na poľnohospodársku plochu, založená na nariadeniach EU týkajúcich sa Common Agriculture Policy (CAP – Spoločná Poľnohospodárska Politika) – Nariadenie č. 3508/92 článok 4 a článok 8.4 uvádza, že národná administratíva môže využiť metódy DPZ pri kontrole výmer a využívania parciel. Ďalšou nariadením je Nariadenie č. 2419/01 – článok 23 (predtým nariadenie číslo 3887/92).

Táto forma kontroly dotácií je momentálne preferovanou metódou kontroly vo väčšine členských krajín EU. V priemere sa v členských krajinách skontroluje minimálne 10% žiadostí, z toho niečo viac ako polovica práve touto metódou. Jej kľúčovou výhodou je časová efektivita kontroly veľkého množstva poľnohospodárskych subjektov v krátkom časovom horizonte, v ktorom môžu byť kontroly vykonané. Preto je aj kontrola pomocou DPZ chápaná ako filter pre kontroly na mieste (on-the-spot control).

Kontrola pomocou DPZ pozostáva z viacerých na seba naväzujúcich krokov v striktných časových etapách. Výsledky z kontroly pomocou DPZ sa používajú na dokladovanie vykonávania kontrol vyžadovaných CAP nariadeniami.

Kontrola záujmového územia RO MPSR Nové Zámky bola vykonávaná v spolupráci s JRC (Joint Research Institute – Výskumné Stredisko Európskej Komisie) v Ispre v rámci Pilotných Projektov CwRS (kontroly pomocou DPZ) v 9 kandidátskych krajinách. Toto výskumné stredisko je zodpovedné za metodiku kontroly a externú kontrolu procedúry. Zo strany JRC boli obstarané a následne poskytnuté satelitné obrazové záznamy z kontrolovaného územia. JRC zabezpečilo metodické školenie – pracovníkov VÚPOP-u v marci 2003 a v júni 2003 prebehlo pracovné stretnutie riešiteľských kolektívov kandidátskych krajín. JRC uskutočňuje kontrolu výsledkov, ktoré im boli zaslané v súhrnnej štruktúrovanej správe (termín 30. 10. 2003) a digitálne údaje diaľkového prieskumu Zeme použité pri kontrole, ako sa to bežne robí pri štátoch, ktoré participujú na tomto programe.

Výsledok kontroly ukázal, že v ostrej prevádzke IACS za požitia metodík DPZ na kontrolu oprávnenosti poberania dotácii na plochu a plodinu, by bolo z celkového počtu 39 skúmaných subjektov 6 subjektov akceptovaných, 12 subjektov by malo malé nezrovnalosti a 22 subjektov by bolo neakceptovaných. Na úrovni užívateľských parciel by bolo 47,68% v rámci technických tolerancií, pri 20,69% bola deklarovaná nižšia výmera ako bola zistená obrábaná výmera a pri zvyšných 31,64% deklarovaná výmera bola väčšia ako zistená obrábaná výmera (over-declaration).

Hlavným dôvodom, prečo je taký vysoký počet parciel mimo tolerancie je ešte nedostatočná znalosť nového systému (LPIS/IACS) zo strany zástupcov poľnohospodárskych subjektov. Je to spôsobené hlavne používaním fyzických (farmárskych) blokov namiesto katastrálnych parciel, s ktorými sa poľnohospodári doposiaľ zväčša stretávali z čoho i vychádzajú nesprávne deklarované výmery.

Výsledky, ako aj spracované údaje, boli zaslané do JRC. Z ich strany bol projekt hodnotený kladne, pričom JRC vykonáva aj kontrolu kvality projektu. Výsledky projektu boli prezentované aj na 9. Konferencii CwRS v Kolíne.

Európska komisia na budúci rok odporúča terajším kandidátskym krajinám skontrolovať 20% žiadostí a použitá metóda sa ukázala ako objektívna, časovo a finančne vysoko efektívna.

Kľúčové slová: Kontrola Diaľkovým prieskumom Zeme, kontrolné miesta, žiadosti, satelitné obrazové záznamy, ortofotomapy, LPIS (register poľnohospodárskych produkčných blokov)

INTRODUCTION

1. Backround/Objectives

SSCRI (Soil Science and Conservation Research Institute) is the focal point of Remote Sensing activities in Slovak agriculture. SSCRI plays the key role in IACS (Integrated Administrative and Control System) Establishment. According the resolution from 9th session of Ministry of Agriculture top – management (4th of April 2002) the Establishment of the Land Parcel Identification System (LPIS) was entrusted to the Soil Science and Conservation Research Institute. In the frame of "Pilot Projects on Control with Remote Sensing in Accession Countries" managed and coordinated by Joint Research Centre of EC, SSCRI solved above mentioned project in Slovak conditions.

The project has two main parts:

- qualitative task: determination of rightness or difference between declared area and really farmed area
- quantitave task: determination of rightness or difference between declared crop and interpreted (satellite image or fied measure) crop

In 2002 campaign 15 agricultural subjects with 5 604.77 ha in districts of Piešťany, Hlohovec and Banská Štiavnica were checked.

The 2003 campaign is also solved as a part of pilot of IACS project done by IACS system integrator AXA company and it is based on Slovak national scheme. The pilot sites are the parts of Regional department of MoA (districts Nové Zámky) and Regional department of MoA (districts Prešov, Sabinov).

The VHR images are used for solving of both above mentioned tasks.

JRC supported SSCRI with knowledge and expertises, but also directly provided the documents:

– Common Technical Specifications and Recommendations
– Guidelines for Best Practice and Quality Checking of Ortho Imagery and other related documents
– JRC provided 3 satellite scenes for the 2003 campaign
– organised training course 24. – 26. March 2003, three experts from SSCRI completed this training course and active participated on workshop July 24. – 25th, 2003.
– JRC assisted our Administration to take the crucial decision on:
  - using CwRS in year 2004 as a part of operational control process
  - to choose digital LPIS based on orthophotos and physical block system
– SSCRI had strong interest on technical exchange within the EU and the network of conferecies organized by the JRC:
  - presentation of CwRS results at annual conferencies on Control with Remote Sensing
  - organization of local workshops concerning LPIS and CwRS with participation of experts from Accesion Countries: PL, CZ, HU, SK, LV, LT, RO, BG and HR, very good colaboration between SR and the other new MS
  - real lively contacts (technical support, exchange,disscusions...) with JRC experts

MATERIALS AND METHODS

2. Selection of Site

As it was mentioned above 2003 CwRS pilot project is a part of IACS pilot project. Therefore the CwRS sites are identical with sites selected (based on agreement between the IACS system integrator the AXA company and MoA) for IACS pilot project.

The site selection was based on the character of nature and agricultural land (intensively and middle intensively used), because the geo-ecological conditions influence also the character of agricultural land use of land of Slovakia, which are often very different. This fact is mainly caused by the terrain (especially according to altitude and its difference), on which the other conditions and their changes are depended.

Two sites were choosen

- district Nové Zámky, which represents intensively used agricultural land
- district Prešov – which represents middle intensively used agricultural land

The Nové Zámky site (control site 1) cover a circle with radius of 25 km with center near the town Nové Zámky. The Regional Department of MoA (RD MoA) – Prešov includes two districts (Prešov and Sabinov) and it is identified as control site 2.

3. Description of Site

The control site 1 – Nové Zámky

The interesting area includes a circle with radius of 25 km with center near the Nové Zámky town.

The site is located on Podunajská nížina (Danubian Lowland) in the south part of Slovakia. The altitude of the area ranges from 102 to 395 m above sea level with elevation 293 m. The lowest point of the area (102 m above sea level) is a confluence of the rivers Ipeľ and Dunabe. The highest point is top of Burdov Hill (395 m above sea level), which occurs in Burda Mountains.

Country represents typically intensively cultivated arable land. Its area is about 134 676 ha. It is agricultural intensively used lowland country with the land use mosaic of 80.4% of agricultural land (it contains 91.6% arable soil, 2.1% green land, 2.4% vineyards and 1.6% of orchards) and 7.7% of the wood land. The area represents 6.5% from overall arable land of Slovakia. Arable land is covered mainly by cereals (wheat, maize, barley, sunflower, soya, vegetables and tobacco.

During control verification 844 subject were contacted (link between farmers and agriculture land was establish for IACS/LPIS purposes), from which 29 were controlled in 2003 CwRS pilot project.

The control site 2 – Prešov

The interesting area involves the Prešov and Sabinov districts (RD MoA Prešov). The site is located in the north-east part of Slovak Republic and in a part of Spišsko-Šarišské medzihorie, Čergov, Branisko, Bachureň, Šarišská vrchovina and Košická kotlina. The mosaic of landuse is created by arable land, meadows, pastures and woods (typical mixture of up-down land). The altitude of the area ranges from 200 to 1 171 m above sea level with elevation 971 m in Prešov disctrict and from 185 to 1 128 m above sea level with elevation 943 m in Sabinov disctrict. The area of site is about 141 703 ha.

The control site represents middle intensively agricultural land, where agriculture area covers 43.4%, from which arable is just 23.8% of all area. The pastures and meaddows cover relatively large acreage. Rest area is covered mainly by forest. Arable land is vegetated predominant by cereals (barley, oats, rye, wheat), forage crops, rape and potatoes.

Average block size is much lower as in Nové Zámky district. The blocks borders are undulated and complicated.

4. Timing of imagery

Table 1 Charakteristics of satellite scenes

acquisition window	IRS	IRS	SPOT
	Spring 1	**Spring 2**	**Summer 1**
organization	EUROMAP	EUROMAP	EURO IMAGE
satellite	IRS-1D	IRS-1D	SPOT 5
instrument	LISS-III	LISS-III	HRG 1
resolution	25 m	25 m	2,5 m
spectral characteristics	multispectral	multispectral	panchromatic
date of acquisition	6.5.2003	6.6.2003	30.6.2003
date of order	13.5.2003	17.5.2003	
date of creation	15.5.2003	18.5.2003	7.7.2003
date of delivery	17.5.2003	20.6.2003	9.7.2003
data volume	180 MB	190 MB	555 MB
data format	IRS-1C/1D (EUROMAP Fast Format C)	IRS-1C/1D (EUROMAP Fast Format C)	GeoTIFF

The orthorectification of IRS satellite scenes were completed by external sub--contractor (Data Image company) and it took 3 days per scene. The orthorectification and control of orthorectification of SPOT satellite scene was made by staff of SSCRI and it took 3 day, too.

RESULTS AND DICUSSION

5. Description test/Work performed

Software environment: ERDAS IMAGINE 8.6
ArcGIS 8.3 with extensions: Image Analyst
3D Analyst
Spatial Analyst

Source and ancillary data:
- 3 satellite scenes provided by JRC
- LPIS vector layer (after control verification) maintained by SSCRI
- orthophotomaps (created for LPIS/IACS purposes managed by SSCRI in scale 1:5 000, June 2002)
- applications data (co-operation with RD MoA SR Nové Zámky)

Staff: – CAPI – 1 person
– field visit – 4 person (2 teams)

Image pre-processing:

As it was mentioned before, the orthorectification of IRS satellite scenes was made by external contractor and orthorectification of SPOT scene was made by staff of SSCRI. The IRS satellite scenes were orthorectified in ERDAS IMAGINE 8.5 software environment. The SPOT scene was orthorectified in ERDAS IMAGINE 8.5 and ArcGIS 8.3 with mentioned extensions.

Table 2   Orthorectification characteristics of satellite scenes

Orthocorrection	IRS 6. 5. 2003	IRS 6. 6. 2003	SPOT 30. 6. 2003
GCP's source	analog topo maps 1:25 000	analog topo maps 1:25 000	digital orthophotomaps
GCP's number	20	17	21
correction procedure	2nd order polynom warp	2nd order polynom warp	orthocorrection
DEM	no	no	yes
$rmse_{xy}$ (pixel)	0.31	0.31	0.59
$rmse_{xy}$ (m)	7.75	7.75	1.47

The satellites scenes were orthorectified right after delivery.

The DEM which was used for orthorectification of SPOT scene was pre-processed DEM which was used for orthorectification of aerial photographs (exploited for LPIS creation). The source was 5 m grid with break lines. It was triangulated to TIN and then converted to image (*.img).

No tessellating, merging and classification were performed on any of used satellites scenes.

Area check:

The parcel borders were based on the LPIS vector layer with correction based on the SPOT scene. LPIS vector layer (physical blocks) was created on digital orthophotomaps (flight 2002) background. Therefore in some cases were updated parcel boundaries according recent SPT scene. The used buffer width for calculation of parcel area measurements tolerances was 3 m, as it is specified in Common Technical Specification for the 2003 campaign of Remote-sensing control of arable and forage land area-based subsidies for usage of recent archive aerial photo combined with satellite PAN image. The results at parcel level are in the table 3.

Table 3   The results from area checks (at parcel level)

Code	C^{3+}	OK	C^{3-}
Number	278	499	273

The main reason for such many parcels outside tolerance is unknowing the new system (LPIS, IACS, …) from farmers site especially system (usage) of physical (farmers) blocks, because they have been used cadastre parcels till now. The next reason is our Cadastre system – borders of cadastre parcels don't really correspond with the reality. There were some cases where cadastre parcel was divided in to two physical blocks and farmer has declared eligible area based on cadastre parcel. The reason of this fact is that the farmer didn't detect that the borders of physical block didn't correspond with the borders of cadastre parcel. Another reason is the actuality of our cadastre system. Some problems occurred in the cases when the blocks bordered with forest. For example the cadastre with area of 20 ha includes physical block with area just 15 ha and the rest (5 ha) is forest now. So the cadastre borders were not relevant.

The next reason is fact that also roads, balks and so on are included and calculated into the cadastre parcels area. Last but not least we have used orthophotomaps from previous year – the crop borders, witch have been an orientation point for the farmers, were often changed.

Crop check:

The CAPI was made in ERDAS software environment with band combination of 123 (RGB) for IRS scenes. It is hard to determine the time consuming per dossier because of very various eligible area per dossier (from 16 ha to 6 800 ha). The CAPI of all dossier (29 dossiers, 1 050 parcels) took 2 days (for 1 person) – so in general we can say that it was CAPI-ed approximately 65 parcels per hour. The results from CAPI (at parcel level) are in the table 4.

Table 4a The results from crop checks (at parcel level) in hectares

RD MoA SR	OK		C^1		C^{3+}		C^{3-}		C^4		T^6	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
NZ	10 636.25	39.12	299.25	1.10	8 400.90	30.90	7 691.65	28.29	157.88	0.58	0.87	0.00

Table 4b The results from crop checks (at parcel level) in number of parcels

RD MoA SR	OK		C^1		C^{3+}		C^{3-}		C^4		T^6	
	number	%	number	%	number	%	number	%	number	%	number	%
NZ	451	42.95	41	3.90	270	25.71	240	22.86	44	4.19	4	0.38

In C1 code group are parcels mainly for two reasons. The first reason is that in one block are two crops, one of them is from neighbour block and that means that the crop borders were declared not correctly. The second one is that there are non-eligible areas or areas where crop has failed in the block.

Control:

The control phase had 4 basic tasks:

- quality control of orthorectified satellite scenes
- control of photointerpreted crops
- control of photointerpreted parcel areas/borders
- control of the performed work

Quality control of orthorectified satellite scenes:

Table 5 Quality control of orthorectified satellite scenes

	IRS 6.5.2003	IRS 6.6.2003	SPOT 30.6.2003
CHK´s source	digital orthophotomaps	digital orthophotomaps	digital orthophotomaps
CHK´s number	16	16	14
rmsexy (pixel)	0,71	0,66	0,79
rmsexy (m)	17,80	16,55	1,97

All tested satellite scenes were within their tolerance.

Control of photointerpreted crops:

All blocks with C^1 or C^4 code (85 blocks) and 58 (5.52%) blocks with OK, C^{3+} or C^{3-} codes were checked in field.

The results form control of blocks with C^1 or C^4 code is in the table 6.

Table 6 The results of control of block with C^1 or C^4 code

code	**C^1**		**C^4**	
declaration	Good	wrong	good	wrong
number	15	26	35	9

9 from 15 blocks with C^1 code and found as good declaration were CAPI-ed as case of crop failed.

In control of parcels with OK, C^{3+} or C^{3-} codes 4 errors (from 58 checked blocks) were found – in 3 cases the block was declared and CAPI-ed as vineyard and was found arable land in field and in 1 case the block was declared and CAPI-ed as orchard and in field arable land was found.

Control of photointerpreted areas:

18 blocks with acreage of 420 ha were checked using stand alone DGPS with real-time differential correction (accuracy sub 1 m ?).

On 3 of them occurred discrepancies with difference between interpreted and field measured area about 0.5 – 1 ha. The discrepancy was caused by measuring of different borders. For example, the physical block contains a cart-track (which can by plough-up) which was not included in field measurement. On the other hand on the rest 15 blocks was average error only 0.04 ha in considering the fact that were measured blocks with huge acreage for example 120 ha and twice 80 ha, too. Even on 7 of 15 measured blocks were found discrepancy smaller then 0.00 ha?

Control of the performed work:

All work steps were externally (with another person) checked – it means:

- quality control of orthorectified satellite scenes: all satellite scenes were found inside theirs tolerance – see chapter Quality control of orthorectified satellite scenes before
- typing (digitalization) of declarations: 2 errors were found – on the map was declared one crop and on the paper form another. Later, in the field control phase, further error was found– an exchange of the crops in one farmer's block.
- photointerpretation of blocks: all blocks with C^1 or C^4 code and some blocks with OK, C^{3+} or C^{3-} code were checked. No error was found.
- control of completeness of farmers: 2 shapes were found that have not been photointerpreped. There were 2 little shapes generated in process of delimitation of farmer's blocks to crop blocks.
- control of results of CwRS at crop group and farmers level: some errors were found
- field control of photointerpreted crops: 4 errors were found - see chapter Control of photointerpreted crops before
- field control of photointerpreted areas: see chapter Control of photointerpreted areas before

Other use of the VHR data set:

The VHR data set was used only for CwRS Pilot Project. It is expected and planned to use in year 2004 further VHR satellite images also for control of SAPS and Agri- environmental measurement.

CONCLUSIONS

6. Actual vs. planned time schedule:

Time table:
– orthorectification of satellite scenes: IRS scenes were orthorectified right after their delivery. SPOT scene war orthorectified after delivery of DEM – 27. 8. 2003
– quality control of rectified satellite scenes: right after orthorectification
– delivery of application data from RD MoA Nové Zámky: 5. 9. 2003
– digitalization of application data: 8. – 9. 9. 2003
– CAPI with categorization of blocks: 16. – 17. 9. 2003
– summary of results at crop group and farmer level:19. and 22. 9. 2003
– control of the work – completeness and categorization: 23. – 24. 9. 2003
– field visits: – crop checks: 3 days between 25. 9. and 2. 10. 2003
– area ckecks: 3 days between 29. 9. and 7. 10. 2003
– working-out the results from field visits and writing reports: right after field visit — 26. 9. – 10. 10. 2003
– summarizing of the work and writing reports: from 6. 10. 2003

7. Evaluation of results

7.1. Major problems encountered: Some problems occurred in process of fotointrpretation (CAPI) at separation of summer crops. It was caused by using only 3 satellite images – Spring 1, Spring 2 and Summer 1. It will be better if we should have a Summer 2 image, too. Generally, we prefer if it will be 5 satellite images per site in campaign as it is in case of member states.

7.2. Eventual delays w.r.t. original planning and/or operational timing: Whole process was based on application data which were delivery on SSCRI from RD MoA on 5.9.2003.

7.3. Need for RFV: As it was mentioned above all blocks with C^1 or C^4 code (85 blocks) and 58 (5.52%) blocks with OK, C^{3+} or C^{3-} codes were checked in field.

7.4. CwRS diagnosis: From 34 crop groups with code R were 11 at least in one of RP group.

Table 7 Results from sorting of rejected groups

RP1			RP2			RP3		
	from all	from R		from all	from R		from all	from R
number	%	%	number	%	%	number	%	%
1	1.47	2.94	10	14.71	29.41	5	7.35	14.71

7.5. Follow-up procedure: For sorting of rejected groups we used thresholds as they are defined in Common Technical Specification for the 2003 campaign of CwRS (≤ 0.5 ha, ≤ 2% and ≤ 2 ha).

7.6. Use of VHR data in CwRS campaign

In general, the advantages of VHR scenes against orthophotomaps consist in the rate of their acquisition and multifunctional use (in this case – for crop and area control, too). Also their short shadows are one important adventage. On the other hand their expensiveness of acquisition is high. Their disadvantage in comparision with other satellite scenes is that only very small area is covered by one scene.

In CwRS campaign the SPOT 2.5 m panchromatic scene was used (from 30.06). It was used for both tasks – area measurement either crop interpretation. On this scene it could be interpreted and differentiated summer and winter/spring crops. The winter/spring crops are bright and summer crops are dark even in base of different pattern it could be differentiated sunflower and maize. In the area measurement it seems that the pixel size of 2.5 m is right enough as it shows the results of the field control.

In general VHR data are relatable for CwRS either in area measurement either in crop interpretation.

8. Future strategy:

8.1. SAPS or Full Scheme: The Slovak Government by Resolution n. 447 from 5th of June 2003 decided to use SAPS scheme. The SAPS conditions are already implemented into process of the creating IACS. We would like to start to test the pilot project on 2 Regional Departments and central level in next 3 weeks.

8.2. General approach for control of declarations: Administrative controls on applications will be made on regional a central level. On regional level will be controlled only completeness and rightness of typing applications into system. Cross-checks and risk analyses will be made on the central level. Regional departments of PPA (Poľnohospodárska platobná agentúra – Agricultural Payment Agency) will carry out also on-the-spot controls with implementation of the result into the system.

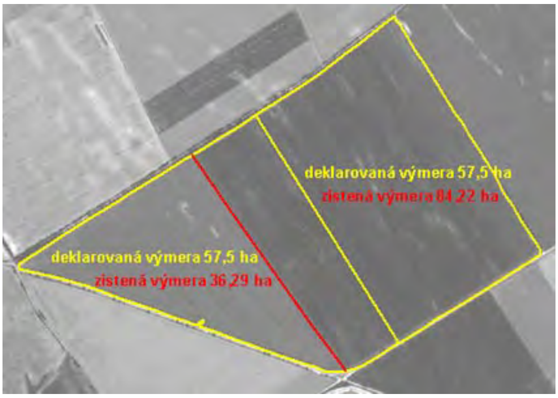
8.3. Applicability of Remote Sensing and (if relevant) backup solution in case of poor imagery: Backup solution will be based on radar images combinated with field visits.

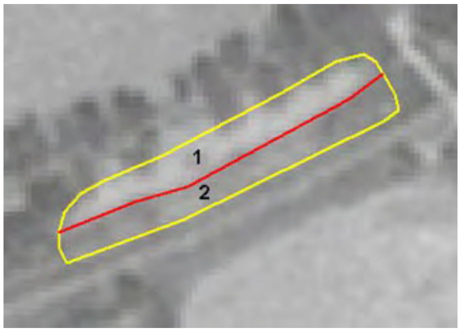
8.3. Sites & dossiers selection: There will be 2 sites (most likely with 25 km radius) with selection based on risk analysis. It is accepted to control approximately 4 – 5% of the dossiers but it depends on sites locations.

Incorrect declaration of the border between agriculture parcels

1, declared: barley

found: barley





2, declared: barley
found: grassland

a, orthophotomap from June 2002

b, satellite image IRS from 6. 5. 2003 (combination 123)

c, satellite image IRS from 6. 6. 2003 (combination 123)

d, satellite image SPOT from 30. 6. 2003

1, declared: peas	found: peas
2, declared: sunflower	found: peas
3, declared: sunflower	found: sunflower
4, declared: sunflower	found: barley

REFERENCES

Sviček, M., 2001: Detection and Mapping of Eroded Soil Areas on Trnavska Hilly Land Using Remote Sensing Methods. In: Jambor, P. (ed.): Proceedings of the Trilateral Co-opertion Meeting on Physical Soil Degradation. SSCRI, Bratislava, p. 65.

Sviček, M., 2003: Modelling of potencial Erosion and Detection of eroded Soil Areas on Trnavska Hilly Land and Highland of Krupina using Remote Sensing Methods. In: Nestroy, O., Jambor, P. (eds.): Aspects of the Erosion by Water in Austria, Hungary and Slovakia. SSCRI, Bratislava, p. 137.

TOWARDS THE STRATEGY OF WATER RESOURCES PRESERVATION AGAINST POLLUTION BY NITROGEN FROM AGRICULTURE IN THE SLOVAK REPUBLIC

K STRATÉGII OCHRANY VODNÝCH ZDROJOV PRED ZNEČISTENÍM DUSÍKOM Z POĽNOHOSPODÁRSTVA V SLOVENSKEJ REPUBLIKE

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ABSTRACT

In the paper policy principles for water resources preservation against pollution by nitrogen from agriculture are analysed. In Slovakian conditions the decisive factor that influences mentioned pollution is usually management of animal manures, nitrogen fertilisers, soil and crop management. Implementation of European legislation into national one represents the first step at water resources preservation against pollution. The measures related to farm management are the matter of good agricultural practice that was in Slovak conditions already published. Substantial parts of this document, considering relevant national legislation, represent action programme and is the subject of Ministry of Agriculture decree. The best agricultural practice in broader sense embraces legislation and expert activities and is subdivided into tree degrees as follows: level of unacceptable farming that leads to the water resources pollution, level of acceptable farming corresponding with good agricultural practice, and level where farming practices are going beyond the good agricultural practice. The agricultural measures within last level are mainly based on voluntary entry of agricultural subject into agri – environmental program of the Slovak Republic that subsequently will be mandatory for these farmers and financially subsided. Permanent increase of farmer environmental awareness through available information, additional education and training activities as well as functional advisory service significantly promotes the successfulness and efficiency the realisation of good/best agricultural practice measures.

Keywords: water resources preservation, nitrate nitrogen, fertilisers, manures, Nitrate Directive, best agricultural practice

ABSTRAKT

Príspevok analyzuje zásady ochrany vodných zdrojov pred znečistením dusíkom z poľnohospodárskych zdrojov. V podmienkach Slovenska rozhodujúcim momentom, ktorý spravidla ovplyvňuje uvedené znečisťovanie, je manažment hospodárskych a dusíkatých priemyselných hnojív, manažment pôdy a plodín. Implementácia európskej legislatívy do národnej legislatívy predstavuje prvý krok pri riešení ochrany vodných zdrojov pred znečistením. Opatrenia, týkajúce sa manažmentu v poľnohospodárskych podnikoch sú predmetom zásad správnej poľnohospodárskej praxe, ktoré v rámci Slovenska boli už publikované. Podstatné časti tohto dokumentu, s prihliadnutím na jestvujúce zákony, predstavujú akčný program a sú predmetom výnosu MP SR. Najlepšia poľnohospodárska prax v širšom slova zmysle, zahrňuje legislatívne dokumenty a odborné činnosti a člení sa na tri stupne: neakceptovateľné hospodárenie vedúce k znečisťovaniu vodných zdrojov, akceptovateľné hospodárenie rešpektujúce zásady správnej poľnohospodárskej praxe a oblasť hospodárenia, ktoré ide nad rámec predchádzajúceho hospodárenia. Aktivity v treťom stupni sú založené predovšetkým na dobrovoľnom vstupe poľnohospodárskych podnikov do agro-environmentálneho programu SR, ktorý následne pre týchto farmárov bude záväzným a finančne dotovaný. Trvalé zvyšovanie environmentálneho povedomia poľnohospodárov prostredníctvom dostupných informácií, dodatočného vzdelávania a školenia ako aj funkčného poradenstva významne podporuje úspešnosť a účinnosť uplatňovania opatrení správnej/najlepšej poľnohospodárskej praxe.

Kľúčové slová: ochrana vodných zdrojov, dusičnanový dusík, priemyselné hnojivá, hospodárske hnojivá, dusičnanová smernica, najlepšia poľnohospodárska prax

INTRODUCTION

Preservation of natural resources, water inclusive, belongs to the primary tasks of mankind at guarantying the sustainability and present life quality on the Earth in the future. Agriculture is considered as sector that significantly contributes to the pollution of water resources (e.g. Bell, Bielek, 2001; Burt et al., 1993; Collective, 2003; Follett, Hatfield, 2001; Jones, 1993; Wilson et al., 1999). Significance of mentioned confirms many activities relevant to adoption of legal and technical measures such as European and national legislation documents relevant to water quality protection, codes of good agricultural practice as well as national agro-environmental programmes within common agricultural policy EU.

MATERIAL AND METHODS

The aim of paper is to inventory the fertiliser and manure use and analyse the policies for control of water pollution from agriculture by nitrogen with regard to concept of good and best agricultural practice in the Slovakian conditions. The analysis of intensity of fertiliser and manure loading is based on current statistical data – from year 2002. The concept of best agricultural practice (Redman, 2003) is considered as basic platform and discussed.

RESULTS AND DISCUSSION

Intensity of fertiliser and manure use together with nutrient balance is the first factor that is considered at evaluation of potential agricultural impact on water quality. The status in this area is possible to characterise as follows:

- after 1990, intensity of fertilisation in Slovak Republic was reduced several times in comparison to period 1980 – 1990, and crop production is maintained first of all by nitrogen from fertilisers and animal manures; mentioned reduction was realised on account of phosphorus and potassium fertilisers

- in consumption of fertilisers dominate nitrogenous ones and crop demands on phosphorus and potassium are covered mainly from soil reserves
- production of animal manures is the function animal production intensity that in last years dropped on level below 0.4 livestock unit per 1 ha of agricultural soil

Average national values of the soil load per hectare of agricultural land in 2002 were as follows:

41.6 kg N.ha^{-1}, 8.7 kg P_2O_5.ha^{-1}, 8.3 K_2O.ha^{-1} in fertilisers, 0.33 LU.ha^{-1}, 21 kg N.ha^{-1} from animal manures. Loading of agricultural land by nitrogen from fertilisers and animal manures on district level in 2002 illustrate the Figures 1 to 2. As follows from calculated data loading of agricultural land by nitrogen from animal manures ranged from 5.0 kg N ha^{-1} in Revúca district (RV) to 42.0 kg N.ha^{-1} in Topoľčany district (TO). Loading of agricultural land by fertiliser nitrogen ranged from 2.4 kg N.ha^{-1} in Kysucké Nové Mesto (KM) to 70.9 kg N.ha^{-1} in Šaľa district (SA).

Average loading of 1 ha of agricultural soil by nitrogen represents only provisional values. As results from existing knowledge agricultural subjects do not use the agricultural soil equally intensively. Application of fertilisers as well as farm manures is more concentrated on market crops on arable land. In average, permanent grasslands are loaded by nutrients, at least. Within agriculture farm application of farmyard manure is managed by crop demands (crops cropped in first, second and third sequence). The demand of uniform liquid manure distribution within agricultural soil of farm remains actual problem as from effective utilisation of applied nutrient as well as from view of frequent locally high loading of soil by nutrients.

As follows from above introduced results and literary sources (e.g. Powlson, 1997; Goulding, 2000; Bujnovský, 2003), the decisive moment at preservation of water resources against pollution from agriculture consists in substantial improvement of management and harmonisation of cropping demands with need of sustaining/improving the water resources quality. Environmentally friendly management in agricultural sector is considered as prime area that needs significant progress.

Figure 1 Loading of agricultural soil by nitrogen from fertilisers in 2002 (kg N/ha^{-1})

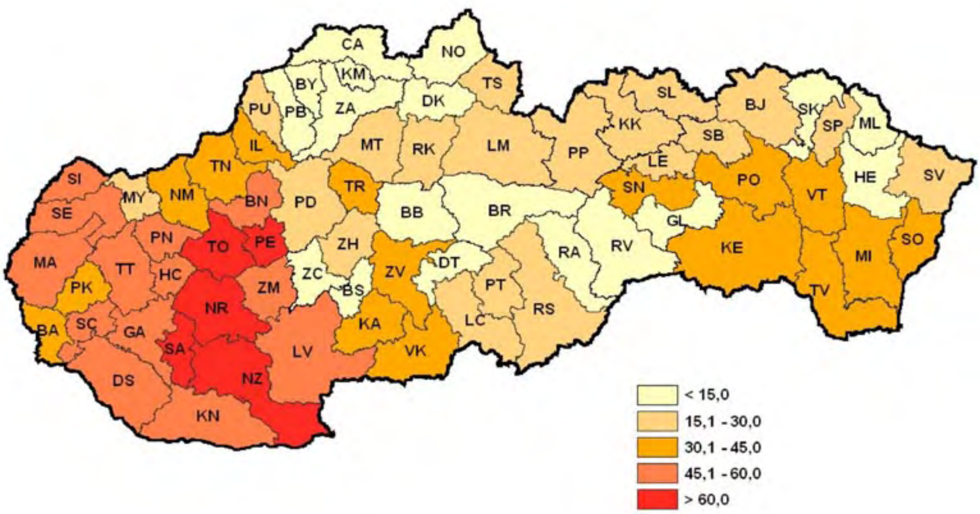
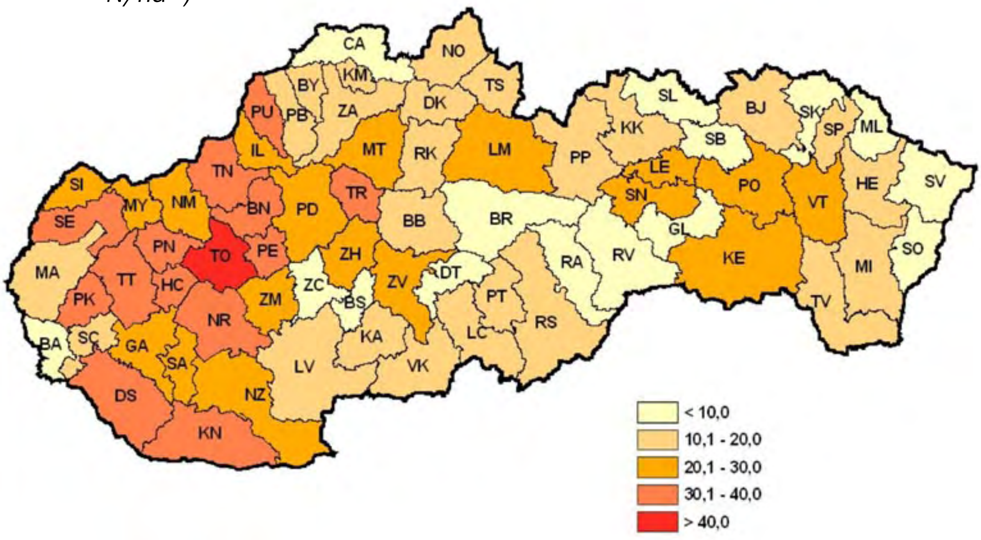


Figure 2 Loading of agricultural soil by nitrogen from animal manures in 2002 (kg N/ha^{-1})



For reaching some progress in mentioned area it is necessary to create sufficient legal environment that incorporates opinions from EU (harmonisation of EU legislation with national one) as well as practical opinions that correspond with regional/national specialities. Summary of measures following from existing legislation illustrates Table 1.

Generally, policy instruments and measures for promoting best agricultural practice in broader sense are as follows:

– disincentives for dropping below the minimum level of environmental management practice that is acceptable (economic measures)
– appropriate interventions for promoting and sustaining the minimum level of environmental management practice (promotion of farmer awareness of good practice, mandatory training of farmers, advisory system for farmers)
– incentives to go beyond the minimum level of environmental management practice and deliver a higher level of environmental performance (promotion of farmer awareness, use of compensatory payment for adopting measures beyond the good agricultural practice, increase financial support for agricultural extension and advisory services, training for extension and advisory workers etc.).

Areas, where soil, crop and fertiliser/manure management has sufficient reserves for improvement, especially in Slovak conditions, illustrates Table 2.

Table 1 Summary of measures oriented to water protection against pollution from agriculture based on current national legislation

Measures category	**Measure description**	**Relevant legislation or document**
Compulsory management following from legislation often without compensation and mandatory respecting principles of good agricultural practice (GAP) in vulnerable zones	• use of manure and fertilisers that will not harm the environment • provision necessary storage capacities for fertilisers, manures and other agricultural wastes (silage juice)	Act No. 136/2000 on fertilisers
	• animal breeding subjects with 40,000 pcs of poultry or 2,000 pcs pigs (over 30 kgs) or 750 pcs saws through BAT provision as necessity to have integrated permission of relevant authority produced wastes must be stored and foiled in environmentally friendly manner	Act No. 245/2003 on integrated prevention and control of environment pollution and Act No. 127/1994 on Environmental impact assessment in wording of next novels and Ministry of Environment decree No. 283/2001 to the Act on wastes No. 223/2001
	• respecting defined measures in concrete conditions of preservation of drinking water preservation zones	Regulation of Ministry of Environment No. 398/2002 on details at definition of drinking water preservation zones and measures on water preservation
	• respecting defined measures relevant to preserved water management areas	Act No. 184/2002 on waters (water act)
	• respecting defined agricultural measures of good agricultural practice in vulnerable zones and fertiliser management, soil and crop management	Prepared Ministry of Agriculture regulation on agricultural measures in sense of Water act
	• respecting the loading of agricultural soil by sludge	Act No. 188/2003 on sludge application
Voluntary management defining standard level of management outside vulnerable zones	• respecting of elements of good agricultural practice relevant to manure	Code of good agricultural practice in the Slovak Republic (2001)
Agricultural management behind standard level after acceptance compulsory and with compensation	• agro-environmental shemes – respecting the requirements of GAP and other defined requests related to nitrogen input limits, loading of agricultural soil by animals	Proposal of agro-environmental measures as part of Rural development plan (to be in force in 2004)

Table 2 Review of activities and measures in agriculture sector that are significant to water resources pollution

Types of measures/activities	Measure/activity description
fertiliser management	– accounting the nitrogen from animal/organic manures at fertiliser N application – avoiding of application of combined NPK fertilisers in autumn to the spring crops – to use of soil/crop analysis for precision of the timed N – rates according to crop demands – to respect preservation strips around water courses
manure management	– to avoid liquid manure in the autumn to the spring crops – to have sufficient and safe capacities to store the animal manures during period when application is suppressed or inappropriate – to respect preservation strips around water courses
soil and crop management	– to avoid bare soil over winter and use crop cover – ploughing-up of grass/clover leys in autumn should be followed by winter crop – to minimise the soil cultivation
other activities	– to elaborate farm plan for fertilisers and manure application – to keep evidence on realised measures within farm on field level

The code of good agricultural practice represents standard level of farming with regard to Nitrate directive implementation and in the Slovak Republic was recently published (Anonym, 2001). Implementation this directive through action programmes represents next milestone that is under preparation into legal form. At present implementation of Nitrate directive is assumed on area 58% of agricultural soil. In comparison to many EU countries share of designed vulnerable zones seems relatively great. Respecting rules of good farming by farmers in these zones will be compulsory. Measures of action programme that is subject recently accepted directive of the Ministry of agriculture embrace the period when the application of manure or fertiliser is prohibited, storage capacities for animal manures, restrictions of fertilisers or manures containing nitrogen. Within defined vulnerable zones intensity of fertiliser and manure application is splitted into three zones that respect as soil conditions (soil depth, texture, humus content) as well as groundwater level.

As follows from literary findings (Goulding, 2000; Bradley, 2002) pro-environmentally oriented production systems contribute to the reducing nitrate loses through leaching as introduce. Within organic farming higher nitrate loses can await especially after ploughing-up the grass/clover leys. Improvement of fertilisation within integrated crop management system can not substantially reduce the nitrogen leaching loses. It is possible only through converting intensive arable and horticultural cropping to extensive unfertilised grass. Above mentioned indicates some limitation of improvement of manure and fertiliser N management with regard to substantial decrease of N loses to water resources.

Good/best practice for agriculture usually embraces the environmental standards that are necessary to ensure minimum environmental protection on farmland. REDMAN (2003) introduces three zones of environmental performance: the first one represents zone within that agriculture with highest probability pollutes water resources. Second zone represents measures that respect the minimum level of environmental management that it is considered "reasonable" to expect a farmer to undertake as part of "usual" farm management and without expecting any form of compensation/financial assistance. The third zone involves a higher level of environmental management practice that delivers greater environmental benefit, but usually at greater "cost" to the farmer which may require some form of compensatory payment. A good agricultural practice embraces as soil and crop management as well as manures storage and use and thus addresses the problems related with non-point and point source. Additionally, nature of large livestock units is classified as "agro-industrial units" that should respect best available techniques (BAT).

CONCLUSIONS

In the Slovak Republic, creation and application of Best agricultural practice is connected mainly with Agro-environmental schemes that are part of program of rural development for years 2004 – 2006 (ANONYM, 2003). This program involves also the measures that are beyond of common good agricultural practice. The structure of agro--environmental measures is as follows:

- basic scheme
- preservation of arable soil, vineyards or orchards against erosion
- conversion of arable land into temporal or permanent grasslands
- preservation of biotops of natural and semi-natural grasslands
- non-forest wood vegetation
- preservation of water and wetlands biotops
- breeding and maintenance endangered animal species
- ecological agriculture.

In areas designed as Natura 2000 one the farmers must compulsory apply basic scheme for arable land and permanent grasslands in preserved birds areas (EEC Directive No. 409/1979) and/or preservation of biotops of natural and semi-natural grasslands in habitat areas (EEC Directive No. 43/1992).

The level of environmental management/performance is determined by many factors. First of all there are concrete agronomic, environmental and socio-economic conditions in which farmers are operating. Subsequently follow **the availability of appropriate policy instruments for encouraging farmers to adopt more demanding pollution control practices as well as availability of appropriate knowledge and other technical resources necessary for provision standard and over-standard practices.**

REFERENCES

Anonym, 2001: Preservation of waters against nitrate pollution by from agricultural resources. Code of good agricultural practice in Slovak Republic. MP SR, Bratislava, 56 p. (in Slovak).

Anonym, 2003: Rural development plan of the Slovak Republic. Ministry of Agriculture, Bratislava, 169 p. (in Slovak).

Bell, P., Bielek, P., 2001: Endangered water from agricultural production. Project Management Group, Dublin, 48 p. (in Slovak).

Bradley, B.D., Christodoulou, M., Caspari, C., Di Luca, P., 2002: Integrated crop management systems in the EU. Agra CEAS Consulting, London, 141 p.

Bujnovský, R., 2003: Evaluation of nitrogen inputs into agricultural soil as source of potential pollution of water resources. Ekológia (Bratislava) 22, No. 1, 51 – 56.

Burt, T.P., Heathwaite, A.L., Trudgill, S.T., (eds.), 1993: Nitrate: Processes, patterns and management. J. Willey & Sons, Chichester, 444 s.

Collective, 2003: Europe´s environment: the third assessment. Environmental assessment report No. 10. EEA, Copenhagen, 344 p.

Follet, R.F., Hatfield, J.L., 2001: Nitrogen in the environment: Sources, problems and management. In: Galloway, J., Cowling, E., Erisman, J.W., Wisniewski, J., Jordan, C. (eds.), Optimizing nitrogen management in food and energy production and environmental protection. Proc. 2nd Int. Nitrogen Conf. A.A. Balkema Publishers – TheScientificWorld, Lisse, 920 – 926.

Goulding, K., 2000: Nitrate leaching from arable and horticultural land. Soil Use Management 16, 145 – 151.

Jones, J.G. (ed.), 1993: Agriculture and the environment. Ellis Horwood Ltd., New York, 200 p.

Powlson, D.S., 1997: Integrating agricultural nutrient management with environmental objectives – current state and future prospects. Proc. of the Fert. Soc. London, No 402, 42 s.

Redman, M., 2003: Recommendations for policy reforms for the introduction of best agricultural practice in the central and lower Danube river basin countries. Project report, GFA Terra Systems, Hamburg, 39 p.

Wilson, W.S., Ball., A.S., Hinton, R.H. (eds.), 1999: Managing risks of nitrates to humans and the environment. Proc. of Conf. the Royal Society of Chemistry, Cambridge, 347 p.

SOIL WATER REGIME IN THE TERRITORY OF ČUŇOVO WATER RESERVOIR IMPACT WITH ASPECT TO GROUND WATER CAPILLARY INFLOW

VODNÝ REŽIM PÔD V OBLASTI VPLYVU ZDRŽE ČUŇOVO Z ASPEKTU KAPILÁRNEHO VZLÍNANIA PODZEMNEJ VODY

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ABSTRACT

In period 1999 – 2003 was in territory of the Žitný ostrov, in the area touched by the Hydro-work Gabčíkovo monitored agricultural soils with purpose to obtain information of Hydro-work impact, its objects and made arrangements on ecological conditions of the area. On monitoring plots (MP) there was evaluated soil water regime in various Hydro-work and its objects impact areas on the base of soil moisture, ground water level and precipitation measurements.

The focus of this work is soil water and moisture regime comparison in the area of water reservoir Čuňovo shore zone and there are compared soil with ground water level in capillary inactive gravel and sandy soil layers (MP 3) and soil with ground water level in capillary active soil layers, which allow water inflow highly up to soil profile (MP 1). It was observed during five years in period 1999 – 2003.

From the results we found that on the MP 3 is capillary inflow very low and unsaturated zone soil moisture depends on precipitation, it is very low and during year relatively stabile. There in the MP 1 capillary layer impacts root zone and it participates on direct water supplying of plants.

KEYWORDS: soil water regime, soil moisture regime, ground water level, precipitation

ABSTRAKT

V období rokov 1999 až 2003 boli na území Žitného ostrova v oblasti dotknutej výstavbou Vodného diela Gabčíkovo monitorované poľnohospodárske pôdy s cieľom získať informácie o vplyve vodného diela, jeho jednotlivých objektov a prijatých opatrení na prírodné podmienky daného územia. Na vybudovaných monitorovacích plochách bol hodnotený vodný režim pôd v jednotlivých oblastiach vplyvu vodného diela a jeho objektov na základe merania vlhkosti pôdy, hladiny podzemnej vody a atmosférických zrážok.

V tejto práci sme sa zamerali na porovnanie vodného a vlhkostného režimu pôd v zóne priľahlej k vodnej zdrži Čuňovo, a to jednak pôdy s hladinou podzemnej vody v kapilárne neaktívnych štrkových a piesočnatých pôdnych vrstvách (MP 3) a pôdy s podzemnou vodou prítomnou v kapilárne aktívnych pôdnych vrstvách, umožňujúcich jej vzlínanie vysoko do pôdneho profilu (MP 1). Sledovali sme obdobie piatich rokov 1999 – 2003.

Výsledky ukázali, že na MP 3 je výška kapilárneho výstupu podzemnej vody veľmi malá a vlhkosť nenasýtenej zóny pôdy je preto závislá od atmosférických zrážok, je spravidla nízka a počas roka pomerne stála. Na MP 1 kapilárna vrstva periodicky zasahuje koreňovú zónu pôdy a podieľa sa na priamom zásobovaní rastlín vodou.

KĽÚČOVÉ SLOVÁ: vodný režim pôd, vlhkostný režim pôd, hladina podzemnej vody, atmosférické zrážky

INTRODUCTION

Monitoring of agricultural soils in the Hydro-work Gabčíkovo construction and operation impact area is running from June 1989. Its purpose is long-term soil properties condition and development information collecting and evaluating of them in connection to initial conditions and to conditions induced by Hydro-work construction and operation. There are 3 phases from the point of time and subject of monitoring.

In the first phase, in period 1989 – 1992, were observed and characterized initial soil properties and processes conditions, i.e. the situation for last four years before activation of Hydro-work into operation.

In the second phase, in period 1992 – 1997, were observed and evaluated soil properties conditions and development for five years after activation of Hydro-work into operation.

The third phase, from the year 1999, is interlocking in vista of subject and scale to the second phase.

From present results of Hydro-work impact on soils and agriculture monitoring (FULAJTÁR 2001) there is evident that the Hydro-work impacts on soils and agriculture manly by changes of ground water levels and by them it affects soil water regime and consequently another soil properties. The main role is here ground water level, sediments character where ground water interferes and depth of gravel sediments with cover fine-grained sediments interface.

MATERIAL AND METHODS

Monitoring plots MP 1 and MP 3, which are in the topic of this work, are used for data collecting in the area of water reservoir Čuňovo (except them also MP 2). They vary mainly with interface depth of cover fine-grained and base gravel sediments. In the plot MP 1 (Calcaric Fluvisols, WRB 1994) is this interface in the depth 2 m while ground water varies in depths 2 – 3 m. On the plot MP 3 (Calcaric Fluvisols, WRB 1994) is gravel in the depth 1 m only and ground water in 3.5 – 4.5 m.

Soil moisture was measured by neutron-procedure, the tool NZK 30, in soil profile for 10 cm layers down to ground water level. Soil moisture measurement includes 21 cycles of 15-days interval frequency. In winter months November – February there is soil moisture measures only one a month. Synchronize with soil moisture measurement there is measure ground water level and precipitation, too.

Measured data of soil moisture, ground water level depth and precipitation we execute in table and graphical format.

Soil water regime displays time and space stratification of soil water content in whole non-saturated soil zone. Soil moisture and its space and time stratification is expressed with the chronoisopleths form in five-percentage soil volume moisture intervals.

Soil moisture regime displays time course of soil water content and main hydro-limits in 1 m soil profile thickness divided to upper – mould (0.0 – 0.3 m) and lower – ground (0.3 – 1.0 m) layer. Soil moisture content in evaluated layers and their main hydro-limits are expressed in mm of water. Parts of graphical presentation of soil moisture regime are precipitation and ground water level depth course, too and main hydro-limits (wilting point WP, decreased availability point DAP, field capacity FC, full saturation S).

RESULTS AND DISCUSSION

Soil moisture

Soil moisture of monitoring area is depending mainly on precipitation and ground water level depth. Measured amount of precipitation on monitored plots from April 1999 is depicted in the Table 1 and in graphs of soil moisture regime, where their course strictly correlate with course of upper (0 – 30 cm) soil layer moisture (Figures 1 and 2).

From the aspect of water supplying for plants we use to summarize of precipitation according to time periods.

These periods are:

January – March, winter and spring moisture storage important for coming vegetation

April – August, vegetation period, biggest water demand of crops

September – December autumn moisture storage important for winter crops

Table 1 Total precipitation according to periods (mm)

Year	Plot	Month			
		I. – III.	IV. – VIII.	IX. – XII.	I. – XII.
1999	MP 1	–	226*	76	302**
	MP 3	–	299*	96	394**
2000	MP 1	217	103	120	440
	MP 3	222	132	146	500
2001	MP 1	106	109	112	327
	MP 3	103	95	126	324
2002	MP 1	143	226	235	604
	MP 3	119	160	182	461
2003	MP 1	81	222	104	407
	MP 3	83	198	96	377

* V. – VIII.
** V. – XII.

Precipitation course listed above more influences soil moisture on the plot MP 3 without impact of ground water. Ground water on the plot MP 1 periodically inflows up to unsaturated zone of soil profile. While in the plot MP 1 soil moisture of upper layer (0 – 30 cm) use to decrease in dry summer months to so-called semi-arid interval (between hydro-limits decreased availability point and wilting point), on the plot MP 3 it use to decrease bellow wilting point to so-called arid interval. In ground layer (30 – 100 cm) there was soil moisture on the plot MP 1 most of time in so-called semi-uvid interval (between decreased availability point and field capacity), which is optimal moisture condition from agronomical and ecological point of view. On the plot MP 3 soil moisture of ground layer used to decrease in summer (2000, 2001, 2002) to semi-arid interval.

Soil water regime

Soil water regime of monitoring area influences, except precipitation, ground water level too, mainly if it increases to fine-grained sediments of the soil profile.

Ground water level of the plot MP 3 is situated in capillary inactive gravel and sandy soil layers in the depth of 3.5 – 4.5 m (Fig. 4). Capillary elevation is here very low, circa 0.3 m. Moisture of the whole unsaturated soil zone is therefore depended on precipitation, it is usually low and during year more-less stabile. More markedly soil moisture dynamics use to be only in surface layer of thickness 0.5 to 1.0 m in depending of precipitation amount and frequency.

On the plot MP 1 is ground water level in the depth 2.5 – 3.3 m and it is periodically present in capillary active soil layers, which enables uprising of water highly to the soil profile (Fig. 3). So that is above ground water level present marked capillary zone with high moisture (over 35% vol.), which decreases up to soil surface. When this capillary layer interferes soil root zone, it participates on direct water supplying of crops. When it is deeper in the profile, it use to decrease soil profile infiltration thickness, thereby it reduces percolation and infiltration of precipitation water down to lower layers, it increases accumulation and total efficiency of water.

Soil moisture regime

Soil moisture regime of mould layers (0.0 – 0.3 m) tightly correlates to precipitation regime. Mainly absence as well as shortage of precipitation is suddenly depicted in mould moisture changes. In climatic dry summer periods in years 2000 – 2003 soil water storage decreased on the plot MP 1 to semi-arid and on the plot MP 3 even to arid moisture intervals Fig. 1, 2).

From soil water storage course in connection to basic hydro-limits listed above, we can assume mould moisture regime of monitored soils evaluate as less favourable because of soil moisture is here for longer time (summer months) in lightly available till unavailable form.

Soil moisture regime of ground layers (0.3 – 1.0 m) is less depended to precipitation but in more scale to ground water level depth. While total soil water storage in this layer on the plot MP 3 used to decrease in summer months (2000 – 2002) to semi-arid moisture interval, on the plot MP 1 was soil water content generally in optimal moisture interval, which characterizes sufficiency of easy available water for plants and sufficient aeration.

Figure 1 Soil moisture regime on the plot MP 1

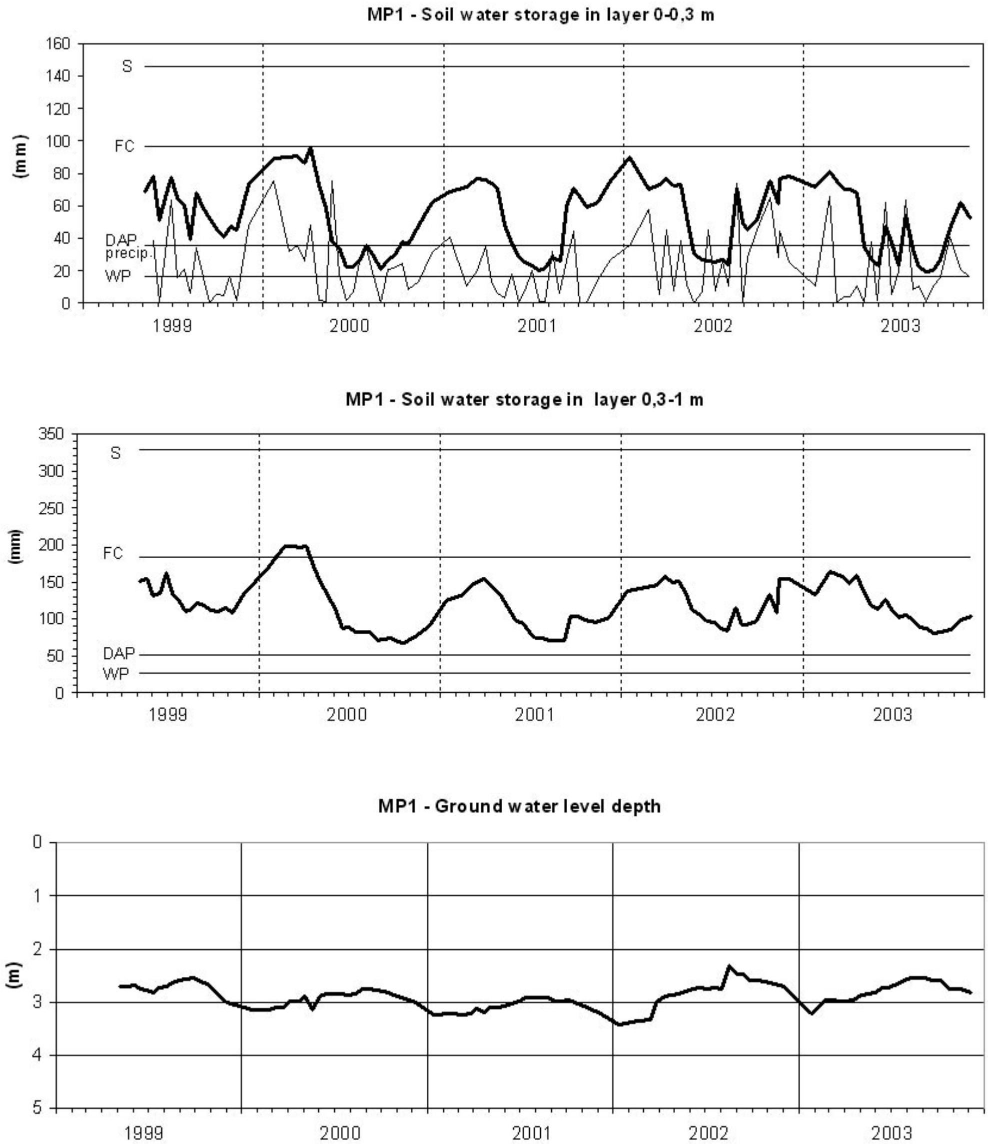


Figure 2 Soil moisture regime on the plot MP 3

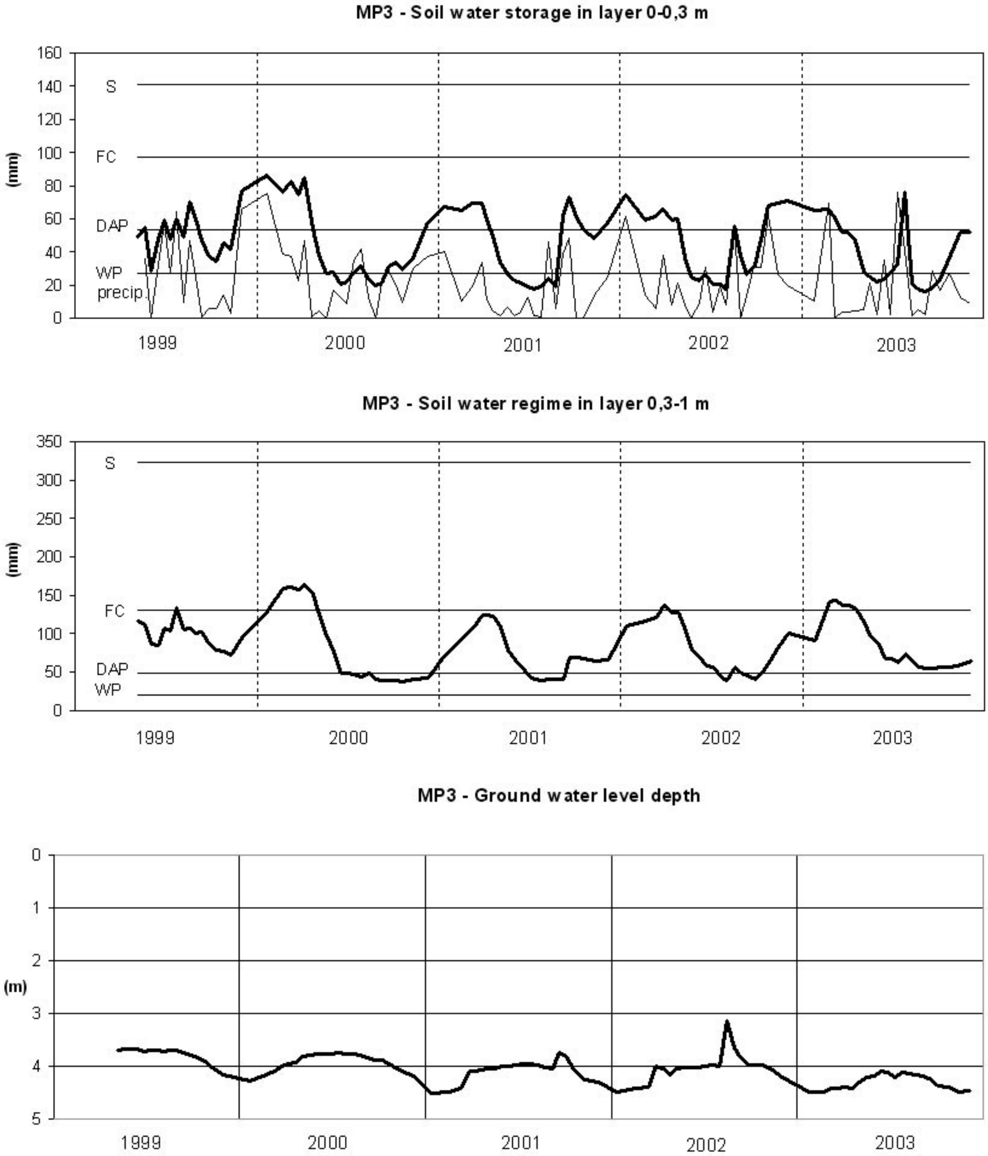


Figure 3   Soil water regime on the plot MP 1

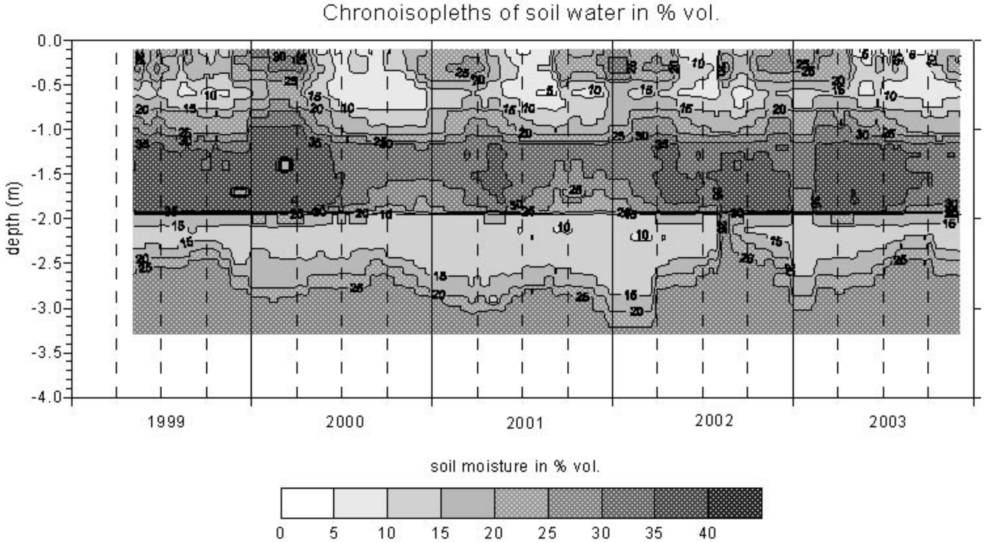
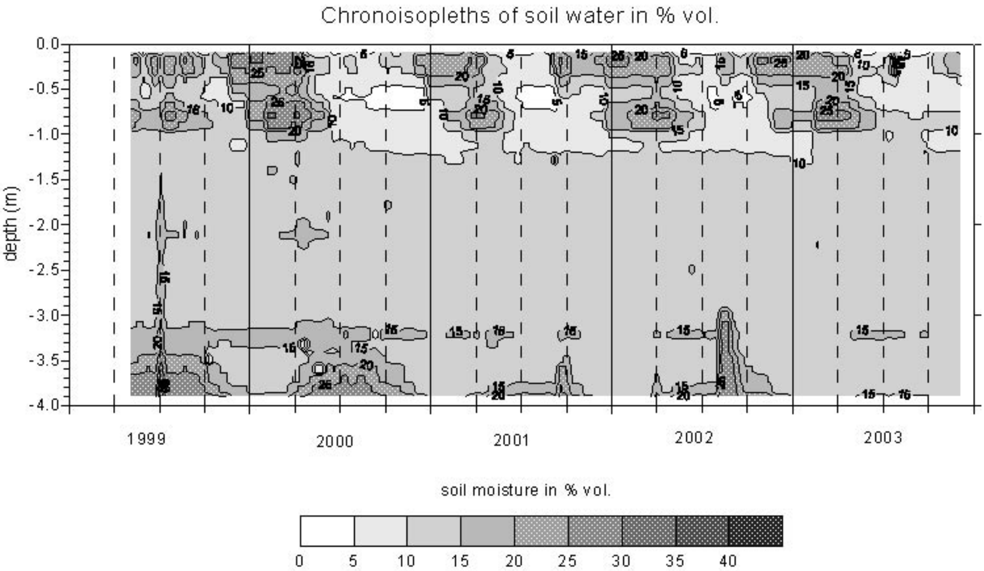


Figure 4   Soil water regime on the plot MP 3



CONCLUSIONS

After Water reservoir Čuňovo filling (October – November 1992) ground water gradually increased on the plot MP 1 about 4 m and on the plot MP 3 about 2 m. When water level in reservoir drops, ground water level drops too. With swing out more than 0,5 m, mainly when reservoir water level drops, it is this change markedly reflected in decrease of ground water level in adjacent area and therefore also in decrease of soil moisture. Increase of groundwater to 2.5 – 3 m below soil surface resulted in MP 1 soil profile in transient zone extinction. Above ground water level created circa 1 m rough capillary zone with high moisture 30 – 40% and it is followed by evaporation zone. In comparison with initial condition created capillary zone increase soil water content any 5 – 10%, which is in calculation for 1-metre layer soil water content higher about circa 50 – 100 mm. Primal automorphic conditions of soil development on the plot MP 1 changed to semi-hydromorphic. It means that soil moisture regime, which was before reservoir filling depended on precipitation regime, is now endowed by capillary elevation of ground water to root zone.

On the plot MP3, where is soil cover layer shallow (1 metre) and where ground water level remains still in gravel ground, is water regime after reservoir filling untouched and it is still depended on precipitation or irrigation.

In term of condition and development of soil properties and soil processes as well as in term of field crops demands on soil environment, is moisture of cover 1-metre rough layer determining, because there is 95 – 100% of field crops roots situated. This condition is characterized by soil moisture regime.

After well-marked increase of soil water content in ground layer (0.3 – 1.0 m) on the plot MP 1 cause by reservoir Čuňovo filling is now here soil water content in optimal semi-uvidic interval of moisture. Water supplying plants is now in comparison with initial condition in optimum.

On the plot MP 3, where is soil cover layer shallow (1 metre) is moisture regime characterized by frequent decreasing of water content in mould till under wilting point into semi-arid interval. This moisture regime retains after ground water damming, too. Increased ground water level, which remains in gravel horizons, does not influence soil moisture regime.

In term of total agricultural production conditions, changed ground water level in depth 2 – 3 m on the plot MP 1 and capillary elevation to root zone create higher soil water storage in soil profile which is already right available for wide range of field crops. This soil water regime situation creates more favourable conditions for yields stabilisation. On the plot MP 3, where ground water level is in gravel sediments, soil moisture regime remains unchanged and henceforth depending on precipitation and irrigation.

REFERENCES

FULAJTÁR, E. a kol., 2000: Monitoring poľnohospodárskych pôd v r. 1999 pre potreby plnenia medzivládnej dohody vlád Slovenskej republiky a Maďarskej republiky, podpísanej dňa 19. apríla 1995. Hodnotiaca správa za r. 1999. Bratislava. 41 s.

FULAJTÁR, E. a kol., 2001: Monitoring poľnohospodárskych pôd v r. 2000 pre potreby plnenia medzivládnej dohody vlád Slovenskej republiky a Maďarskej republiky, podpísanej dňa 19. apríla 1995. Hodnotiaca správa za r. 2000. Bratislava. 41 s.

FULAJTÁR, E. a kol., 2001: Monitoring poľnohospodárskych pôd v r. 2001 pre potreby plnenia medzivládnej dohody vlád Slovenskej republiky a Maďarskej republiky, podpísanej dňa 19. apríla 1995. Hodnotiaca správa za r. 2001. Bratislava. 41 s.

FULAJTÁR, E. a kol., 1998: vplyv vodného diela Gabčíkovo na poľnohospodárske pôdy. VÚPOP Bratislava, 199 s.

MIKLOVIČ, D., 2002: Wheat and corn maize yields development in the territory of the water-work Gabčíkovo with aspect to soil water regime. Vedecké práce č. 25. VÚPOP Bratislava, s. 105 – 113.

ŠÚTOR, J., GOMBOŠ, M., TALL, A., 2002: Chronoizoplety obsahu vody v zóne aerácie pôdy modifikované hydrolymitmi a ich využitie. Acta Hydrologica Slovaca No 2, Bratislava, s. 238 – 246.

NEW LAW OF AGRICULTURAL SOILS OF SLOVAKIA PROTECTION AND SOIL SERVICE

Nový zákon o ochrane poľnohospodárskej pôdy Slovenska a pôdna služba

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ABSTRACT

The quality of soil and land-use management is the basis for good conditions of inhabitants. For this reason this issue should be at the core of any soil policy. Soil is basic resource, which supports the development of life. Soil provides multiple functions. According to the new Act of the soil conservation and utilisation, which is active since May 1st, 2004, everybody is obliged to protect soil natural functions and prevent any action that could lead to farmland deterioration. The way of farmland use must be adequate to natural conditions in given landscape and at the practical level of farming. It must not threaten an ecological stability of the territory.

Keywords: soil, agricultural soil, soil conservation, soil service, soils functions, environmental function, degradation, water and wind erosion, compaction

ABSTRACT

Kvalita pôdy a jej využívanie je základom pre život ľudí. Pôda je multifunkčný fenomén umožňujúci produkovať potraviny a suroviny a je súčasťou prírodného prostredia, filtruje a zadržiava vodu, umožňuje využívať a zhodnocovať slnečnú energiu, zabezpečuje kolobeh a ekologicky vyváženú bilanciu látok v prírode Starosltivosť o pôdu je prejavom vyspelosti štátu a kultúrnej úrovne jeho obyvateľstva. Súčasná poznatková základňa o pôde a kvalifikovaný výkon štátnej správy pri ochrane a využívaní pôdy sú nutnou podmienkou akceptovania SR pre vstup do EÚ.

Nový zákon o ochrane a využívaní poľnohospodárskej pôdy, ktorý vstupuje do platnosti 1. mája 2004 pre tento účel stanovil vznik novej aktivity – Pôdna služba na Výskumnom ústave pôdoznalectva a ochrany pôdy.

Kľúčové slová: pôda, poľnohospodárska pôda, ochrana pôdy, pôdna služba, funkcie pôdy, environmentálne funkcie, erózia vodná a veterná, zhutnenie, degradácia pôdy

INTRODUCTION

The limitations of the availability of soil resources are a critical issue when considering global food security. High quality soils are rare and should be most protected.

Although sustaining soil quality is recognised as an important issue by all countries, the extent and trends in soil degradation processes have yet to be determined for many countries. The soil quality issue is significant to policy makers because some aspects of soil degradation are only slowly reversible (decline organic matter) or irreversible (erosion).

Given the importance of maintaining soil quality to ensure agricultural productivity, expenditure on soil conservation, both from private and government sources, is frequently a substantial share of total agri-environmental expenditure. Government policies, dealing with a soil quality improvement, commonly provide a range of approaches, including investment and loans, to promote conservation practices, and advices on soil management.

Enhancing soil quality and quality of land-use management is essential for maintaining agricultural productivity and basis for good conditions of inhabitants. It can be degraded through degradation processes:

- Physical processes – erosion, compaction and waterlogging
- Chemical processes – acidification, salinisation
- Biological processes – declines in organic matter

These degradation processes are linked to changes in farm management practices, climate and technology. There can be lags between the incidence of degradation, the initial recognition of a problem by farmers and the development of conservation strategies.

The limitations of the availability of soil resources are a critical issue when considering global food security. High quality soils are rare and at risk of degradation and loss through. Although sustaining soil quality is recognised as an important issue by all countries, the extent and trends in soil degradation processes have yet to be determined for many countries. The soil quality issue is significant to policy makers because some aspects of soil degradation are only slowly reversible (decline organic matter) or irreversible (erosion) ones.

MATERIAL AND METHODS

By the introductory provision of the new law on farmland conservation the farmland is assessed as an irretrievable natural resource and unique component of an environment. Everybody is obliged to protect soil natural functions and prevent any action that could lead to the farmland deterioration. The way of farmland use must be adequate to natural conditions in given landscape and at the practical level of farming. It must not threaten an ecological stability of the territory. Everybody who uses farmland for agricultural production is doing duty to utilise farmland in such a way, which conserve its natural fertility. The new law about agricultural soil protection has been approved by Parliament and it will be active since May 1st, 2004.

This law determinates:

a) protection properties and function of agricultural soil
b) protection environmental function of agricultural soil, which are production of biomass, filtration, neutralisation and transformation substance in nature

By the §4 has been installed a new activity Soil service, which will be created on Soil Science and Conservation and Research Institute. Soil services execute soil survey and recommend safety-measures in degradation area. Soil service proposal includes:

a) main identification data about type of agricultural land according cadastral data
b) threaten analyse of agricultural soil
c) proposal safety-measures to elimination degradation

By the new law of the agricultural soil conservation and utilisation will be protected four groups of the highest quality soils without financial payments. In the case of permanent and temporary land delimitation out of the farmland there is a duty to cut humus horizon and accomplish some measures for optimal use of the spoil material. In the case of temporal land delimitation out of the farmland cited Act orders soil return back into original status. In the case the soil may be deteriorated (degraded), the Act charges recultivation measures with return the soil into the original status regarding the soil quality.

RESULTS AND DISCUSSION

Soil quality can be degraded through three processes – physical, chemical and biological degradation.

Physical degradation, mainly covers the processes of wind and water erosion, soil compaction and water logging. The on-farm results of these processes include lower land productivity, which partly depends on soil structure, tilth and water-holding capacity. Soil compaction may be increased by use of heavier agricultural machinery. The off-farm effects of soil erosion, can impair air and water quality-causing damage to aquatic habitants and human health. Soil erosion also reduces the capacity for soil to fix carbon dioxide.

Most serious farmland problem in Slovak Republic is water erosion. Water erosion risk includes 1 360 000 ha (approximately 55%) of farmland.

Table 4 Erosion risk extent in Slovakia

Erosion risk	Farmland total		Arable land		Grassland	
	%	ha	%	ha	%	ha
medium	19.0	475 784.6	24.2	362 467.4	13.3	113 317.2
strong	17.4	435 179.6	15.1	226 638.2	24.6	208 541.4
extreme	18.0	449 844.5	4.2	62 171.8	45.6	387 672.7

Wind erosion potential is relatively low. Extreme risk is recognised only on 1.3% of the farmland, strong erosion risk is observed on 0.4%, and medium risk on 4.8% of farmland.

Relative high extent of compacted soils was registered in Slovakia, occurred in approximately 192 000 ha of farmland. Compaction processes have been potentially running in further 457 000 ha of farmland.

In the case of permanent and temporary land delimitation out of the farmland there is a duty to cut humus horizon and accomplish some measures for optimal use of the spoil material. In the case of temporal land delimitation out of the farmland cited

Act orders soil return back into original status. However it may be soil deteriorated (degraded), the Act charges recultivation measures with return the soil into the original status regarding the soil quality.

Chemical degradation consists of the loss of soil nutrients and organic matter, and accumulation of heavy metals and other toxic compounds, leading to loss of fertility, salinisation, acidification, and toxic contamination.

Biological degradation includes declines in organic matter content and the amount of carbon from biomass (C sequestration). It also includes reduced activity and diversity of soil biota. Soil biota is responsible for many of the key processes and functions of soil including the decomposition of plant and animal residues, transformation and storage of nutrients, infiltration of water and exchanges of gases, and synthesis of humic compounds.

Fundaments, principles and objectives of the soil service

Present level of knowledge in the field of soil use and soil degradation indicates gradual decrease in soil quality potentials, which should have very unfavourable consequences for future generations. In such context of knowledge and activities Council of Europe admitted in 1972 the European Soil Charter and accepted recommendations for soil conservation.

In the European Soil Charter soil is considered to be one of the most valuable treasures of the mankind, which enables plants, animals and mankind to live on the Earth. This document emphasizes that the soil is limited and easily destroyable natural resource, and shall be protected against damages from agriculture, erosion, contamination and any other degradation. Necessity of effective national soil conservation policies with permanent soil resources inventory and maintained systematic soil research including international cooperation is also assumed to be of great importance.

Soil conservation must be an interest of the state and whole society. The rules mentioned above were in may 1992 highlighted again and actualized by the Council of Europe in the „Recommendation on Soil Protection" No. R (92)8, from which an unified definition of soil for the EC countries is derived: Definition of soil: Soil *is integrated part of ecosystem of the Earth, situated between Earth surface and under-layer. Soil profile is partition to layers – horizons, with specific physical, chemical and biological properties and different function*

Recommendation of the EC "R (92) 8" on soil conservation is based on the appraisal of the main soil functions as follows:

- producing food,
- storing, filtering and transforming minerals, water, organic matter, gases, etc.,
- providing raw materials,
- being the platform for human activity.

Backordering to this document all the soil functions are of equal importance. Permanent conditions must be maintained for harmonized supplementation and protection of all soil functions. Harmonisation of the Soil charter with Agenda 21 must respect principle, by which in case of conflict between economical and ecological interests the ecological ones has to be preferred.

Soil conservation represents a basic part of individual and social awareness of developed countries with accepting an axiom that "any soil degradation leads to degradation of welfare and perspectives for life".

Initial basis for back up the importance of Soil Service represents also very rich base of data and knowledge about gradual degradation of agricultural soils in the area of our country. In such context of activities in soil degradation not just in our country, but in each developed country worldwide the creation of Soil Service appears to be highly actual and commonly desirable also in Slovakia.

The main objective of the Soil Service is to be a professional supervisor for any activities in the field of soil conservation, a preferred provider of information related to soil and soil quality and to formulate professionally justified measures for soil protection against degradation processes and damages.

Activities of the soil service

The Soil Service is established within the frame of practical implementation of new law about soil conservation and use of agricultural soil (Act No. 220/2004), but mainly as an apparatus helping to make information about the state of agricultural soils, their properties, need of reclamation, and possibilities of their use and conservation more transparent. Its function is not only restrictive, but helps to the land owners, land users and managers in rational way of soil use, soil protection from degradation with respect to the principles of sustainable resource management. In the portfolio of Soil Service following main activities are included:

- analyse, evaluation and quantification of the state and trends in soil degradation
- proposals and justification of solutions and projects development for the soil conservation and management at specific locations
- creation and maintenance of the Information system of agricultural soils endangered by degradation, providing soil related information

These activities are carried by the Soil Service on its own initiative (as a result of own research), but also on request from the state soil conservation authorities, other state authorities, local authorities, other scientific and research bodies, foundations, enterprises or any legal or physical persons having information about soil degradation or any risk of such degradation.

To fulfil these generally formulated objectives following specific activities will take place:

Activities mandated by the law – Act No. 220/2004.

According to the § 4 of above mentioned law the Soil Service is mandated to carry a survey of the agricultural soils, to keep register of the areas potentially endangered by soil degradation, and to propose protection measures to prevent or eliminate any soil damage, especially:

- according to the § 5 identification of soil erosion and proposals for erosion control and reclamation of eroded soils
- according to the § 6 identification of compacted soils and proposals for reduction of soil compaction and reclamation of compacted soils

- according to the § 7 identification of areas where limit for deficit in soil organic matter was exceeded and proposals for organic fertilization
- according to the § 8 identification of areas where any limit for risk substances content in soil was exceeded and proposals to exclude contaminated land from the food production

Soil Service issues obligatory professional recommendations for decisions of the state soil conservation authorities in following cases:

- when a kind (cadastral) of land category is changed, when non-agricultural soil is changed into agricultural, in cases of agricultural land forestation (according to the § 9)
- in the decision in doubts, if the land belongs to the category of agricultural land (according to the § 10)
- when agricultural land is used for non-agricultural purposes (according to the § 19)

Professional services and consultancy

Soil service maintains processing of the reclamation projects for degraded soils, projects of soil protection against degradation processes and expert opinions for such projects elaborated by other subjects. Soil service deals with projects focused on these topics:

- soil pH adjustment through limestone application
- organic matter content increase in sandy or other poor soils with help of selected substances and technologies
- other measures for maintaining or/and improving soil quality
- ecological consolidation of agricultural soils damaged or endangered by water erosion, permanent water logging, natural disasters, or soil excluded from agricultural use
- sludge (municipal, industrial) analysis before application on agricultural soil
- analysis and assessment of soil composition and quality
- technological evaluation and quality control of realised soil reclamation and soil conservation works
- outputs from the Soil information system

Activities for land consolidation projects: field soil survey, soil quality assessment, proposals for ecological stabilization measures.

Other products:

- Auditing of sustainable soil use and soil management systems for agricultural subjects
- Auditing upon requests of the state and public authorities
- Auditing upon requests of national and international institutions, agencies and supporting foundations
- Auditing for the purposes of potential investors (selection of suitable locality with respect of land related and other specified criteria)

– Information for taxation, subsidies, price and other economically based tools implemented in management of agricultural sector
– Consultancy, public relation, information activities
– Education and training

Geographical information system of the Soil service.

Fundaments of the Soil service GIS creation are represented by the data sources from the Soil Information System of the Soil Science and Conservation Research Institute (VÚPOP), which are permanently updated and shall be replenished by the information obtained from the surveys and investigations carried out within the frame of the Soil service activities, other activities of the VÚPOP (Soil Monitoring System – ČMS-P, regional mapping of environmental geofactors, waterworks system Gabčíkovo monitoring, remote sensing data sources interpretation, other research activities and projects), and also available information from other subjects (Central Checking and Testing Agricultural Institute – ÚKSÚP, Forest Research Institute – LVÚ, Daphne, etc.).

Information system of the Soil service will consist of:

a) register of degraded soils and soils endangered by degradation
b) register of recultivated areas
c) register of sludge applications on soil

Soil Service shall issue on yearly basis an information reports on the state and trends in soil degradation in Slovakia and about priorities in conservation of agricultural soils.

Proposal of the Soil service structure

Soil service as a particular and specialized unit represents an integral part of the Soil Science and Conservation Institute (VÚPOP) in Bratislava. Person responsible for the activities of Soil service is the director of the VÚPOP. Mandated by performance of the Soil service activities are the workers under professional management of the person nominated by the director (Soil service manager). Places of residence are the VÚPOP workplaces with following territorial competence:

VÚPOP Bratislava, Gagarinova 10 – Bratislava, Trnava, Nitra and Trenčín region

VÚPOP Bratislava, regional branch Banská Bystrica – Banská Bystrica and Žilina region

VÚPOP Bratislava, regional branch Prešov – Prešov and Košice region

Responsible for the performance of the Soil service activities on regional workplaces are their respective managers.

CONCLUSIONS

Soil service as an independent department will be created in SSCRI Bratislava with regional department in Banská Bystrica and Prešov. It will be new activity, which included monitoring and survey of degradation farmland by new scientific and research methods.

Thus Soil Service within in framework special control will be practice research and monitoring agricultural land, keep a database of information about agricultural land and prepare proposal to elimination degradation according §3 to §8 and expert view-point according §9, 10 and 19.

REFERENCES

Kol. autorov, 2000: Koncepcia ochrany a využívania poľnohospodárskej pôdy (Conception of conservation and use of farmland). MP SR, VÚPOP, Bratislava.

Ilavská, B., 2001: Bonitačný informačný systém a jeho vývoj do budúcnosti (Bonitation system and its future development). Pedologické dny, Zbornik z konferencie: Puda jeji funkce, vlastnosti a taxonomie v zemědělské a lesní krajině, Brno.

Linkeš, V. a kol, 1996: Príručka pre používanie máp bonitovaných pôdno-ekologických jednotiek (Guidelines of BPEU map using). VÚPÚ, Bratislava.

Nariadenie vlády SR č. 152/1996 z.z. o základných sadzbách odvodov za odňatie poľnohospodárskej pôdy z PPF.

Zákon SNR č. 307/1992 o ochrane poľnohospodárskeho pôdneho fondu.

Zákon NR SR č....../2004 o ochrane a využívaní poľhospodárskej pôdy a o zmene zákona č.245/2003 Z.z. o intergovanej prevencii a kontrole znečisťovania životného prostredia a o zmene a doplnení niektorých zákonov.

ECOLOGICAL SOIL FUNCTIONS IN REGARD OF THEIR VULNERABILITY

INDIKÁTORY EKOLOGICKÝCH FUNKCIÍ PÔD Z POHĽADU ICH ZRANITEĽNOSTI

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ABSTRACT

In this paper evaluation and development of the main indicators of selected soil functions (filtration, accumulation, buffering) regarding anorganic contaminants (heavy metals) is presented. The filtration fuction determine with mobile Cd, Pb, Cu and Zn is characterized by the first factor, which can be interpreted as the factor of negatively pH dependent effective mobility of heavy metals and the second and third factors which reflect the influence of organic matter. These three factors explain 88.4 to 93% of the total variation. The accumulation function depends directly on total content of heavy metals in soil and indirectly on content and quality of organic matter, pH value and on depth of humic horizon. The two main factors explain 77.8 to 87.9% of total variation. On the basis of factor analysis we determined the direct indicator of buffering function which is pH value and the main indirect indicators like soil texture, quality and content of organic matter which explain 70.6% of the total variability. The factor analysis showed the main indicators that potencially influence selected ecological functions of soil regarding heavy metals. There are direct indicators like mobile content and total content of heavy metals, soil pH value and indirect indicators like content and quality of organic matter, soil texture, depth of humic horizon and soil texture. The development of some indicators which are the part of database of Partial monitoring system – Soil shows the negative trends in the case of pH value (Cambisosl and Fluvisols) and organic carbon content (all soil types). These trends increase the vulnerability of selected soil types according to protection of their ecological functions.

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

ABSTRAKT

Pri stanovení minimálneho súboru indikátorov vzhľadom na ekologické funkcie pôd sme vychádzali z nasledujúcich podmienok: indikátory musia byť súčasťou existujúcej databázy ČMS – pôda a na základe výsledkov faktorovej analýzy majú priamy alebo nepriamy vplyv na sledované ekologické funkcie pôd. Faktorovú analýzu sme aplikovali na súbor vytvorený z kľúčových lokalít ČMS – pôda. Na základe faktorovej analýzy môžeme stanoviť minimálny súbor indikátorov filtračnej funkcie pôd, priamy indikátor mobilný obsah anorganických kontaminantov a nepriame indikátory hodnota pôdnej reakcie, obsah a kvalita organickej hmoty. Stanovené tri faktory vysvetľujú 88,4 až 93% celkovej variability. Minimálny súbor indikátorov, ktoré majú vplyv na akumulačná funkciu pôd zahrňuje: priamy indikátor, celkový obsah ťažkých kovov a nepriame indikátory, a to obsah a kvalitu organickej hmoty a hodnotu pôdnej reakcie, ktoré vysvetľujú 77,8 až 87,9% celkovej variability priamych faktorov. Minimálny súbor indikátorov, ktoré majú vplyv na pufračnú funkciu pôd zahrňuje: priamy indikátor, ktorým je pôdna reakcia a nepriame indikátory, a to obsah ílových častíc menších ako 0,01 mm, obsah organickej hmoty, kvalitu organickej hmoty, a to s väčším dôrazom na kvalitu organickej hmoty a hrúbku humusového horizontu. Jednotlivé indikátory ovplyvňujú ekologické funkcie rôznou mierou. Akceptovateľný rozsah indikátora predstavuje určitý interval, v ktorom sa hodnota daného indikátora môže pohybovať, aby si pôda plne zabezpečovala svoje ekologické funkcie. Sledovanie zmien indikátorov v 1. a 2. odberovom cykle ČMS-pôda ukazuje negatívne trendy vývoja hodnôt pôdnej reakcie ako aj vývoja hodnôt obsahu a kvality pôdnej organickej hmoty v skupine pôd kambizemí (využívaných ako orné pôdy) a fluvizemí (využívaných ako orné pôdy), v ktorých sa pokles hodnoty pH kumuluje znížením obsahu organickej hmoty v pôde, čím dochádza k zvýšeniu zraniteľnosti ekologických funkcií v týchto pôdnych typoch.

KĽÚČOVÉ SLOVÁ: ekologické funkcie pôdy, indikátory, zraniteľnosť ekologických funkcií pôd

INTRODUCTION

The soil is an open system, which exchanges matter and energy with an aqueous and atmospheric environment (HANSEN et al., 2001). "Soil health" is determined by its biological, chemical and physical properties, processes and reciprocal interaction as well as by interactions with other parts of the environment. "Healthy soil" is able to secure all its functions in terrestrial environment in optimal level. From the anthropic point of view, the soil functions can be divided into production and non-production ones. The non-production soil functions can be divided into ecological and socio-economic (BARANČÍKOVÁ, MADARAS, 2002). The filtration, accumulation, transforming and transporting, buffering function, biological habitat and gene reserve are the main ecological functions of soil.

In this paper the evaluation and development of the main indicators of selected soil functions (filtration, accumulation, buffering) regarding inorganic contaminants (heavy metals) is presented. The filtration function influences heavy metals movement in the soil during the interaction with soil components. The accumulation function influences the heavy metals accumulation, indicates the ability of soil to keep and accumulate the heavy metals in various forms. The accumulation function is very important in respect of heavy metals, because heavy metals can not be destroyed or degraded. The buffering function regarding acidification determines the soil ability to counteract the effect of protons. The resistance of the soil against acidification represents the ability of the soil to resist decreasing pH value with buffer mechanisms.

MATERIAL AND METHODS

Status and development of indicators of the main ecological soil functions have been observed in the frame of Partial monitoring system – Soil including 292 soil samples in basic network and in key network (21 soil samples) that represents all of the most frequent soil types and subtypes of main regions of Slovakia (Kobza, 1999).

In the soil samples were analysed exchangeable pH value pH/$CaCl_2$, cation exchange capacity (Fiala, 1999). Organic carbon content (C_{org}) was determined by wet combustion (Nikitin, 1972). Humus fractionation was determined by Kononovova and Belčikova method (1961) in which the amount of humic acid carbon – C_{HA} and fulvic acid carbon – C_{FA} and the ratio of optical densities measured in humic acid solution at 465 nm and 665 nm (Q_4^6) were determined (Fiala, 1999). By selective sequential extraction procedure (Zeien & Brümmer, 1989) mobile fraction of heavy metals were determined. For determination of total content was used mixture of acids (HF, HNO_3, HCl) (Fiala, 1999). The statistical program STATGRAPHICS 5.0 was used.

RESULTS AND DISCUSSION

Two requirements were used for minimal collection of indicators of soil ecological functions. First requirement on indicators represents their relationships to soil ecological functions according to results of factor analysis. Factor analysis was used for key network of Partial monitoring system – Soil. Second requirement on indicators is that, they must be multidimensional, development, numeric or point evaluating values and belong to existing basic database of Partial monitoring system – Soil.

The factor analysis selects the main factors which determine the total variation of processes as well as show the interactions between measured properties. The varimax rotation was used in order to increase the share of second or third factors in the explanation of the total variation (Militký, 1994).

The filtration function concerning the sorptive ability of soil towards mobile or easily mobile content of contaminants and to prevent its transport to plants or groundwater. The direct indicators for filtration function are mobile content of heavy metals regarding to heavy metal contamination. The mobile heavy metal content depends on soil pH value, content and quality of organic matter, cation exchange capacity, depth of humic horizon, soil particle < 0.01 mm as well as porosity (Alloway, 1990; Gupta, 1993; Wilcke, 1996; Tessier, 1979; Ziehen, Brümmer, 1989; Makovníková, 2000). The results of factor analysis of dates are shown in Table 1 and 2. Each table of factor analyssis belongs to a table of communalities which gives information about the participation of common factors on the variability of some variable.

The most general feature of relations, which was derived from the factor analysis is the fact, that mobile Cd, Pb, Cu and Zn are characterised by the first factor, which can be interpreted as the factor of negatively pH dependent effective mobility of heavy metals and the second and third factors reflect the influence of organic matter. These three factors explain in this set of variables 88,4 to 93% of the total variation. Communalities to factor analysis of the set are potential high for all parameters, that means, that their variance is explained with three factors in a significant degree. Potential high relationship was determined between mobile content of heavy metals and depth of humic horizon, too.

The accumulation function is connected with filtration and transporting functions. The direct indicators for accumulation function are total content of heavy metal in soil. Total heavy metal content is in uenced by anthropogenic and natural sources, depth of humic horizon, soil pH value, content and quality of organic matter, cation exchange capacity and soil particle < 0.01 mm (Alloway, 1990; Gupta, 1993; Wilcke,

1996; TESSIER, 1979; ZIEHEN, BRÜMMER, 1989; MAKOVNÍKOVÁ, 2000). The results of factor analysis of date are in Table 3 and 4.

Table 1 Factor analysis for filtration function (Varimax rotated factor matrix)

Parameter	Factor loads			
	Cd mobile fraction	**Pb mobile fraction**	**Cu mobile fraction**	**Zn mobile fraction**
pH in $CaCl_2$	-0.878	-0.792	0.854	-0.806
C_{ox} in %	0.769	0.802	-0.686	0.733
Q_4^6	0.884	0.894	-0.909	0.902
soil particle < 0.01 mm in %	-0.480	-0.540	-0.561	-0.276
depth of humic horizon	-0.648	-0.649	0.675	-0.662
porosity	-0.578	-0.531	0.578	-0.586
CEC	0.063	0.071	0.005	0.078
Factor 1 cum. %	74	68.2	65.2	68.6
Factor 2 cum. %	86	81.5	78.6	81.7
Factor 3 cum. %	93	90.7	89.1	88.4

Table 2 Communalities to the factor analysis given in Table 1

Parameter	Communalities of factors for filtration function			
	Cd mobile fraction	**Pb mobile fraction**	**Cu mobile fraction**	**Zn mobile fraction**
pH in $CaCl_2$	0.786	0.601	0.995	0.648
C_{ox} in %	0.866	0.968	0.978	0.486
Q_4^6	0.789	0.823	0.982	0.785
soil particle < 0.01 mm in %	0.724	0.849	0.995	0.759
depth of humic horizon	0.707	0.640	0.993	0.675
porosity	0.691	0.454	0.911	0.546
CEC	0.782	0.899	0.842	0.776

Table 3 Factor analysis for accumulation function (Varimax rotated factor matrix)

Parameter	Factor loads			
	Cd total content	**Pb total content**	**Cu total content**	**Zn total content**
depth of humic horizon	-0.758	-0.706	0.769	-0.762
C_{ox} v %	0.699	0.756	-0.695	0.698
Q_4^6	0.910	0.910	-0.914	0.912
soil particle < 0.01 mm in %	-0.005	0.029	-0.048	0.006
pH in $CaCl_2$	-0.837	-0.797	0.824	-0.834
Factor 1 cum. %	62.7	73.5	75.1	75.0
Factor 2 cum. %	77.8	86.7	87.0	87.9

These two factors explain in this set of variables 77.8 to 87.9% of total variation.The accumulation function depends directly on total content of heavy metals in soil and indirectly on content and quality of organic matter, pH value and on depth of humic horizon.

Table 4 Communalities to the factor analysis given in Table 3

Parameter	Communalities of factors for accumulation function			
	Cd total content	Pb total content	Cu total content	Zn total content
depth of humic horizon	0.465	0.457	0.570	0.469
C_{ox} in %	0.365	0.622	0.350	0.351
Q_4^6	0.686	0.743	0.757	0.659
soil particle < 0.01 mm in %	0.063	0.106	0.796	0.754
pH in $CaCl_2$	0.514	0.506	0.503	0.502

The buffer function determined by changes of soil pH value is fixed with filtration, transporting and accumulation functions. Direct indicator for buffer function is soil pH according to accidification, which is influenced with soil buffer mechanismus (Kanianska, 2000) and further depends on soil texture, CEC, content and quality of soil organic matter, porosity. The results of factor analysis of dates are in Table 5 and 6.

Table 5 Factor analysis for buffer function (Varimax rotated factor matrix)

Factor load	Parameter					
	depth of humic horizon	CEC	soil particle < 0.01 mm in %	C_{ox} in %	Q_4^6	porosity
pH in $CaCl_2$	0.681	-0.348	0.963	-0.771	-0.890	0.580
Factor 1 cum. %	53.3					
Factor 2 cum. %	70.6					

Factor 1 is associated with soil texture and depth of humic horizon, factor 2 is associated with content and quality of organic matter.

Table 6 Communalities to the factor analysis given in Table 5

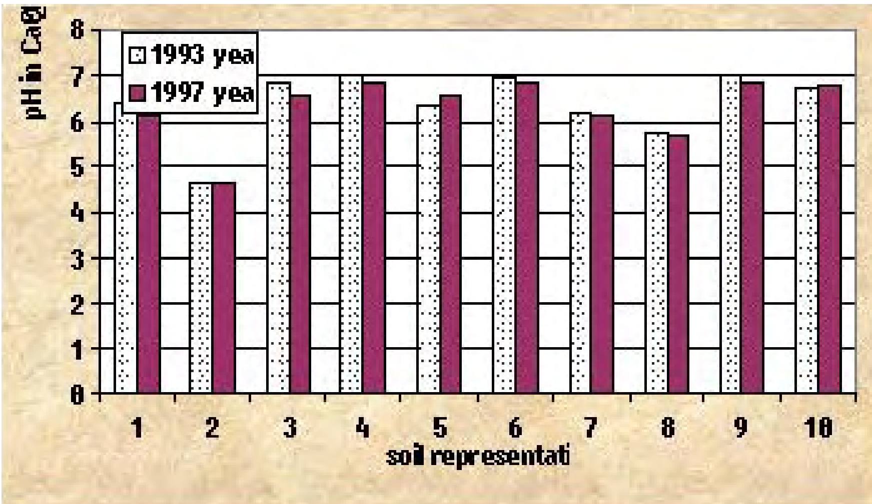
Communalities of factors for buffer function	Parameter					
	depth of humic horizon	CEC	soil particle < 0.01 mm in %	C_{ox} in %	Q_4^6	porosity
pH in $CaCl_2$	0.639	0.370	0.860	0.543	0.860	0.403

On the basis of factor analysis we were determined the direct indicator which is pH value and the main indirect indicators like soil texture, quality and content of organic matter which explain 70.6% of the total variability.

The factor analysis showed the main indicators, which potentially in uence selected ecological functions of soil regarding to heavy metals. There are direct indicators like mobile content and total content of heavy metals, soil pH value and indirect indicators like content and quality of organic matter, soil texture, depth of humic horizon and soil texture. These indicators in uence filtration, accumulation and buffering functions with various intensity.

In the Partial monitoring system – Soil were determined the development of pH value and content and quality of organic matter. The changes of total content and mobile content of heavy metals, soil texture and porosity were not determined in the second cycle. The development of pH value and content and quality of organic matter which are the part database of Soil Monitoring System – Slovakia show the figure 1 and 2.

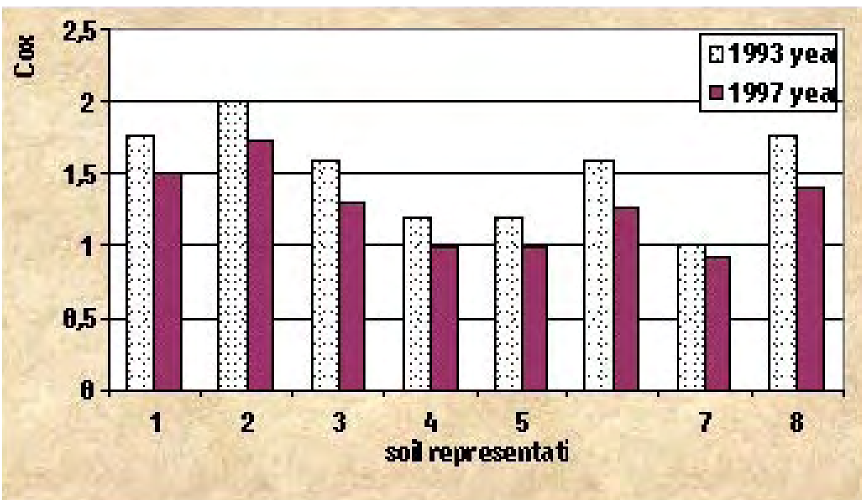
Figure 1 Development of pH value in $CaCl_2$ in the main Slovakian soil representatives



1 – Cambisols – AL, 2 – Cambisols – GL, 3 – Fluvisols – AL, 4 – Haplic Chernozems, 5 – Haplic Luvisols – AL, 6 – Mollic Fluvisols – AL, 7 – Planosols – AL, 8 – Planosols – GL, 9 – Rendzic Leptosols – AL, 10 – Rendzic Leptosols – GL, AL – arable land, GL – grassland

The changes in pH value between year 1993 and 1997 were statistically significant in the case of Cambisols (MAKOVNÍKOVÁ, 2002). Deviations to acidification was recorded in the case of Fluvisols.

Figure 2 Development of C_{ox} in the main Slovakian soil representatives (BARANČÍKOVÁ, 2002)



1 – Rendzic Leptosols – AL, 2 – Mollic Fluvisols – AL Cambisols – GL, 3 – Fluvisols – AL, 4 – Planosols – AL, 5 – Haplic Luvisols – AL, 6 – Haplic Chernozems, 7 – Eutric Regosols, 8 – Cambisols – AL, AL – arable land, GL – grassland

From obtained dates can be concluded decreasing organic carbon content on topsoil of arable lands between year 1993 and 1997. No crucial changes in qualitative humus parameters between first and second sampling on localities of basic monitoring network were found (Barančíková, 2002).

The development of the main indirect indicators of selected soil ecological functions shows the negative trends in the case of pH value (Cambisols and Fluvisols) and organic carbon content (all soil types). Synergy effect of two negative changes increase the vulnerability of selected soil types according to protection of their ecological function.

CONCLUSIONS

The way how to prevent entering of heavy metals to get into food chain and into underground waters is the optimalization of the main indicators, which regulate soil ecological functions regarding heavy metals. The factor analysis showed the main indicators that potentially influence selected ecological functions of soil. There are direct indicators like mobile content and total content of heavy metals, soil pH value and indirect indicators like content and quality of organic matter, soil texture, depth of humic horizon and soil texture. The indicators influence with various intensity filtration, accumulation and buffering functions of soil.

The development of the main indirect indicators of selected soil ecological functions shows the negative trends in the case of pH value (Cambisols and Fluvisols) and organic carbon content (all soil types). These trends increase the vulnerability of selected soil types in the view of protection their ecological functions.

REFERENCES

Alloway B. J., 1990: Heavy metal in soils. Halsted press, Wiley, London.

Fiala, K. a kol., 1999: Záväzné metódy rozborov pôd. VÚPOP, Bratislava, s. 135

Barančíková, G., 2002: Monitoring obsahu a kvality pôdnej organickej hmoty. In: Kobza, J. a kol.: Monitoring pôd Slovenska. Aktuálny stav a vývoj monitorovaných pôd. VÚPOP Bratislava, s. 54 – 73.

Barančíková, G., Madaras, M., 2002: Kvalita pôdy a prístup k hodnoteniu mimoprodukčných funkcií pôdy. In: Pôda-jedna zo základných zložiek životného prostredia. Zborník referátov, s. 109 – 115.

Gupta, S.K., Vollmer, M.K, Krebs, R., 1996: The importance of mobilisable and pseudo totalheavy metal fractions in soils for three level risk assessment. The Science of the Total Environment 178.

Hansen, H.Chr.B., Kobza, J., Schmidt, R., Szakál, P., Borgaard, O.K., Holm, P.E., Kanianska, R., Bognarova, S., Makovníková, J., Matúšková, L., Mičuda, R., Styk, J., 2001: Environmental Soil Chemistry. Scriptum, 191 pp.

Kanianska, R., 2000: Acidifikácia vplyvom kyslých atmosférických polutantov. Pedo-disertationes. Bratislava, 96 s.

Kobza, J. a kol., 2002: Monitoring pôd Slovenska. Aktuálny stav a vývoj monitorovaných pôd. VÚPOP Bratislava, s. 180.

Makovníková, J., Kanianska, R., 2001: Evaluation of differences between active and exchangeable soil reaction. Vedecké práce 24, Bratislava, s. 39 – 44.

Makovníková, J., 2000: Závislosti medzi vybranými pôdnymi parametrami a prístupným obsahom kadmia, olova, medi a zinku. Rostl. výroba, 46, s. 289 – 296.

NIKITIN, B.A., 1972: Metody opredelenija soderžanija gumusa v počve. Agrochimija, 3: 123 – 125.

MAKOVNÍKOVÁ, J., 2002: Acidifikácia pôd. In: KOBZA, J. a kol.: Monitoring pôd Slovenska. Aktuálny stav a vývoj monitorovaných pôd. VÚPOP Bratislava, s. 21 – 32.

MELOUN, M., MILITKÝ, J., 1994: Štatistické spracovanie experimentálnych dát. Praha, s. 837.

WILCKE, W., 1996: Kleinraumige Heterogenitat in Boden (Dissertation), Universität Bayreuth, 137 s.

TESSIER, et al., 1979: Sequential extraction Procedure for the speciation of Particulate Trace Metals. Analyt. Chem., 51.

ZEIEN, H., BRŰMMER, G. W., 1989: Chemische extractionen zur Bestimmung von Schwermetallbindungsformen in Bőden; Mitteilgn. Dtsch. Bodenkundl. Gesellsch., 59/I., s. 505 – 510.

RISKS FROM SOIL CONTAMINATION IN CENTRAL SPIŠ TERRITORY

RIZIKÁ ZO ZNEČISTENIA PÔD REGIÓNU STREDNÝ SPIŠ

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ABSTRACT

Central Spiš territory includes more than 17 000 ha, of it farmland acreage is 30.2%. In statistical expression heavy metal load are presenting elements Hg, Cu, Pb, Zn and As. Central Spiš region has been long-term loaded by adjustment industry processing mined and imported colour metal ores. In given territory two marked emission centres have been located-Krompachy producing, particularly Cu, Pb and Zn pollutants, and mine Rudňany producing particularly Hg pollution (until 1993). Farmland in neighbourhood of mentioned pollution centre has been contaminated by Hg, Cu, Pb, Zn a As. With ecotoxicological aspect, mercury contamination is most risky.

KEYWORDS: Contamination, soil, risk, arsenic, copper, lead, mercury, zinc

ABSTRAKT

Stredný Spiš je územie o výmere viac ako 17 000 ha, z čoho asi 30,2% predstavuje poľnohospodársku pôdu. Zo štatistického vyhodnotenia ťažkých kovov vyplýva, že zaťaženie je spôsobené hlavne Hg, Cu, Pb, Zn a As. Zaťaženie životného prostredia v skúmanej oblasti je výsledkom dlhodobého pôsobenia exhalátov z ťažby a spracovania vyťaženej rudy na polymetalickom ložisku. V danej oblasti sú dve významné emisné centrá Krompachy produkujúce emisie obsahujúce Cu, Pb a Zn, a Rudňany hlavne s emisiou Hg. Poľnohospodárske pôdy v blízkosti týchto centier sú kontaminované hlavne Hg, Cu, Pb, Zn a As. Z ekotoxikologického hľadiska hlavne kontaminácia s Hg je veľmi riziková.

KĽÚČOVÉ SLOVÁ: Kontaminácia, pôda, riziká, arzén, meď, olovo, zinok, ortuť

INTRODUCTION

The concentration of pollutants in moving air or rivers tends to be diluted fairly rapidly due to mixing and dilution but in the case of soil many pollutants tend to accumulate. Soil acts as a sink for pollutants due to absorption process which bound inorganic and organic pollutants with varying strength to the surface of soil colloids.

Heavy metal pollution can affect all environment but its effects are most long lasting in soils due to relatively strong adsorption of many metals onto the humus and clay colloids in soil. The duration of contamination may be for hundreds and thousands years in many cases (e.g. first half lives: Cd 15 – 1100 years, Cu 310 – 1500 years and Pb 740-5900 years depending on the soil type and physico-chemical parameters (ALLOWAY, 1994).

Human and any animals are exposed to chemicals via water, air, soils, dust and their diet. The chemical enters to body by ingestion, inhalation and dermal contact. In the most cases, the toxic effects only occur after the pollutant has entered the bloodstream following adsorption through the gut, the lungs or the skin (RODRICKS, 1992).

The most toxic metals for both higher plants and several microorganisms are Hg, Cu, Ni, Pb, Co, Cd (KABATA-PENDIAS and KABATA, 1984).

MATERIAL AND METHODS

For means of data processing of risk from central Spiš soils we were concentrated on metals As, Cu, Pb, Zn and Hg, where has been found anomalous contents. These elements were evaluated on basis of data Soil Geochemicals Atlas, part V (1999) as well as data of Disertation Work (VOJTÁŠ, 1999) according to valid legislative.

RESULTS AND DISCUSSION

Soils of central Spiš have been originated on rocks Slovenské Rudohorie, where in his northern part predominate agricultural soils and pastures. These soils were most under influence of exhalation from Krompachy and Rudňany (main components of emission were Cu, Pb, Zn, As, Hg and SO_2 and NO_x).

Table 1 Statistical interpretation the main pollutants in A-horizon of soils (mg.kg^{-1})

	As	Cu	Hg	Pb	Zn
Average	36.6	263.1	3.015	54.8	102
Modus	9	22	0.18	18	78
Minimum	3.4	10	0.07	10	12
Maximum	531	22 360	50.33	810	1 865
Count	110	110	110	110	110

Comparison the most probable value of background of territory Spiš and Slovakia (table 2). We can see expressively and in case of mercury several times increment this value.

Table 2 Comparison of value "modus" for territory Slovakia and Spiš in A-horizon of soils (mg.kg^{-1})

Slovakia	**As**	**Cu**	**Hg**	**Pb**	**Zn**
Modus	5.7	18	0.05	16	56
Region Spiš	**As**	**Cu**	**Hg**	**Pb**	**Zn**
Modus	9	22	0.18	18	78

Risk from elements in contaminated land

- Direct ingestion of contaminated soil (grazing livestock)
- Inhalation of dust, toxic gases and vapour from contaminated soil
- Uptake by plants of contaminants hazardous to animals and people through food – chain.

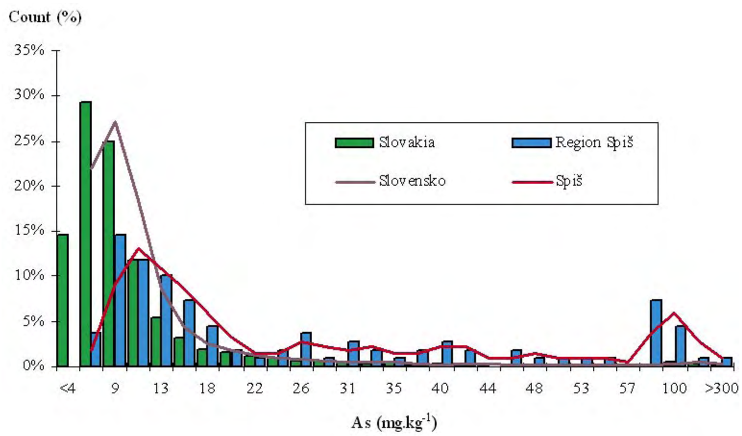
Risk assessment of environmental pollutant is concerned firstly with identifying the hazards, which metals or substances pose to the health of people, animals and plants and any damage which they may cause to structures and commodities and secondly with estimating the probability of these types of harm occurring (ALLOWAY, 1994).

Arsenic

A toxic non essential element that has been used as a pesticide or wood preservative. It is also present in many of sulphide metals ores and is therefore emitted from metals smelter as an atmospheric pollutant. Coal ashes are a significant source of arsenic, which can be leached out into waters or the soil. The toxicological importance of arsenic is a partly due to its chemical similarly with phosphorus which means that arsenic can disrupt metabolic pathway involving phosphorus. Both acute and chronic toxicity are recognized and the continual inhalation of airborne forms of As can disrupt metabolic pathways involving P. Arsenic can by methylated in environment through the action of enzymes secreted by microorganisms.

More likely value of background "mode", for this area is 9 mg.kg^{-1}. Distribution is expressive anomaly in interval 100 mg.kg^{-1}.

Figure 1 Distribution of arzenic in A-horison (arable soils)

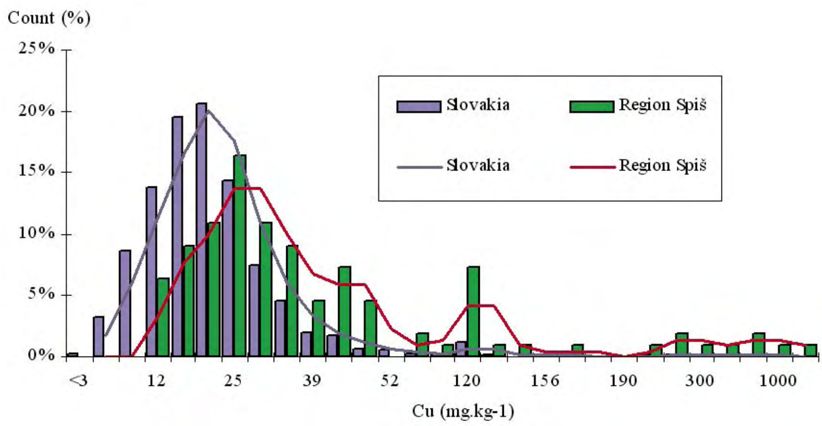


Copper

Probably value of background "mode" for this area is 22.0 mg.kg^{-1}. Distribution is asymmetry normal, with expressively anomalies in interval 37 – 90 mg.kg^{-1}a 100 – 600 mg.kg^{-1}.

Micronutrients that can be deficient in some soils causing severe loss of yield in several crops, especially cereals can be deficient in some soils. Toxicity problem occurs in crops in polluted soils and livestock grazing herbage growing on polluted soils. Sheep are the livestock most sensitive to Cu toxicity, but they (and cattle) are also prone to deficiency disorders. Herbage with < 5 µg/g Cu can lead to deficiency in both sheep and cattle but if the herbage contains > 10 µg/g Cu then toxicity to likely to occur in sheep. Copper pollution can arise from Cu mining and smelting and excessive use of Cu based agrochemicals.

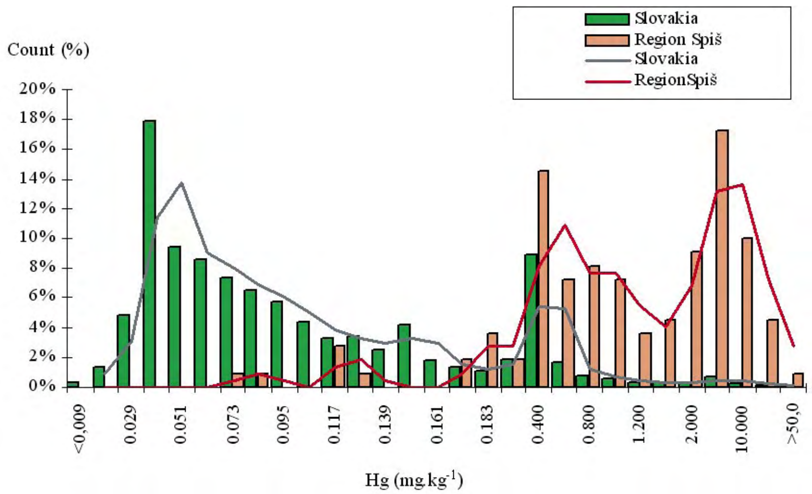
Figure 2 Distribution of cooper in A-horison (arable soils)



Mercury

Mercury is non-essential element. Mercury is the only metal that is liquid at normal temperatures.

Figure 3 Distribution of mercury in A-horison (arable soils)



It has a high volatility, the maximum allowable level of any toxic vapour ((threshold limit value) for mercury is set 0.05 mg Hg per m^3 air. Most mercury compounds are relatively volatile, even mercuric sulphide (HgS) that is the major mercury ore mineral, cinnabar, gives 10 ng Hg m^{-3} in dry air. Mercury exists in the 0, +1 and +2 oxidation states, and methylation is an important feature of its cycle, particularly with regards to its uptake by fish and humans. Methyl mercury is major mercury species found in fish an about 90% of the $CH_3\ Hg^+$ eaten is absorbed by humans.

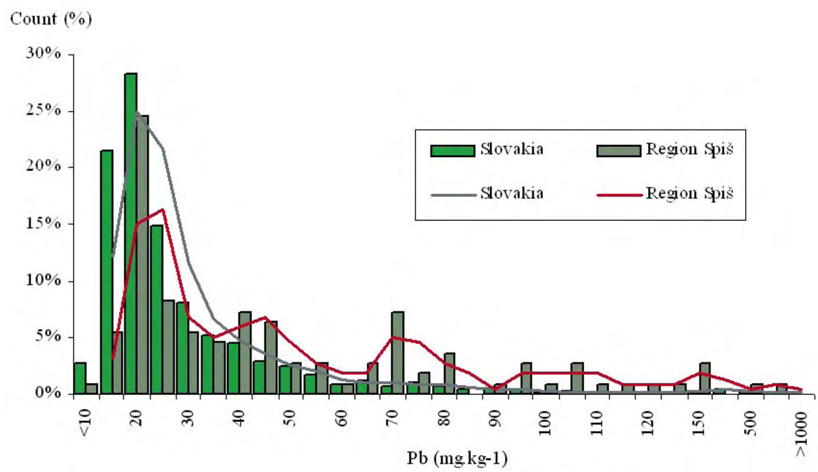
The target organ of methyl mercury in human's body is the brain, where it disrupts the blood-brain barrier, upsetting metabolism of the nervous system. The main toxic effects of inorganic mercury are that it tends to disrupt the functions of the kidneys and liver. Mercury has suggested that the intake for adults should be less than 0.3 mg total mercury per week, of which no more than 0.2 mg should be methyl mercury.

Descriptive statistic and a distribution histogram detected several various level of contamination – areas with small influence of emission, weakly influence, hard influence and areas with very hard influence (anomalies over 20 mg.kg^{-1}).

Lead

Lead is non-essential element. It is a neurotoxin and a good example of a multimedia pollutant. The main sources of Pb pollution in the environment are petrol (air pollutant, but can also water and soil pollutant from spillage), fossil fuel combustion in soil (soil pollutant – taken up by plants and also ingested with plant food crops), Pb pollution from mining and smelting of the ore. As a result of exposure Pb occurs kidney damage and inhibition of haem synthesis (anemia) Pb is powerful neurotoxin. Probable value "mode" of background for this area is 18,0 mg.kg^{-1}. Distribution of contamination exhibit expressive emission (anomaly in interval 70 mg.kg^{-1}).

Figure 4 Distribution of lead in A-horison (arable soils)

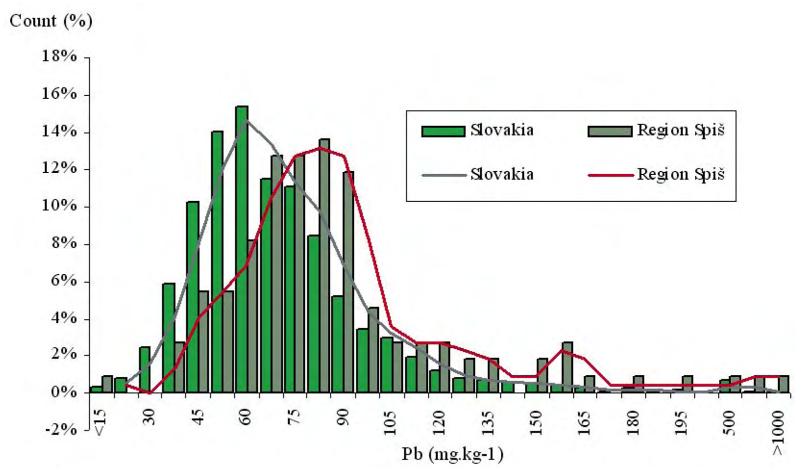


Zinc

Zinc is micronutrient that is the most serious deficiency problem in crops. In the context of pollution, Zn is a mainly a cause of phytotoxicity and has a relatively low toxicity to animals and humans. Zinc pollution is often associated with mining and smelting. Mining causes pollution of air, water and soil with fine tailings particles. The geochemical association with Cd implies that impure Zn compounds may contain Cd, but also Zn-Cd antagonism may mitigate some of the effects of Cd contamination.

Probable value "modus" of background for this area is 78 mg.kg^{-1}, very expressive anomaly is in the interval 100 mg.kg^{-1}.

Figure 5 Distribution of zinc in A-horison (arable soils)



CONCLUSIONS

Raising environment concentration of heavy metals is very serious hygienic problem.

Long term degradation of environment by human activity in the territory central Spiš has been caused heavy metals contamination, which belong between high toxic and hazard. High concentrations of Hg, As, Pb, Cu and Zn are very dangerous. Human and other animals are exposed to chemicals via soils, water, air dust and their diets. In humans and higher animals metabolic conversion of compounds not essential for normal biological functions, takes place mainly in the liver but some metabolism can occur in the lungs, intestines, kidneys, and the skin.

Many countries have established lists of critical concentrations for the risk assessment of site. The basis for these different sets of values varies according to the target groups they are intended to protect from the effect of the pollutants.

REFERENCES

ALLOWAY, B.J., AYRES, D.C., 1994: Chemical principles of environmental pollution. Blackie A London.

BENEŠ, S., 1993: Obsahy a bilance prvku ve sférách životního prostředí. Praha.

GEOCHEMICKÝ ATLAS SR- ČASŤ PÔDY, BRATISLAVA, 1999

KABATA-PENDIAS, A., PENDIAS, H., 1984: Trace elements in soils and plants. CRC Press, Boca Raton, Florida.

MATÚŠKOVÁ L MEDVEĎ, M. VOJTÁŠ, J., 2003: Pedogeochemické anomálie a eliminácia vstupu rizikových prvkov do potravového reťazca VTP 27-07, ČÚ 04, VÚPOP, Bratislava.

VOJTÁŠ J., 1998: Návrh doplnenia kódu kontaminovaných pôdno-ekologických jednotiek pre kontaminované pôdy (KDP); VÚPÚ Bratislava.

EVALUATION OF SOIL COVER IN SLOVAKIA ACCORDING TO ITS WATER-PROTECTIVE FUNCTION

HODNOTENIE PÔDNEHO KRYTU SLOVENSKA VZHĽADOM NA JEHO VODOOCHRANNÚ FUNKCIU

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ABSTRACT

This paper presents an approach for an evaluation of the soil quality according to the water-protective function (WPF) and its spatial representation for agricultural soils of Slovakia. The specific study evaluation of a soil cover in general follows the recommendations of the Water Framework Directive (2000/60/ES) in groundwater sphere (water directive). Accepting the recommendations of water directive, three soil cover characteristics were chosen for WPF evaluation: (i) retention (ii) transport, (iii) organic matter and (iv) sorption complex characteristics. Input soil data, which are essential for soil quality evaluation with respect to WPF, and their spatial estimations were obtained from some digital geo-referenced and non-spatial soil databases, primarily Digital database of pedo-ecological units (PEU-DB) and Digital database of selected soil profiles (KPP-DB). The evaluation process results to delimitation of soil cover respecting WPF and its target parameter categorisation within four ordinal categories (A – D). Vector data representation (type polygon) was chosen for visualisation and for spatial evaluation of achieved results. Generally, soil cover with suitable WPF (category B) is the most frequent one (more then 45%) on agricultural soil stocks of Slovakia. This category is represented mainly by agricultural soils of lowland and inner-carpathian basin regions. A bit more than 5% of the area is covered by soils with very poor WPF (category D), which are especially situated in highlands of central and north Slovakia and, moreover, in the Záhorská nížina lowland.

Keywords: water-protective function of soils, geo-referenced soil databases, pedotransfer functions, agricultural soils of Slovakia

ABSTRAKT

Predkladaný príspevok sa zaoberá hodnotením kvality pôdy s ohľadom na vodoochrannú funkciu pôdy (WPF) v rámci pôdneho krytu poľnohospodárskej krajiny Slovenska. Účelové hodnotenie pôdneho krytu vychádza z odporúčaní rámcovej smernice o vodách (2000/60/ES) v oblasti podzemných vôd (smernica o vodách). S ohľadom na odporúčania smernice o vodách boli pre potreby hodnotenia WPF ako parametre hodnotenia zvolené

(i) retenčné vlastnosti, (ii) transportné vlastnosti, (iii) vlastnosti organickej hmoty a (iv) charakteristika sorpčného komplexu. Údaje o pôde potrebné pre kvantifikáciu a priestorové hodnotenie pôdneho krytu boli získané z viacerých údajových báz (priestorových aj nepriestorových), pričom ako základ pre aplikáciu hodnotiacej metodiky bola zvolená Digitálna databáza pôdno-ekologických jednotiek (PEU-DB) a Digitálna databáza výberových sond komplexného prieskumu poľnohospodárskych pôd Slovenska (KPP-DB). Výsledkom hodnotenia je účelová delimitácia pôdneho krytu do štyroch kategórií (A – D) pre každú hodnotený parameter a výslednú WPF. Pre potreby vizualizácie a priestorového hodnotenia výsledkov delimitácie pôdneho krytu bola zvolená vektorová dátová reprezentácia (typ polygon). Vo všeobecnosti je možné z hľadiska hodnotenia WPF väčšinu územia poľnohospodárskych pôd Slovenska (viac ako 45%) zaradiť do kategórie s dobrou WPF (kategória B), pričom táto kategória vystihuje najmä pôdny kryt nížin a kotlín Slovenska. Iba niečo viac ako 5% územia poľnohospodárskych pôd Slovenska predstavuje pôdny kryt s veľmi slabou WPF (kategória D), sú to prevažne pôdy v horských oblastiach stredného a severného Slovenska a ľahké pôdy Záhorskej nížiny.

KĽÚČOVÉ SLOVÁ: vodoochranná funkcia pôdy, georeferencované údajové bázy o pôde, pedotransférové funkcie, poľnohospodárske pôdy Slovenska

INTRODUCTION

Considering relations of soils to other components of the geo-ecosystem, soil properties in their mutual combinations define soil functions. The soil function – as a specifically defined soil property – can be classified in several ways (e.g. BEDRNA 2002), however its classification in two main groups is most common: (i) ecological soil functions, which are represented by soil functions (properties) related to other components of ecosystem, could be perceived as simple or partially complex functions (e.g. biomass production, accumulation function, transport function, transforming function, gene reserve) and (ii) socio-economic soil functions, which can be perceived more anthropocentric, are defined mainly by their relation to some human activities in landscape (e.g. soil as a natural resource, soil as space for human activities, historical function). They together constitute environmental soil functions, which are more comprehensive and respect both ecological and socio-economical view (e.g. WPF as an evaluation of several ecological functions with respect to potential negative anthropic impact in landscape).

An application of soil function concept into the evaluation process of soil cover involves a definition of soil quality. Soil quality can be defined as an ability of soil to preserve defined soil functions with respect to its actual utilization. The concept of soil quality becomes very important for specific landscape evaluations nowadays and it represents the effective tool for complex and system evaluation of soil cover regarding to specific socio-economic activities in landscape. BUJNOVSKÝ et JURÁNI (1999) present stepwise approach for soil quality evaluation starting at (i) soil functions or soil properties (chosen with respect to defined purpose), through (ii) soil parameters, as a quantitative formulation of soil functions, to (iii) criteria as a way to evaluate the parameters for defined purposes.

As far as we take into consideration some mutual interactions between pedosphere, hydrosphere (groundwater reservoirs respectively) and socio-economic sphere in landscape, it can be assumed positive as well as negative effect of soil cover on ground-water quality. Positive effect is expressed as a potential of soil to buffer negative impacts of human activities into the groundwater via direct positive influence of soil properties (functions) – soil quality, as well as indirectly through dynamic ability of soil to resist this negative impact preserving soil quality – soil resistance. Negative effect is understood as an influence of naturally or anthropogenically degraded soil cover both directly (contaminated soil as a source of further contamination of environment) and indirectly through decreased soil quality (soil is not able to buffer negative impacts of human activity due to various degree of unfavourable aberration of its properties (functions).

Nowadays many national and international activities at a decisive and a policy-making level are running with aim to preserve various components of environment. Most of them require purposeful information on soil cover as crucial or auxiliary inputs. Water Framework Directive (2000/60/EC) at field of groundwater is one of them and it recommends completing the characteristics of groundwater bodies (particularly those most endangered ones by potential pollution) by auxiliary characteristics of other landscape components, which could have some effect on groundwater quality. Except of surface sediments, it is highly recommended to describe selected parameters of soil cover (i.e. soil depth, soil permeability, soil porosity and soil absorption properties). Therefore a complex estimation approach of soil cover via evaluation of its quality seems to be the suitable one. The Water-Protective Function (WPF), which includes the evaluation of several parameters considered as partial soil ecological functions, was proposed as a tool for soil quality evaluation with respect to maintenance of groundwater quality.

This paper especially deals with problems of definition and evaluation of relevant parameters of WPF as well as with functional delimitation of soil cover of agricultural landscape of Slovakia and its spatial representation using GIS tools. It also provides a view on how to deal with lack of exact soil data needed for quantification of individual soil parameters and functions.

MATERIAL AND METHODS

Parameters for evaluation of WPF as well as appropriate methodology were proposed with respect to (i) fulfil the recommendations of the Water Directive, which expects additional characteristics for groundwater bodies, (ii) achieve as complex characterisation of soil cover as possible (iii) taking into consideration the availability and quality of digital soil data enabling spatial evaluation process (by GIS tools).

The evaluation methodology was proposed as a system of queries applied on input data sources. Several interpretations (co-interpretation respectively) were applied on quantitative or parameterised qualitative input soil data (using nominal or ordinal coding when variable was not a number) with aim to obtain the semi-quantitative first-order categorisation (ordinal 1 – 10 scaling) of individual parameters values. Results of first-order categorisation inputted (i) the WPF calculation (using same scaling as for individual parameters), or (ii) the second-order evaluation resulting to categorisation of individual parameters and WPF to the nominal scale of soil quality:

- A soil with very high quality of evaluated parameter/function
- B soil with high quality of evaluated parameter/function
- C soil with low quality of evaluated parameter/function
- D soil with unfavourable quality of evaluated parameter/function

Some existing data sources were used to derive input data for evaluation of soil properties as they are summarised in the table below (Table 1).

Table 1 Short description of used data sources and their place in the evaluation process

PEU-DB	Pedo-ecological unit database. Digital, geo-referenced (co-ordination system S-JTSK) database in vector data representation (type polygon). PEU-DB stores data about spatial distribution of synthetic mapping units (BPEJ) in agricultural land of Slovakia. BPEJ represents the synthetic spatial unit (topic dimension) of some pedological and non-pedological parameters: soil classification unit, soil depth, coarse fragment content and soil texture, slope and slope aspect, climatic region. In the evaluation process, these attributes of PEU-DB were used: • spatial delineation of evaluated mapping units in agricultural land • soil mapping unit - HPJ • soil texture • soil depth • coarse fragments content • base saturation (generated as qualitative value)
KPP-DB	Selected soil profile of agricultural soils survey database. Digital, geo-referenced (co-ordination system S-JTSK) database in vector data representation (type point). KPP-DB stores profile data of basic morphological and analytical properties of agricultural soils of Slovakia. In the evaluation process KPP-DB was used for following inputs (as an average values related to HPJ): • exchange soil acidity • cation exchangeable capacity • humus content
Rosetta	Respecting the demands on hydropedological data (retention and hydraulic parameters of soils), which are not directly included in soil databases, the Rosetta model and its calibration database was used for estimation of lacking inputs. Rosetta (Schaap 2000) is used as a pedotransfer environment for estimation of soil permeability, retention and some complementarily hydro-physical soil properties. Calibration database of the Rosetta model includes representative soil texture data (respecting USDA textural triangle) and related values of hydro--physical soil properties. In the evaluation process this calibration database and model Rosseta were used for calculation of average values of field water capacity, which was consecutively related to the soil texture categorisation of PEU-DB.

Spatial delimitation of agricultural soils according to all individual parameters as well as WPF was based on data inputs discussed above and processed in GIS (ESRI ArcGIS) and MS Access environment. Delineation of elementary mapping units copy pedo-ecological unit polygons provided by PEU-DB. PEU-DB, its attribute table respectively, was also used as a base for interpretation of soil properties. All other relevant data, which were derived from KPP-DB or Rosseta calibration database, were attached to PEU-DB relational database through specific identifiers (HPJ, soil texture classes) using 1:N relations. Completed relational database was queried and processed by using SQL and VB scripts with aim to interpret and categorise soil data. Results of WPF and individual parameter evaluation were visualised as digital geo-referenced vector layers (type polygon) on a crucial scale 1:5000 (with respect PEU-DB reference spatial resolution). The resultant spatial layer of WPF and its parameters was processed for some statistics in ArcGIS software environment.

RESULTS AND DISCUSION

WPF is defined as a complex soil function expressing a potential of soil cover to buffer unfavourable human impacts to the groundwater. It is calculated as shown below (Eq. 1).

Eq. 1 WPF = (11 – PARAMETER 1) + PARAMETER 2 + PARAMETER 3 + PARAMETER 4,

where PARAMETER 1 denotes soil water permeability, PARAMETER 2 is the water retention capacity, PARAMETER 3 is the soil organic matter content and PARAMETER 4 is the soil sorption capacity. PARAMETER 1 is inversed to other parameters, because higher permeability of soil denotes lower soil quality with respect to its WPF. To obtain WPF categorization, first-order values of individual parameters (see below) were used by Eq. 1 and the resultant score was consecutively categorised to second-order categories according to table 2.

Table 2 Second-order categorisation of WPF

WPF category	WPF score	WPF quality evaluation
A	7 – 15	very suitable
B	16 – 23	suitable
C	24 – 31	moderate
D	32 – 39	weakly

Short descriptions of the individual parameters and the interpretation procedures are presented below. For each evaluated parameter, apart from its characterisation, we summarize the evaluation technique including (1) parameterisation and calculation of input values, (2) the first-order categorisation and (3) the resultant second-order category evaluation.

PARAMETER 1

Parameter 1 – soil water permeability – can be presented as a partial evaluation of transport function of soil with respect to percolation of surface water to subsurface layers. PARAMETER 1 first-order evaluation involves the co-interpretation of parameterised semi-quantitative variables, namely the soil texture and the coarse fragment content, and its consequential weighting by soil depth with an aim to quantify the intensity of this parameter.

A. Parameterisation of input values:

Table 3 Parameterisation of used PEU-DB values

COARSE FRAGMENTS CONTENT		
PEU-DB entry/categorisation		parameterised value
without coarse fragments	< 10 %	1
low coarse fragment content	10 – 25 %	2
medium coarse fragment content	25 – 50 %	3
high coarse fragment content	> 50 %	4
SOIL DEPTH		
PEU-DB entry/categorisation		parameterised value
deep soils	> 60 cm	1
medium deep soils	30 – 60 cm	2
shallow soils	< 30 cm	3
without differentiation		4
SOIL TEXTURE		
PEU-DB entry/categorisation		parameterised value
coarse	P, HP	1
medium – coarser	PH	2
medium	H	3
fine	IH	4
very fine	IV,I	5

B. First-order categorisation

Table 4 Partial evaluation of parameterised values – co-evaluation of soil texture and coarse fragment content (frag_tex)

Coars fr./texture	1	2	3	4	5
4	1	1	3	6	8
3	1	2	4	7	9
2	1	2	5	8	10
1	2	3	6	9	10

Table 5 First-order categorisation - weighting of frag_tex by soil depth

depth / frag_tex	1	2	3	4	5	6	7	8	9	10
3	1	1	2	3	4	5	6	7	8	9
2,4	1	2	3	4	5	6	7	8	9	10
1	2	3	4	5	6	7	8	9	10	10

C. Second-order categorisation:

Table 6 Second-order categorisation of PARAMETER 1

resultant category	first-order category	quality evaluation
A	9,10	very weakly permeable soils
B	6,7,8	weakly permeable soils
C	3,4,5	permeable soils
D	1,2	very high permeable soils

PARAMETER 2

Parameter 2 – soil water retention capacity – can be presented as a partial evaluation of the accumulation function for water retention in a soil profile. First-order categorisation of PARAMETER 2 weights values of field water capacity (FWC) by soil depth aiming to quantify intensity of parameter. Estimation of FWC for textural classes used in PEU-DB assumes a complicated procedure, which is described below. Despite the fact that it is quite uncertain we had to decide for this approach because no information on soil hydro-physical parameters was included in soil database of the Slovakian agricultural land.

A. Calculation and parameterisation of input values:

Table 7 Average estimations of FWC (%) for soil textural classes by USDA (Soil Survey Staff 1996) and by MSCS (Collective 2000) generated by the Rosseta model

soil texture - USDA	texture - MSCS	FWC(%)	soil texture - USDA	texture - MSCS	FWC(%)
clay	ti	34.12	clay loams	si	26.80
silty clay	ts	33.12	loam	sh	24.73
silty clay loam	ssi	32.07	sandy clay loams	spi	23.74
silty loam	ssh	31.27	sandy loam	sp	17.73
silt	ss	30.57	loamy sand	lh	11.03
sandy clay	tp	28.40	sand	lp	5.52

The average value of FWC for individual Novak textural categories (used in PEU-DB) was estimated as an average of FWC for individual MSCS textural classes (used in KPP-DB) weighted by their frequency in histogram presentation of KPP-DB. Histograms of MSCS textural classes calculated for individual Novak textural classes are presented by Fig. 1. Frequencies of MSCS categories serve as weights for averaging of FWC in individual Novak categories using values in Tab. 7.

Figure 1 Histograms of KPP-DB record frequencies of individual MSCS triangle textural categories for textural categories by Novak classification (x co-ordinate – MSCS textural category, y co-ordinate frequency of KPP-DB records)

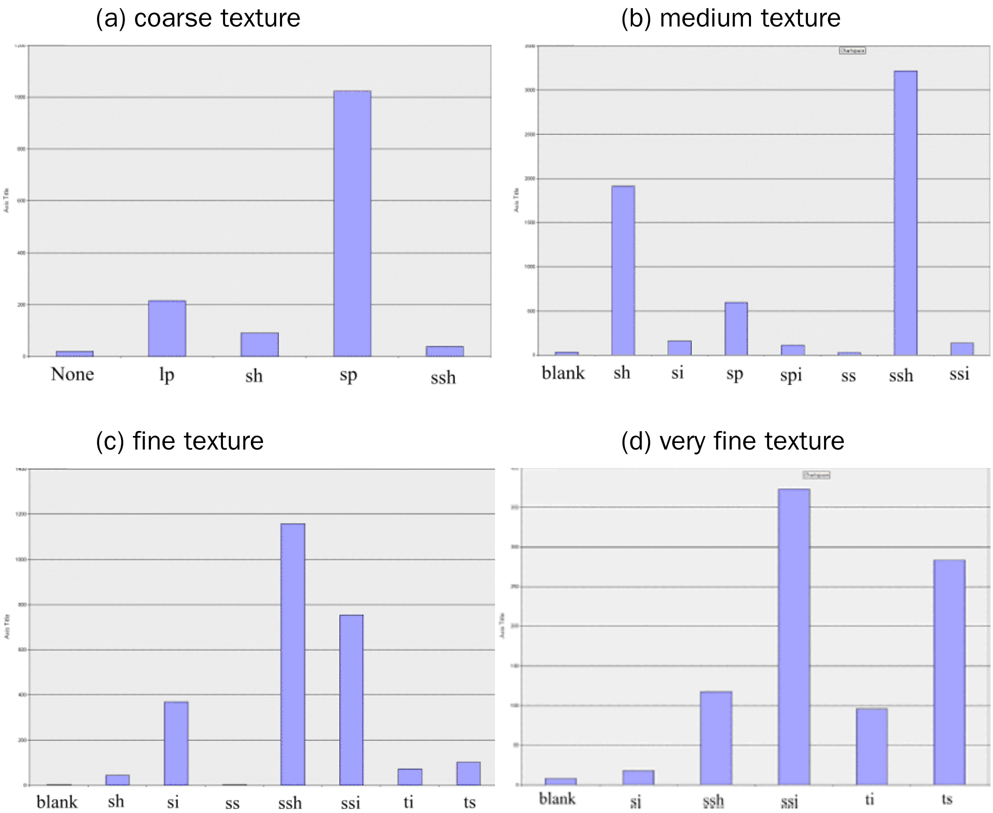


Table 8 Parameterisation of averaged FWC values for individual PEU-DB textural classes using the first-order categorisation scaling

PEU-DB textural category	averaged FWC (%)	FWC coding
1	13	10
2	23	7
3	28	4
4	31	2
5	32	1

B. First-order categorisation

Table 9 First-order categorisation – weighting of FWC code with soil depth

depth/FWC code	1	2	4	7	10
1	1	1	3	6	9
2,4	1	2	4	7	10
3	2	3	5	8	10

C. Second-order categorisation

Table 10 Second-order categorisation of PARAMETER 2

resultant category	first-order category	quality evaluation
A	1,2	very high retention
B	3,4,5	high retention
C	6,7,8	medium retention
D	9,10	low retention

PARAMETER 3

Parameter 3 – soil organic matter content - can be presented as a partial evaluation of the both accumulation and filtering function with respect to hazardous substances in the environment. The first-order evaluation of the PARAMETER 3 takes into account the average humus content per HPJ, which is categorised as shown by Tab. 11.

A. Calculation and parameterisation of input values:

Average values of soil organic matter content obtained for the individual HPJ were parameterised to semi-quantitative categories using intervals presented by ČURLÍK et ŠURINA (1998).

B. First-order categorisation

Table 11 First-order categories for humus content intervals

humus content	first-order value		humus content	first-order value
< 0.5	10		< 2.5 – 3.0)	5
< 0.5 – 1.0)	9		< 3.0 – 3.5)	4
< 1.0 – 1.5)	8		< 3.5 – 4.0)	3
< 1.5 – 2.0)	7		< 4.0 – 4.5)	2
< 2.5 – 2.5)	6		> 4.5	1

C. Second-order categorisation

Table 12 Second-order categorisation of PARAMETER 3

resultant category	first-order category	quality evaluation
A	1,2	high
B	3,4,5	medium
C	6,7,8	low
D	9,10	very low

PARAMETER 4

Parameter 4 - soil sorption potential - can be presented as a partial evaluation of accumulation and filtering function with respect to hazardous substances in environment. The first-order categorisation of PARAMETER 4 co-interprets base saturation, cation exchange capacity (as soil potential indicator parameters) and exchange soil acidity (as actual pedo-chemical balance indicator parameter), which were added to the individual HPJ.

A. Calculation and parameterisation of input values:

Table 13 Parameterisation of estimated average values of exchange soil acidity (pH KCl), cation exchange capacity (CEC) and base saturation (expressed as qualitative value) for individual HPJ

CEC	value	pH(KCl)	value	base saturation	value
≥ 30	1	≥ 7.2	1	carbonate	1
<25 – 30)	2	< 6.5 – 7.2	2	carbonate/saturated	2
<13 – 25)	3	< 5.5 – 6.5	3	saturated	3
<8 – 13)	4	< 4.5 – 5.5	4	saturated/non-saturated	4
< 8	5	< 4.5	5	non-saturated	5

B. First-order categorisation

The resultant score is calculated as a sum of parameterised values of pH(KCl), CEC and base saturation according to Eq. 2 and consecutively parameterised into 1 – 10 ordinary scale following Tab. 14.

Eq. 2. PARAMETER 4 = pH KCl + CEC + base saturation

Table 14 PARAMETER 4 score parameterisation using first-order categorisation scaling

score	first-order category	score	first-order category
4	1	9	6
5	2	10	7
6	3	11	8
7	4	12	9
8	5	13	10

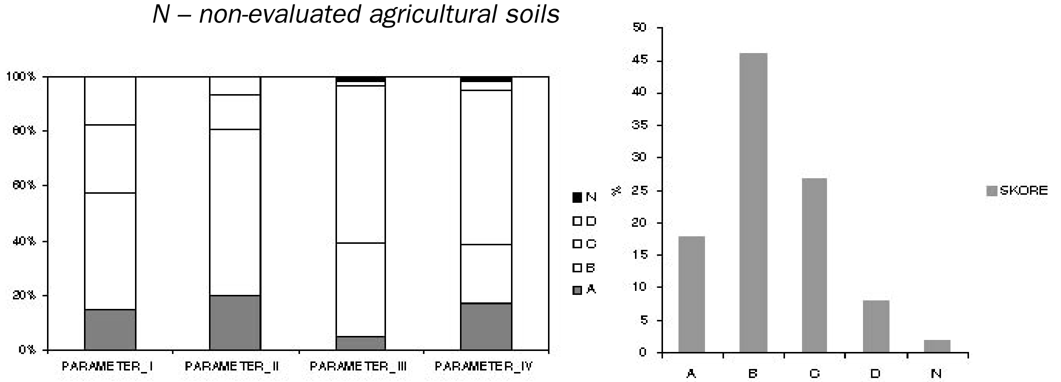
C. Second-order categorisation

Table 15 Second-order categorisation of PARAMETER 4

resultant category	first-order category	quality evaluation
A	1,2	very high sorption potential
B	3,4,5	high sorption potential
C	6,7,8	moderate sorption potential
D	9,10	low sorption potential

Described evaluation of WPF and its individual parameters (parameter 1 – 4) was applied for data structures, furthermore its results for agricultural landscape in Slovakia are visualised by Fig. 3 – 7. Fig. 7 shows WPF quality, its spatial presentation respectively. The frequency histogram (Fig. 2) shows that the prevailing part of the evaluated area (cca 45% of soil cover) belongs to B category (suitable soils), whereas less area (cca 25%) is covered by soils belonging to the C category (soils with moderate WPF quality) and approximately cca18% is abounded by soils in the A category (very suitable soils). Soils belonging to D category (low WPF quality) cover approximately 7% of the area and, finally, about 2% of the area of agricultural soils could not be evaluated due to lack of input data.

Figure 2 Percentage of agricultural soils belonging to individual second-order categories (A-D) for evaluated WPF parameters (on the left) and for WPF (on the right). N – non-evaluated agricultural soils



From a regional point of view, we can say that the most suitable quality of soil cover is located in lowlands and hilly lands as well as in the inner-carpathian basin regions, where well-developed and deep soil from moderately heavy to fine unconsolidated pre-quaternary and quaternary sediments (alluvial, slope sediments, loose) prevail. Some discordance in general trend can be observed, e.g. in the part of the Záhorská nížina lowland, where soils are developed from coarse sandy sediments. The low quality of WPF is found mainly in mountain regions, where shallow, partially unsaturated and stony soils occur.

As it is evident from Fig. 2, most of the area of agricultural soils is covered by soils belonging to B category (PARAMETER 1, PARAMETER 2) and C category (PARAMETER 3, PARAMETER 4). We can summarize that agricultural soils generally have suitable water permeability and retention properties (medium textured soils prevail) and have relative low sorption potential (because of relative low organic matter content in prevailing soils). This trend is generally followed also by WPF results (notice Fig. 7).

However, it is very important to perceive that presented results of soil cover delimitation according to WPF, or its individual parameters respectively, are the potential ones. It is evident that evaluation of groundwater protection must always count on other landscape realities, such as depth and fluctuation of groundwater table, bedrock character, actual land use and human activities in the evaluated area etc. This synthetic level approach is not discussed in this paper. Žitný ostrov region (part of Podunajská nížina lowland) as well as some parts of mountain regions can support the idea mentioned above. Despite of high quality of the soil cover for WPF, the significance of such function is reduced in the Žitný ostrov territory because of high groundwater table and its fluctuation. Similarly the rating of soil cover in the groundwater protection can be challenged also in the karst regions due to some specific bedrock conditions and a groundwater regime, which highly affect groundwater sensitivity (e.g. ADAMCOVÁ et. al. 2002). On the other hand, groundwater in some mountainous regions, where low quality of WPF was estimated, can be highly resistant against pollution because of profound groundwater table or solid bedrock in landscape.

The significance of soil quality evaluation with respect to chosen purpose, as well as validity of results and their spatial estimations, is predominantly defined by input data and used evaluation (interpretation) methodology. Successful applications of some evaluation methodology, or its developing if it does not exist, are highly influenced by availability and quality of both spatial and attribute input data.

With respect to the actual state-of-the-art of digital soil data in Slovakia we used a simple query system as a basis for WPF evaluation methodology in this paper. Originally proposed SQL queries and expert algorithms were applied on attribute database of PEU-DB with an aim to complete and generate some average data (numerical or ordinal) from profile soil database (KPP-DB) using simple pedo-transfer functions and relations. The final evaluation of WPF and its individual parameters is presented as a highly unified qualitative generalization attached to PEU-DB mapping units and, considering mentioned above, it must be understood only as a coarse estimation.

A more accurate and exact approach involves more unbiased numerical evaluation methods resulting in more precise and statistically valuable spatial estimations of predefined soil cover parameters (e.g. BALKOVIČ et al., 2003). Considering the most important digital soil datasets of Slovakia, i.e. PEU-DB and KPP-DB, an application of numerical methods to these datasets is limited due to (i) absence of some substantial soil attributes in databases (e.g. hydrological soil properties) and (ii) inconsistency in spatial representation of datasets (i.e. KPP-DB contains a lot of profile analytical data but they are presented as a point type). Lack of spatial data can be partially solved by zonation of some averaged values to existing delineated spatial units, as it is partly realised in this paper, or by an application of some other progressive methods to gather suitable spatial models of required parameters. Some more precise pedo-transfer functions can be employed to estimate lacking parameters from existing ones, as well as some interpolation methods can be applied to obtain interpolated surfaces of defined parameters from geo-referenced point data (e.g. ORFÁNUS et al., 2003). An additional potential to gather missing spatial data is identified in existing analogue soil databases therefore an attention must be paid to digitize them soon.

CONCLUSIONS

Employing of the soil function concept to the soil quality evaluation process seems to be a suitable way to obtain approximate information on soil cover in the landscape. This paper evaluates WPF and some its partial functions. Evaluation process resulted into the spatial and attribute estimation of the soil cover potential to buffer the negative impacts of human activities to groundwater and the final delimitation of soil cover is an input for more complex landscape-ecology evaluations.

Respecting validity aspect of obtained results of further evaluation, we must consider that the application of some more or less sophisticated evaluation methodology is highly depending on input data quality. Attribute and spatial quality of currently available digital geo-referenced soil cover data of Slovakia highly determines methodology, which has been chosen to fulfil a target aim. A simple query system, as the basis for WPF evaluation methodology, leads to quite coarse attribute and spatial estimation. A more accurate and exact approach may be used when existing gaps in soil spatial data will be eliminated.

Figure 3 Quality evaluation of agricultural soils according to soil water permeability – transport soil function

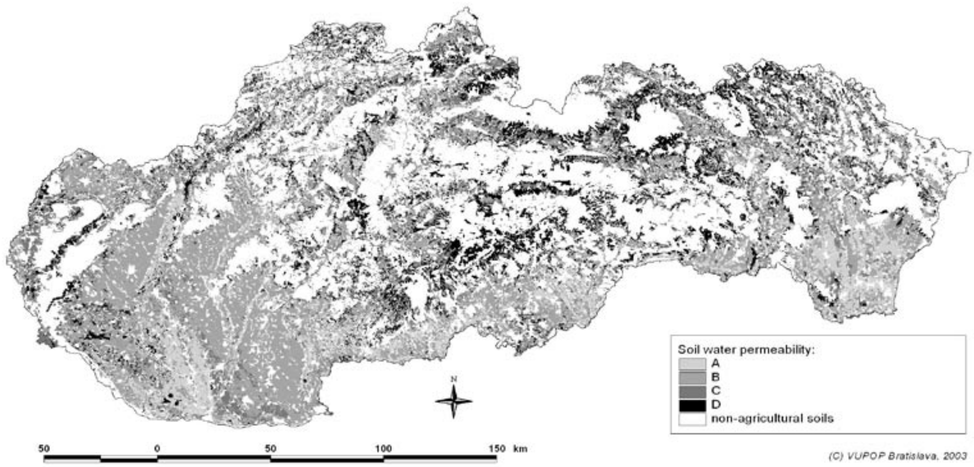


Figure 4 Quality evaluation of agricultural soils according to soil water retention – accumulation soil function evaluation

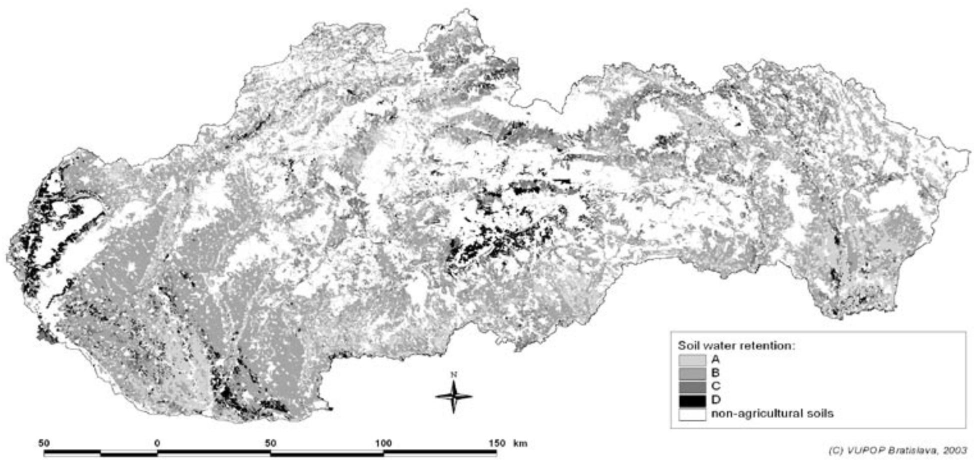


Figure 5 Quality evaluation of agricultural soils according to soil organic matter content – filtering soil function partial evaluation

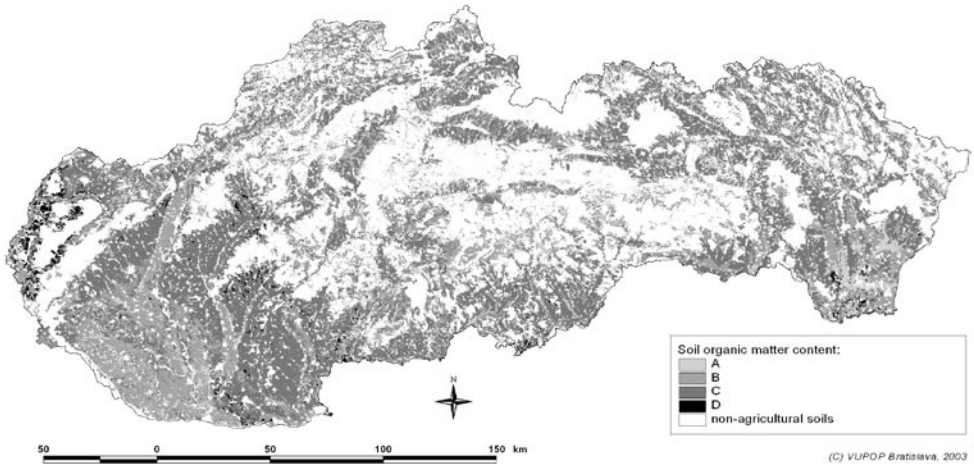


Figure 6 Quality evaluation of agricultural soils according to soil sorption potential – filtering soil function partial evaluation

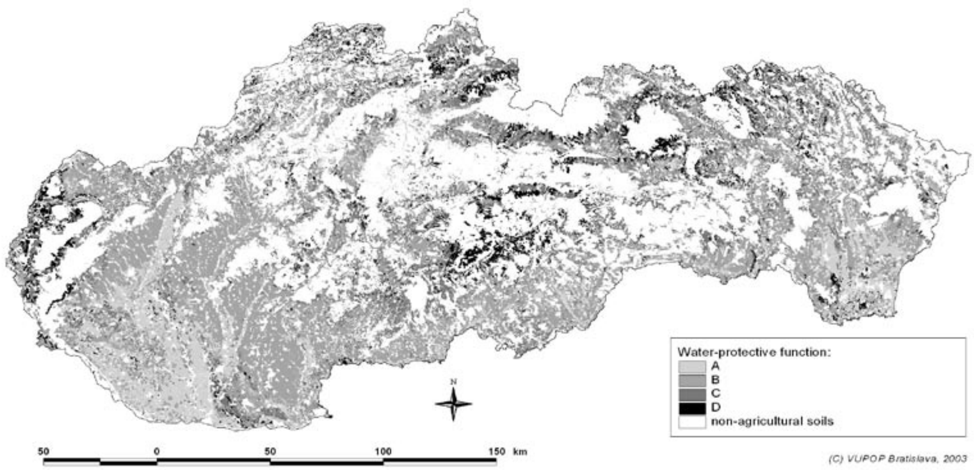
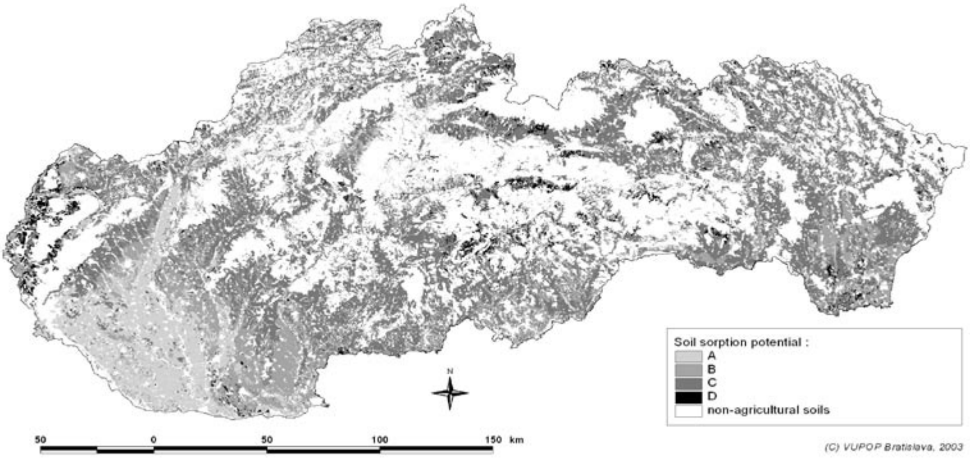


Figure 7 Quality evaluation of agricultural soils according to water-protective function



REFERENCES

Adamcová R., Dubíková M., Durn G., Miko S., Skalský R., Ottner F., Kapelj S., 2002: Soil cover as pollution barrier in karst areas – brief summary of research results, In: Anonym, Groundwater quality and voulnerability, Procc. of Conf. (12 december 2002, Sosnowiec), Comenius University Bratislava, Slaski university, Sosnowiec, p. 3 – 4.

Anonym, 2000: Directive (2000/60/ES) of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Official J. Eur. Commun., No. L327.

Balkovič, J., Hutár, V., Skalský, R., 2003: Continuous Soil Classification and Diffuse Soil Map Creating by Methods of Fuzzy k-means. Phytopedon (Bratislava), Vol. 2., 2003/1, p. 1 – 14. (A)

Bedrna, Z., 2002: Environmental Pedology (in Slovak). VEDA, Bratislava, 352 pp.

Bujnovský, R., Juráni, B., 1999: Soil Quality – its Definition and Estimation (in Slovak). SSCRI, Bratislava, 42 pp.

Collective, 2000: Morphogenetic soil classification system of Slovakia (in Slovak). SSCRI, Bratislava, 76 pp.

Čurlík, J., Šurina, B., 1998: Handbook for Soil Survey and Mapping Soils (in Slovak). VUPU, Bratislava.

Orfánus, T., Balkovič, J., Skalová, J., Šútor, J., 2003: A methodic for creating spatial maps of soil retention properties with using Soil Information System (ISOP) (in Slovak). 11th international poster day: Transport of water, chemicals and energy in the system soil-crop canopy-atmosphere, Bratislava, 20. 11. 2003, p. 427 – 440.

Schaap, M.G., 2000: Rosetta Version 1.2. U.S. Salinity laboratory ARS-USDA 450 W. Big Springs Road Riverside, CA 92507.

Soil Survey Staff, 1996: Field Book for Describing and Sampling Soils. USDA-NRCS Lincoln, Nebraska, 1996.

DESCRIPTION OF TECHNOGENIC SPOIL BANK AND ITS INFLUENCE ON AGRICULTURAL SOILS (A CASE OF NICKEL METALLURGY REFUSE AT SEREĎ)

POPIS TECHNOGÉNNEJ HALDY A JEJ VPLYV NA POĽNOHOSPODÁRSKE PÔDY (PRÍKLAD HALDY LÚŽENCA PRI SEREDI)

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ABSTRACT

The Nickel foundry in the Sereď region is thought to be tightly connected with environment pollution in the region, even though it undoubtedly already stopped its production activity. Nevertheless there are some indications of further contamination in surrounding soils and ground water. The environmental load is caused by about 5.5 mil. tons of technogenic material – product of nickel metallurgy refuse displaced on 54 ha area at former smelting work. An estimated area of agricultural soils on what it can be presumed increased content of Ni, Co and Cr is of 1 500 ha. Soils in Sereď area has got 7 – 8 times higher concentration of nickel than other areas. One of the goals of the paper is to describe, analyse and classify the technogenic alkaline spoil bank (as anthrozemic soil type) using pedological methods. Assessment of technogenic material influence on running soil-forming processes is a part of our research. Properties of these soils are unusual by their nature and help to identify Anthrosols. The second goal is to point out the technogenic spoil bank impact and/or infliction on surrounding agricultural soils and ground water. The paper describes geochemical processes of nickel as one of compound causing environment pollution. On the base of several analytical results we have tried to define other possible pollution resources of this area as it was formerly assumed. A part of environmental survey of risk areas represents also re-cultivation measures what were depending upon characteristics of obtained analytical results.

Keywords: nickel metallurgy refuse, Anthrosol, contamination, Nickel foundry Sereď

ABSTRAKT

So znečisťovaním životného prostredia je veľmi úzko spätá Niklová huta š.p. Sereď, ktorá síce zastavila výrobnú činnosť, ale napriek tomu je možné, že sa naďalej podieľa na kontaminácii okolitých pôd a podzemných vôd. Environmentálnu záťaž spôsobuje asi 5,5 mil. ton lúženca uloženého na 54 ha pri bývalom podniku. V súčasnosti sa odhaduje, že výmera poľnohospodárskej pôdy, kde možno predpokladať zvýšený obsah Ni, Co a Cr je 1 500 ha. Pôda v oblasti Seredi má 7 – 8 násobne vyššiu koncentráciu niklu než ostatné oblasti. Jedným z cieľov práce je pomocou pôdoznaleckej metodiky popísať, analyzovať a klasifikovať technogénnu haldu lúženca ako antrozemný pôdny typ.

Súčasťou výskumu je hodnotiť vplyv technogénneho materiálu na prebiehajúce pedogenetické procesy. Vlastnosti týchto pôd sú svojou povahou nezvyčajné a napomáhajú identifikovať antrozeme. Druhým cieľom je poukázať na vplyv, resp. zaťaženie okolitých poľnohospodárskych pôd a podzemných vôd kontamináciou z haldy lúženca. V príspevku sa zaoberáme geochemickými procesmi niklu, ako jednej zložky znečistenia okolitého prostredia. Na základe viacerých analýz sme sa pokúsili definovať iné možné zdroje znečistenia tejto lokality, než sa pôvodne predpokladalo. Súčasťou environmentálneho prieskumu rizikových oblastí sú aj rekultivačné opatrenia, ktoré vyplývajú z charakteristík získaných analytických výsledkov.

Kľúčové slová: lúženec, antrozem, kontaminácia, niklová huta Sereď

INTRODUCTION

The Nickel foundry was built in the years 1959 – 1964 in Sereď for nickel and cobalt production. Nickel-cobalt ore imported from Albania was re-worked. The production was stopped in 1993 due to strong pollution of air, soil and ground water. There was produced enormous number of refused Fe-concentrate material deposited in spoil bank form on the area of 54 ha. Its quantity can be estimated about 5.5 mil. tons. It is assumed that permanent wind blowing causes diffusion of weakly stabilized spoil bank material by vegetation in surrounding agricultural land and polluted it.

We have introduced behaviour processes of nickel in soil profile. However the main reason for ceasing re-working metallurgy activities in the region was prevailingly ground water contamination (at the level 2.5 – 3 m under surface) by sulphur and nitrogen compounds. These elements represent mobile substances in soil medium with fast transfer ability to waterlogged layer of the river Váh alluvium. The soil and ground water contamination is presented as significant environmental load of this region.

To assess the nickel content in soils efficiently it is inevitable to be aware of its geochemical behaviour and geology of an investigated area. The Ni status in soils is highly dependent on parent material. However, the Ni concentration in surface soils also reflects soil-forming process and pollution.

Nickel is an element geochemically linked to cobalt which both show certain affinity towards iron abounded in the Earth's crust (Bouška et al., 1980). Ni as a siderophile element tends to accumulate in ultrabasic rocks. Due to this fact, its highest concentration occurs in ultrabasic rocks and gradually decreases down to acid granite rocks (Alloway, 1990), see in Tab. 1.

Table 1 Ni content in different rock types according to Alloway (1990)

Rocks	Mean content of Ni (mg/kg)	Concentration range (mg/kg)
Ultrabasic rocks	2000	270 – 36 000
Basic rocks	140	45 – 410
Acid granite rocks	8	2 – 20
Limestones	20	–
Sandstones	2	–

Some authors claim (Alloway, 1995; British Geological Survey, 1991) that the highest level of Ni was found in the stream sediments as silicate and oxide formations. It results from its decreased solubility and mobility. On the other hand, Ni mobility is significantly limited by its sorption to clays. During weathering, Ni is easily released and mobilized in waters over long distance, though. Later, Ni is concentrated at those sites where secondary Fe and Mn oxides are forming. In addition, due to Ni's significant affinity towards the organic matter, it is abounding in organic-rich soils.

During sedimentations processes, Ni tends to fix to the clayey minerals that explains its highest concentration found in deep marine clays (POLAŃSKI, 1978). In sedimentary rocks, nickel appears to occur mainly in Fe and Mn clastic silicate rocks, as well as in clastic hydrated Fe-Mn oxides formed in rocks, likewise in clayey rocks.

According to above mentioned, it is clear that Ni distribution in soils is related either to secondary Fe-Mn oxides or to organic matter and depending on clay fraction. In surface soils, nickel is likely to occur in organically bound forms, a part of which may be easily soluble chelates (KABATA-PENDIAS, PENDIAS, 1992).

ALLOWAY (1990) assumes that more than 50% of overall Ni content in soils is bound to residual fraction, in other words Ni is a part of primary and secondary minerals, whereas only 20% is fixed to Fe-Mn oxides. Nevertheless, nickel is believed to occur less in carbonate form.

The Ni solubility is mainly determined by pH of soils. With the lowering both of pH and CEC (cation exchange capacity) the release of Ni increases. Other factors determining nickel distribution in soils, such as the content of clay and Fe-Mn oxides seem to be less important since those factors are thought to be pH dependent, too.

Soils throughout the world contain Ni within the broad range 0.2 – 450 $mg.kg^{-1}$. The highest Ni content is always found in clay and loamy soils, e.g. Cambisols, Rendzinas, as well as in soils developed from ultrabasic parent rocks (serpentine) and in some by organic matter enriched soils (KABATA-PENDIAS, PENDIAS, eds., 1993).

MATERIAL AND METHODS

The survey of technogenic material (nickel metallurgy refuse) likewise adjacent agricultural soils was carried out by standard methods according to Manual of soil survey and mapping (ČURLÍK, ŠURINA, 1998). Description of spoil bank soil profile including sampling of soil horizons for pedological analysis was done. Samples were submitted following analyses:

- soil texture (grain size fraction and following textural triangle determination)
- physical properties: actual moisture content, bulk density ($g.cm^{-3}$), particle density ($g.cm^{-3}$), maximal capillarity capacity (vol. %), maximal porosity (vol. %), retention capacity (vol. %), non-capillar porosity (vol. %), semi-capillar porosity (vol. %) and minimal air capacity (vol. %).
- chemical properties: pH in H_2O, pH in KCl, CO_3^{2-} content, Cox content (%), P and K content ($mg.kg^{-1}$).

Thanks to the FERROMIN company which is owner of this spoil bank, we have gained valuable analytical data about chemical composition of this technogenic material, grain size fractionation and results of ground water contamination monitoring.

The soil probe with chemical properties characteristics of A-horizon was chosen (ČURLÍK, ŠEFČÍK, VOJTEK, 1997) to ascertain the present status of agricultural soils in surrounding of spoil bank.

The soil profile was described according to the latest Morphogenetic Soil Classification System of Slovak Republic (MSCS) (Collective, 2000), specifically by classification of anthropogenic soils and substrata (SOBOCKÁ, et al., 2000). On contrary to natural soils description – diagnostics and characteristics of anthrozemic soil type is not to be used often in soil survey, therefore each survey of such soils (sometimes called like substrate soils) is considered as "novelty". In this aspect we shortly introduce the basic diagnostic horizon of Anthrosol (name Anthrozem in Slovak language) with following characteristics:

Anthrozemic soil horizon Ad – formed by man from heterogeneous transported materials and earths of natural, natural-technogenic or technogenic providence which has got:

- thickness > 1 cm
- content of oxidizable organic C > 0.3%
- possible presence of artefacts (fragments of bricks, glass, plastic materials, iron, slag, coal, etc.)

Varieties of horizon:

Anthrozemic initial Adi – primitive stage of soil formation from anthropogenic materials at thickness of heaped material > 60 cm.

Anthrozemic re-cultivation Adr – in surface layer can be observed signs of re-cultivation measures improved assumptions for vegetation growth, i.e. processes of biological re-cultivation (heap of humose material, purposeful humification of anthropogenic materials) on technical levelled areas.

Useful knowledge on geochemical Ni-cycle we obtained from all available and significant literature sources. It relates to processes of concentrations, migration and stabilization of Ni in soil and other bounds with soil compounds and properties.

RESULTS AND DISCUSSION

Soil profile description:

Location: Sereď, technogenic spoil bank (nickel-cobalt metallurgy refuse material)

Landscape: anthropogenic, artificially formed spoil bank with 10 – 15 m relative elevation

Vegetation: primitive initial stage of ruderal vegetation (natural regeneration by bush and tree communities, poplar, willow)

Location use: derelict industrial area

Location age: about 30 years.

Classification according to:

MSCS SR (2000): Antrozem initial, calcareous, alkaline, contaminated, form spoil bank, loamy-sandy, from technogenic industrial parent material, signature: $ANä^{czx}$-lh/at6

FAO (1994): Urbic Anthrosol

WRB (1994): Urbi-antropic Regosol

Figure 1 Pedon description

Adic (0 – 3 cm) – 2,5Y 2/1, dry, loose, loamy-sandy, weakly polyhedral structure, moderate rooting, small artefacts presence, calcareous initial horizon distinct transition to

C1c (3 – 45 cm) – 2,5Y 2/1, dry, extremely loose, loamy-sandy, polyhedral jointing, moderate rooting, presenting transported and accumulated material from upper parts of spoil bank distinct transition to

C2c (45 – 90 cm) – 2,5YR 2/2, dry, extremely loose, loamy-sandy, polyhedral jointing, here and there platy layering, alkaline and carbonate soft powdery, fragments of anthroskeleton of unknown providence, rarely rooting, distinct transition to

C3c (> 90 cm) – 2,5YR 2/2, dry, firm, loamy-sandy, prismatic layering carbonate industrial technogenic substrate (at6).

Pedological analyses

Table 2 Grain size of technogenic material

Sampling depth (cm)	> 0.25 mm (%)	0.25 – 0.05 mm (%)	0.05 – 0.02 mm (%)	0.02 – 0.002 mm (%)	< 0.002 mm (%)
0 – 20	7.43	66.43	10.81	12.92	2.41
50 – 70	2.34	76.87	9.08	11.38	0.33
90 – 110	2.09	75.47	9.10	13.01	0.33

Table 3 Textural triangle (by MSCS SR 2000)

Sampling depth (cm)	0.05 – 2.00 mm (% sand)	0.002 – 0.05 mm (% silt)	< 0.002 mm (% clay)	Textural triangle
0 – 20	73.86	23.73	2.41	lh (loamy-sandy)
50 – 70	79.21	20.46	0.33	lh (loamy-sandy)
90 – 110	77.56	22.11	0.33	lh (loamy-sandy)

Table 4 Physical properties

Depth (cm)	Q	ρd	ρs	MCC	P	RWC	PN	PS	AC
5 – 20	20.38	1.21	3.94	48.6	69.4	34.9	24.2	10.4	29.5
> 45	29.7	1.42	4.29	55.6	66.9	44.4	13.2	9.3	18.4

Explanations: Q – moisture content
ρd – bulk density ($g.cm^{-3}$)
ρs – particle density ($g.cm^{-3}$)
MCC – maximal capillary capacity (vol. %)
P – total porosity (vol. %)
RWC – retention water capacity (vol. %)
PN – non-capillary porosity (vol. %)
PS – semi-capillary porosity (vol. %)
AC – minimal air capacity (vol. %).

Figure 2 Alkaline and carbonate soft powder in soil profile

The pedological characteristics assessment of technogenic material results in similarity of the profile morphology to with initial soils, i.e. initial surface horizon "inherits" features of substrate in our case technogenic one. There is observed an evidence of weathering supported by ruderal vegetation regeneration. The colour is unnaturally black gained in re-working processes therefore cannot be authoritative at humus horizon diagnostics. Soil structure appears to be weakly developed, since being found only in top horizon. Abundance of alkaline and carbonate efflorescence, irregular distribution in soil profile (Figure 2) as well as anthroskeleton presence is often recognized.

Soil texture of fine earth (< 2 mm) represents loamy-sandy technogenic material with minimal presence of silt and clay (Tabs 2 and 3). From physical features there is interesting particle density ρs whose values are very high (4.29 $g.cm^{-1}$) not obvious in natural soils (normally 2.60 $g.cm^{-1}$). Similarly values of total porosity as well as maximal capillary capacity are very high not typical for natural soils (HOUŠKOVÁ, 2001). Some of these properties can be considered as diagnostic feature for newly proposed classification of anthropogenic soils from technogenic substrate.

Table 5 Chemical properties of spoil bank material

Depth (cm)	pH/H_2O	pH/KCl	CO_3^{2-} (%)	Cox (%)	Humus (%)	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)
5 – 20	8.13	8.00	4.00	0.99	1.706	< 0.56	37.0
> 45	8.46	8.09	4.5	0.87	1.499	0.56	45.5

In chemical features (table 5) we can recognize an evidence of increased values of actual and exchangeable pH, and carbonates. Content of organic carbon was calculated to humus content and ranges in 1.5 – 1.7%. Anyway top horizon fulfils the condition for anthrozemic Adi horizon: thickness > 1 cm and content of oxidizable organic C > 0.3%. A presence of available nutrients is strongly under normal values.

Soil contamination

Nickel metallurgy refuse presents spoil heap material with about 52% of Fe or other Fe compounds (Fe_2O_3, FeO) therefore it is called as Fe-concentrate (table 6).

The Fe-enriched material is assumed to be worth for secondary re-working and production of Fe. There are elaborated very special projects for iron-making process in blast-furnaces. The problem for furnace operation presents fine grain material of Fe-concentrate what cannot be used for melting before agglomeration or pelletization of this material.

Table 6 Chemical analyse of spoil bank (FERROMIN materials)

Fe	49 – 52%	P_2O_5	0.06 – 0.18%
Fe_2O_3	42 – 43%	SO_3	0.08 – 0.10%
FeO	27 – 28%	MnO	0.3 – 0.4%
Fe metamorph.	0.25 – 0.35%	K_2O	0.08 – 0.10%
SiO_2	8 – 10%	Ni	0.27 – 0.29%
Al_2O_3	4 – 6%	Cu	0.01 – 0.02%
CaO	3 – 4.5%	TiO_2	0.10 – 0.12%
MgO	2 – 3%	Na_2O	0.20 – 0.21%
Cr_2O_3	3.4 – 3.8%	H_2O	15 – 18%

Table 7 Sieve analyses of spoil bank

Fractions	%
> 200 μm	1.60
200 – 90 μm	10.90
90 – 70 μm	13.80
70 – 60 μm	4.70
60 – 50 μm	10.95
40 – 30 μm	11.75
30 – 20 μm	10.95
20 – 10 μm	7.60
10 – 5 μm	17.05

From the sieve fractionation of Fe-concentrate (table 7) we can result that respirable dust introduced in worldwide literature as PM_{10}, i.e. particle matter < 10 μm (Lebowitz et al., 2000) presents the most percentage of spoil bank (17%). It means that these particles can be discharged delicately in air and caused latent health hazard for living population. The spoil bank is contaminated mainly by Fe-compounds, likewise by compound of Si, Al, Ca, Mg, Cr and Mn. Further elements are negligible.

Table 8 Chemical analyse of surrounding agricultural soils (Mollic Fluvisol calcareous, loamy from calcareous fluvial sediments) (Čurlík, Šefčík, 1999)

	pH/KCl	pH/KCl	$CaCO_3$	Cox (%)	Humus (%)
A-horizon	7.66	7.28	2.40	1.70	3.424

Table 9 Analyse of risk elements of agricultural soil (Mollic Fluvisol calcareous, loamy from calcareous fluvial sediments) (Čurlík, Šefčík, 1999)

	As	Be	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn
A-hor.	7.00	1.2	0.30	11.0	208.00	26.00	0.80	114.00	29.00	81.00

As it results from tabs 8 and 9 in the soils of investigated area, around the Nickel foundry factory, in Sereď, there were recorded the increased Ni contents, in accordance with the Decree of Ministry of Agriculture Slovak Republic, number 531/1994-540. Therefore, nickel is thought to cause significant spatial contamination in the given area, along the overall alluvial area of the Váh river (Čurlík, Šefčík, Vojtek, 1997). The arisen Ni content in the soils of the Sereď region is thought to be tightly related to the long-term metallurgical activities of the regional Nickel foundry.

However, results obtained by Čurlík, Šefčík, and Vojtek, (1997) show that the contamination of adjacent soils by Ni is not only caused by up waving the contaminated dust from the spoil bank, but also by the mobilization of Ni dissolved forms down the ground waters in the river Váh alluvium. Thus, it comes happening to repeatable Ni re-sorbing into organic matters and sesquioxides found in gleyic horizons of Molli-gleyic Fluvisols. So, it explains the increased Ni contents recorded in lower horizons of examined soils of the region.

A bulk part of the arable soils in the Sereď region, encompassing the spoil bank, are prevailingly neutral and/or to alkaline reaction. Apart of that, these soils are carbonate-rich soils. The higher carbonate content seems to be the limiting factor for Ni bioavailability in the soil-plant system. So far, none of surveys were carried out in order to demonstrate the Ni toxicity symptoms on agricultural crops in the focal region. However, it does not necessarily denote that the problem of a potential risk of Ni toxicity in plants is worthless to pay any attention.

In a summary, it can be concluded that the increased Ni content in soils of the Sereď region might be caused by various anthropogenic sources such as, the release of highly polluted technical waters during the Ni-works activity, ground waters in the alluvium of the rivers Váh, Čierna Voda a Dudváh, and at last, but not least, the technogenic spoil bank and up waving its dust in the adjacent area (POLTÁRSKA, 2000).

It has to be pointed out that the Ni re-sorption tendency is unambiguous and dependent on many other factors such as, groundwater elevation, soil type, and occurrence of barriers, where Ni can be readily accumulated. It is inevitable to take into consideration vulnerability of the ecosystem where it comes to happen to Ni mobilization within the soil profile and so its availability for the plants under even delicate change of the soil pH condition. Even though the carbonate soils are believed to be resistant against the acidic impacts, these soils under the permanent hydromorphic effects are vulnerable and change their properties with respect to the presence of excess water, in other words due to so-called waterlogged regime (POLTÁRSKA, 2000).

Groundwater contamination

The groundwater contamination seems to be the most severe environmental problem in the investigated region. The table stated below (Table 10) shows that to the most ground water pollutants belong to compounds of sulphur and nitrogen, not nickel or cobalt. These compounds can be remarked like secondary products of nickel-ore reworking firstly accumulated in soil and then transported though this medium into ground water.

Table 10 Ground water contamination (mg.l^{-1}) monitoring in 2000

Sonda 1	Co	Ni	SO_4	NH_4	NO_2	NO_3
I./2000	0.003	0.033	227.8	0.48	0.11	25.0
V./2000	0.007	0.041	223.0	0.04	0.20	83.6
VII./2000	0.004	0.028	213.5	0.02	1.55	117.0
X./2000	0.005	0.023	119.3	0.14	0.36	108.0

Sonda 2	Co	Ni	SO_4	NH_4	NO_2	NO_3
I./2000	0.002	0.081	261.0	0.36	0.95	21.8
V./2000	0.005	0.041	237.3	7.50	23.00	92.8
VII./2000	0.003	0.030	246.8	8.0	2.75	98.0
X./2000	0.003	0.024	256.2	50.0	9.75	74.9

Table 10 Ground water contamination ($mg.l^{-1}$) monitoring in 2000, continue

Sonda 3	Co	Ni	SO_4	NH_4	NO_2	NO_3
I./2000	0.002	0.036	189.8	0.46	0.85	67.5
V./2000	0.003	0.21	204.1	0.02	0.01	63.2
VII./2000	0.21	0.012	223.0	0.31	1.05	75.1
X./2000	0.005	0.029	213.5	20.50	0.03	12.0

Sonda 4	Co	Ni	SO_4	NH_4	NO_2	NO_3
I./2000	0.002	0.026	227.8	24.0	0.23	215.0
V./2000	0.004	0.019	237.3	47.50	0.65	176.5
VII./2000	0.002	0.015	227.8	38.00	0.189	192.0
X./2000	0.003	0.017	237.3	32.50	0.20	181.0

Recultivation measures

Consequences of both long-term former re-working and smelting activities of the ceased Ni works as well as spoil heap of nickel metallurgy refuse are thought to represent significant severe environmental load of this region that deserves an attention. There is a need to solve this problem by reasonable financial supporting. From above mentioned results that impact assessment of the existing technogenic spoil bank on the adjacent soils has to be done carefully since factors influencing the risk elements mobilization and distribution in soils have to be taken into consideration

Figure 3 Spoil bank at Sereď

Stabilization and conservation of spoil heap is the first matter to do. Most of this area undergo by strong erosion impact as it can be seen in figure 3. It is due to weak stabilization of spoil bank by systematically established vegetation cover. Greening was accomplished only on small part, other green area is a result of natural grass, bush or tree regeneration. Regular sprinkle by water is inevitable measure in order to avoid small solid and contaminated particle in air and soil. The main reason for spoil bank conservation is probability of its secondary re-working for iron separation. All significant environmental elements are currently monitored.

Many studies (Blaško, Hrnčár, and Tupý, 1994) deal with proposing the optimal re-cultivation measurements of the spoil bank. However, some of those re-cultivation intentions were carried out in practice since optimal plant species were sown in the upper parts of the spoil bank in efforts to prevent dustiness. So far, this re-cultivation measure seems to be economically the most reasonable. Whether it is the effective one shows results of the continual research on the soil contamination in the Sereď region in close future.

CONCLUSIONS

Even though the Ni-works activity ceased recently, the existing technogenic spoil bank representing the severe potential environmental risk in the region is part of unwanted heritage for further generations. By means of both water and wind weathering, the Fe-rich dust from the spoil bank is thought being constantly spreading around in the adjacent areas. That might be a reason for Fe/Ni enrichment of those soils. Such an approach of assessing the impact of the technogenic spoil bank, as a main source of the Ni soil pollution, needs to be quantitatively as well as qualifiedly provable.

REFERENCES

Alloway, B.J., 1990: Heavy metals in Soils. London, Pergamon Press, 342 p.

Alloway, B.J., 1995: Heavy metals in Soils. 2nd edition, London, Blackie Academy and Professional, 368 p.

Blaško, D., Hrnčár, A., Tupý, P., 1994: Sereď a Žiar nad Hronom – možnosti rekultivácie skládky lúženca a kalovych poli v Žiari nad Hronom. ENVIGEO s.r.o., Banská Bystrica. 58 p.

Bouška, V., Jakeš, P., Pačes, T., Pokorný, J., 1980: Geochemie. Academia Praha, Nottingham. 95 p.

Čurlík, J., Šefčík, P., 1999: Geochemický atlas Slovenska. Čast V. Pôdy. VÚPOP Bratislava, 365 – 374p.

Čurlík, J., Šefčík, P., Vojtek, R., 1997: Súbor regionálnych máp geofaktorov ŽP regiónu modelového územia Galanta v mierke 1:50 000. Záverečná správa, VÚPOP, Bratislava, 25 p.

Čurlík, J., Šurina, B., 1998: Príručka terénneho prieskumu a mapovania pôd. VÚPOP Bratislava, 134 s.

Houšková, B., 2001: Anthropogenic Soils - Some Physical Properties and Characteristics. In: Sobocká, J. (ed): Soil Anthropizatin VI. Proc. Int. Workshop Bratislava, June, 20-22 2001, pp. 113 – 116.

Kabata-Pendias, A, Pendias, H., 1992: Trace elements in Soils and Plants. CRC Press London, 2nd Edition, 365 p.

Kabata-Pendias, A, Pendias, H., eds, 1993: Chrom, Nikiel I glin w środowisku, problemy ekologiczne metodyczne. Zeszyty Naukowe 5, Wydawnictwo Polskiej Akademii Nauk, Wroclaw-Warszawa-Krakow, 257 p.

KOLEKTÍV, 2000: Morfogenetický klasifikačný systém pôd Slovenska. Bazálna referenčná taxonómia. VÚPOP, Societas pedologica slovaca, 2000. Bratislava, 76 s.

Lebowitz, M.O., O´Rourke, M.K., Rogan, S., Rese, J., Vande Water, P., Blackwell, A., Moschandreas, D.J., Gordon, S., Robertson, G. 2000: Inhalation Toxicology. 12(Suppl. 1), 139 – 144 Coden: INHTES; ISN: 0895-8378.

Polański, A., Smutikowski, K., 1978: Geochemia. SNP, Bratislava, 607 p.

Poltárska, K., 2000: Difúzna kontaminácia pôd niklom v regióne Galanta. Diplomová práca, PRIFUK, Bratislava, 76p.

SOBOCKÁ, J., BEDRNA, Z., JURÁNI, B., RAČKO, J. 2000: Anthropogenic Soils in the Morphogenetic Soil Classification System of Slovakia. In: Burghardt, W., Dornauf, Ch. (eds): Proceed. 1st Inter. Conf. SUITMA, July 12. – 18. 2000. University of Essen, vol. I, p. 277 – 281.

HEAVY METALS POLLUTION AND EVALUATION OF SOIL RESISTANCE TOWARDS CONTAMINATION

ZNEČISTENIE PÔD ŤAŽKÝMI KOVMI A HODNOTENIE ICH ODOLNOSTI VOČI KONTAMINÁCII

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ABSTRACT

Relation between soil contamination and physical and chemical properties of soil is solved by help scheme of evaluation soil resistance, where on basis physical and chemical properties we proposed classification system of soil evaluation towards contamination. Resulting is Map of soil resistance. *Proposed system of evaluation of soil resistance towards contamination is solved by authors in contract of Ministry of agriculture of SR – Potentials of risks from soil contamination SR (2003), where is described, too.*

KEYWORDS: pollution, heavy metals, soil, physical and chemical properties, resistance

ABSTRAKT

Vzťah medzi kontamináciou a fyzikálno-chemickými vlastnosťami pôd je riešený pomocou hodnotenia odolnosti pôd, kde na podklade fyzikálno-chemických vlastností pôd je navrhnutý klasifikačný systém hodnotenia odolnosti pôd voči kontaminácii. Výsledkom je mapový výstup Mapa odolnosti poľnohospodárskych pôd. *Navrhnutý systém hodnotenia odolnosti pôd je súčasťou autormi riešeného kontraktu s MP SR Potenciály rizík zo znečistenia pôd SR (2003, kde je aj popísaný).*

KĽÚČOVÉ SLOVÁ: kontaminácia, ťažké kovy, pôda, fyzikálno-chemické vlastnosti, odolnosť

INTRODUCTION

Hazardous metals are passing into soil by via natural and anthropogenetic process. Soil pollution in Slovakia is connected especially the industry, mining and metal treating activity. Their effects are expressing on the soil, where we can observe impairment of physical, chemical and biological properties, affecting of soil regime and increasing of receipt harmful substances with input into food chain.

Attendance of pollution in soil environment have a large effect to utilization soil resources and may cause high exposure for people living directly or in neighborhood place of pollution.

From this point of view of the effect on people there are three most important ways of exposition:

- Direct contact – through soil
- Through food chain
- Inhalation of volatile compounds

As hazard pollutants account As, Cd, Cr, Co, Cu, Hg, Ni, Pb and Zn.

MATERIAL AND METHODS

Hygienically status of the soil resources was assessed based on agronomic characteristics of farmland and criteria for the farmland contamination judgment by valid legislation. Soil of Slovak Republic hygienically status was elaborated based on soil characteristics and valid legislation (Resolution of Agricultural Ministry SR n. 531/ 1994-540). Data of soil pollution were assumed from Slovakia Soil Geochemical Atlas part V. – Soils (1999), as well as data of the Soil Information System of the soil Science and Conservation Research Institute.

RESULTS AND DISCUSSION

Soils distinguished with conjunction of contamination with heavy metals may be characterized as soils with high grades of potential jeopardize of quality live in quoted regions. Spatial reach of contamination have impact on the agricultural producer, where mainly small-scale producer producing for own necessity, can be expressively stricken group, which directly is jeopardized by soil contamination.

Table 1 Types of contamination over run B value according of Resolutions n. 531/ 1994-540

Contamination with 1 element	As I Cd I Co I Cr I Cu I Hg I Ni I Pb I Zn
Contamination with 2 elements	As, Cr I As, Cu IAs, Pb I As, Zn ICd, Cr I Cd, Pb I Cd, Zn I Cr, Cu I Cr, Ni ICu, Hg I Cu, Ni I Cu, Pb I Cu, Zn I Hg, Ni I Pb, Zn I
Contamination with 3 elements	As, Cd, Zn I As, Co, Hg I As, Cr, Ni I As, Cu, Hg I As, Cu, Ni I As, Cu, Zn I Cd, Cu, Ni I Cd, Cu, Zn I Cd, Hg, Pb I Cd, Ni, Zn I Cd, Pb, Zn I Cr, Cu, Zn I Cr, Cu, Zn I Cu, Hg, Ni I Cu, Hg, Zn I Cu, Ni, Zn
Contamination with 4 elements	As, Cd, Hg, Zn I As, Cu, Hg, Pb I As, Cu, Hg, Zn I As, Cu, Ni, Zn I Cd, Cr, Cu, Ni I Cd, Cu, Hg, Pb I Cd, Cu, Hg, Zn I Cd, Cu, Pb, Zn I Co, Cr, Cu, Ni I Co, Cr, Ni, Zn
Contamination with 5 elements	As, Cd, Hg, Pb, Zn I As, Cu, Hg, Ni, Zn I As, Cu, Hg, Pb, Zn I Cd, Cu,Hg, Pb, Zn I
Contamination with 6 elements	As, Cd, Cu, Hg, Pb, Zn I As, Co, Cr, Cu, Hg, Ni I

As originates from this, these areas are to contaminate by multi-element pollution, where we can create up to 6-element combination of contamination.

Relation between pollution and physical and chemical properties of soils is solved through the evaluation of resistance the soils, where on basis of physical-chemical properties of soils is suggested the classification system of soil resistance towards impurity. As a result has been constituted Map of resistance agricultural soil SR against contamination.

Figure 1 Spatial identification of polluted arable soil of Slovakia for B value

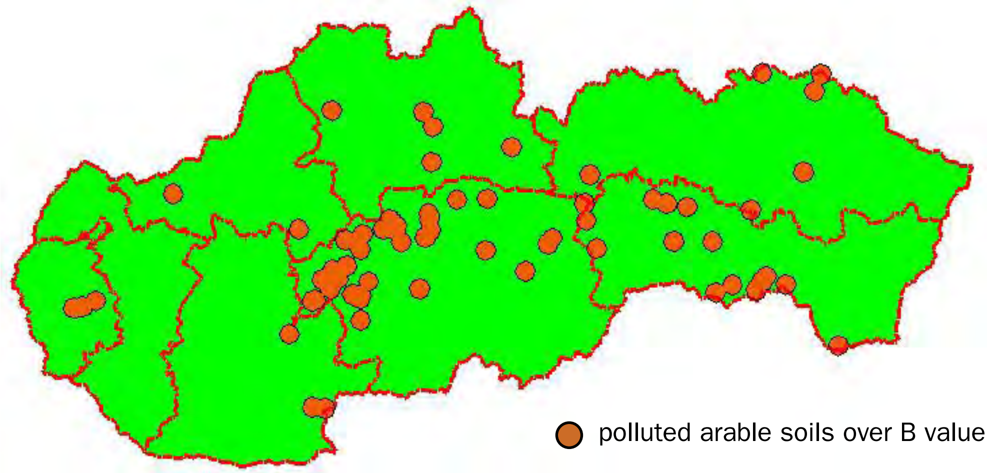


Table 2 Parameters for valuation soil's resistance

	Parameter	Symbol
1	Contents of skeleton	Sk
2	Graininess	Zr
3	Contents of carbonate	Rca
4	Content of humus	Qhf
5	Soil reaction	Ph
6	Depth of horizon	Hlb
7	Slope of relief	Rlf

Pointed valuation for individual parameters is based on agricultural properties of soils. To every parameter has been associated value as equivalent of his qualitative properties.

Table 3 Pointed range for individual parameters

Symbol	Skeleton and stone (x > 50%)	Points (min)	Points (max)	Skeleton and stone (x < 50%)	Points (min)	Points (max)
Sk	Contents of skeleton	0	1	Contents of skeleton	1	5
Zr	Graininess	1	4	Graininess	1	6
Rca	Contents of carbonate	0	8	Contents of carbonate	0	3
Qhf	Content of humus	0	3	Content of humus	0	8
Ph	Soil reaction	0	3	Soil reaction	0	3
Hlb	Depth of horizon	0	1	Depth of horizon	1	3
Rlf	Slope relief	0	4	Slope relief	0	4
Xoc	Sum	1	24	Sum	3	32

Calculation of evaluation of resistance is according to relation:

Xoc = Sk + Zr + Qhf + Rca + Ph + Hlb + Rlf

Table 4 Classification of soil according the resistance

Resistance of soils	Classification of resistance	Point	Number of group
High resistant soils	7	29 – 32	4
Good resistant soils	6	26 – 28	3
Resistant soils	5	22 – 25	4
Relatively resistant soils	4	16 – 21	6
Low resistant sensitive soils	3	11 – 15	5
Low resistant very sensitive soils	2	6 – 10	5
Non sensitive soils	1	2 – 5	4
Range of points		1 – 32	31

On the basis of soil resistance we can see (Tab. 2), that numerous class (Fig. 2) in Slovakia is 4th class of resistance (relatively resistance soil).

Figure 2 Distribution of soil resources (PPF) according to class's resistance

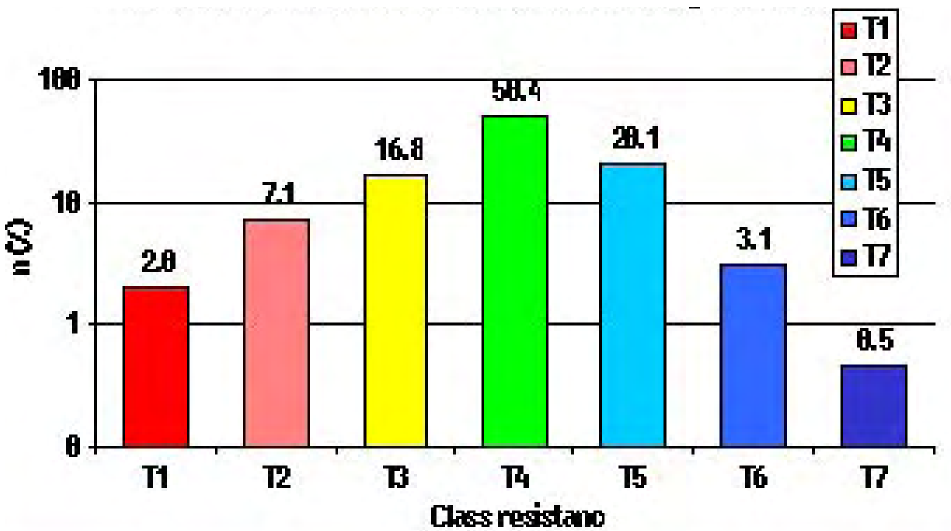


Figure 3   Distribution of soil resource according to evaluation of resistance

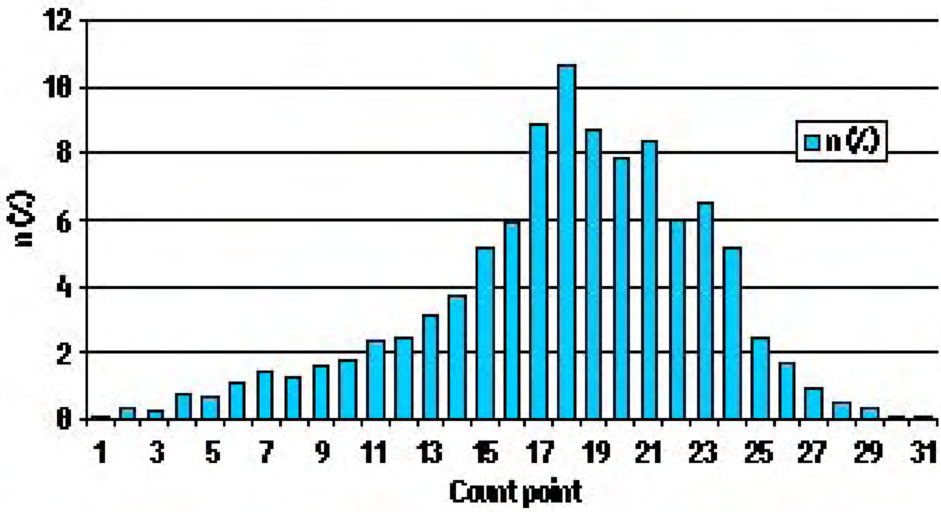
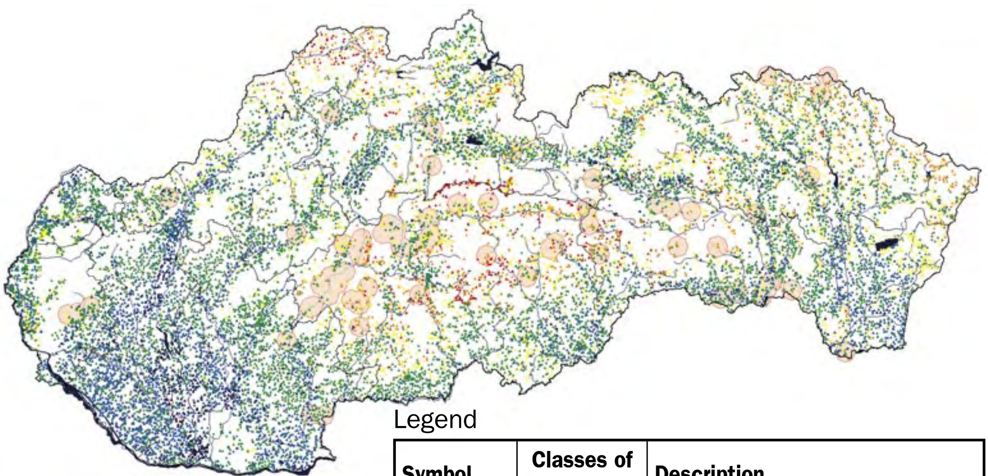


Figure 4   Map of soil resistance in Slovakia for selected area (B value of contamination)



Legend

Symbol	Classes of resistance	Description
	T1	Non sensitive soils
	T2	Low resistant very sensitive soils
	T3	Low resistant sensitive soils
	T4	Relatively resistance soils
	T5	Resistant soils
	T6	Good resistant soils
	T7	High resistant soils

Sign	Mean of sign
octagon	Area with contamination > B – value
	Boundary of Slovakia

CONCLUSIONS

Whereby the connection of contamination and physical -chemical properties has been created evaluation system for assessment of potential risk of polluted soils on production of health safe agricultural product.

This map ascent is well applied on:

- Recommendation next exploitation to contaminate soil in separate system maintenance
- Suggested price valuation soil
- Working-out financial sanction for subject contamination farmland soils.

REFERENCES

MATÚŠKOVÁ, L., VOJTÁŠ, J., 2003: Potenciály rizík zo znečistenia pôd SR. Kontrakt MPSR, VÚPOP, Bratislava.

AISOP-PC verz.1.1 (1991): Výberové sondy KPP 1961 – 1970, VÚPÚ Bratislava.

ČURLÍK, J. a kol., 1999: Geochemický atlas pôd Slovenska časť V. Pôdy. Bratislava.

REACTIVE ALUMINIUM AND IRON IN SELECTED PROFILES OF ANDOSOLS AND PODZOLS

Reaktívny hliník a železo vo vybraných profiloch andozemí a podzolov

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ABSTRACT

This paper is focused on evaluation of reactive aluminium and iron in genetic horizons of studied profiles of Andosols and Podzols. Four profiles were analysed for oxalate and pyrophosphate iron and aluminium and, moreover, also for activity of Al^{3+} in the soil solution by conventional soil survey. The paper offers a view on profile distribution of reactive forms of Al and Fe as for their quality and quantity. Two qualitatively different forms of Al and Fe were selectively extracted for each genetic horizon of studied profiles of Andosols and Podzols; i.e. organically associated Al, Fe (Al_{org}, Fe_{org}) and short-range-order minerals of Al and Fe (Al_{min}, Fe_{min}). We also discuss the solubility mechanisms of Al_{min} and Al_{org} in the aluminium buffer range as an important environmental parameter affecting phytotoxicity of soil environment in such acid soils.

Keywords: reactive aluminium, reactive iron, aluminium solubility, Andosols, Podzols

ABSTRAKT

Príspevok je venovaný hodnoteniu reaktívneho hliníka a železa v genetických horizontoch študovaných profilov andozemí a podzolov vo vybraných pohoriach Slovenska. Vo vzorkách horizontov štyroch študovaných profilov bolo stanovené množstvo železa a hliníka v extraktoch oxalátového a pyrofosforečnanového činidla a navyše bola experimentálne stanovená aktivita Al^{3+} iónu v suspenzii pôdy s 0.01 M roztokom $CaCl_2$. Uvedené analytické procedúry umožňujú hodnotenie profilovej distribúcie reaktívnych foriem Al a Fe. Hodnotené sú dve základné formy reaktívneho hliníka a železa, a to organicky viazané (Al_{org} a Fe_{org}) a nekryštalické minerálne formy (Al_{min}, Fe_{min}). V príspevku je venovaná pozornosť aj mechanizmom pufrovania pôdnej kyslosti substanciami Al_{org} a Al_{min} v pufračnej oblasti hliníka ako dôležitému environmentálnemu parametru ovplyvňujúcemu fytotoxicitu pôdneho prostredia v takýchto pôdach.

Kľúčové slová: reaktívny hliník, reaktívne železo, rozpustnosť hliníka, andozem, podzol

INTRODUCTION

Podzols and Andosols are typical representatives of acid soils in mountain regions of Slovakia. They both have some similar features in chemical properties, which result from very acid conditions and humid and cold pedoclimate. Although these soils principally differ in soil genesis, both leading processes (andic soil genesis as well as podzolization) are accompanied by creating of so-called reactive aluminium and iron phase. Reactive pedogenic aluminium and iron include namely short-range-order hydrous minerals such as allophone, imogolite or (oxy)hydroxydes and, moreover, organically associated aluminium and iron (DAHLGREN et al., 1993; GUSTAFSSON et al., 1998). Reactive part of Al and Fe plays a fundamental role in soil genesis of studied profiles influencing their chemical and physical character. Moreover it also determines environmental parameters and functions of such soils as for acidification processes, heavy metal mobility, anion retention, nutrient regime, etc.

Podzols and Andosols are known to be highly affected by an acidification stress in Slovakia especially due to their location and natural acid character. The mechanisms of acidity buffering together with aluminium solubility becomes crucial for such acid soils from the environmental point of view. A lot of work has been already done especially on aluminium chemistry of acidified soils and its fundamental impact on environment (e.g. WESSELINK et al., 1996; FARMER, 1999; JOHNSON et MCBRIDE, 1991; SKYLLBERG, 1999).

This paper deals with comparison between quality and quantity of reactive Al and Fe in different horizons of studied Podzols and Andosols. We used traditional selective extractions to estimate organically associated Al and Fe and non-crystalline mineral Al and Fe as described below. Oxalate extraction under darkness is used for dissolution of both organically associated and soluble short-range-order mineral portions whereas pyrophosphate agent selectively dissolves only Al and Fe organic complexes (WADA 1989). Without more complex separation technique considering also reactive silica, there is no way to realize more detail speciation of reactive aluminium and iron than organically bound (Al_{org}, Fe_{org}) and mineral (Al_{min}, Fe_{min}) pedogenic fraction. However achieved separation is sufficient to consider environmental importance of reactive phase and it creates the basic assumption for additional evaluation and understanding of Podzol and Andosol genesis and chemistry.

MATERIAL AND METHODS

Two profiles of Andosols and Podzols are evaluated by the study. Information on their location, classification and parent material is summarised by table 1. They are located in mountainous regions of Malá Fatra Mts. (Martinské hole), Kremnické vrchy Mts. and Vtáčnik Mts.

Soil profiles were sampled in various depths respecting genetic soil horizons. Air-dried and sieved (< 2 mm) soil samples were analysed for the soil reaction with 0.01 M $CaCl_2$ (1:5) as introduced by DLAPA et al. (1997) and Al content in supernatant was analysed by the aluminon method (PAUWELS et al., 1992) spectrophotometrically after 1 hour extraction on a horizontal shaker. Organic carbon (C_{ox}) was determined by the Walkley-Black method (USDA/NRCS/NSSC 1996). Non-crystalline aluminium and iron (Fe_{ox}, Al_{ox}) were extracted by the 0.2 M ammonium oxalate solution (1:100) under darkness by the procedure according to PAUWELS et al. (1992). Al and Fe were consequently analysed after mineralization (HACH Digesdahl at 440 °C) by aluminon method spectrophotometrically (Pauwels et al., 1992). Organically associated aluminium and iron (Al_{pyr}, Fe_{pyr}) were measured in the sodium pyrophosphate extracts (1:100) after 12 hour shaking on a horizontal shaker (procedure adopted from USDA/NRCS/NSSC 1996) and analysed by ICP-AES at the Geological Institute at Faculty of Natural Science, Comenius University in Bratislava.

Table 1 Information on studied profiles (nomenclature according to WRB '98)

	WRB ´98	X	Y	Altit.	Substrate	Location
		S-JTSK		M		
A1	Sili-Dystric Andosol	427 830	1 227 817	1 066	PA	Kremnické vrchy Mts.
A2	Fulvi-Dystric Andosol	454 933	1 237 126	1 235	PA	Vtáčnik Mts
P1	Cambic Podzol	439 172	1 189 187	1 380	Gr	Malá Fatra Mts.
P2	Cambic Podzol	439 023	1 188 899	1 400	Gr	Malá Fatra Mts.

PA – pyroxenic andesite, Gr – granite

Basic fractionation of reactive aluminium and iron is understood as described by the following scheme:

Relative Al, Fe ← – – — Al_{ox}, Fe_{ox}

→ Al_{min}, Fe_{min} ← – – — $Al_{ox} – Al_{pyr}$, $Fe_{ox} – Fe_{pyr}$

→ Al_{org}, Fe_{org} ← – – — Al_{pyr}, Fe_{pyr}

RESULTS AND DISCUSSION

We studied the contents and profile distribution of reactive aluminium and iron in genetic horizons of Andosol and Podzol profiles, where two different qualitative forms, namely Al/Fe-organic complexes (Al_{org}, Fe_{org}) and short-range-order Al/Fe-minerals (Al_{min}, Fe_{min}), were distinguished. We also try to follow individual relations between aluminium solubility, as an important environmental factor for acidification, and qualitative composition of reactive Al-phase considering differences between Andosols and Podzols. It is evident that soil chemistry of reactive iron and aluminium is quite different and must be described individually.

(i) reactive aluminium

Reactive aluminium content grows with depth and it reaches the maximum values in pedogenic subsurface B-horizons of both Andosols and Podzols, with consequential decrease in B/C horizons. It is evident that intensive weathering processes, which accompany andic soil genesis, evoke building of significant amount of pedogenic non-crystalline aluminium phase. Organically associated aluminium (Al_{org}) is a dominant fraction of reactive aluminium in the surface horizons of Andosols, which are rich in organic carbon (notice Fig. 1 i, ii). These horizons are known as non-allophanic ones, if classification criteria for andic properties are fulfilled, where high amount of organic carbon together with low pH inhibit formation of allophanelike minerals (Nanzyo et al., 1993). Higher amounts of mineral reactive aluminium (Al_{min}) occur in andic Bvn-horizons and it especially accounts for allophones, imogolite or gibbsitelike minerals.

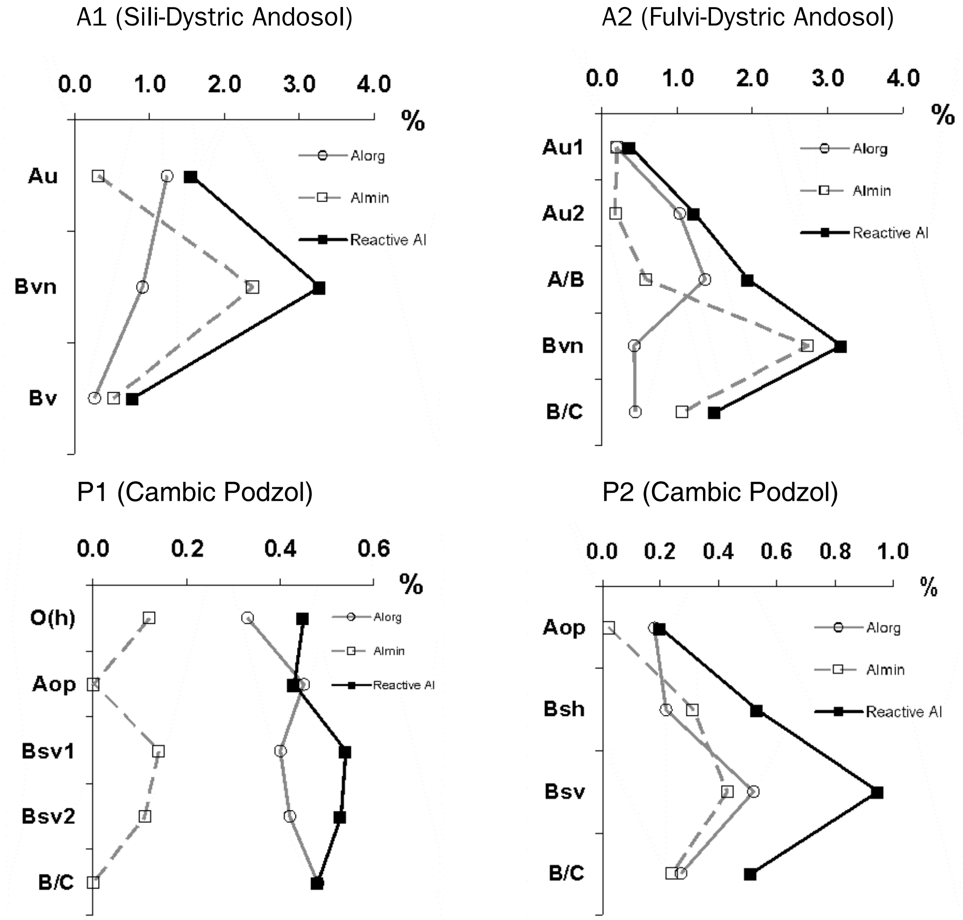
Table 2 Results of reactive aluminium and iron separation in studied Podzols and Andosols

	Horizon	pH $CaCl_2$	Cox	Al_{pyr} [%]	Al_{ox} [%]	$Al_{ox} - Al_{pyr}$ [%]	Fe_{pyr} [%]	Fe_{ox} [%]	$Fe_{ox} - Fe_{pyr}$ [%]	$(Al^{3+})_{0.01CaCl_2}$ [mol/dm³]
P1	O(h)	3.26	29.77	0.33	0.45	0.12	0.40	1.10	0.70	2.00 E^{-4}
	Aop	3.64	5.7	0.45	0.43	0.00	0.49	0.98	0.49	9.50 E^{-5}
	Bsv1	3.79	3.9	0.4	0.54	0.14	0.15	0.92	0.77	1.26 E^{-4}
	Bsv2	3.84	3.83	0.42	0.53	0.11	0.31	1.11	0.80	9.84 E^{-5}
	B/C	4.06	2.63	0.48	0.48	0.00	0.16	0.46	0.30	6.67 E^{-5}
P2	Aop	2.97	13.2	0.18	0.2	0.02	0.20	0.21	0.01	1.13 E^{-4}
	Bsh	3.57	2.78	0.22	0.53	0.31	0.34	0.90	0.56	9.72 E^{-5}
	Bsv	4.02	1.95	0.52	0.95	0.43	0.22	0.37	0.15	1.35 E^{-4}
	B/C	4.24	0.48	0.27	0.51	0.24	0.07	0.19	0.12	3.29 E^{-5}
A1	Au	4.22	10.2	1.24	1.56	0.32	0.54	0.32	0	5.34 E^{-5}
	Bvn	4.38	2.1	0.91	3.28	2.37	0.02	0.62	0.6	2.18 E^{-5}
	Bv	4.34	0.42	0.27	0.78	0.51	0.02	0.41	0.39	9.86 E^{-6}
A2	Au1	3.19	15.9	0.2	0.39	0.2	0.3	0.54	0.24	2.14 E^{-4}
	Au2	3.87	12	1.04	1.23	0.19	0.05	0.38	0.33	1.95 E^{-4}
	A/B	4.19	8.4	1.37	1.94	0.58	0.09	0.31	0.22	8.13 E^{-5}
	Bvn	4.51	6	0.44	3.18	2.74	0.04	0.21	0.17	1.66 E^{-5}
	B/C	4.7	0.9	0.45	1.51	1.06	0.03	0.05	0.02	7.08 E^{-6}

Podzolization is a process associated with aluminium motion through complexation with DOC and high saturation of organic matter by Al is a logical consequence of spodic processes. Figure 1 iii, iv shows the distribution of Al_{org} and Al_{min} in profiles of Cambic Podzols. Organically bound aluminium is the leading fraction in studied horizons. Mineral non-crystalline aluminium content increases in podzolic Bs-horizons where stabilization of DOC allows its creation.

Based on achieved results we can summarize that andic soil genesis induces higher contents of reactive aluminium compared to podzolization in similar pedo-climatic conditions. Well developed andic horizons contain approximately 3 times more reactive Al than well developed spodic horizons.

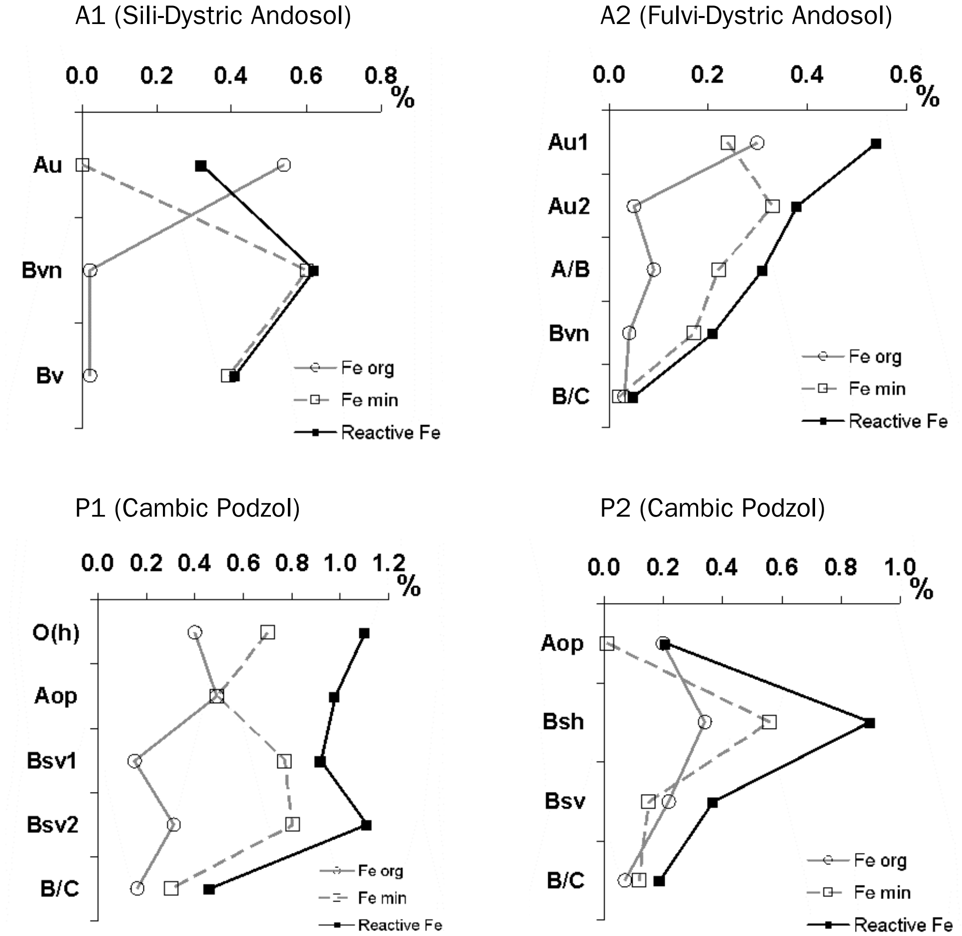
Figure 1 Profile distribution of reactive aluminium, its organic (Al_{org}) and mineral (Al_{min}) fractions



(ii) reactive iron

Reactive iron is typical for high thermodynamical stability of its short-range-order (oxy)hydroxides (Childs et al., 1990) therefore Fe chemistry differs from aluminium. Except of young and very humic topsoil horizons, the mineral iron (Fe_{min}) prevails in Andosol as well as Podzol profiles as proved by results shown by Figure 2. Total reactive iron (Fe_{ox}) accumulates in Bs-horizons of Podzols due to stabilization of Fe-organic substances. Silandic Andosol (Sili-Dystric Andosol – A1) contains the maximum content of reactive iron in cambic Bvn-horizon, where it develops partially due to andic processes and partially because of brunification. Well developed Fulvi-Dystric Andosol (A2), which is typical for deep incorporation of humus, shows the decrease in reactive iron with depth. It can be explained probably by mineralogy of parent material and degree of weathering. Some deviations in oxalate and pyrophosphate extraction for iron, which are described e.g. by USDA/NRCS/NSSC, 1996), cause relatively high uncertainty in reactive iron estimations and its result interpretation.

Figure 2 Profile distribution of reactive iron and its organic (Fe_{org}) and mineral (Fe_{min}) fractions



(iii) solubility of reactive aluminium

The results of Al separation discussed above show some regular differences in contents and distribution of its organic and inorganic forms in studied profiles. Many general assumptions with respect to environmental soil properties can be infer from idea on distribution and quality of reactive Al-substances, however, a solubility of reactive aluminium is probably the most discussed and important one. Aluminium solubility is directly related to buffering of soil acidity and releasing of phytotoxic Al^{3+} in the aluminium buffer range (in sense of ULRICH, 1983). It is especially non-crystalline Al, which is the most reactive in the soil acidity buffering.

Considering two different forms of reactive aluminium, i.e. non-crystalline Al-minerals (Al_{min}) and Al-organic complexes (Al_{org}), two different mechanisms of H^+ buffering exist. Both of them are accompanied by releasing of Al^{3+} into the soil solution following rules set by Eq. 1, or Eq. 2 respectively.

Dissolving of gibbsite ($Al(OH)_3$) quite fairly simulates buffering mechanism of Al_{min} in both Andosols and Podzols because of high range in logK° values.

Eq. 1 $Al(OH)_3$ (s) + $3H_2O \Leftrightarrow Al^{3+} + 3H_2O$; $\log(Al^{3+}) = \log K^{o} – 3pH$,

where logK° = 7,74 – 10,38 (commonly 8.04 by Lindsay 1979). The idea on buffering mechanisms with Al-saturated organic matter (Al_{org}) is generally accepted in simplified notation as proposed by Wesselink et al. (1996).

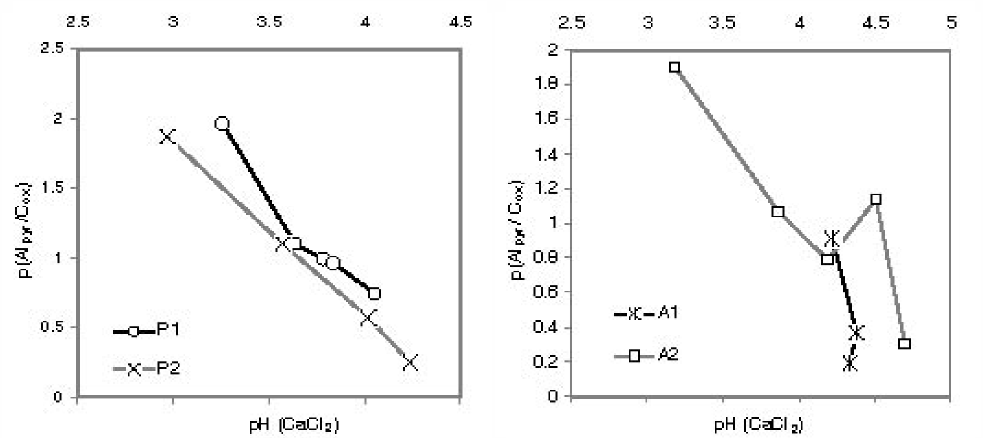
Eq. 2 $RAl^{(3-x)+} + xH^{+} \Leftrightarrow RHx + Al^{3+}$; $\log(Al^{3+}) = \log K_m – xpH – p([Al_{pyr}] / [C_{ox}])$,

where activity of Al^{3+} depends on pH, mixed equilibrium constant K_m and Al-saturation of organic matter $[Al_{pyr}] / [C_{ox}]$ The stoichiometric coefficient x is usually less than 2.

It can be noticed that the saturation of organic matter by Al, expressed as the negative common logarithm of ratio $[Al_{pyr}] / [C_{ox}]$ in fig. 3, nearly exponentially grows with increasing pH_{CaCl2}. Studied soil samples of Podzols and Andosols show similar dependence of $p([Al_{pyr}] / [C_{ox}])$ on pH at soil reaction less than approximately 4.2, which is a buffer range of Al_{org}.

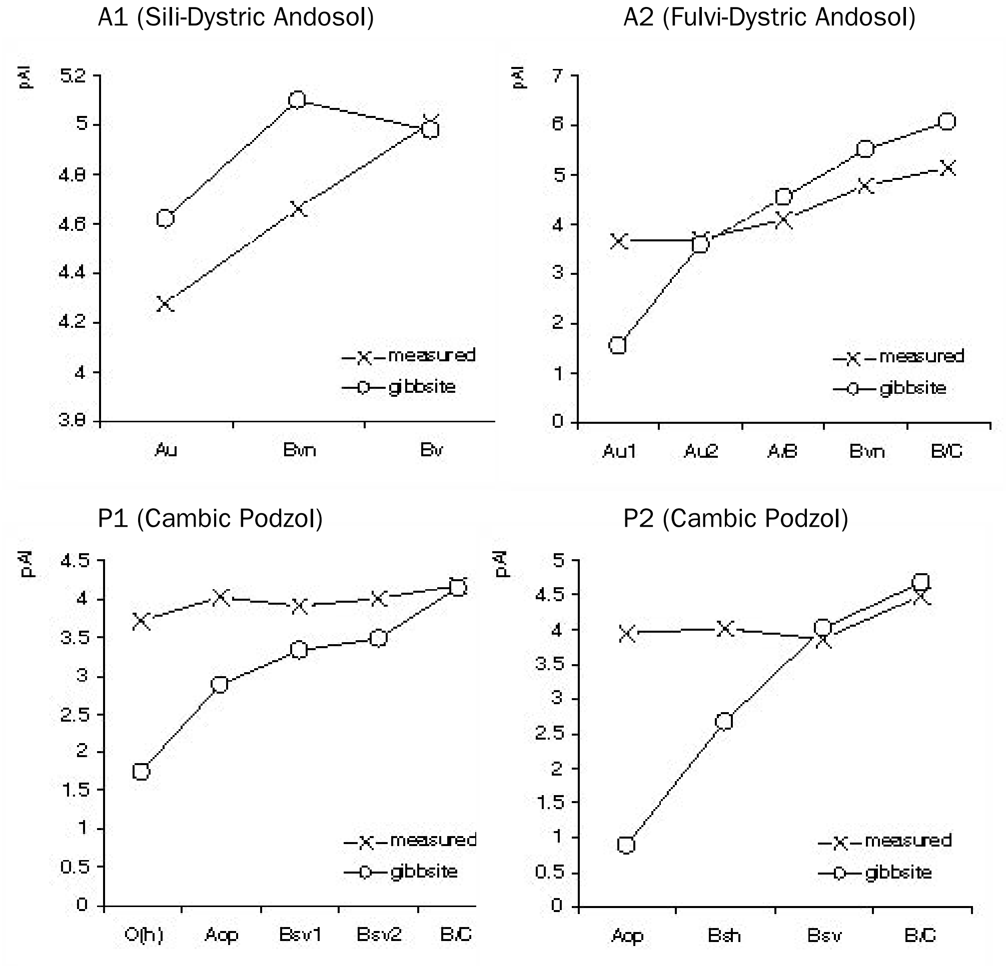
Figure 3 Al-saturation of organic carbon as a function of soil reaction

(i) podzolic soils (ii) andic soils



Relative low Al-saturation of organic substances in the topsoil horizons determines, that the Al_{org} buffering process releases less Al^{3+} into the soil solution compared to that, which is realised by dissolving of Al_{min} (e.g. gibbsite) or highly saturated Al_{org} at the same pH. Measured activities of Al^{3+} published in table 2 are highly undersaturated with respect Al_{min} in extremely acid topsoil horizons. Fig. 4 compares measured Al activities in studied genetic horizons of Andosols and Podzols with activities of Al^{3+}, which should be measured if aluminium solubility would be controlled by Al_{min} (gibbsite, logK° = 8.04).

Figure 4 A comparison of measured Al^{3+} activities with potential activities of Al^{3+} provided by reactive Al_{min} (namely gibbsite)



Measured field activities of Al^{3+} are much more lower in horizons with extremely acid pH compared to values calculated for Al_{min} (gibbsite) buffering mechanism by Eq. 1. It is apparent that Al_{org}-type of buffering mechanism occurs under such conditions. In the case of Aop-horizon (P1), there was observed even little decrease in Al^{3+} activity with decreasing pH, what disagree with Eq. 1 as well as Eq. 2 and it is probably caused by a leaching effect of podzolization.

CONCLUSIONS

We studied two profiles of Andosols and Podzols situated in similar climatic conditions of Slovakian mountains (Malá Fatra Mts., Kremnické vrchy Mts., Vtáčnik Mts.) for their reactive aluminium and iron. As expected both soil types show high amounts of reactive Al, however, Andosols contain approximately 3 times more of reactive Al than Podzols. In both soil types reactive Al increases with depth from the topsoil to the subsurface B horizons and it decreases in B/C horizons. It is the proof that both podsolization and andic soil genesis lead to creation of reactive Al phase. In the surface horizons of Andosols, organically associated aluminium prevails over short-range-order Al minerals. As published for some andic soils in Slovakia, high amount of organic carbon accompanied by low pH inhibits formation of allophane and Al-organic complexes together with opaline silica dominate in A-horizons (Balkovič et Bartošová, 2003). Andic Bvn-horizons show the significant content of short-range-order Al-minerals and the presence of allophanelike aluminosilicates can be expected here. Contrary to Andosols, organic substances of reactive aluminium dominate in whole profile of Podzols. Mineral Al occurs in higher contents only in spodic Bs horizons, however, usually in minor contents that organically associated one.

The fractionation of reactive iron to inorganic and organic part shows that mainly non-crystalline (oxy)hydroxides accumulates in Andosols as well as Podzols. Only A-horizons rich in organic matter contain more organic than mineral Fe-substances. This is fully in accordance with findings published by Childs et al. (1990) who assigned higher stability to mineral non-crystalline Fe. However the amount of iron in the profile is highly dependent on parent material.

The quality of reactive aluminium determines the buffering mechanisms of soil acidity. It is evident, that Al^{3+} activity is undersaturated with respect to the reactive Al-minerals in extremely acid horizons and it is controlled by organic Al substances here. Besides soil acidity, especially degree of organic matter saturation by aluminium play a fundamental role in the aluminium buffer range.

REFERENCES

Balkovič, J., Bartošová, M., 2003: Active aluminium, iron and silica in volcanic soils of Slovakia. Phytopedon (Bratislava), Vol. 2., 2003/1: p. 42 – 50.

Childs, C.W., Matsue, N., Yoshinaga, N., 1990: Ferrihydrite in volcanic ash soils of Japan. Soil. Sci. Plant. Nutr., 37: p. 299 – 311.

Dahlgren, R., Shoji, S., Nanzyo, M., 1993: Mineralogical characteristics of volcanic ash soils. In: Shoji, S., Nanzyo, M., Dahlgren, R.A., 1993: Volcanic ash soils: Genesis, Properties and Utilization. Developments in Soil Science No 21, Elsevier, Amsterdam.

Dlapa, P., Juráni, B., Kubová, J., 1997: Chemical conditions of forest soils in the village of Nálepkovo surroundings (in Slovak). In: Šomšák, L. (ed.): Rozpad sekundárnych smrečín okolia obce Nálepkovo. Univerzita Komenského, Bratislava, s. 16 – 24.

Farmer, V.C., 1999: The solubility characteristics of organic Al precipitants in allophanic Bs horizons could mimic those of Al hydroxides, and indicate the solubility of associated allophanes. European Journal of Soil Science, 50: p.

Gustafsson, J.P., Lumsdon, D.G., Simonsson, M., 1998: Aluminium solubility characteristics of spodic B horizons containing imogolite-type minerals. Clay Minerals, 33: p. 77 – 86.

Johnsson, M.G., McBride, M.B., 1991: Solubility of aluminium and silicon in acidified spodosols: Evidence for soluble alumosilicate. In: Wright, R.J. (ed.): Plant-soil interactions at low pH. Kluwer Academic Publishers, Netherlands: p. 15 – 24.

Lindsay, W.L., 1979: Chemical equilibria in soils. John Wiley and Sons, New York – Chichester – Brisbane – Toronto, 449 pp.

NANZYO, M., DAHLGREN, R., SHOJI, S., 1993: Chemical characteristics of volcanic ash soils. In: SHOJI, S., NANZYO, M., DAHLGREN, R.A., 1993: Volcanic ash soils: Genesis, Properties and Utilization. Developments in Soil Science No 21, Elsevier, Amsterdam.

PAUWELS, R.L., VAN RANST, E., VERLOO, M., NVONDO ZE, A., 1992: Manuel de laboratoire de pedologie – Méthodes d´analyses de sols et de plantes, equipment, gestion de stocks de verrerie et de produits chemiques. Publications Agricoles – 28, Dschang-Bruxelles, 265 pp.

SKYLLBERG, U., 1999: pH and solubility of aluminium in acidic forest soils: a consequence of reactions between organic acidity and aluminium alkalinity. European Journal of Soil Science, 50: p. 95 – 106.

ULRICH, B., 1983: Soil acidity and its relations to acid deposition. In: ULRICH, B., PANKRATH, J., (EDS.): Effect of accumulation of air pollutants in forest ecosystems. D. Reidel Publ. Co., Dordrecht: p. 127 – 146.

USDA/NRCS/NSSC, 1996: Soil Survey Laboratory Methods Manual – Soil Survey Investigation Report No 42, 716 pp.

WADA, K., 1989: Allophane and Imogolite. In: DIXON, J.B., WEED, S.B. (EDS.): Minerals in soil environment. 2nd ed. Soil. Sci. Soc. Amer. No. 1: p. 1051 – 1087.

WESSELINK, L.G., VAN BREEMEN, N., MULDER, J., JANSSEN, P.H., 1996: A simple model of soil organic matter complexation to predict the solubility of aluminium in acid forest soils. European Journal of Sloil Science, 47: p. 373 – 384.

COMPREHENSIVE CHANGES OF SOIL ORGANIC MATTER PARAMETERS ON EUTRIC ARENOSOL DURING MONITORING PERIOD

SÚHRNÉ ZMENY PARAMETEROV PÔDNEJ ORGANICKEJ HMOTY NA REGOZEMI ARENICKEJ POČAS MONITOROVACIEHO OBDOBIA

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ABSTRACT

In presented paper comprehensive changes of soil organic matter of Eutric Arenosol on key monitoring locality Moravský Ján are evaluated. Organic carbon content of Eutric Arenosol is very low, about 1% and this value is characteristic for this soil type. During monitoring period (1993 – 2003) changes of C_{org} had fluctuated trends and were in agreement with N_t changes. Between C_{org} and N_t on Moravský Ján locality significant linear correlation was found. Qualitative parameter of SOM – C_{HA}/C_{FA} showed predomination of fulvic acids over humic acids and it is characteristic for this soil type. During monitoring period no substantial changes of this parameter were observed. Value of another qualitative parameter of SOM Q_6^4, mainly in last two sampling, increase and could be showed on more labile structure of Eutric Arenosol SOM. Besides basic SOM parameters on this locality also humic acids (HA) were isolated and chemical structure of HA (elemental analyses, carboxylic groups, optical parameter and ^{13}C NMR parameters) is determined through the time scale. In this paper values of these parameters from sampling 1995, 1998 and 2001 are showed. On the basis data receiving from elemental analyses, optical parameter, carboxylic groups and data from ^{13}C Nuclear Magnetic Resonance Spectroscopy, it can be suggested oxidation trends in chemical structure of Eutric Arenosol HA (increase of O and O/C, decrease of optical parameter $E_6^{1\%}$, COOH groups and decrease of α) during monitoring period.

Keywords: Eutric Arenosol, organic carbon, total nitrogen, C_{HA}/C_{FA}, Q_6^4, humic acids, elemental analyses, carboxylic groups, ^{13}C NMR

ABSTRAKT

V predloženom príspevku sú hodnotené súhrnné zmeny v základných kvantitatívnych ako aj kvalitatívnych parametroch pôdnej organickej hmoty (SOM) počas monitorovacieho obdobia (1993 – 2003) regozeme kultizemnej, variete silikatovej na eolickych pieskoch na kľúčovej monitorovacej lokalite Moravský Ján.

Hodnota organického uhlíka na uvedenej lokalite sa pohybuje okolo 1% a je charakteristická pre daný pôdny typ. Počas monitorovacieho obdobia zmeny C_{org} mali kolísavý charakter a boli v zhode so zmenami celkového dusíka, čo potvrdzuje aj signifikantná lineárna korelácia medzi C_{org} a N_t. V skupinovom zložení humusu prevládajú fulvokyseliny, čo je charakteristické pre uvedený pôdny typ. V priebehu monitoringu neboli pozorované podstatné zmeny v pomere C_{HK}/C_{FK} avšak hodnoty optického parametra Q_6^4 hlavne v posledných odberoch boli vyššie, čo môže poukazovať na zlabilnenie štruktúry POH. Okrem základných parametroch SOM boli na lokalite Moravský Ján v rokoch 1995, 1998 a 2001 izolované aj humínové kyseliny (HK) a stanovené ich základné chemické a spektrometrické parametre. Na základe výsledkov získaných z elementárnej analýzy, stanovenia karboxylových skupín a údajov získaných z ^{13}C NMR spektier môžeme konštatovať, že v priebehu monitorovacieho obdobia boli pozorované v štruktúre HK oxidačné trendy, ktoré môžu viesť k zlabilneniu štruktúry humínových kyselín.

KĽÚČOVÉ SLOVÁ: regozem kultizemna, silikatova varieta na eolickych pieskoch, organický uhlík, celkový dusík, C_{HA}/C_{FA}, Q_6^4, humínové kyseliny, elementárna analýza, karboxylové skupiny, ^{13}C NMR

INTRODUCTION

Soil organic matter (SOM) represents one of the most important parameters controlling physical, chemical and biological properties in soil. SOM is a key attribute of soil quality, because it is a nutrient sink, enhances soil structural conditions, and promotes biological activity. At present time SOM was also cited as "perhaps the single most important indicator of soil quality" (National Research Council, 1993). For this reason content and quality of soil organic matter is carried out in Soil Monitoring System.

At the preset time, soil monitoring includes three subsystems:

1. Basic network of monitoring localities on agricultural and forest soils
2. Area investigation of agriculture soils contamination
3. The soil monitoring on selected typical key localities

The third subsystem contributes to particular observation of soil properties evaluation. In addition to organic carbon content (C_{org}) as quantitative parameter and basic qualitative parameters (ratio of humic acids to fulvic acids and optical parameter Q_6^4) on key monitoring localities also chemical structure of humic acids (HA) is also investigated. Humic acids represent predominant fraction of humic substances that are very active in interaction with organic/inorganic contaminants and correspond to 16% C turnover (STEVENSON, 1994, SPITELLER, HAIDER, 1997, SENESI and LOFREDO, 1999, DOANE et al., 2003). At the present days characterization of EUROSOILS by isolating their HA components and investigating their compositional, structural, and functional properties in EUROSOILS-Project is realized (SENESI et al., 2003). The knowledge of the composition, structure, and functionalities of HA is essential for understanding and predicting their chemical behaviour and reactivity towards soil contaminants.

On key monitoring localities elemental analyses, carboxylic groups, optical parameter and parameters of ^{13}C nuclear magnetic resonance (NMR) spectra, which represent chemical structure of HA are determined.

In this paper comprehensive changes of basic quantitative and qualitative parameters of SOM and also detailed changes in chemical structure of HA on Eutric Arenosol are showed.

MATERIAL AND METHOD

On locality Moravský Ján (Eutric Arenosol) soil samples were collected from topsoil (0 – 10 cm). The basic chemical and physical parameters of this key monitoring locality you can find in Kobza et al., (2003). In this paper organic carbon content (C_{org}) and total nitrogen (N_t) from the top soil of soil sampling collected from 1995 to 2003 and basic qualitative parameters of SOM (C_{HA}/C_{FA} and Q_6^4) from period 1995 – 2000 are reported. Soil samples on Eutric Arenosol for particular characterization of SOM (chemical structure of HA) have been collected every three years. In this paper data from sampling 1995, 1998 and 2001 are showed.

C_{org} was determined by wet combustion (Nikitin, 1972). Humus fractionation (C_{HA}/C_{FA}, Q_6^4) was determined by Kononovova and Belčikova method (1961). Humic acids were isolated according to the IHSS method (Swift, 1996). Elemental analysis of HA was determined using Perkin-Elmer CHN 2400 analyzer. Oxygen was calculated by difference. The carboxyl groups of HA were determined according to Schnitzer & Gupta (1965). Optical density values of 1% solution of HA at 600 nm ($E_6^{1\%}$) were obtained using a Specol 11 spectrometry. ^{13}C Nuclear Magnetic Resonance (NMR) spectra of HA were obtained using a Varian VXR-300 NMR spectrometer at an observation frequency of 75.4 MHz for ^{13}C. Spectra were divided into the following chemical shift regions:

15 – 43	ppm alkyl C (C-C)
43 – 87	ppm O-alkyl and di-O-alkyl C (C-O, C-N)
87 – 106	ppm anomeric C
106 – 143	ppm aromatic and olefinic C (C-C, C-H)
143 – 157	ppm aromatic and phenolic C (C-O)
157 – 184	ppm karboxyl amide or ester C
184 – 230	ppm carbonyl (in keto or aldehydic groups)

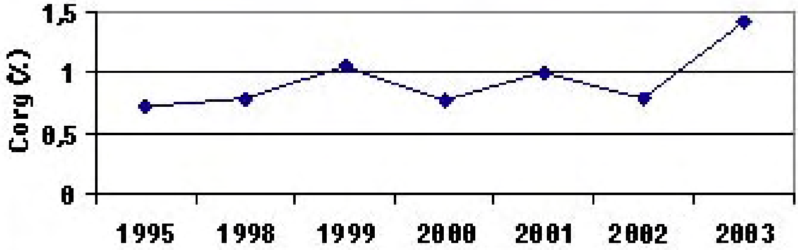
Aromatic carbon (C_{ar} %) is represented in the δ 106 – 157 ppm spectral region. Aliphatic carbon (C_{aliph} %) is represented in the δ 15 – 106 ppm spectral region. The degree of aromaticity of HAs (α) was calculated by the procedure of Hatcher (3).

RESULTS AND DISCUSSION

Changes in basic quantitative and qualitative parameters of soil organic matter

During monitoring period content of organic carbon (C_{org}) on evaluated locality Moravský Ján had fluctuated character and its value according to Sotáková was low (Sotáková, 1982). Values of C_{org} about 1% are typical for this soil types, because Eutric Arenosols are characteristic by the lowest amount of soil organic matter among soil types of Slovakia (Linkeš et al., 1997; Kobza et al., 2002). Also at the present time (third monitoring sampling realized in 2002) average values of C_{org} on Eutric Arenosols are about 1.2% (Barančíková, 2003).

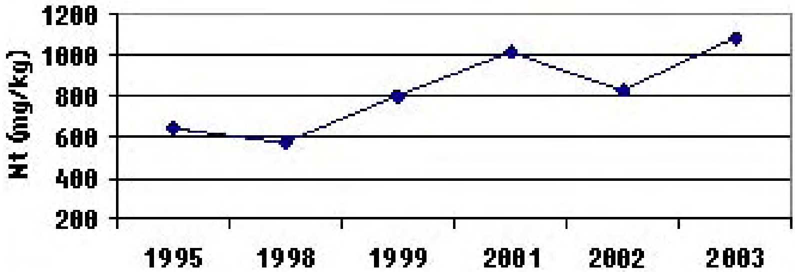
Figure 1 Organic Carbon content (C_{org}) on Eutric Aerosol during monitoring period



Values of organic carbon on locality Moravský Ján are below threshold value of C_{org} for agricultural soils, because LOVELAND and WEBB (2003) reported as threshold value for soil organic carbon 2%, below which potentially serious decline in soil quality will occur.

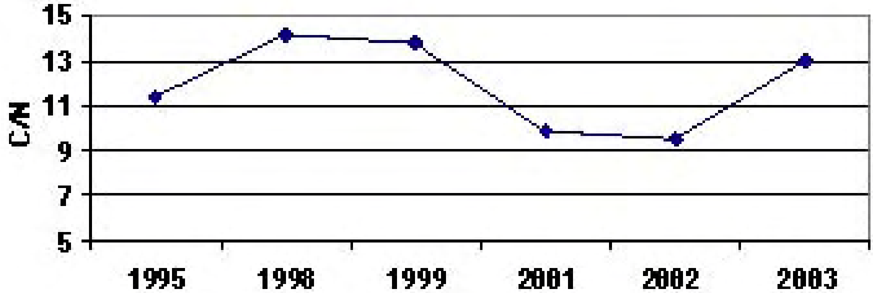
In agreement with organic carbon content on evaluated Eutric Arenosol are also values of total nitrogen (N_t). Between C_{org} and N_t on Moravský Ján locality significant linear correlation was found (R = 0.84**, n = 6). Values of N_t during monitoring period are in range from 600 to 1 090 mg/kg and its can be seen on Figure 2. From 1999 this parameter has slight increasing tendency.

Figure 2 Total nitrogen (N_t) on Eutric Aerosol during monitoring period



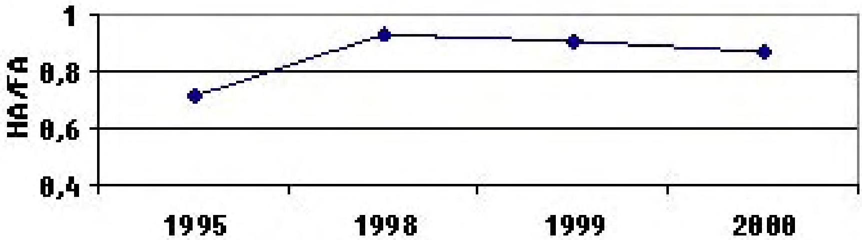
One of most important qualitative indicator of soil organic matter is ratio C/N. FRANZLUBBERS (2002) found high stratification ratios of soil C and N pools could be good indicators of dynamic soil quality, independent of soil type and climatic regime. During monitoring observation values of this parameter were from 9 to 14 and have fluctuated tendency (Figure 3). According to Sotáková (1982) these values of C/N ratio indicated from medium to low supply of total nitrogen in soil organic matter.

Figure 3 C/N ratio of Eutric Aerosol during monitoring period



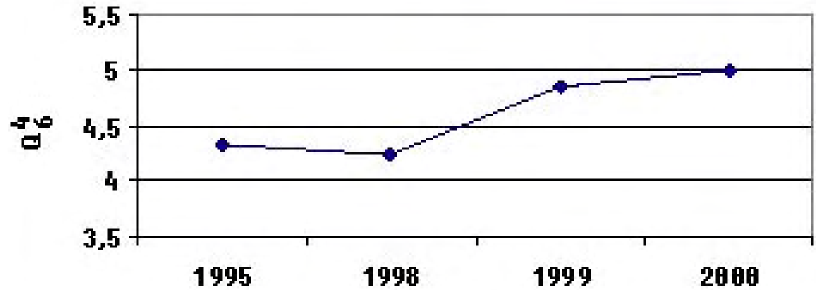
Another basic indicator of soil organic matter quality is ratio of humic and fulvic acids (C_{HA}/C_{FA}). During monitoring period values of C_{HA}/C_{FA} were below 1 (Figure 4), it means in SOM of evaluated Eutric Arenosol (Moravský Ján) fulvic acids are dominant. These values of C_{HA}/C_{FA} are characteristic for this soil type and are in agreement with average value of this parameter on Slovak Eutric Arenosols determined at previous period (LINKEŠ et al., 1997).

Figure 4 Ratio HA/FA on Eutric Aerosol during monitoring period



Value of another qualitative parameter of SOM Q_6^4 was in range from 4.2 to 5 (Figure 5). In last two observed sampling value of this parameter has increased tendency. It can be showed on more labile structures in soil organic matter of evaluated Eutric Arenosol.

Figure 5 Optical parameter Q_4^6 of Eutric Arenosol during monitoring period



Changes in chemical structure of humic acids

Humic acids represent together with fulvic acids and humin three basic fraction of soil organic matter. Collection of selected parameters of HA can be more sensitive as basic qualitative parameter C_{HA}/C_{FA}. Value of HA and FA ratio could not change, however some changes in chemical structure can be observed. These changes can express actual trend in changes of humus quality. Some of these chemical parameters of HA can be very useful for classification of soil into specific taxonomic unit (WEBER, 1997). In this paper detailed characteristic of comprehensive changes in HA chemical structure of Eutric Arenosol from three sampling 1995, 1999 and 2001 is presented.

Basic parameter of determination of HA structure is elemental analyses C, H, N, O, which reflects the featured of soil humification. Higher amount of carbon and lower percentage of hydrogen is characteristic for higher humification of humic acids structure. Carbon and hydrogen content (42 atom. % C and 37% H) of Eutric Arenosol HA is very similar to Ortic Luvisol HA (BARANČÍKOVÁ, 1999). During monitoring period values of C, H. N had fluctuated character, but content of oxygen and values of O/C ratio increase (Table 1). Higher values of O can indicate slight oxidation of organic matter characteristic for intensive arable land (Rosel et al., 1995). Higher value of O/C ratio can show lower aromaticity of HA. Similar oxidation trend as Eutric Arenosol also on more oil types of intensive agriculture land was observed (Barančíková, 2002).

Table 1 Basic parameters of chemical structure of Eutric Arenosol HA on Moravský Ján locality

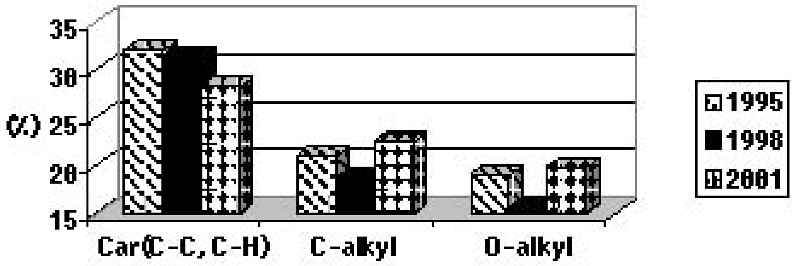
year/ parameter	atom. %			meq/1g HA			anomeric C	%		α
	C	H	O	O/C	COOH	E6		C_{aliph}	C_{ar}	
1995	42.6	37.25	16.69	0.392	3.62	22	1.56	41.77	38.6	48.03
1998	41.7	38.3	16.8	0.403	3.42	21	2.84	37.15	38.99	46.14
2001	42.14	36.96	17.49	0.415	2.5	13	4	46.4	34.9	42.9

Another important parameter of HA chemical structure is content pf carboxylic groups, because progress in humification is characteristic by carboxylation of aliphatic parts of HA. COOH groups play very important environmental role in the bonds of metal ions by soil HA (Barančíková et al., 1997; Cocoza and Miano, 2002). HA of evaluated Eutric Arenosol in comparison to another soil types has medium content of carboxylic groups. During monitoring period degrease of COOH groups was observed (Table 1). This tendency is in agreement with oxidation trend of HA.

Spectral methods in visible spectral region represent great contribution to knowledge of chemical structure of HA. The evaluation of the brown colour of HA, based on their optical properties, may be an indication of extent of humification. In this work optical parameter $E_6^{1\%}$ which represents the absorbance coefficient for 1% HA solution at 600 nm, recommended by Kumada (1987) is adopted. Higher value of $E_6^{1\%}$ represents higher humification degree (Kumada 1987). As can be seen from Table 1 during monitoring period decrease of this parameter was determined. Orlova and Bakina (2002) reported decrease of optical parameter value on soils without sufficient adding of manure. Decrease of $E_6^{1\%}$ and COOH indicate more labile HA structure and it I in agreement with oxidation trend observed in elemental composition of Eutric Arenosol HA.

One of the most promising spectroscopic method for HA chemical structure determination is Nuclear Magnetic Resonance ^{13}C. ^{13}C NMR enables quantitative determination of individual carbon types in humic acid structure (Mather et al., 2000). In comparison to another soil types (Chernozem, Planosol), HA of Eutric Arenosol have medium aromaticity degree (Barančíková, 1999) likewise elemental composition, optical parameter and COOH groups. During monitoring period, mainly in comparison 1st and last sampling, decrease of aromatic structure was observed (Table 1). Decrease of C_{ar} and increase of C_{aliph} reflected in decrease of aromaticity degree (Table 1). Similar decrease of α also during monitoring of Andozem and Luvisol HA wee observed (Barančíková, 2002). Decease of aromaticity and carboxyl groups is characteristic for limitation of humification processes (Olk, 1995; Kaczmarek and Dziadowiec, 1999). At detail analyse which types of carbon are responsible for these changes decrease of aromatic and olefinic carbon (C-C, C-H structure) was observed, however value of alkyl C increase on minimum and O-alkyl structure were almost identical in comparison fisrst and last sampling (Figure 6). Increase of C_{aliph} during monitoring period can be due to partial O-alkyl C, but mainly substantial increase of anomeric carbon in last sampling (Table 1), despite of their lox content in comparison of O-alkyl/C-alkyl carbons.

Figure 6 Selected types of carbon of Eutric Arenosol HA during monitoring period



CONCLUSIONS

Key monitoring locality of Eutric Areosol – Moravský Ján contents low amount of soil organic carbon and it is characteristic for this soil type. During monitoring period changes of C_{org} had fluctuated trends and were in agreement with N_t changes. Between C_{org} and N_t on Moravský Ján locality significant linear correlation was found.

Qualitative parameter of SOM – C_{HA}/C_{FA} showed predomination of fulvic acids over humic acids and it is characteristic for this soil type. During monitoring period no substantial changes of this parameter was observed. Value of another qualitative parameter of SOM Q_6^4, mainly in last two sampling, increase and could be showed more labile structure of Eutric Areosol SOM.

Also oxidation trends in chemical structure of Eutric Areosol HA (increase of O and O/C, decrease of optical parameter $E_6^{1\%}$, COOH groups and decrease of α) observed during monitoring period could be showed on same trends.

REFERENCES

Barančíková, G., 2003: Monitoring obsahu a kvality pôdnej organickej hmoty. In: Kobza a kol.: Výsledky čiastkového monitorovacieho systému – Pôda, ako súčasť Monitoringu životného prostredia SR za rok 2003. Priebežná správa, Bratislava, s.

Barančíková, G., 1999: Monitoring obsahu a kvality pôdnej organickej hmoty. In: Kobza a kol.: Výsledky čiastkového monitorovacieho systému – Pôda, ako súčasť Monitoringu životného prostredia SR za rok 1999. Priebežná správa, Bratislava, s. 67 – 84.

Barančíková, G., 2002: Monitoring obsahu a kvality pôdnej organickej hmoty. In: Kobza a kol.: Výsledky čiastkového monitorovacieho systému – Pôda za obdobie 1997 – 2001 (2. cyklus). Bratislava, s. 54 – 73.

Barančíková, G., Brečková, V., Dlugoš, J., 1997: Retencia Cd pôdami a humínovými kyselinami. Rostl. Výr., vol. 43, s. 107 – 112.

Cocozza, C., Miano, T.M., 2002: Structural resolution of metal-humic acids interactions through deconvolution FT-IR spectroscopy. In: Humic Substances: Natures's most versatile materials, Proceedings, Boston, s. 264 – 267.

Doane, T.A., Devevre, O.C., Horwáth, W.R., 2003: Short-term soil carbon dynamics of humic fractions in low-input and organic cropping systems. Geoderma, vol. 114, s. 319 – 331.

Franzluebbers, A.J., 2002: Soil orgnic matter stratification ratio as an indiator of soil quality. Soil. Till. Res., vol. 66, s. 95 – 106.

Kaczmarek, J., Dziadowiec, H., 1999: Humification process of soil organic matter in various forest stand. Humic Subst. Envir., vol. 1, s. 27 – 33.

Kobza., J., Schlosserová, J., Pavlenda, P., Barančíková, G., Čepková, V., Došeková, A., Fulajtár, E., Houšková, B., Ilavská, B., Makovníková, J., Matúšková, L., Styk, J., 2003: Výsledky čiastkového monitorovacieho systému – Pôda, ako súčasť Monitoringu životného prostredia SR za rok 2003. Priebežná správa, Bratislava, s.

Kononovová, M.M., Beľčiková, N.P., 1961: Uskorenyje metody opredelenija sostava gumusa. In: Počvovedenije (Moskva), N. 10, pp. 125 – 129.

Kumada, K., 1987: Chemistry of soil organic matter. Tokyo, Elsevier, s. 17 – 30.

Linkeš, V., Kobza, J., Švec, M., Ilka, P., Pavlenda, P., Barančíková, G., Matúšková, L., 1997: Monitoring pôd lovenskej republiky. Súčasný stav monitorovaných vlastností. Bratislava, 128 s.

Loveland, P., Webb, J., 2003: Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. Soil Till. Res., vol. 70, s. 1 – 18.

Mathers, N.J., Mao, X.A., Xu, Z.H., Saffigna, P.G., Berners-Price, S.J., Perera, M.C.S., 2000: Recent advances in the application of 13C and 15N NMR spectroscopy to soil organic matter studies. Aust. J. Soil Res., vol. 38, s. 769 – 787.

National Research Council, 1993: Soil and Water Quality: an Agenda for Agriculture. National Academy Press, Wahington, D.C., 516 pp.

Nikitin, B.A., 1972: Metody opredelenija soderžanija gumusa v počve. In: Agrochimija, N. 3, pp. 123 – 125.

Olk, D.C., Casman, K.G., Fan, T.W.M., 1995: Characterization of two humic acid fractions from a calcareous vermiculit soil: implications for the humification process. Geoderma, vol. 65, s. 195 – 208.

Orlova, N.E., Bakina, L.G., 2002: Sovremennyje procesy gumusoobrozovanija v kuľturnych dernovo-podzolistych počvach severo-zapada Rosiji. Agrochimija, č. 11, s. 5 – 12.

Rosell, R.A., Zech, W., Haumaier, L., Miglierina, A.M., 1995: Physicochemical properties of humus of a semiarid pampaean soil under two crop rotations. Arid Soil Research and Rehabilitation, č. 9, s. 379 – 387.

Senesi, N., D´Orazio, V., Ricca, G., 2003: Humic acids in the first generation of EUROSOLS. Geoderma, vol. 116, s. 325 – 344.

Senesi, N., Loffredo, E., 1999: The chemistry of soil organic matter. In: Sparks, D.L. (Ed.), Soil Physical Chemistry, ed. CRC Press, Boca Raton, s. 239 – 370.

Schnitzer, M., Gupta, U.C., 1965: Determination of acidity in soil organic matter. In: Soil Sci. Soc. Am. Proc., vol. 29, pp. 274 – 277

Sotáková, S., 1982: Organická hmota a úrodnosť pôdy. Bratislava, Príroda, 234 s.

Spiteller, M., Haider, K., 1997: Characterization of the interaction of natural organic matter and xenobiotics. In: Drozd, J., Gonet, S.S., Senesi, N. Weber, J. (eds.): The role of humic substances in the ecosystems and inenvironmental protection. Wroclaw, s. 689 – 695.

Stevenson, F.J.: Humus Chemistry: Genesis, Composition, reactions, In: ed. Wiley, New York, 496 s.

Swift, R.S., 1996: Organic matter characterization. In: Methods of soil analysis. Part 3. Chemical Methods-SSSA, Book Series, vol. 5, pp. 1011 – 1069.

Wegner, K., Grzelakowska, A., Gonet, S.S., Pempkowiak, J., 1999: Parameters of humic acids as diagnostic features of the soils. Humic Substances in Ecosystems 3, s. 117 – 124.

THE INFLUENCE OF SOIL pH VALUE AND SOME SORPTION PARAMETERS ON SOIL CALCIUM MOBILITY

VPLYV pH PÔDY A NIEKTORÝCH SORPČNÝCH PARAMETROV NA POHYBLIVOSŤ PÔDNEHO VÁPNIKA

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ABSTRACT

Due to polyfunctional significance of soil calcium as well as the application of common soil extract Mehlich III for some years the agrochemical practice feels the need to declare at least the "border" or the "treshold" extractable soil calcium concentration.

On the basis of the regressional-statistical evaluation of a relative high populated (n = 952) soil data set having medium coarse structure assessing high significant relation Mehlich's III extractable calcium – exchangeable soil pH the border-line concentration for this Ca-species has been proposed.

Taking into consideration both mentioned statistical relation, pedological and agrochemical aspects of soil calcium – aluminium reactions, some soil sorption parameters and several compatibility with previous soil extract Mehlich II the reasonable treshold Ca-level for medium coarse soils such as 1 400 mg Ca.kg^{-1} it has been proposed.

KEYWORDS: Mehlich II and Mehlich III soil extractants, extractable soil calcium, exchangeable soil pH, cation exchange capacity, treshold concentration

ABSTRAKT

Na základe signifikantnej regresnej závislosti medzi extrahovateľným (Mehlich III) pôdnym vápnikom a výmenným pH pôdy odhadla sa „prahová“ koncentrácia Ca v uvedenom výluhu pre súbor stredne ťažkých pôd (n = 952). Navrhovaná hodnota 1 400 mg Ca.kg^{-1} približne zodpovedá hodnote nasýtenosti katiónovej výmennej kapacity (KVK) vápnikom na 59%, čo je tesne pod hranicou ľavostranne ukončeného intervalu optimálneho rozsahu tohto katiónu v pôdnom sorpčnom komplexe z aspektu KVK.

KĽÚČOVÉ SLOVÁ: Pôdny výluh Mehlich II a Mehlich III, mobilný pôdny vápnik, výmenné pôdne pH, hraničná hodnota, katiónová výmenná kapacita

INTRODUCTION

The agrochemical, biochemical and pedological importance of soil calcium, especially its "mobile" or "exchangeable" forms is well-known. It is one of the yield-making elements, it controls soil sorption complex and its exchange reactions in soil environment, forms and stabilizes favourable soil structure and its pH value. As the macrobiogenic element it governs a many biochemical processes into a plant and acts positively on a plant-soil interaction (FECENKO, LOŽEK, 2000).

According to many theoretical and practical knowledge the optimal proportion of exchangeable Ca in soil sorption complex varies depending on soil type and texture within the range 60 – 80% of the cation exchange capacity (CEC) – (BUJNOVSKÝ, HOLOBRADÝ, 1997; VOSTAL, PENK, 1989).

Nowadays, in the agrochemical practice absents the Ca-soil criterion determining its quantitative nutrient status from view-point of "exchangeable" and/or "plant-available" species. This exists only for "plant available" forms of soil phosphorus, potassium and magnesium in Mehlich's III prognostic soil extract being in the current use (HALÁS, GÁBORÍK; 2000).

Until 2000, within X^{th} and XI^{th} cycles of the Agrochemical Soils Testing (ASP) it has been possible to evaluate the "extractable" soil Ca by Mehlich's II solution (NEUBERG et al., 1990) despite of that frequently more comprehensive aspect i.e. lime requiring has been favourized (KOTVAS et al., 2000).

On the other hand, just close relationship between soil pH value and soil calcium extractable form encourages us to find an appropriate at least "borderline" of this Ca-form using Mehlich's III soil extract.

MATERIAL AND METHODS

To the study above mentioned relationship, top soil samples originated from cadastres of four agricultural enterprises (Lefantovce – 229 soil samples; Kočín – 105 ones; Moravské Lieskové – 229; Osikov 144) and from larger region, representing soil conditions of Trnava Hilly Lands – 250 soil samples have been used. The details on agrochemical and pedological characteristics of individual regions can be found in references cited (FIALA, 2002; FÖLDEŠOVÁ et al., 1997; MIKLOVIČ, 1996).

In first stage of work, analytical results of soil calcium extracted by Mehlich III solution (Ca/M III) and soil exchangeable pH values in 1M KCl solution (pH/KCl) were evaluated. Basic descriptive statistical parameters are presented in Table 1.

Table 1 Descriptive statistic of tested data set (n = 952)

Variable \ Parameter	Arith. Mean	Minimum	Maximum	Range
pH/KCl	5.93	3.49	7.71	4.22
Ca/M III (mg.kg^{-1})	2 403	70.0	9 000	8 930

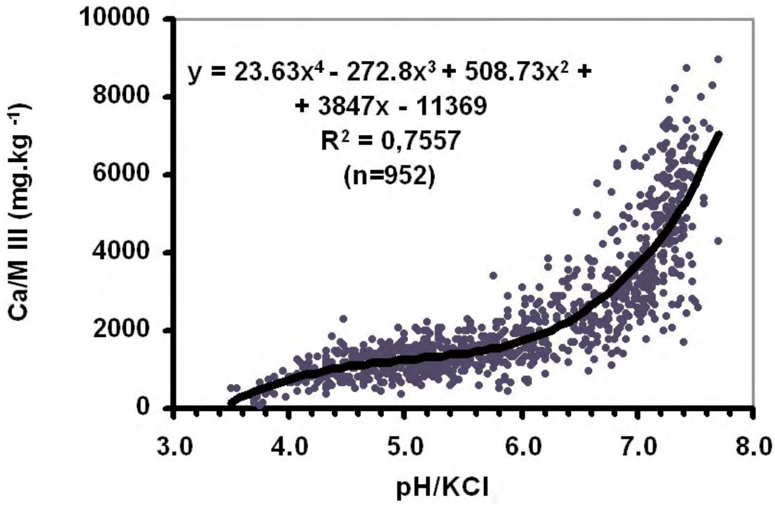
RESULTS AND DISCUSSION

Following the extreme values were rejected, 952 results of soil samples, representing prevailingly the medium coarse soil structure have been evaluated statistically.

The dependence of soil Ca concentration in Mehlich III solution on soil pH value is possible to describe with high enough statistical significance by multiple regression presented in Figure 1 and in Table 4 (equation [1]). From its form the real local extreme, which simultaneously is the function break-point has been calculated (VOJTĚCH, 1959).

This inflex point value is at the vicinity of pH/KCl value 5.07. From Figure 1 there is evident relative extensive plateau in pH region 4.80 – 5.50 where Ca concentration arises practically linearly with the average gradient approximately 32 mg Ca.kg^{-1} as pH value changes by 0.1 unit. Before and behind this plateau region (in more acid and more alkaline one) is the concentration gradient steeper.

Figure 1 Relationship between exchangeable soil pH and Mehlich's III soil Ca



According to the literature data frequently applicated in agrochemical practice, just the soil pH value 5.5 appears to be a starting point of "secure region" where effective blocking of "active" Al-forms and following considerable restriction of Al toxic influence onto plants is occurring (Bujnovský, Holobradý, 1997; Fecenko, Ložek, 2000). In many experimentally aimed papers, see e.g. Kozák, Borůvka, 1998; Makovníková, Kanianská, 1996 even at soil pH value 5.0 and more a considerable declination of Al-mobility occurs and "active" Al is held at very low and near constant level.

Probably just in the vicinity of exchangeable soil pH value 5.1 occurs in soil set studied a saturation of the most attractive exchangeable positions by Ca ions and after the overcome "break" soil pH value 5.5 more intensive growth its concentration in soil sorption complex and in soil solution takes place.

The "border-line" concentration of soil Ca for soil set studied occurs hence in a vicinity of soil pH value ≥ 5.1 for that the Ca soil concentration by regression equation [1] ≥ 1 283 mg Ca.kg^{-1} is adequate. Similarly this, for pH/KCl value of 5.5 is adequate Ca concentration in Mehlich III solution 1 416 mg.kg^{-1}. The difference between these two concentrations are not so significant taking into consideration that in measuring process of soil extract the 25-fold dilution and difference between 2 parallel determination of 0.5 mg Ca.l^{-1} results in difference of 125 mg Ca.kg^{-1}.

Comparing these values with the paper by Halás, Gáboríк (2000), it is possible at least roughly to convert our Ca-soil values (Ca/M III) to their level in formerly used Mehlich II solution. By regression equation for medium coarse soils are our Ca/M III concentrations adequate to 1 327 and 1 463 mg Ca.kg^{-1} for Mehlich II solution. But just by 1 400 mg Ca.kg^{-1} value in Mehlich II soil extract was right-closed the interval for "low" category of medium coarse soils (Neuberg et al., 1990).

Despite of this agreement and traceability of Ca concentrations between Mehlich II and Mehlich III especially for pH/KCl value at 5.5 we considered the "border line" value derivation exceptionaly on the basis only one regression equation for hazardous and non-precise. Besides, even in theoretical anticipations must be possible Al-soil-plant interaction reduced to minimum. To share this precaution, as starting point we evaluated relationship Ca/M III vs pH/KCl at its value 5.6, where "active" Al threat is minimized yet.

Next important view-point for "optimal" Ca soil concentration is the extent of soil sorption complex saturation with this element. For this purpose we have utilized some sorption parameters (REEUWIJK, 1995), obtained by soils analysis of Trnava Hilly Land region (FIALA, 2002). From this analysis data set the subgroup of medium coarse, non-carbonate soils was selected. This "subset" (n = 81) from view point of cationic saturation extent was weak up to near-to-full saturated. Basic descriptive statistic of this subset is in Table 2. The mutual statistical relationships among used variables (paired correlation coefficients) are in Table 3, regression relationships, used to following evaluations are in Table 4.

Table 2 Descriptive statistic of "non-carbonate" soils' set (n = 81)

pH/KCl		Ca/M III mg.kg^{-1}		Ca_{ex}		$\sum kat_{ex}$		CEC_{pot}		V %	
				cmol(+).kg^{-1}							
Mean	5.53	Mean	1 752	Mean	11.89	Mean	16.04	Mean	20.51	Mean	78.39
Median	5.53	Median	1 600	Median	11.48	Median	15.90	Median	19.42	Median	77.74
Range	2.79	Range	3 300	Range	15.27	Range	22.46	Range	23.48	Range	33.87
Min.	4.17	Min.	900	Min.	6.49	Min.	8.32	Min.	12.17	Min.	63.62
Max	6.96	Max	4 200	Max	21.76	Max	30.77	Max	35.65	Max	97.50

Table 3 Correlation relationships among variables tested

	pH/KCl	Ca/M III	Ca_{ex}	$\sum kat_{ex}$	CEC_{pot}	V (%)
pH/KCl	1.000	0.582	0.519	0.521	0.229	0.760
Ca/M III	0.582	1.000	0.946	0.930	0.851	0.234
Ca_{ex}	0.519	0.946	1.000	0.971	0.901	0.237
$\sum kat_{ex}$	0.521	0.930	0.971	1.000	0.920	0.258
CEC_{pot}	0.229	0.851	0.901	0.920	1.000	Nesign.
V (%)	0.760	0.234	0.237	0.258	Nesign.	1.000

Critical values of correlation coeficients (n = 81)

α	0.1%	1%	5%
r	0.357	0.283	0.217

Table 4 Estimated and used regression equations

Eq. No.	Formula used	R2 value (adjust.)	n
[1]	Ca/M III = 23.63x4 – 272.8x3 + 508.73x2 + 3847x – 11 369	0.7557	952
[2]	V = 9.07(pH/KCl) – 3.4×10^{-3} x (Ca/M III) + 31.194	0.6428	81
[3]	Ca_{ex} = 4.15×10^{-3} x (Ca/M III) + 4.626	0.8928	81
[4]	$\sum kat_{ex}$ = 1.2716 x.Ca_{ex} + 0.9154	0.9431	81

Units: [Ca/M III] = [mg.kg^{-1}] [V] = [%] [Ca_{ex}, $\sum kat_{ex}$] = [cmol(+).kg^{-1}] x = pH/KCl

As can be computed from Table 4 (equation [1]), for pH/KCl value of 5.6 (this pH occurs in "safe region" yet) 1 459 mg Ca.kg^{-1} (Ca/M III form) is adequate. Putting this both values in equation [2] we obtain the extent of saturation with bases, i.e. Ca_{ex}+Mg_{ex}+K_{ex}+Na_{ex} = $\sum kat_{ex}$ equal to 80%. Similarly, by step-by-step putting of appropriate values into equations [3] and [4] we can estimate that 1 459 mg Ca.kg^{-1} is adequate to Ca_{ex} value of 10.68 cmol(+).kg^{-1} and this is consequently equal to $\sum kat_{ex}$ of 14.50 cmol(+).kg^{-1}. In this sum of bases ($\sum kat_{ex}$) shares the Ca_{ex} (adequate to 1 459 mg Ca.kg^{-1} in Mehlich III solution) so much as (10.68/14.50)x100% = 73.67%. Hence, from the total saturation extent shares thus the Mehlich's III Ca form 80% x 0.7367 = 58.9%. With change this Ca/M III value to 1 400 mg.kg^{-1} (proposed "border concentration") this result will be changed negligibly and practically is the same.

The Ca value of 1 400 mg.kg^{-1} is thus close under optimal saturation interval of of cation exchange capacity and it could be, for the first approximation at least, considered as "border" Ca concentration. For its validation or higher precision the range of experimental results should be spread to other soil structure categories, i.e. to fine and coarse ones. The crucial criterion would be the results of quantification of the competitive interactions between soil and plant Ca/Al content, depending on the soil pH value.

Very important factor for this or similar solution approach considerably influencing the verification process is the method validity for the determination both "total" CEC value and its cation exchange forms. As far as nowadays are mentioned sorption parameters determined by several methods with their many modifications (e.g. HRAŠKO, 1962; HANES, 1995; REEUWIJK, 1995; etc.) it should be desirable for the results comparability to use only one method such as STN ISO 13536 (2001).

CONCLUSIONS

One of several possible approaches to assess „sufficient“ soil status of "extractable" calcium is to utilize a close relationship between this Ca soil form (in Mehlich III soil extract) and soil pH value. In the vicinity of pH 5.6 value where dangerous influence of "active" soil aluminium is negligible the adequate Ca concentration near to 1 400 mg.kg^{-1} satures the soil cation exchange capacity to nearly 59%.

This favourable data combination prompts us to believe that soil "extractable" Ca concentration 1 400 mg.kg^{-1} forms the first approximation of "sufficient", or more precisely, the "border" Ca soil status for soils with medium coarse structure.

REFERENCES

BUJNOVSKÝ, R., HOLOBRADÝ, K., 1997: Metodika úpravy kyslej pôdnej reakcie vápnením. VÚPOP Bratislava. 30 s.

FECENKO, J., LOŽEK, O., 2000: Výživa a hnojenie plodín. SPÚ Nitra+Duslo Šaľa, a.s. 442 s.

FIALA, K., 2002: Základné chemické parametre na posúdenie kvality pôd v regióne (Záverečná správa). VÚPOP Bratislava, 12 s.

FÖLDEŠOVÁ, D., KUBICOVÁ, Z., ŠEFČÍK, P., 1997: Variabilita pôdnej reakcie a obsahov prístupného fosforu na modelovom podniku PVOD-Kočín. In: Vedecké práce VÚPOP Bratislava, 20/II, s. 149 – 156.

HALÁS, L., GÁBORÍK, Š., 2000: Porovnanie analýz pôd metódami Mehlich III a Mehlich II. Agrochémia, IV.(40.)/3, s. 21 – 24.

HALÁS, L., 2000: Kritériá hodnotenia výsledkov agrochemických analýz pôdy metódou Mehlich III a ich využitie pre hnojenie. Agrochémia, IV.(40.)/2, s. 11 – 13.

HANES, J. et al., 1995: Pedológia (praktikum). Vydavat. a edičné stredisko VŠP. 154 s.

HRAŠKO, J., 1962: Rozbory pôd. Slovenské vyd.pôdohospodárskej literatúry, 335 s.

KOTVAS, F., KOUTNÝ, B., KOBORA, M., 2000: Výsledky agrochemického skúšania pôd na Slovensku v rokoch 1995 – 1999 (X.cyklus ASP). ÚKSÚP+VÚPOP Bratislava. 100 s.

KOZÁK, J., BORŮVKA, L., 1998: Species of Al ions as related to some characteristic of both agricultural and forest soils of the Šumava region. Rostlinná výroba, 44, s. 419 – 426.

MAKOVNÍKOVÁ, J., KANIANSKÁ, R., 1996: Aktívny hliník a jeho súčasný stav v pôdach SR. Rostlinná výroba, 42, s. 289 – 292.

MIKLOVIČ, D., 1996: Agrochemické testovanie pôdy z hľadiska jej trvale udržateľnej úrodnosti. In: Projekt racionálneho využívania pôd na ŠM Moravské Lieskové. VÚPÚ Bratislava. 12 s.

NEUBERG, J. a kol., 1990: Komplexní metodika výživy rostlin. ÚVTIZ Praha. 327 s.

REEUWIJK, L.P., van, 1995: Procedures for Soil Analysis, 5th Edition, ISRIC, Wageningen. 273 p.

STN ISO 13 536, 2001: Kvalita pôdy. Stanovenie potenciálnej katiónovej výmennej kapacity a obsahu vymeniteľných katiónov za použitia roztoku chloridu bárnatého s hodnotou pH = 8,1. SÚTN Bratislava. 12 s.

VOJTĚCH, J., 1959: Základy matematiky ke studiu věd přírodních a technických. Nakl. ČSAV, Praha. 478 s.

VOSTAL, J., PENK, J., 1989: Hnojení, kvalita produkce a životní prostředí. MZaV ČSR, České Budějovice. 151 s.

THE BALANCE ORGANIC MATTER IN THE SOIL ON CHOSEN AGRICULTURAL FARM

BILANCIA ORGANICKEJ HMOTY V PÔDE NA VYBRANOM POĽNOHOSPODÁRSKOM PODNIKU

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ABSTRACT

The balance of soil organic matter was calculated from the area of 939 ha of arable land in chosen agricultural farm during three years period. It was confirmed that the negative balance of soil organic matter does not exceed 2 tons of organic carbon per hectare when applied 40 tons of organic fertilizers (manure) per hectare (once in three years). The negative balance of soil organic matter more than 8 ton per hectare was reached on 41% area of arable land (e.g. 381 ha). The losses of organic matter from the soil in some fields reach more than 10 t C.ha^{-1} in dependence on cropping system structure. The average dose 47.3 t.ha^{-1} of organic fertilizers is necessary to balance the found deficiency. It is also needful to regulate the share of individual grown crops and to cultivate more crops with positive influence on soil organic matter – legumes, their mixtures with grass and temporary grass.

KEYWORDS: balance of soil organic matter, organic fertilization, deficiency of organic matter in the soil

ABSTRAKT

Bilancia organickej hmoty v pôde bola vypočítaná na výmere 939 ha ornej pôdy vo vybranom poľnohospodárskom podniku v priebehu troch po sebe nasledujúcich rokov. Bolo overené, že dávka maštaľného hnoja 40 t.ha^{-1} je dostatočná na to, aby straty organickej hmoty v pôde neprevyšovali hodnotu 2 t.ha^{-1}. Negatívna bilancia organickej hmoty vo výške viac ako 8 ton na hektár ornej pôdy bola dosiahnutá na výmere 381 ha, čo predstavuje 41% celkovej výmery ornej pôdy. V závislosti od štruktúry osevu sa na podniku nachádzajú aj hony, na ktorých negatívne bilancia organickej hmoty v pôde dosiahla hodnoty vyššie ako 10 t.ha^{-1}. Na odstránenie deficitu organickej hmoty v pôdach vybraného podniku je potrebná priemerná dávka 47,3 t maštaľného hnoja na hektár ornej pôdy. Je taktiež potrebné upraviť zastúpenie jednotlivých plodín v osevnom postupe a pestovať na väčšej výmere plodiny s vyšším pozitívnym vplyvom na organickú hmotu v pôde – strukoviny, ich zmesi s trávami a dočasné trávy na ornej pôde.

KĽÚČOVÉ SLOVÁ: bilancia organickej hmoty v pôde, organické hnojenie, deficit organickej hmoty v pôde

INTRODUCTION

The soil organic matter belongs to the determining factors of soil fertility due to its wide influence on physical, chemical and biological soil properties. The productive and non-productive (ecological) soil functions (e.g. transformation, filtration, accumulation) depend on the contents and quality of soil organic matter.

The care of the soil organic matter is the basic assumption of productive potential soil protection, especially of arable soil, where is the intensive crop production. The losses of organic matter from the soil, which are caused by mineralization and humification of organic materials, eventually by erosion, should be compensated by inputs of fresh organic matter into the soil.

The regular control of soil organic matter in each field of arable soil is the part of good agricultural praxis. The quantification of sources and losses of organic materials is the basic condition of this control. The method of this balance has been worked out in Soil Science and Conservation Research Institute, Bratislava. It is based on long-term results of research in various soil and climatic conditions of Slovakia (JURČOVÁ, BIELEK, 1997). These experimental results were evaluated by statistical methods (polynomial regression). They allow to make balance of soil organic matter in each field of arable soil in Slovakia when taking account on:

- bonited soil ecological unit (BPEJ)
- the yields of main product of cultivated crops during recent three years
- the level of organic fertilization during recent three years

MATERIALS AND METHODS

Both the balance of soil organic matter and the determining of organic fertilization requirement were calculated for the farm Agrozoran Michaľany (district Trebišov). The software PEDOPT 2000 (VILČEK et al., 1999) was used for calculation soil parameters.

Characteristics of the territory

The farm Agrozoran Michaľany is situated in southwestern part of Eastslovakian Lowland in Trebišov district. It borders with Hungary in western part. The Zemplin Mountains create the eastern border. The highest point of the farm is in 225 m a.s.l., the lowest one in 108 m a.s.l. The area belongs to the maize technologic type with maize-barley subtype.

From the climatic point of view all the area belongs into one climatic zone – warm, too dry, plain, continental. The average annual air temperature is 8.7 – 9.2 °C, the average amount of precipitation is 400 – 450 mm (MŽP SR, 2002).

The structure of utilization of agricultural soils in the farm is presented in Table 1. It is remarkable that arable land is almost on three quarters of total agricultural land in the farm. It is too high share in these soil and ecological conditions. From the point of view of soils the Mollic Fluvisols dominate with 42% of the total area, Cambisols cover 17%, Fluvisols 16% of the total area. The humus contents in the soils ranges between 1.0 and 3.0%, the soils are most deep. Only Cambisols are shallow with increased skeleton contents.

Table 1 Structure of utilization of agricultural fund

Sort of land	Area (ha)	Share of agricultural soil area (%)
Agricultural soil	1 303	100,0
Arable soil	957	73,4
Permanent grassland	338	26,0
Vineyards	1	0,1
Orchards	7	0,5

Balance of soil organic matter

"Soil organic matter" is understood as the comparison of sources (inputs into the soil) and losses (outputs of organic materials out of the soil) in chosen field of arable land by means of simple model (mathematical equation). In this model the amount of balanced soil organic matter is expressed in tons of organic carbon per hectare during one year (JURČOVÁ, BIELEK, 1997). The mentioned amount of organic matter is calculated as follows:

$$B_c = (/u \times K_c/ + /D_H \times C_H/) - (C_m \times K_m), \qquad [1]$$

where:

B_c = balance of organic carbon – in t C.ha^{-1}.year^{-1}

u = yield of main product of cultivated crop in the year, when the balance is calculated – in t.ha^{-1}

K_c = coefficient of re-calculation of crop remains on carbon for given interval of yields

D_H = the ration of organic fertilizers applied in the year when the balance is calculated – in t.ha^{-1}

C_H = coefficient of re-calculation of organic fertilizer ration on carbon – in t C on 1 t of fertilizer

C_m = basic losses of carbon from the soil due to mineralization in given soil category – in t C.ha^{-1}.year^{-1}

K_m = coefficient of crop influence on the total carbon losses from the soil in given soil group.

RESULTS AND DISCUSSION

The area of cultivated crops and their yields in recent three years were used as initial data for the calculation of soil organic matter balance. The data are presented in Table 2.

The following results were reached on the base of calculation of soil organic matter balance in software PEDOPT 2000 (VILČEK et al., 1999).

The organic fertilizers (manure) with average ration 37 t.ha^{-1} were applied on 231 ha from 939 observed hectares. Only ensilage maize, sunflower and sugar beet were fertilized with manure. The smallest loss of organic carbon was on these 9 fields – average value reached 1,9 t C per hectare. It is not important which crops were cultivated in other two years, the mentioned ration of manure could cover the carbon loss from the soil during three years period. On the other side, the highest losses – about 10 t.ha^{-1} – were reached on the fields where only dense sawn cereals and corn maize were cultivated. It is noteworthy that on 381 ha, e.g. 41% of total area of arable land the negative carbon balance was more than 8 tons per hectare (Table 3), what indicates insufficient care about soil fertility from the side of farmer.

Table 2 Area and yields of cultivated crops

Crop \ Year	2001		2002		2003	
	Area (ha)	Yield (t.ha^{-1})	Area (ha)	Yield (t.ha^{-1})	Area (ha)	Yield (t.ha^{-1})
Winter wheat	380	3.73	380	4.16	260	3.02
Winter barley	25	3.22	5	1.94	30	2.46
Spring barley	60	2.57	35	3.43	95	3.71
Winter rye	–	–	15	3.04	15	1.28
Oats	20	1.97	–	–	–	–
Corn maize	60	4.07	85	5.17	125	1.55
Winter rape	75	2.65	100	1.73	10	0.33
Sunflower	100	1.81	100	2.04	165	1.56
Pea	40	1.12	40	2.20	40	2.27
Soybean	45	1.35	40	2.67	58	1.03
Lens	–	–	–	–	15	0.52
Sugar beet	45	37.5	50	34.4	57	22.34
Silage maize	21	37.40	21	33.23	15	33.78
Spring mixture	36	14.85	40	14.9	22	13.9
Grass on arable land	33	1.47	–	–	–	–
Perennial fodder crops	19	4.60	20	4.64	20	2.36

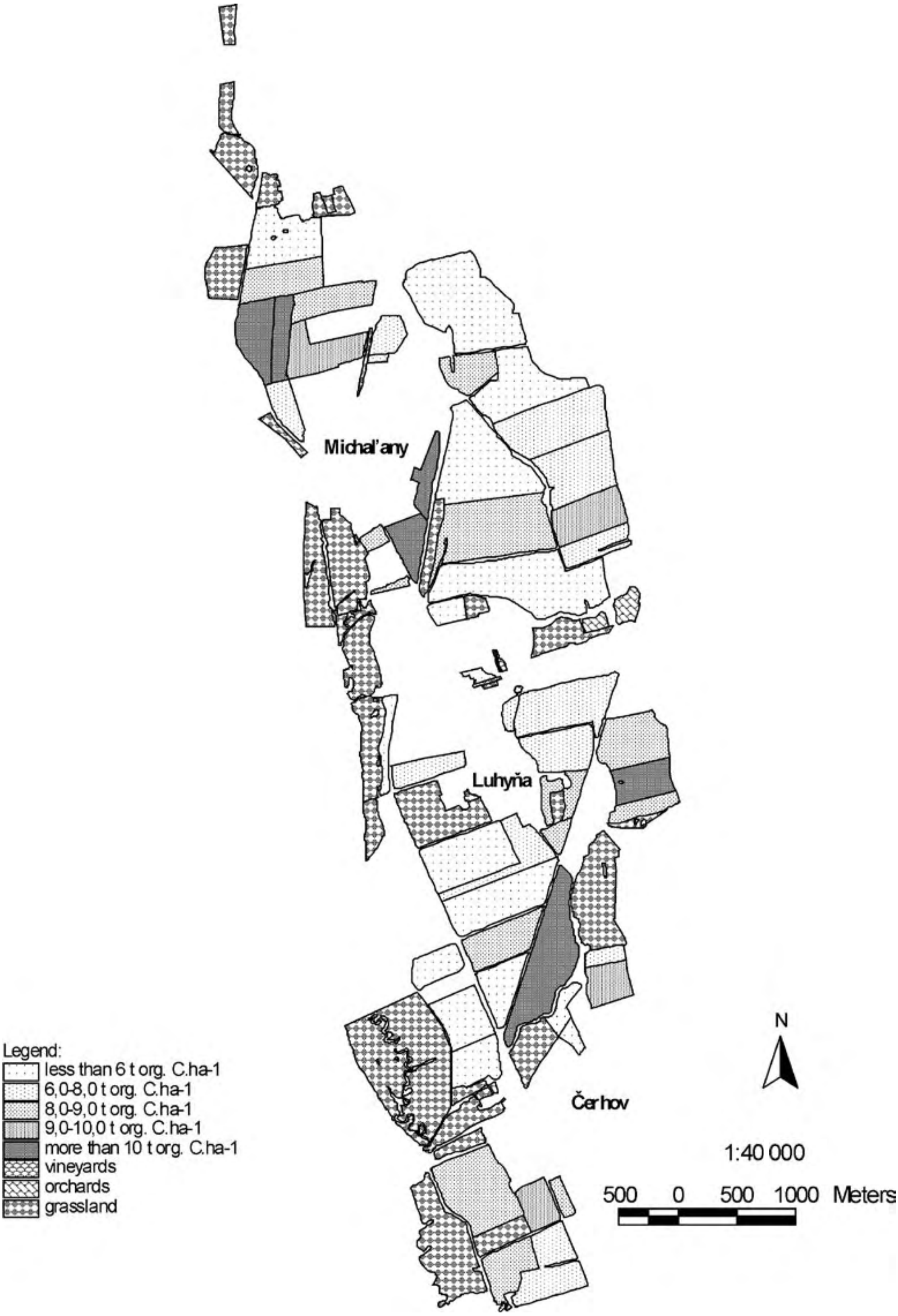
The fields were divided into 6 groups according to carbon losses from the soil. These ones are presented in Table 3 and Figure 1.

Table 3 Classification of fields according to organic matter losses

Group of losses	Range of organic carbon losses (t.ha^{-1})	Number of fields	Area (ha)
1. group	less than 6	16	353.7
2. group	6 – 8	14	204.3
3. group	8 – 9	14	217.5
4. group	9 – 10	4	61.8
5. group	10 – 11	6	101.6

In the first group there are the fields that are fertilized with manure in recent three years and deficit of organic carbon were not more than 6 tons per hectare. In next groups 585 ha of arable land are classified, where the deficit of organic carbon is higher than 6 tons. Just this value is regarded as the limited one from the point of view of contents and quality organic matter jeopardy on the soils with humus contents less than 1.5% (MP SR, 2003).

Figure 1 The soil organic matter balance in individual fields of chosen agricultural farm – Agrozoran Michaľany

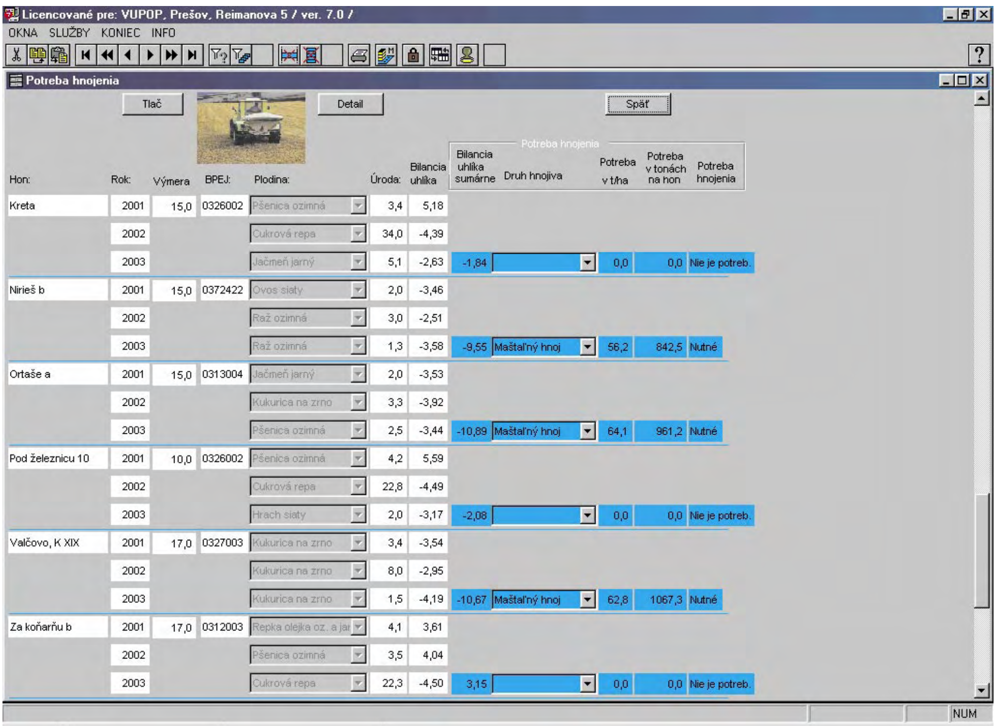


The total loss of organic carbon from the soils in mentioned farm according to balanced model reaches the value of 6 226 tons and average carbon loss from one hectare is 6.63 tons. It is necessary to apply an average ration 47.3 tons of manure per hectare of arable land to eliminate this deficit. The total need of manure for elimination of carbon deficit on the whole farm is 30 805 tons.

The annual production of manure in the farm (6 000 – 6 200 tons) secures to fertilize only 150 – 160 ha of arable land (e.g. 16 – 17% of total area) with the ration 40 t.ha^{-1} each year. It means that only the organic fertilization can not solve this problem. It would be necessary to regulate both the organisation of agricultural fund in harmony with given soil and climatic conditions and crop rotation. The small seed cereals together with corn maize were cultivated on almost 60% of total arable land area in recent three years, meanwhile perennial crops only on 2.0% of the same area. In framework of crop rotation this is too little to equal the deficit of organic matter in the soil.

In the Figure 2 and Table 4 is presented the fragment of software PEDOPT 2000, where the balance of organic matter in the soil is calculated according individual fields. On this Figure it is also calculated the requirement of organic fertilization. In the fields Kreta, Pod železnicu 10 a Za koňarňu b was applied the manure in the ration 40 t.ha^{-1}, when sugar beet was cultivated and the deficit of organic carbon reaches only 1.8 – 3.15 tons per hectare in these fields. In the fields Nirieš b, Ortaše a a Valčovo only cereals and corn maize were cultivated during recent three years and the loss of organic carbon is still too high 9.5 – 10.9 t C.ha^{-1}. Just in these field it is necessary to apply

Figure 2 The soil organic matter balance in individual fields and the requirement of organic fertilization of chosen agricultural farm Agrozoran Michaľany (fragment from software PEDOPT 2000)



Hon:	Rok:	Výmera	BPEJ:	Plodina:	Úroda:	Bilancia uhlíka	Bilancia uhlíka sumárne	Druh hnojiva	Potreba v t/ha	Potreba v tonách na hon	Potreba hnojenia
Kreta	2001	15,0	0326002	Pšenica ozimná	3,4	5,18					
	2002			Cukrová repa	34,0	-4,39					
	2003			Jačmeň jarný	5,1	-2,63	-1,84		0,0	0,0	Nie je potreb.
Nirieš b	2001	15,0	0372422	Ovos siaty	2,0	-3,46					
	2002			Raž ozimná	3,0	-2,51					
	2003			Raž ozimná	1,3	-3,58	-9,55	Maštaľný hnoj	56,2	842,5	Nutné
Ortaše a	2001	15,0	0313004	Jačmeň jarný	2,0	-3,53					
	2002			Kukurica na zrno	3,3	-3,92					
	2003			Pšenica ozimná	2,5	-3,44	-10,89	Maštaľný hnoj	64,1	961,2	Nutné
Pod železnicu 10	2001	10,0	0326002	Pšenica ozimná	4,2	5,59					
	2002			Cukrová repa	22,8	-4,49					
	2003			Hrach siaty	2,0	-3,17	-2,08		0,0	0,0	Nie je potreb.
Valčovo, K XIX	2001	17,0	0327003	Kukurica na zrno	3,4	-3,54					
	2002			Kukurica na zrno	8,0	-2,95					
	2003			Kukurica na zrno	1,5	-4,19	-10,67	Maštaľný hnoj	62,8	1067,3	Nutné
Za koňarňu b	2001	17,0	0312003	Repka olejka oz. a jar	4,1	3,61					
	2002			Pšenica ozimná	3,5	4,04					
	2003			Cukrová repa	22,3	-4,50	3,15		0,0	0,0	Nie je potreb.

Table 4 The soil organic matter balance in individual fields and the requirement of organic fertilization of chosen agricultural farm Agrozoran Michaľany

Field	Year	Area (ha)	BPEJ[1]	Crop	Yield	C balance	C balance total	Sort of fertilizer	Requirement $t.ha^{-1}$	Requirement t per field	Fertilization need
Kreta	2001	15.0	0326002	Winter wheat	3.4	5.18					
	2002			Sugar beet	34.0	-4.39					
	2003			Spring barley	5.1	-2.63	-1.84		0.0	0.0	No need
Nierieš b	2001	15.0	0372422	Oats	2.0	-3.46					
	2002			Winter rye	3.0	-2.51					
	2003			Winter rye	1.3	-3.58	-9.55	Manure	56.2	842.5	Needful
Ortaše a	2001	15.0	0313004	Spring barley	2.0	-3.53					
	2002			Corn maize	3.3	-3.92					
	2003			Winter wheat	2.5	-3.44	-10.89	Manure	64.1	961.2	Needful
Pod železnicu 10	2001	10.0	0326002	Winter wheat	4.2	5.59					
	2002			Sugar beet	22.8	-4.49					
	2003			Peas	2.0	-3.17	-2.08		0.0	0.0	No need
Valčovo, K XIX	2001	17.0	0327003	Corn maize	3.4	-3.54					
	2002			Corn maize	8.0	-2.95					
	2003			Corn maize	1.5	-4.19	-10.87	Manure	62.8	1 067.3	Needful
Za koňarňu b	2001	17.0	0312003	Winter rape	4.1	3.61					
	2002			Winter wheat	3.5	4.04					
	2003			Sugar beet	22.3	-4.50	3.15		0.0	0.0	No need

[1] Bonited pedo-ecological unit

immediately 56 – 64 tons of manure per hectare to eliminate the mentioned deficit of organic matter in the soil.

The reached results point out the fact that in such soils with middle and lower production capacity, the losses of organic matter are too high without organic fertilization.

CONCLUSIONS

It was confirmed that the negative balance of soil organic matter does not exceed 2 tons of organic carbon per hectare when applied 40 tons of organic fertilizers (manure) per hectare (once in three years). Without organic fertilization and depending on cropping system structure the losses of organic carbon reach more than 10 tons per hectare. The negative balance of soil organic matter more than 8 ton per hectare was reached on 41% area of arable land (e.g. 381 ha). The average dose 47.3 $t.ha^{-1}$ of organic fertilizers is necessary to equal the found deficiency. It is also needful to regulate the share of individual grown crops and to cultivate more crops with positive influence on soil organic matter – legumes, their mixtures with grass and temporary grass.

REFERENCES

Jurčová, O., Bielek, P., 1977: Metodika bilancie pôdnej organickej hmoty a stanovenia potreby organického hnojenia: (Methodology of soil organic matter balance and determining of organic fertilization requirement). Bratislava: VÚPÚ. 154 s. ISBN 80-85361-26-4

MP SR, 2003: Návrh zákona o ochrane a využívaní poľnohospodárskej pôdy. (The proposal of law of agricultural soil protection and utilization). www.mpsr.sk/pk/html/357_2003_410/priloha_1.htm

MŽP SR, 2002: Atlas krajiny. ESPRIT, spol. s r.o. Banská Štiavnica, ISBN 80-88833-27-2

Vilček, J. a kol., 1999: Pôdnoekologické parametre usporiadania a využívania poľnohospodárskej krajiny. Záverečná správa za VTP 514-79. (Soil and ecological parameters of agricultural land utilization. Final report). VÚPOP Bratislava, 113 s.

CONTRIBUTION ON GENESIS OF DARK-COLOURED SOILS IN NON-CHERNOZEMS REGIONS OF SLOVAKIA AND PROBLEM OF THEIR CLASSIFICATION

PRÍSPEVOK KU GENÉZE TMAVO SFARBENÝCH PÔD NEČERNOZEMNÝCH OBLASTÍ SLOVENSKA A PROBLÉM ICH KLASIFIKÁCIE

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ABSTRACT

Dark-coloured soils of non-chernozem regions have a special position in soil cover of Slovakia. These soils are extended mostly in cooler and in more or less moist regions with low inclination (3 – 5° and more) often with gravel content in soil profile. Described soils belong to fertile soils with occurrence of mollic humus horizon and therefore they are often cultivated (arable soils).

Several soil profiles from soil monitoring network in Slovakia are evaluated in this contribution. Unified analytical procedures for soil monitoring system have been used. Following parameters have been analysed in selected soils: pH, cation exchange capacity (CEC), humus content and fractional composition of humus, content of labile carbon, potentially mineralisable nitrogen.

On the basis of obtained results it may be said that the dark-coloured soils in non-chernozem regions opposite similar soils chernozems regions have higher content of labile carbon and higher index of lability as well as higher C_L (labile carbon): N_{pot} (potentially mineralisable nitrogen) ratio. It is probably reflection of (old) hydromorphic conditions under origin vegetation influence. Given parameters (C_L, N_{pot}) could be potentially included into the specification of mollic humus horizons in more details. Finally, it would be helpful at differentiation of dark-coloured soils with the same structure of soil genetic horizons.

KEYWORDS: dark-coloured soils, non-chernozem regions, soil genesis, humous arable soils, labile carbon, potentially mineralisable nitrogen, soil classification

ABSTRAKT

Špeciálne postavenie v pôdnom kryte Slovenska majú tmavo sfarbené pôdy, ktoré sa vyskytujú aj mimo černozemných oblastí. Tieto pôdy sú rozšírené prevažne v chladnejších a vlhkejších oblastiach so svahovitosťou 3 – 5°, ale i viac a často i s obsahom skeletu v pôdnom profile. Popisované pôdy patria k úrodným pôdam s výskytom molického humusového horizontu, a preto sú často využívané ako orné pôdy.

V príspevku je hodnotených niekoľko pôdnych profilov študovaných pôd, ktoré sú zahrnuté v pôdnej monitorovacej sieti Slovenska. Boli použité jednotné analytické metódy, ktoré sú zaužívané v monitorovacom systéme pôd Slovenska. Zisťované boli nasledovné parametre pôd: pH, katiónová sorpčná kapacita (CEC), obsah humusu i frakčné zloženie humusu, obsah labilného uhlíka a potenciálne mineralizovateľného dusíka.

Na základe dosiahnutých výsledkov možno konštatovať, že tmavo sfarbené pôdy nečernozemných oblastí na rozdiel od podobných pôd černozemných oblastí majú vyšší obsah labilného uhlíka, ako aj vyšší index lability. Taktiež vyšší je pomer C_L (labilný uhlík) : N_{pot} (potenciálne mineralizovateľný dusík). Je to pravdepodobne odrazom (starších) hydromorfných podmienok pod vplyvom pôvodnej vegetácie. Uvedené parametre (C_L, N_{pot}) by mohli byť potenciálne zahrnuté v bližšej charakteristike molických humusových horizontov a tak v lepšom odlíšení tmavo sfarbených pôd s tou istou konfiguráciou pôdnych genetických horizontov.

KĽÚČOVÉ SLOVÁ: tmavo sfarbené pôdy, nečernozemné oblasti, genéza pôdy, humózne orné pôdy, labilný uhlík, potenciálne mineralizovateľný dusík, klasifikácia pôd

INTRODUCTION

In natural conditions it is often possible to find dark-coloured and humous soils not only in chernozem regions but also in outside regions, as well. I have in the mind mostly agricultural soils above all arable soils. These soils are often characteristic with different soil substrates, content of gravel and degree of inclination (mostly in the range 1 – 3° and more) where the horizonation is the same like in dark-coloured soils of chernozem regions (A-C, resp. A-CG). In spite of existence of mollic humus horizons (Am) in these soils, probable differences can be presupposed just in quality of existing horizons. These soils were classified as Cambisols during Complex Soil Survey in Czechoslovakia (1961 – 1970). Nowadays, it is well-known that it is impossible these soils to be classified as Cambisols, because no cambic process has been running here and therefore also no cambic horizon was created in described soils, as well. On the contrary, some features of hydromorphism and influence of origin vegetation (accumulation of soil organic matter in moist conditions) can be observated in these soils occurring mostly in cooler and moist regions. Dark-coloured humus (mostly mollic) horizon (colour 10YR 2/2, 3/2) with depth 30 cm and more is typical for studying soils. Such horizon has been created under little different soil-climatic conditions (cooler and moist) opposite similar horizons in chernozem region, what is in correlation to character and quality of humus horizons in non-chernozem regions.

Therefore some qualitative parameters of dark-coloured humus horizons of soils in non-chernozem regions are evaluated in the paper.

MATERIAL AND METHODS

In this paper some observated sites of stabile soil monitoring network of Slovakia have been used. Five monitoring sites of dark-coloured humous soils (arable soils) were selected occuring outside of chernozem region. All of them are classified as Mollic Fluvisols or Hapli-Gleyic Chernozems (WRB 1994), in Slovak – Čiernica (ČA) including carbonateous and non-carbonateous varieties. In addition, some soils from chernozem region (Voderady at Trnava and Macov at Dunajska Streda) were compared with dark-coloured soils in non-chernozem regions. Analytical procedures have been used according to unified methods for soil monitoring system in Slovakia (FIALA et al., 1999). Some analysis have been prepared in the framework of cooperation with Department of Soil Science and Geology in Slovak Agricultural University in Nitra (exchangeable cations, CEC, labile carbon, mineralisable nitrogen). Soil samples (from depth 0 – 10 cm and 35 – 45 cm) have been prepared by standard procedures and analysed for the following parameters:

- pH value (in water, 0.01 M $CaCl_2$ and 0.2 M KCl)
- exchangeable cations (Ca^{2+}, Mg^2, Na^+, K^+) according to HRAŠKO et al., (1962)
- C_{ox} (according to FIALA et al., 1999)
- humus fractional composition (according to FIALA et al., 1999)
- content of labile carbon (LOGINOW et al., 1987, 1993)
- potentially mineralisable nitrogen (N_{pot}) according to SOTÁKOVÁ (1982).

In addition, non-labile carbon content ($C_{NL} = C_t – C_L$) and lability index were calculated (BLAIR et al., 1995, SZOMBATHOVÁ, 1999).

RESULTS AND DISCUSSION

In the Table 1 basic chemical properties of selected soil profiles from Zvolenská kotlina (basin) – Badín, Turčianska kotlina (basin) – Príbovce, Liptovská kotlina (basin) – Dúbrava and Popradská kotlina (basin) – Spišská Belá. It is going about humous soils (C_{ox} > 2%) with thickness of humus horizons about 30 cm and more, mostly slightly acid to neutral soils.

Table 1 Basic soil properties of selected sites in non-chernozem regions

N	Site	Soil	Depth (cm)	pH/KCl	C_{ox} (%)	N_t (%)	C/N
1	Badín	$ČA_m$	0 – 10 35 – 45	6.30 6.50	2.10 1.75	0.23 0.17	9.13 10.29
2	Príbovce	$ČA_m^c$	0 – 10 35 – 45	7.12 7.16	3.41 2.66	0.42 0.37	8.12 7.19
3	Dúbrava	$ČA_m$	0 – 10 35 – 45	5.57 4.25	2.57 1.21	0.30 0.15	8.56 8.06
4	Kežmarok	$ČA_m$	0 – 10 35 – 45	5.39 5.54	2.26 0.63	0.21 0.08	10.76 7.87
5	Spišská Belá	$ČA_m$	0 – 10 35 – 45	6.28 6.21	2.16 1.45	0.20 0.15	10.80 9.66

Total content of nitrogen (N_t) is running from 0.20 to 0.42% what is medium to very high content of this element in described soils (BIELEK, 1998). In harmony with this author high to very high content of nitrogen (N_t) is characteristic just for dark-coloured soils. C : N ratio is running from 8.12 to 10.80 what represents mull humus form (C : N = 8 – 12) according to ŠÁLY (1982). Mull consists of dark colloid nitrogen newly-created compouds – humic matters, from among humic acids are predominated.

Fractional composition of humus is given in the following Table 2.

Table 2 Fractional composition of humus substances in sites of non-chernozem regions

N	Site	Soil	Depth (cm)	HA (%)	FA (%)	HA/FA	Q_6^4
1	Badín	$ČA_m$	0 – 10	19.74	10.16	1.94	4.00
2	Príbovce	$ČA_m^c$	0 – 10	22.43	14.25	1.57	3.56
3	Dúbrava	$ČA_m$	0 – 10	16.95	22.44	0.75	4.40
4	Kežmarok	$ČA_m$	0 – 10	20.06	10.16	1.97	3.94
5	Spišská Belá	$ČA_m$	0 – 10	22.57	13.14	1.72	3.74

On the basis of obtained results (Tab. 2) it can be confirmed that in the most part of compared soils the humic acids are predominated what is characteristic feature for these soils. Higher content of fulvo acids on site Dubrava (Liptovská kotlina – depression) is connected to a certain extent probably with more expressive hydromorphic and cooler conditions what related to the highest value of colour quotient (Q_6^4 = 4.40) from among compared soils. Higher HA : FA ratio and lower colour quotient value (Q_6^4) indicate ripe and stabile humus as well as higher degree of humification (BARANČÍKOVÁ, KOBZA, 1999). In addition, on the basis of obtained results some qualitative parameters (HA : FA, Q_6^4) are similar as in dark-coloured soils of chernozem regions (BARANČÍKOVÁ, ex. KOBZA et al., 2002).

Therefore at comparison of quality of humus horizons we have tried about determination of labile carbon as well as the other parameters with are given in the Table 3.

Table 3 Labile organic carbon and potentially mineralisable nitrogen of dark soils with comparison of chernozem and non-chernozem regions (depth 0 – 10 cm)

Site	Soil	C_t (%)	C_L ($g.kg^{-1}$)	Portion C_L from C_t (%)	C_{NL} (C_l/C_{NL})	L (C_l/C_{Nl})	N_{pot} ($mg.kg^{-1}$)	$C_L : N_{pot}$
Voderady (at Trnava)	$ČM_m^c$	1.75	2.028	11.6	15.47	0.131	147	13.80
Macov	$ČA_m^c$	1.65	1.176	7.0	15.32	0.077	120	9.80
Sp. Belá	$ČA_m$	2.51	4.226	16.8	20.87	0.203	109	38.80

C_t – total organic carbon
C_L – labile carbon
C_{NL} – non-labile carbon
L – index of lability
N_{pot} – potentially mineralisable nitrogen

In the Table 3 are given some important parameters of soil humus where we have tried to compare these parameters in dark-colour soils in chernozems regions (Voderady at Trnava, Macov at Dunajská Streda) with non-chernozem regions (Spišská Belá near Kežmarok). Labile carbon content in compared soils is running between 1.17 and 4.22 $g.kg^{-1}$. The highest value of labile carbon content was obtained just in dark-coloured soil in non-chernozem region – Spišská Belá (4.22 $g.kg^{-1}$). During evaluation and comparison of values of labile carbon content in humus horizons of some soils in Slovakia the lowest labile carbon content was found out, especially on arable soils with low content of less qualitative humus (e.g. Regosols, some Fluvisols) running from 0.9 to 1.5 $g.kg^{-1}$. On the contrary, the highest content of labile carbon was measured in some mountainous soils (Andosols, Podzols, rendzic Leptosols) in the range 17.8 – 21.5 g.kg^{-1} (ZAUJEC, KOBZA, 2002). Labil carbon content share of its total content is the highest just on site Spišská Belá (16.8%). Content of non-labile carbon is in dark-coloured soils of chernozem regions even-tempered, the highest content was obtained also on site Spišská Belá. Lability index (labile and non-labile carbon content ratio) is the highest in non-chernozem region on site Spišská Belá, too (0.203). High significant relationship was determined between content of labile carbon and content of total carbon as well as labile carbon content and $C_L : N_{pot}$ ratio (Table 3). Potentially mineralisable nitrogen is the lowest in Spišská Belá site (109 mg.kg^{-1}) opposite the soil sites in chernozem regions (120 – 147 mg.kg^{-1}). $C_L : N_{pot}$ ratio is a better reflection of soil organic matter quality than C : N ratio. Therefore for soil organic matter quality can be used ratio $C_L : N_{pot}$, when lower values correspoding to higher quality of soil organic matter. These results confirm the very important role of labile carbon and potentially mineralisable nitrogen content for quality of soil organic matter what corresponds with previous work (ZAUJEC, KOBZA, 2002).

Additional soil chemical properties are given in Table 4.

Table 4 Soil chemical properties of dark soils with comparison of chernozem and non-chernozem regions (depth 0 – 10 cm)

Site	Soil	pH/H_2O	$pH/CaCl_2$	BS (%)	Content of exchangeable cations (mmol p^+.kg^{-1})					
					H^+	Na^+	K^+	Ca^{2+}	Mg^{2+}	C_{EC}
Voderady (at Trnava)	$ČM_m^c$	7.54	7.12	98.9	2.90	2.50	2.20	150	105	263
Macov	$ČA_m^c$	7.99	7.52	98.1	2.60	2.00	2.20	105	30	140
Sp. Belá	$ČA_m$	6.75	6.31	94.4	12.80	2.90	2.20	165	45	228

BS – base saturation level, CEC – cation exchange capacity

There is interesting much higher concentration of H^+ ions in dark-coloured soils of non-chernozem regions where the pH values and base saturation level are the lowest opposite chernozem regions.

Finally, quantity and quality of soil organic matter are important parameters not only for evaluation of soil fertility, especially of arable land, but also as indicators for sustainable development of soils and lanscape, as well. In spite of existing criteria for humus horizons according to ŠÁLY et al. (2000) concerning mollic horizons, in all compared soils in this contribution, all the same, we can find the concrete qualitative differences in dark-coloured soils (in arable soils) between chernozem and non-chernozem regions. Above all it is going about higher content of labile carbon and lability index in non-chernozem regions (often in conditions of cooler and more humid climate) opposite chernozem regions. In addition, also higher ratio of $C_L : N_{pot}$ was found out, which seems to be better qualitative indicator of soil organic matter than C:N ratio. Described parameters are not included in the last Morphogenetic Soil Classification System of Slovakia at determination of surface diagnostic horizons (ŠÁLY et al., 2000) and therefore from among mollic humus horizons it is often possible to find also the humus horizons with the worse quality.

In addition, dark-coloured soils in non-chernozem regions have often smaller area opposite chernozem regions, resp. create motley mosaic together with genetically different light-coloured soils (Fig. 1).

Figure 1 Occurrence of dark-coloured soils in non-chernozem region (spatial heterogeneity)

Figure 2 Soil profile of dark-coloured soil in non-chernozem region

Soils – individual units of soil cover are variable, polychronic and polygenetic formations with large ability of reflection (according to reflection theory in cybernetics). This reality is well-known but only very seldom applicated in soil genesis although is logic, that also relict properties of soils have a large significance not only for genesis and geography of soils but for productive and environmental functions of soils, too. In general, under recent soils significance we can consider only the soils or parts of soil profile which are the result of such interactions of soil forming factors activities and which are in concrete site very similar and timely entered interactions running at present. All other soils are considered under relict ones (Linkeš, 1984). Referring to Fig. 1 it is probably going about relict soils with paleohydromorphic phenomena caused by original different microclimatic conditions and origin vegetation cover on small area. Finally, these factors had been probably the large influence on genesis and development of dark-coloured soils on some depositions of non-chernozem regions. In addition, expression recent or relict soil must be related to concrete site and soil taxonomy, because various soil types during their development have been responded to changing interactions of soil forming factors variously.

CONCLUSIONS

Dark-coloured soils (which arable soils are evaluated in this contribution from) of non-chernozem regions belong also to fertile soils like similar soils (Mollic Fluvisols, Phaeozems, Chernozems) in the chernozem regions with predominant mollic humus horizon but opposite them their occurrence is extended in cooler and moist conditions, sometimes occurring on a slight slope (about 3 – 5° and more), often gravelly, carbonateous and non-carbonateous soils can be distinguished as well.

Humus horizons of dark-coloured soils in non-chernozem regions opposite similar soils in chernozem regions are characteristic with higher content of labile carbon as well as higher lability index. In addition, higher $C_L : N_{pot}$ ratio was found out which seems to be a better indicator of humus quality than C : N ratio. These indicators are not included in the latest Morphogenetic Soil Classification System of Slovakia. In spite of evaluated soils to cover only small areas in non-chernozem regions, these soils are the expressive component of landscape development. They have often phenomena of old paleohydromorphism and original vegetation cover influence. Relict phenomena are often changed with the recent ones on relatively small areas covered by heterogenous soils with motley mosaic of dark- and light-coloured soils (Fig. 1). It is the result of various development on various depositions mostly in depressional regions. It seems that for development during which the soil has been reflected the influence of soil forming factors when is necessary much higher supply of matters and energy as was possible in larger area of soil cover in Slovakia during holocene, resp. its last periods, what is probably example of dark-coloured soils in non-chernozem regions. By the help of self-regulation ability of these soils (including vegetation cover influence) which can resist environment impact especially in case to be in forms of timely non-dense oscillated impulses what is often at studying of pedogenesis underestimated.

REFERENCES

Barančíková, G., Kobza, J., 1999: Changes in content and quality of soil organic matter in Slovakia. In: Proceedings of Soil Conservation in Large-Scale Land Use. Inter. Conf. ESSC 12. – 15.5.1999, Bratislava, 255 – 262.

Bielek, P., 1998: Dusík v poľnohospodárskych pôdach Slovenska. VUPU Bratislava, 256 s. (ISBN 80-85361-44-2).

Blair, G. J., Lefroy, R.D.B., Lisle, L., 1995: Soil carbon fractions based on their degree of oxidation and the development of a carbon managament index. In: Austr. J. Agric. Res., Vol. 46, pp. 1459 – 1466.

Fiala, K., Kobza, J., Barančíková, G., Brečková, V., Búrik, V., Houšková, B., Chomaničová, A., Litavec, T., Makovníková, J., Matúšková, L., Váradiová, D., 1999: Záväzné metódy rozborov pôd. VÚPOP Bratislava,142 s. (ISBN 80-85361-55-8).

Hraško, J., Červenka, L., Facek, Z., Komár, J., Němeček, J., Pospíšil, F., Sirový, V., 1962: Rozbory pôd. SVPL Bratislava, 335 s.

Kobza, J., Barančíková, G., Čepková, V., Došeková, A., Fulajtár, E.,houšková, B., Makovníková, J., Matúšková, L., Medveď, M., Pavlenda, P., Schlosserová, J., Styk, J., Vojtáš, J., 2002: Monitoring pôd SR Súčasný stav a vývoj monitorovaných vlastností pôd 1997 – 2001. VÚPOP Bratislava, 180 s. (ISBN 80-89128-04-1).

Linkeš, V., 1984: Reliktné fenomény v pôdnom pokryve Slovenska a príspevok k ich interpretácii. In: Geografický časopis 36, 2, s. 163 – 178.

Loginow, W., Wisniewski, W., Gonet, S.S., Ciescinska, B., 1987: Fractionation of organic carbon based on susceptibility to oxidation. In: Pol. J. Soil Sci., N. 1, pp. 47 – 52.

Loginow, W., Wisniewski, W., Gonet, S.S., Ciescinska, B., 1993: Testowa metoda oznaczania podatnosti na utlenenie materii organicznej gleb (Testing method for determination of susceptibility on oxidation of soil organic matter).

Sotáková, S., 1982: Organická hmota a úrodnosť pôdy (Organic matter and soil fertility). Bratislava: Príroda, 243 p.

Szombathová, N., 1999: Comparison of soil carbon susceptibility to oxidation by $KMnO_4$ in different farming systems in Slovakia. In: Humic Subst. Environ. vol. 1, N. 2, pp. 35 – 39.

Šály, R. 1982: Pedológia a mikrobiológia. VŠLD Zvolen, 384 s.

Šály, R., Bedrna, Z., Bublinec, E., Čurlík, J., Fulajtár, E. jun., Gregor, J. Hanes, J., Juráni, B., Kobza, J., Kukla, J., Račko, J., Sobocká, J., Šurina, B., 2000: Morfogenetický klasifikačný systém pôd Slovenska. Bazálna referenčná taxonómia, VÚPOP Bratislava, 76 s. (ISBN 80-85361-70-1).

Zaujec, A., Kobza, J. 2002: The content and quality of soil organic matter in key monitoring sites observing by soil monitoring system of the Slovak Republic. In: Agriculture (Poľnohospodárstvo), 48, (9): 492 – 499.

INFLUENCE OF pH ON CADMIUM SORPTION ONTO HUMIC ACIDS

Vplyv pH na sorpciu kadmia na humínové kyseliny

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ABSTRACT

Humic acids (HAs) are considered as predominant metal binders in soil due to their excellent sorption properties, which are dependent on their chemical structure and composition. Aim of this paper is to clarify the nature of cadmium (Cd) – HA interactions on the basis of sorption experiment in which effect of pH on Cd sorption onto HAs was studied, using HAs of different origin and composition. HAs were isolated from soils Chernozem and Cambisol and lignite. Among investigated HAs, significant differences in Cd sorption were observed. The lowest sorption was observed for Cambisol HA within all pH values of original Cd solution (pH 3, 4 and 5). Maximum sorption was measured for Chernozem HA at pH 4 and 5, at pH 3 for lignite HA. Value of Langmuir sorption maximum for all HAs was in evident linear relationship with increasing pH. Based on the result it is hypothesized that the dominant role in Cd sorption in an acid environment is played by carboxyls. In addition to their amount per unit HA weight, their structural arrangement is probably important as well, causing different sorption behaviour of HAs with similar carboxyl content.

Keywords: heavy metals, cadmium, sorption, soil, lignite, humic acid, pH

ABSTRAKT

Pri väzbe ťažkých kovov v pôdach sa za dominantnú pôdnu zložku považujú humínové kyseliny (HK), a to vďaka svojej vynikajúcej sorpčnej schopnosti, ktorá závisí od ich chemického zloženia a štruktúry. Cieľom článku je objasniť povahu interakcií medzi kadmiom (Cd) a HK na základe sorpčného experimentu, pri ktorom sme skúmali vplyv pH na sorpciu Cd na HK rozličného pôvodu a zloženia (izolované z kambizeme, černozeme a lignitu). Medzi skúmanými HK sme pozorovali významné rozdiely v sorpcii Cd. Najnižšiu sorpciu sme zaznamenali na HK kambizeme, a to pri všetkých skúmaných hodnotách pH (3, 4, 5). Najvyššia sorpcia bola zistená pri HK černozeme pri hodnotách pH 4 a 5 a pri lignitickej HK pri pH 3. Hodnota Langmuirovho sorpčného maxima bola pri všetkých HK v lineárnom vzťahu s rastúcou hodnotou pH. Na základe výsledkov sa domnievame, že dominantnú úlohu pri sorpcii Cd humínovými kyselinami hrajú v kyslom prostredí karboxylové funkčné skupiny, no popri ich množstne na jednotku hmotnosti je rovnako dôležité aj ich štruktúrne usporiadanie, ktoré zapríčiňuje, že HK s rovnakým počtom karboxylových skupín sa pri zmenách pH správajú rozdielne.

Kľúčové slová: ťažké kovy, kadmium, sorpcia, pôda, lignit, humínové kyseliny, pH

INTRODUCTION

Soil organic matter, and especially its humified fractions, the humic substances (HS), are universally recognized as important part of soil protection from degradation and contamination. One of the most striking characteristics of HS is their ability to interact with metal ions to form water-soluble, colloidal, and water-insoluble complexes of varying properties and widely differing chemical and biological stabilities. Metal binding by HS is an important function that has been widely studied (STEVENSON and CHEN, 1991; SENESI, 1993; CLAPP et al., 2001). The main fraction of humic substances are humic acids (HAs), which are involved in almost all physical, chemical and biological processes occurring in the soil system (PICCOLO, 1996; DROZD et al., 1997).

In particular, HAs are well known to be very active in interacting with a variety of organic and inorganic chemical contaminants, to various extents and in various ways, including sorption/desorption (SENESI and MIANO, 1995; CLAPP et al., 2001). HAs are the predominant metal binders in soil (SENESI, 1993; CLAPP et al., 2001). Their excellent sorption properties are well known to depend on their chemical structure and composition. HAs isolated from different matrices have different sorption capacity with regard to binding of heavy metals.

Important binding sites of heavy metals on HS are functional groups. The functional groups are composed of a set of active chemical groups that gives the HS their unique chemical behaviour (TAN, 2003). The most important functional groups present in HAs are those containing oxygen (carboxyl COOH, phenolic-OH, alcoholic-OH, carbonyl groups and methoxy groups). In addition to the above, amino groups are also important.

In this paper, we tried to clarify the nature of Cd-HA interactions. We present and discuss results of sorption experiment, in which effect of pH on Cd-HA interactions was studied, using HAs of different origin and chemical composition, isolated from different matrices.

MATERIAL AND METHODS

For sorption experiment we used HAs isolated from two different matrices – soils of types Calcaric Chernozem and Dystric Cambisol and lignite. The method of HA isolation and more information about their chemical structure can be found in our previous work (BARANČÍKOVÁ et al., 2004). In Table 1, only selected chemical properties of HAs, relevant for this work, are shown.

Cd sorption

20 mg of solid HA was poured by 20 ml of 0.01 M $NaNO_3$, pH of which was set to values 3, 4 and 5 by concentrated NaOH or HNO_3. Successively, 5 to 200 µl of $CdNO_3$ solution (1 000 mg/l Cd, pH set to 4 by NaOH) was pipetted into suspension. Suspension was shaken for 1 hour and centrifuged for 5 minutes at 4 500 rpm. Each adsorption point was obtained as average of 2 replications.

Before experiments, a kinetic study with soil HAs had shown that soil-solution equilibrium was obtained within first minutes of reaction. Change of solution acidity was not measured during the adsorption, but in similar experiment with soil HA, drop in pH from 4 to approximately 3.4 was observed (unpublished data). Due to the fact that we didn't measure pH change, all results in this paper are discussed with regard to original pH of the solutions.

Concentration of Cd was measured in supernatant by polarographic analyser EP-100 (Kozáková, 1994). Concentration of Cd sorbed on HA was calculated from the difference between original and equilibrated Cd concentration in solution.

Statistical processing of data

Parameters of Cd sorption in experimental pH ranges were determined in two ways:

1. Linearized Langmuir isotherm: $\mathbf{c_{eq}/a_{eq} = 1/b.\ a_{max} + c_{eq}/a_{max}}$, where c_{eq} is an equilibrium Cd concentration in solution (mg/l), a_{eq} is a concentration of Cd sorbed onto HA (mg/kg), a_{max} is maximum sorption capacity (mg/kg) and b is a constant,
2. Linearized Freundlich isotherm: $\mathbf{\log a_{eq} = \log K_F + 1/n.\ \log c_{eq}}$, where K_F is a Freundlich distribution constant and n is a constant.

Table 1 Selected chemical properties of HAs used for sorption experiment (in order: content of carboxyls, proportion of aliphatic and aromatic carbon, degree of aromaticity)

HA origin	-COOH meq/1 g HA	C_{aliph} %	C_{ar} %	α %
Chernozem	4.2	34	42	56
Cambisol	2.8	49	29	38
Lignite	4.5	35	44	56

RESULTS

Parameters of obtained adsorption isotherms are shown in Tables 2a and 2b. Among investigated HAs, significant differences in Cd sorption were observed, as can be seen from comparison of maximum sorption capacity (a_{max}, Table 2a). The lowest sorption ability was observed for Cambisol HA within all pH ranges. Maximum sorption ability was measured for Chernozem HA at pH 4 and 5, at pH 3 for lignite HA.

Table 2a Parameters of Cd isotherms (Langmuir)

HA origin	pH 3		pH 4		pH 5	
	a_{max}	b	a_{max}	b	a_{max}	b
Chernozem	$22.2 \cdot 10^3$	0.43	$90.9 \cdot 10^3$	0.18	$178.6 \cdot 10^3$	0.115
Cambisol	$6.5 \cdot 10^3$	0.12	$22.8 \cdot 10^3$	0.22	$47.6 \cdot 10^3$	0.13
Lignite	$33.2 \cdot 10^3$	0.12	$76.9 \cdot 10^3$	0.13	$131.6 \cdot 10^3$	0.09

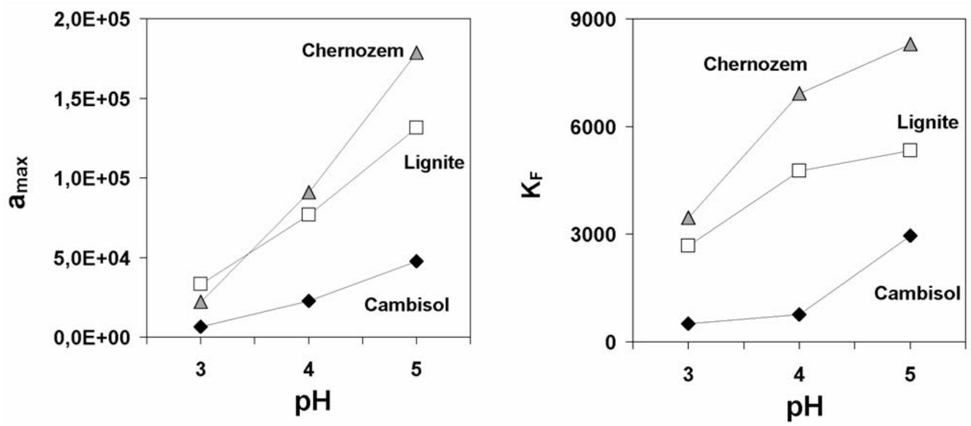
Table 2b Parameters of Cd isotherms (Freundlich)

HA origin	pH 3		pH 4		pH 5	
	K_F	n	K_F	n	K_F	n
Chernozem	$34.6 \cdot 10^2$	1.68	$5.1 \cdot 10^2$	1.44	$26.9 \cdot 10^2$	1.34
Cambisol	$69.2 \cdot 10^2$	1.36	$7.7 \cdot 10^2$	1.45	$47.8 \cdot 10^2$	1.34
Lignite	$83.0 \cdot 10^2$	1.32	$29.6 \cdot 10^2$	1.37	$53.3 \cdot 10^2$	1.33

Value of a_{max} is for all HAs in linear relationship with increasing pH. Slopes of the regression lines (Figure 1) increase in order Cambisol HA < lignite HA < Chernozem HA.

As in case of a_{max}, values of K_F of Freundlich isotherms increase with increasing pH for all three HAs (Table 2b). However, relationship between K_F and pH (Figure 1) is more curvilinear then linear. Slopes of K_F increase in pH range 3 – 4 are in the same order as described for a_{max} in all pH ranges. In pH range 4 – 5, Cambisol HA has the highest increase of K_F.

Figure 1 Maximum sorption capacity a_{max} and Freundlich distribution constant K_F of humic acids, related to pH



DISCUSSION

In natural conditions, humic acids are polyanions with negative charge. The charge originates from H^+ dissociation from functional groups of the humic acid molecule (TAN, 2003). Because dissociation depends on pH of the environment, degree of dissociation at certain pH value is reflected in sorption capacity of humic acid. According to JONES and JARVIS (1981), increasing pH causes ionization of functional groups, which consequently causes increased sorption. Observed dependency of sorption maximum on pH (Figure 1) for all HAs is in agreement with this theory.

According to ANDERSON and CHRISTENSEN (1988, in MESTEK and VOLKA, 1993), positive one-unit pH change leads to fourfold increase in sorption to HAs. In our experiment, increase of such extent was observed in pH change from 3 to 4 for soil HAs (Chernozem 4, Cambisol 3.5-fold). Lignite HA showed in this pH range only 2.3-fold increase of sorption. In slightly acidic pH range (4 – 5), apparently lower increase of Cd sorption within one pH unit was detected – twofold increase in case of soil HAs and 1.7-fold increase for HA isolated from lignite.

Several authors dealing with Cd sorption (YONG et al., 1992; MESTEK and VOLKA, 1993) point out to key role of hydroxyl –OH groups. As the most important, carboxyl –COOH and phenolic –OH groups are referred (Tan, 2003). Phenolic –OH groups start to dissociate at pH 9 and thus addition of their dissociation to Cd sorption can be neglected in our experimental pH range. Dissociation constant of –COOH groups is much lower (pKa = 3) and 99% ionization is reached even at pH = 5. STEVENSON (1982) reported that maximum ionization of carboxyls with various acidities is for HA obtained at pH 7.65. Author considered carboxyl groups as the most important, if not the only responsible for Cd binding onto HA.

Differences in Cd sorption between Chernozem and Cambisol HA can be partially explained by different content of carboxyl groups in humic acid chemical structure (Table 1). On the other hand, in case of lignite HA, which has the highest content of carboxyl groups, sorption maximum was the highest only for pH = 3. For other pH values, higher sorption was observed for Chernozem HA. Thus, it is not sufficient to explain Cd sorption only by the content of carboxyl groups, at least for such different matrices as soil and lignite are. More or less constant proportion between sorption maximums of HA from Chernozem and Cambisol at all pH (for pH 3, 4, 5 the proportion is 3.4, 4.0, and 3.8) could indicate that differences in sorption can be caused only by the amount of carboxyls. Nevertheless different position and slope of lignite HA regression line can indicate different character of sorption.

HA chemical structures, on which -COOH groups are bound, can also influence reactivity of carboxyls. In case of Chernozem and lignite aromatic, in case of Cambisol aliphatic structures dominate (Table 1). Moreover, detailed ^{13}C NMR spectral analysis had shown that lignite HA has larger proportion of aromatic carbon substituted by O and N then HA from Chernozem (BARANČÍKOVÁ at al., 2004).

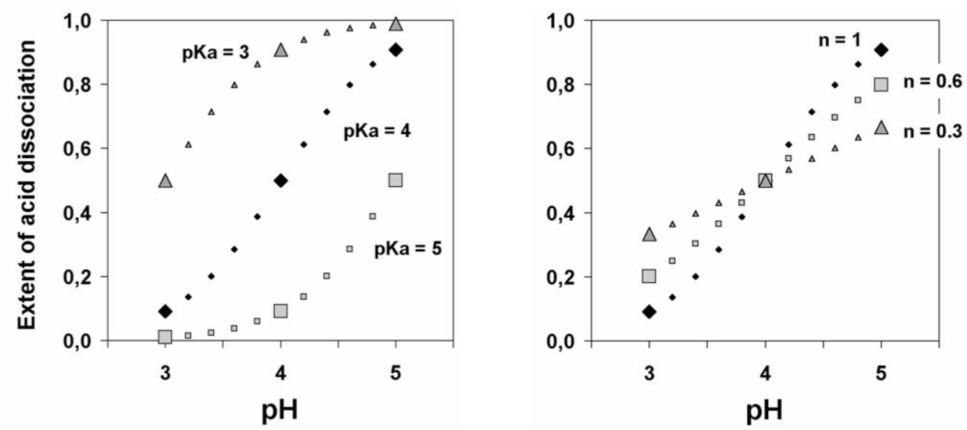
Dissociation of HAs with plenty of various function groups of different pKa values can be satisfactory described by generalized form of Henderson-Haselbach equation (MCBRIDE, 1997):

$$pH = pKa + n.\log \{\alpha / (1 - \alpha)\}$$

where pKa is an apparent dissociation constant of HA, n an empirical constant and α dissociation degree of acid functional groups. Empirical constant is lower then 1, for n = 1 equation describes dissociation of ideal monoprotic acid.

Influence of pKa values on shape of dissociation curves in studied pH range is shown in Figure 2. In comparison with Figure 1, the difference is that the scale in Figure 2 is relative, while potential sorption capacity for HAs used in experiment is not known and thus it is not possible to transform the results into relative scale.

Figure 2 Influence of parameters of generalized Henderson-Haselbach equation on dissociation of humic acid. Left: n = 1, right: pKa = 4



On the basis of comparison of modelled curves in Figure 2 and measured curves (Figure 1) we can state that pKa = 4 for apparent dissociation constant can be estimated from linear shape of curves within pH 3 – 5 for all HAs. After correction to expected pH change due to Cd sorption (see part Material and methods), the pKa is approximately 3.5. This value clearly corresponds with published knowledge about dominant role of carboxyls in Cd adsorption onto HAs in acid environment (STEVENSON, 1982).

Different course of experimental lignite HA curve (lower slope then for HA of Chernozem) can indicate that value of parameter **n** is lower then for soil HAs. Empirical constant **n** in equation expresses the degree of difference in comparison with ideal behaviour. One of the reasons is inhibition of further dissociation of functional groups when pH > pKa. In such conditions, negative charge formed on the HA molecule inhibits further dissociation of non-dissociated groups. From this point of view, lower n value of lignite HA curve could reflect higher density of -COOH groups on the surface of molecule, which can strengthen the above-mentioned "charging" effect.

CONCLUSIONS

On the basis of the results we can conclude that carboxyl groups are responsible for sorption of Cd on HAs in acid environment. 50-percent dissociation of carboxyls takes place approximately at pH 3.5. By dissociation, negatively charged sorption sites are created, which allow binding of cations, e.g. Cd^{2+} in our experiment. In addition to the number of carboxyl groups per weight unit, their structural arrangement is probably important as well. Due to structural differences, HAs with similar amount and acidity of carboxyl groups react differently to changes of H^+ concentration.

REFERENCES

ANDERSON, P.K., CHRISTENSEN, T.H.J., 1993: J. Soil Sci. 39, 15, 1988, refered in: MESTEK, O.,VOLKA K.: Interakce těžkých kovů s půdními složkami. Chemické Listy, 87.

BARANČÍKOVÁ, G., KLUČÁKOVÁ, M., MADARAS, M., MAKOVNÍKOVÁ, J., PEKAŘ, M.: Chemical structure of humic acids isolated from various soil types and lignite. Humic Substances in the Environment, in press (accepted).

CLAPP, C.E., HAYES, M.H.B., SENESI, N., BLOOM, P.R., JARDINE, P.M., 2001: Humic Substances and Chemical Contaminants. Soil Science Society of America, Madison, 502 p.

DROZD, J., GONET, S.S., SENESI, N., WEBER, J., 1997: The Role of Humic Substances in the Ecosystems and in Environmental Protection. PTSH-Polish Society of Humic Substances, Wroclaw, 1002 p.

JONES, L.H.P., JARVIS, S.C., 1981: The Fate of Heavy metals. In. Greenland, D.J. and Hayes M.H.B. The Chemistry of Soil Processes. John Wiley and sons Ltd.

KOZÁKOVÁ, E., 1993: Stanovenie nízkych a stopových obsahov olova a kadmia v pôdnych vzorkách a v kyslých výluhoch metódou pulzovej stripping voltampérie (DPSAV). In: ČAKRT, M. (ed.): Metódy a postupy elektrochemickej analýzy 1. HSC Servis, Bratislava, pp. 137 – 143.

MCBRIDE, M.B., 1994: Environmental Chemistry of Soils, Oxford University Press, NewYork – Oxford, 406 p.

MESTEK, O., VOLKA K., 1993: Interakce těžkých kovů s půdními složkami. Chemické Listy, 87, p. 95 – 806.

Piccolo, A., 1996: Humic Substances in Terretrial Ecosystems. Elsevier, Amsterdam, 675 p.

Senesi, N., 1993: Metal-humic substances complexes in the environment. Molecular and mechanistic aspects by multiple spectroscopic approach. In: Biogeochemistry of trace Metals (ed. D.C. Adriano), Lewis Publishers, Boca Raton, 429 – 496 p.

Senesi, N., Miano, T.M., 1995: The role of abiotic interaction with humic substances on the environmental impact of organic pollutants. In: Huang, P.M., Berthelin, J., Bolag, J.M., McGill, W.B., Page, A.L. (Eds.), Environmental Impact of Soil Component Interaction, Natural and Anthropogenic Organics. CRC Lewis Publishers, Boca Raton, pp. 311 – 335.

Stevenson, F.J., 1982: Humus chemistry – Genesis, Composition, Reaction. John Wiley and Sons, New York, 445 p.

Stevenson, F.J., Chen, Y., 1991: Stability constant of copper (II)-humate complexes determined by modified potentiometric titration. Soil Sci. Soc. Am. J. vol. 55, pp. 1586 – 1591.

Tan, K.H., 2003: Humic Matter in Soil and the Environment. Principles and Controversies. Marcel Dekker, Inc., New York, 386 p.

Yong R.N., Mohamed A.M.O., Warkentin B., 1992: Principles Contaminant Transport in soils, Elsevier, 327p.

DISTINCT SPATIAL HETEROGENEITY OF AVAILABLE PHOSPHORUS AND HUMUS CONTENTS IN THE WATER EROSION AFFECTED SOILS

VÝRAZNÁ PRIESTOROVÁ HETEROGENITA OBSAHOV PRÍSTUPNÉHO FOSFORU A HUMUSU V PÔDACH OVPLYVNENÝCH VODNOU ERÓZIOU

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ABSTRACT

We observed the water erosion negative influence on quantitative changes of available phosphorus and humus contents (as an important production ability of soil forming factors) in the arable soils (two erosive transects) in conditions of various intensity of erosive-accumulation processes.

Universal Soil Loss Equation (USLE) was used for potential erosion determination. On the basis of USLE (Wischmeier-Smith´s equation) applying in the local conditions we calculated the potential soil loss (t/ha/year). The soils of these transects are more or less influenced by water erosion processes (it is confirmed by using of USLE), but their intensity is various (influence of relief, soil, plant, rain intensity, land management).

Distinct spatial heterogeneity of monitored soil properties was found out on the both erosive transects. We determined a significant decreasing of available phosphorus and humus contents (with the depth of soil profile) in the soil of erosive parts and on the contrary their contents have been increasing in the soil of accumulation parts of monitored localities. Visible quantitative changes of these observed properties were caused by soil matter translocation (influence of water erosion) from the erosive parts of slopes and its consequential accumulation to the base of slopes (phosphorus and humus are firmly fixed on the fine soil matter particles surfaces).

KEYWORDS: water erosion, available phosphorus, humus, spatial heterogeneity

ABSTRAKT

Negatívny vplyv vodnej erózie na kvantitatívne zmeny obsahov prístupného fosforu a humusu (ako dôležitých faktorov ovplyvňujúcich produkčnú schopnosť pôdy) v orných pôdach sme sledovali v podmienkach s rôznou intenzitou pôsobenia erózno-akumulačných procesov na pôdu.

Na stanovenie potenciálnej erózie (potenciálna strata pôdy) sme použili všeobecnú rovnicu zmyvu pôdy (VRZP) bežnejšie známu ako „Wischmeier-Smithova rovnica“. Na základe aplikácie VRZP v konkrétnych (lokálnych) podmienkach sme vypočítali potenciálnu stratu pôdnej hmoty (v t/ha/rok). Pôda na sledovaných eróznych transektoch je viac, alebo menej ovplyvnená procesmi vodnej erózie, ale ich intenzita vplyvu na pôdu je rozdielna (vplyv reliéfu, pôdy, rastliny, intenzity zrážok, spôsobu obhospodarovania atď.).

V pôde obidvoch transektov sme zistili výraznú priestorovú heterogenitu sledovaných pôdnych parametrov, keď v eróznych častiach svahov sme zaznamenali výrazné zníženie obsahov prístupného fosforu a humusu (v celej hĺbke pôdneho profilu) a naopak najvyššie obsahy sledovaných parametrov boli namerané v akumulačných častiach sledovaných lokalít (báza svahu). Viditeľné kvantitatívne zmeny monitorovaných vlastností v pôde jednotlivých častí eróznych transektov (vrchol, svah, báza) boli spôsobené translokáciou pôdnej hmoty (vplyv vodnej erózie) z eróznych častí svahov a jej následnou akumuláciou v ich bázach (fosfor a humus sú pevne viazané na povrchy jemných častíc pôdnej hmoty).

Kľúčové slová: vodná erózia, prístupný fosfor, humus, priestorová heterogenita

INTRODUCTION

Degradation of soils by water erosion processes belongs to primary problems of agriculture not only in Slovak conditions, but we can say it is a global problem of agricultural soils. The soil protection could be one of the most important objects of agriculture because the degradation of soil by the processes of water erosion is irreversible process. Reduction of soil natural fertility (production ability) is a primary result of water erosion influence on the soil. It is caused by soil matter loss from erosive parts of slopes and negative changes of soil fertility forming properties (distinct decreasing of their contents in the soil) in water erosion affected regions, as well. Various results about decreasing of soil fertility were published in the literature. Pasák (1984) in his work presented that erosive soil loss of 1 cm thick layer induced 3% decreasing of soil fertility and Karniš (1985) presented 2 – 3% decreasing of soil fertility as a result of 1 mm erosive soil matter loss. These various findings were probably influenced by soil type and degree of soil production potential.

The work objective is the evaluation of water erosion influence on the quantitative soil fertility forming parameters changes (available phosphorus and humus contents in our case) in the soil (spatial differentiation) in chosen (water erosion affected) localities.

MATERIAL AND METHODS

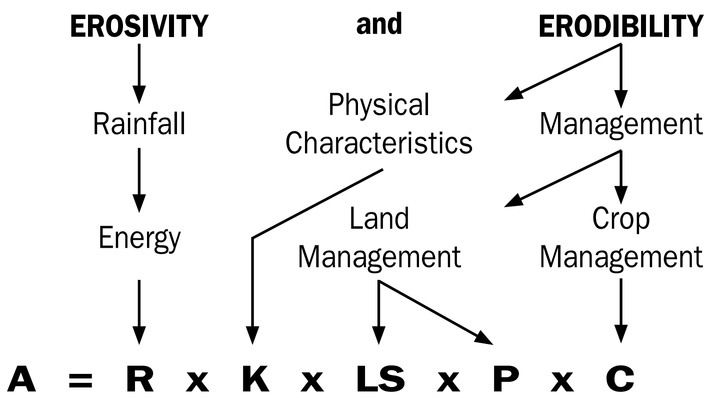
We have observed the influence of water erosion processes on quantitative changes of available phosphorus and humus contents at two erosive transects which are situated near the villages Rišňovce (Nitra district) and Zacharovce (Rimavská Sobota district). Three soil profiles (pedological sites) were diged up and detailed morphological description was prepared on the every chosen erosive transect. The first one was located at the top of slope (this pedological site represents non eroded, or slightly eroded soils), the second one was located at the erosive part of slope (represents eroded soils) and finally, the last one was situated at the accumulative part of slope (represents accumulated soils).

Pedological site situated at the top of erosive transect can be considered as a referential soil profile (revisory) because the soil at this part of the slope is only slightly affected by processes of water erosion. If we want to study the influence of water erosion on spatial differentiation of monitored soil properties we have to compare the contents these properties from erosive and accumulative parts of transect with contents determined in referential soil profile (top of slope).

We have taken the soil samples (from every site located at the erosive transect) from the depth of 0 – 0.10, 0.20 – 0.25, 0.25 – 0.30, 0.30 – 0.35, 0.35 – 0.40 and 0.40 – 0.45 m.

For determination of potential water erosion influence on the soil in the certain conditions we used well – known Wischmeier-Smith´s equation (USLE – Universal Soil Loss Equation) which was elaborated by Wischmeier and Smith (1978). We have obtained quite accurate results on potential water erosion (mean annual soil loss in t per ha per year) using of this equation in particular conditions. Universal soil loss equation is expressed by multiplication of two (R, K) direct factors and four (L, S, C, P) indirect factors (Fig. 1).

Figure 1 Empirical expression of USLE (Laflen, Moldenhauer, 2003)



where:

- A – mean annual soil loss (in t/ha/year)
- R – rainfall factor
- K – soil erodibility factor
- L – length of slope factor
- S – steepness of slope factor
- C – cropping and management factor
- P – conservation practices factor

If we want to evaluate the loss of soil matter which is influenced by water erosion, following soil loss scale can be used (Svíček, 2003):

loss in t/ha/year	**evaluation of erosion**
4 – 4	very low
10 – 10	low
20 – 20	medium
30 – 30	high
40 – 40	very high
50 – 50	extreme
more than 50	tremendous

Humus content in the soil is relatively stable factor (in the framework of certain soil type, certain locality). Its indistinct changes in monitored locality (in our case at the erosive transect) can be influenced by natural spatial heterogeneity of surrounding, but the distinct changes of humus contents at the transect are probably induced by erosive-accumulative processes of water erosion. Humus (from among the soil properties) can be included in the reliable indicators of water erosion influence on the soil (Styk, 2003).

Available phosphorus in the soil is more variable factor opposite the humus. It means that phosphorus content can be relatively easily increased by applying this macronutrient to the soil in the form of various kind of fertilizers and on the contrary his content decreasing is more or less influenced (in the non eroded soil) by the plants consumption (every plant species has individual requirements on the input of phosphorus from the soil inside the plant) (Styk, 2002).

Negative influence of water erosion on the soil is demonstrated in carrying of soil matter away (translocation) from erosive parts of monitored locality and its consequential accumulation to the base (accumulative part) of slope. The result of these erosive-accumulative processes can be the distinct decreasing available phosphorus contents in the soil of erosive parts of transect. It is caused that lower parts of soil profile (which are poor on available phosphorus) are getting up to the topsoil. The natural distribution of this element in our soils is relatively low and its increasing content in the soil can be achieved only by applying of various kinds of fertilizers (Kobza et al., 2002).

Soil properties were analysed in accordance with the standard analytical methods used in the framework of Partial monitoring system – Soil in the laboratories of Soil Science and Conservation Research Institute (Fiala et al., 1999). Available phosphorus content was determined by original Egner´s method because we want to hold the continuity (and possibility of comparison) with analyses which were realised during Complete Soil Survey (1961 – 1970). For the determination humus content in the soil Ťjurin method in modification of Nikitin was used.

RESULTS AND DISCUSSION

Description of studied localities

The erosive transect near Rišňovce village (Nitra district) was localised in moderately rolling relief of Nitrianska hilly land. Medium heavy soils originated on the calcareous loess and blowed sands are typical for this part of the country. Studied locality was situated on the arable soil with inclination 10 – 12° with the length 185 m. Winter rape was grown at the all monitored erosive transect. Molic Fluvisols (WRB, 1994) is characteristic for the base (accumulate part) of monitored locality, Luvi-Haplic Chernozems is located at the top of slope (non eroded soil) and Haplic Luvisols (eroded form) is characteristic for the erosive part of transect (eroded soil).

The long-term negative erosive-accumulative influence of water erosion can be visible at the soil profile formation (in horizontal and vertical direction). It was caused by the soil matter translocation from the erosive parts and consequential its accumulation to the base (accumulation part) of slope. The result is various solum thickness at the individual parts of monitored locality (at the top of slope humus horizon thickness is 0.30 m, at the erosive part its thickness is 0.25 m, but it is visible that this horizon is mixed with the subsoil, at the accumulation part of transect humus horizon thickness is 0.45 m). Sobocká (2003) in her work achieved the similar findings.

Second erosive transect was localised near Zacharovce village (Rimavská Sobota district) in Rimavskosobotská hilly land. This part of the country is characterised by the relatively rolling relief with medium heavy to heavy soils. The length of monitored locality (erosive-accumulative catena) is 115 m and its inclination is 8 – 12°. Heavy Stagni-Haplic Luvisols which originated on polygenetic clays is typical for the all erosive transect. Winter rape was grown on the all monitored locality (similarly as in Rišňovce transect).

Water erosion influence on the soil induced the various solum thickness in the individual parts of monitored transect (as in Rišňovce example). We can say that the referential (revisory) soil profile was at the top of slope (erosive influence on the soil is lower than in other parts). The humus horizon thickness here is 0.25 m. For the comparing with referential soil profile the humus horizon thickness at the erosive part of slope is only 0.20 m and humus horizon thickness at the accumulation part of transect is 0.35 m.

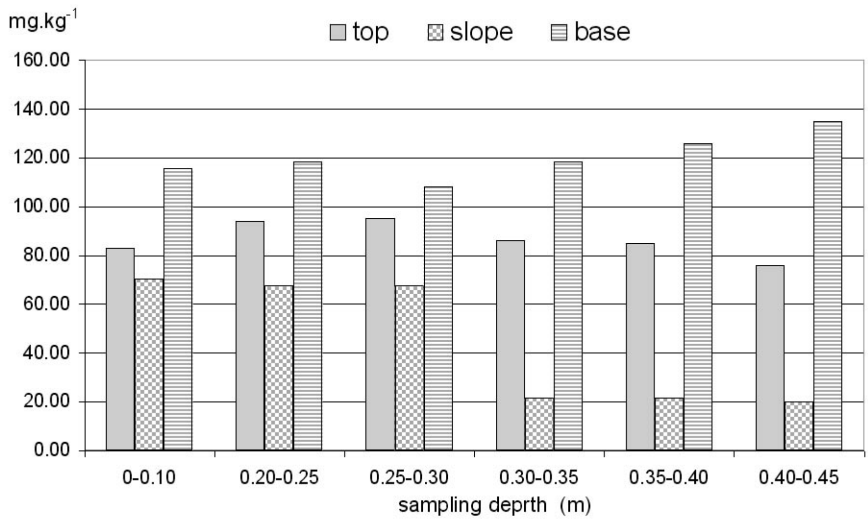
Results from studied localities

Rišňovce

For potential erosion determination we used the most widely accepted method which is known as an Universal Soil Loss Equation (USLE). We determined potential amount of water erosion translocated soil matter (50.88 t/ha/year) on the basis of USLE application in the local conditions. This calculated value shows us a very intensive water erosion influence on the soil (on the basis of this value is transect classified to the category with tremendous potential soil matter loss). Huge intensity of water erosion on this locality is caused above all by the length of erosive transect, its slope inclination, kind and type of soil, growing plant, intensity of precipitation.

The presence of erosive-accumulative processes of water erosion was demonstrated not only in soil matter loss (translocation) but in the distinct spatial differentiation (in the soil profile and in the individual parts of transect) of available phosphorus and humus contents, too (Fig. 2, 3).

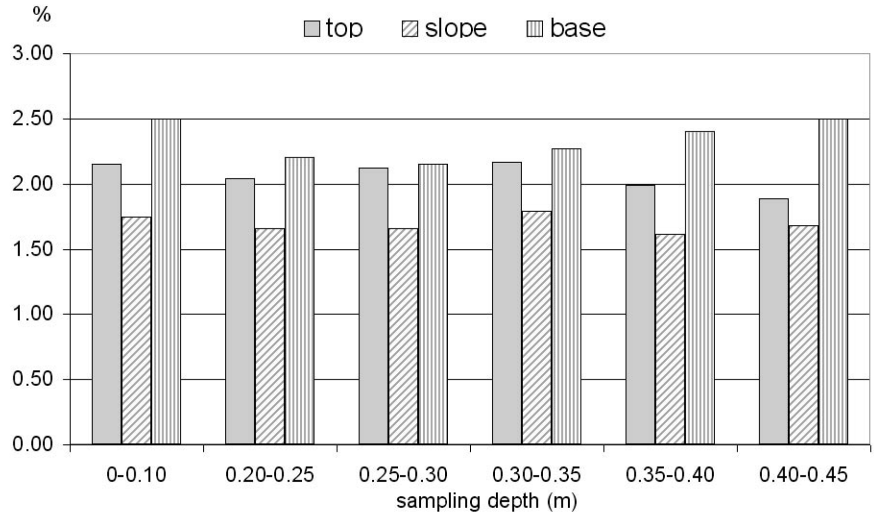
Figure 2 Available phosphorus content in the soil of erosive transect (Rišňovce)



The uppermost available phosphorus content (in all soil profile) was determined at the accumulation part of transect (Fig. 2), on the contrary the lowest content (with the depth of soil profile visible going down) was at the erosive part of locality (where the erosive influence on the soil is most intensive). BEDRNA (1985) in his work demonstrated influence of water erosion on decreasing of macronutrients in the soil. Phosphorus content at the subsoil of erosive part of transect was only approximately 26% and from the base (bottom) of slope was about 177% in comparison with the content from referential profile (100%) at the top of slope (Tab. 1). These results show us increasing tendency of accumulation of this macronutrient to the base (accumulation part) of slope.

The similar situation was observed with the humus content too. Its uppermost content was determined at the soil of accumulation part of monitored locality (base) where was soil matter translocated from erosive parts of monitored locality (Fig. 3). Content of humus was practically the same in every monitored depths of soil profile (to the depth of 0.45 m). Its content (in the depth of 0.40 – 0.45 m) was about 132% of referential profile humus content (Tab. 1). Lower humus contents were measured at the erosive part (slope) of transect (e.g. in the depth of 0.40 – 0.45 was content of humus at the level about 89% of referential profile). The similar results of monitored parameters changes on the eroded and non eroded soils were achieved by FULAJTÁR and JANSKÝ (2001).

Figure 3 Humus content in the soil of erosive transect (Rišňovce)

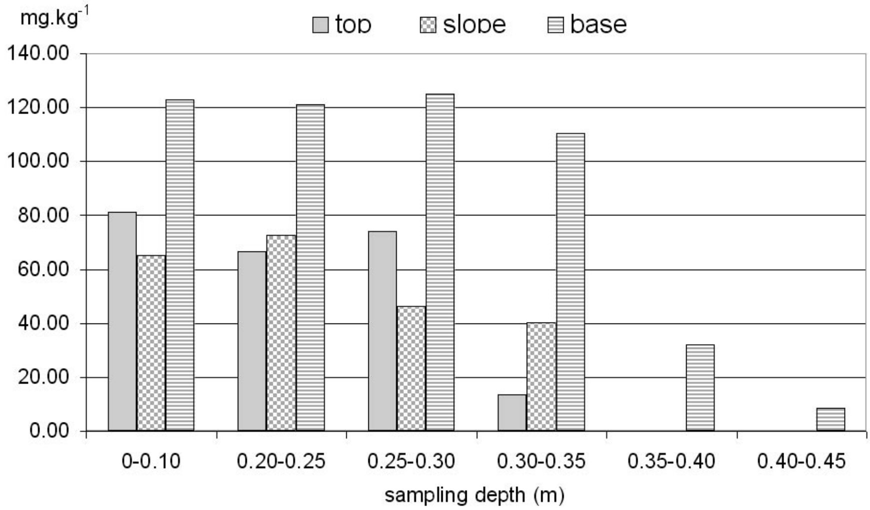


Zacharovce

We determined potential amount of water erosion translocated soil matter (29.80 t/ha/year) on the basis using of USLE on actual conditions of erosive transect (the results showed us a potential soil loss from erosive part of monitored locality). This area belongs to the category with the high potential soil matter loss (soil high endangered by soil erosion). However, the erosive influence on the soil is lower than in Rišňovce transect which is caused by some circumstances, e.g. shorter length of transect, heavy soil, lower intensity of precipitation.

The water erosion influenced the spatial distribution of available phosphorus content at the individual parts of erosive catena as well as in the individual parts of soil profile. In Zacharovce monitored locality as in example Rišňovce transect also the uppermost concentrations of phosphorus (in all sampling depths) were measured at the accumulation part of erosive transect (base), while at the top of slope the content of phosphorus was lower and at the erosive part (slope) was the lowest (Fig. 4). Phosphorus content in the subsoil of accumulation part of slope (0.30 – 0.35 m) is approximately 818% of referential profile phosphorus content (100%).

Figure 4 Available phosphorus contents in the soil of erosive transect (Zacharovce)

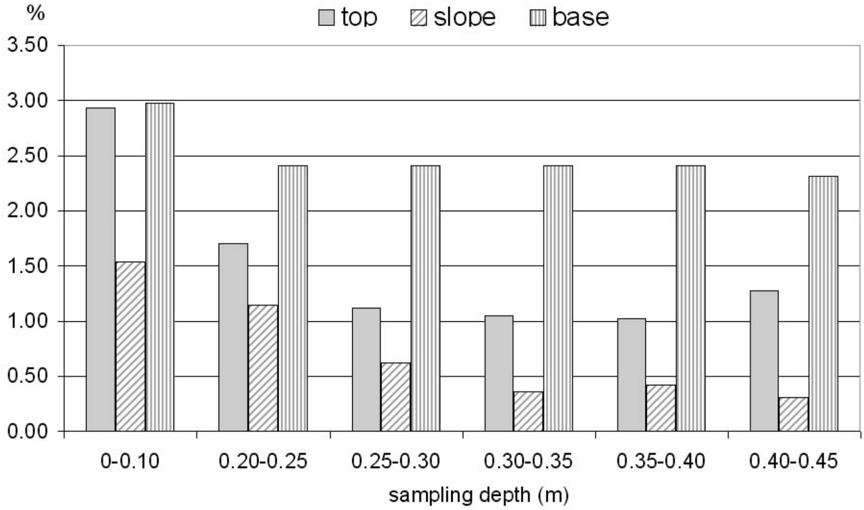


Spatial changes of humus content were observed at the individual parts of erosive catena (Fig. 5). We found out its the lowest content at the erosive part of slope in all monitored soil profile (from the Table 1 is evident that the humus content in the subsoil of erosive part in comparing with referential profile was only at the level 25%). Accumulation of soil matter at the base of slope influenced on the humus distribution in the soil profile. The humus content in the soil this part of the slope was highest in uppermost part (in the individual depths of soil profile) opposite the other parts of slope (content of humus in the subsoil was about 180% of content from eroded part of slope). We achieved a similar results at the erosive transect near Rišňovce village.

Table 1 Percentage comparison of available phosphorus and humus content in the topsoil and subsoil of both erosive transects

Depth (m)	**0 – 0.10**	**0.30 – 0.35**	**0.40 – 0.45**	**0 – 0.10**	**0.30 – 0.35**	**0.40 – 0.45**
Rišňovce	***% share of available phosphorus***			***% share of humus***		
Top	100	100	100	100	100	100
Slope	84.9	25.0	26.3	81.4	82.5	88.9
Base	139.1	137.8	177.6	116.3	104.6	132.3
Zacharovce	***% share of available phosphorus***			***% share of humus***		
Top	100	100	100	100	100	100
Slope	80.2	299.4		52.5	34.3	24.2
Base	151.4	818.5		101.7	229.5	180.5

Figure 5 Humus content in the soil of erosive transect (Zacharovce)



CONCLUSIONS

The negative influence of water erosion processes on distinct spatial heterogeneity of available phosphorus and humus contents was observed on the two various erosive transects (near Rišňovce and Zacharovce villages). We used for potential erosion determination the most widely accepted method which is weel-known as an Universal Soil Loss Equation (USLE). On the basis of USLE application in the local conditions we calculated the potential soil loss (t/ha/year). Determined results showed us the presence of water erosion processes on the both monitored localities but their impact intensity on the soil was various. It is caused above all by the length of erosive catenas, its inclination, kind and type of soil, crop (was the same), intensity of precipitation.

The transect near Rišňovce village was classified (using of USLE) to the category with tremendous potential soil matter loss (soil is extreme endangered by water erosion) and transect near Zacharovce was classified to the category with high potential soil matter loss.

On the both monitored localities the presence of erosive-accumulative processes of water erosion not only in soil matter loss (translocation) but also in the distinct spatial differentiation (in the soil profile and in the individual parts of transect) of available phosphorus and humus contents were demonstrated. Observed parameters are very important from production ability of soil point of view. Changes in available phosphorus and humus contents in the individual parts of erosive catenas were caused by soil matter translocation from erosive parts of monitored localities and its consequential accumulation to the base of slopes (phosphorus and humus are firmly fixed on the fine soil matter particles surfaces). The result is a significant decrease of monitored soil parameters content (with the depth of soil profile) in the soil of erosive parts of transects and on the contrary, their content has an increasing tendency in the accumulation parts of slopes.

The negative influence of water erosion on the soil of erosive threatened localities can be reduced by using of effectual soil conservation technologies helping to minimalise water erosion runoff. JAMBOR (2003) recommends (on the basis of obtained results) for the practice following:

- contour tillage is suitable for all soil conditions up till the slope 9°
- non-till technology (for the soil type Chernozems)
- minimum tillage (for the soil types Chernozems, Haplic Luvisols, Cambisols and some Albic Luvisols
- mulching (suitable for Chernozems, and Haplic Luvisols)
- organisation measures:
  - along contour orientation of fields
  - proper conservation crop rotation

REFERENCES

Bedrna, Z., 1985: Vymývanie živín z profilu pôdy. Výskumná správa. VÚPVR Bratislava, 30 s.

Fiala, K. et al., 1999: Záväzné metódy rozborov pôd. Čiastkový monitorovací systém – Pôda. VÚPOP Bratislava, 142 s.

Fulajtár, E., Janský, L., 2001: Vodná erózia pôdy a protierózna ochrana. VÚPOP Bratislava, 310 s.

ISSS-ISRIC-FAO, 1994: World Reference Base for Soil Resources. Draft. Wageningen/Rome, 161 p.

Jambor, P., 2003: Water erosion control. In: Nestroy, O., Jambor, P.: Aspects of the Erosion by water in Austria, Hungary and Slovakia. VÚPOP Bratislava, p. 77 – 84.

Karniš, J., 1985: Erózia poľnohospodárskych pôd. In: Hraško, J.: Pôda a výživa rastlín. VÚPVR Bratislava, s. 78 – 83.

Kobza, J. et al., 2002: Monitoring pôd SR. Aktuálny stav a vývoj monitorovaných pôd. Výsledky Čiastkového monitorovacieho systému – Pôda za obdobie 1997 – 2001 (2. cyklus). VÚPOP Bratislava, s. 180.

Laflen, J.M., Moldenhauer, W.C., 2003: Pioneering soil erosion Prediction. The USLE story. WASWC, 55 p.

Pasák, V. et al., 1984: Ochrana půdy před erozi. St. zem. nakladatelství, Praha, 160 s.

Sobocká, J., 2003: Water erosion processes identification in soil profile. In: Nestroy, O. - Jambor, P.: Aspects of the Erosion by water in Austria, Hungary and Slovakia. VÚPOP Bratislava, p. 137 – 153.

STYK, J., 2002: Monitoring vplyvu vodnej erózie na zmeny vybraných vlastností pôd. In: KOBZA, J. et al.: Monitoring pôd SR. Aktuálny stav a vývoj monitorovaných pôd. Výsledky Čiastkového monitorovacieho systému – Pôda za obdobie 1997 – 2001 (2. cyklus). VÚPOP Bratislava, s. 142 – 158.

Styk, J., 2003: Utilisation of remote sensing methods (especially IRS Pan satellite image) on detection of eroded agricultural soils. In: Gabriels, D. – Cornelis, W.: 25 years of assessment of erosion. International symposium, Ghent, Belgium. Proceedings. International centre for eremology and Ghent university, p. 457 – 464.

Sviček, M., 2003: Modelling of potential erosion and detection of eroded soil using remote sensing methods. In: Nestroy, O. - Jambor, P.: Aspects of the Erosion by water in Austria, Hungary and Slovakia. VÚPOP Bratislava, p. 137 – 153.

Wischmeier, W.H., Smith, D.D., 1978: Predicting rainfall erosion losses – Guide to conservation planning. Agricultural Handbook 537, USDA.

INFLUENCE OF SOME PHYSICAL PROPERTIES OF SOIL ON ITS TEMPERATURE AND MOISTURE

VPLYV NIEKTORÝCH FYZIKÁLNYCH VLASTNOSTÍ PÔDY NA JEJ TEPLOTU A VLHKOSŤ

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ABSTRACT

Temperature of two soils with different moisture distribution in profile (with depth temporally decreasing – the LVP plot respective increasing – the VP plot) was analysed during vegetation period. Significant difference of soil moisture between research plots was in 0.30 m layer (3.5% of weight) and very significant in 0.40 m (10.6% of weight) and 0.50 m (14.3% of weight). In spite of different soil moisture in deeper layers of soil profile plots differed significantly in temperature of 0.05 m soil layer (1.2 °C), only. Moister soil was also warmer.

Contribution treats about relations among soil temperature, soil moisture and some soil physical properties in soil profile. Profile distribution of soil temperature as well as moisture yields different facts. Soil temperature was connected with soil depth and with other soil properties influencing soil heat capacity and conductance. Soil moisture depended on a level of soil sorption ability. Source of soil water is true in atmosphere as well as soil temperature but on the other hand this water is influenced by gravitation, considerably.

With regard to relation of soil temperature and moisture, more water as good heat accumulator and conductor can be more lasting retained through soil layers with higher sorption capacity. Then, mainly in time beside insolation, these soil layers through their temperature can more or less influence temperature of soil layers lying direct upon them.

KEYWORDS: soil temperature, soil moisture, soil physical properties, profile distribution, correlation

ABSTRAKT

Počas vegetačného obdobia bola analyzovaná teplota 2 pôdnych profilov s odlišnou vlhkosťou v smere do hĺbky (s hĺbkou mierne klesajúca pôdna vlhkosť – plocha LVP (lesná voľná plocha), resp. stúpajúca – plocha VP (voľná plocha)). V danom období v súvislosti s vlhkosťou pôdy boli sledované i zrážky. Pôdne profily sa líšili významne vlhkosťou v 0,30 m hĺbke (3,5% hm.) a veľmi významne vlhkosťou v 0,40 m (10,6% hm.) a 0,50 m (14,3% hm.) vrstve, keď jeden z nich bol ovplyvňovaný vodou stekajúcou po ťažko priepustnej vrstve v hĺbke 0,6 – 0,7 m. Rozdiely v priebehu teploty medzi vlhkostne odlišnými profilmi boli preukazné len pri povrchu pôdy (hĺbka 0,05 m – 1,2 °C).

Príspevok je zameraný na analýzu vzájomných vzťahov medzi pôdnou teplotou, resp. vlhkosťou a inými fyzikálnymi vlastnosťami pôdy v rámci profilu pôdy (profilová distribúcia). Bolo zistené, že teplota pôdy v tomto prípade bola silno závislá predovšetkým od hĺbky, málo od stavu ostatných fyzikálnych vlastností, ktoré vplývajú skôr na tepelnú kapacitu a vodivosť pôdy. Vlhkosť pôdy súvisela jednoznačne s úrovňou sorpčnej kapacity pôdy. Zdroj pôdnej vody je síce v atmosfére tak isto ako pri teplote, ale na druhej strane ona značne podlieha gravitácii. Čo sa týka vzťahu teploty a vlhkosti pôdy, viac vody ako dobrého tepelného akumulátora a vodiča môžu trvalejšie zadržať vrstvy s vyššou sorpčnou kapacitou. Potom, hlavne v čase mimo insolácie, môžu tieto pôdne vrstvy svojou teplotou viac alebo menej vplývať na teplotu vrstiev ležiacich bezprostredne okolo nich.

KĽÚČOVÉ SLOVÁ: teplota pôdy, vlhkosť pôdy, fyzikálne vlastnosti pôdy, profilová distribúcia, korelácia

INTRODUCTION

Soil temperature and moisture are two of important factors that control microbiological activity and the processes involved in the production of plants. Their unfavourable conditions can become a reason of plant stress (TUŽINSKÝ, 1995). Temperature and moisture act often contrary. In continuity with global climate change is possible increase temperature and then decrease moisture in dependence from amount of precipitation (NIEPLOVÁ et al., 1997). More factors can influence their conditions and therefore it is necessary a complete view on their relationchips with other factors (ŠIRÁŇ, 2003; ZEMÁNEK, 2002). In our case, soil temperature and moisture were investigated in relation to their time and spatial variability on the plots with different soil physical properties.

MATERIAL AND METHODS

The measurement was performed not far from Kováčová village. On the LVP (forest free area) plot with depth temporally decreasing soil moisture is characteristic and on the VP (free area) plot one with depth increasing. Distance of plots is 600 m and they are situated in 430 – 460 m above sea level on slope with exposition of WSW and inclination of 14 – 18°.

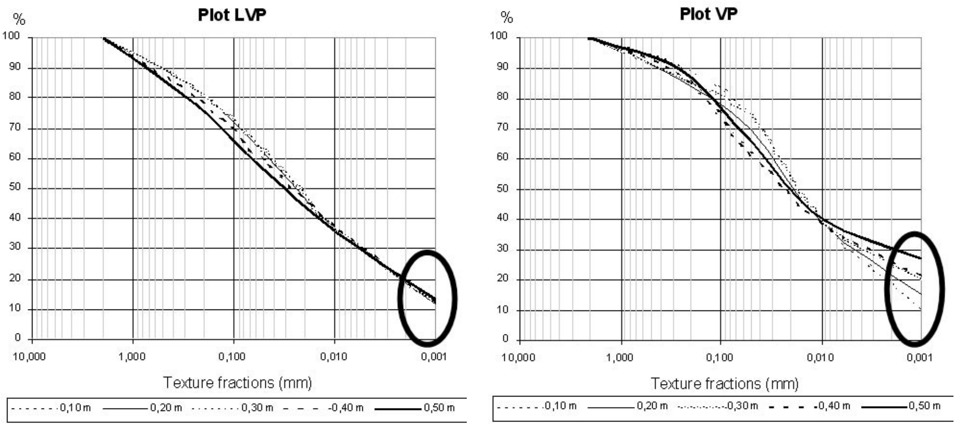
The soils are classified as follows: on the LVP plot it is Tephri-Eutric Cambisol and on the VP plot Stagni-Eutric Cambisol (KOLEKTÍV, 2000, WRB, 1994).

Soil temperature was measured according PALLMANN method (by KUBÍKOVÁ, 1970; STŘELEC, 1993) monthly in depth 0.05 m, 0.20 m and 0.50 m in three repetitions. Soil moisture was investigated near to place of temperature measurement by means of gravimetric analysis weekly in every 0.1 m layer up to depth of 0.50 m in three repetitions. Texture was determined through sedimentation method with using of pipette, humus content oxidometricaly by Tjurin. Obtained data were statistical by evaluated according to t-test of paired samples or correlation (ŠMELKO, 1988).

RESULTS AND DISCUSSION

Soil physical properties of the LVP and VP plots are presented in Tab. 1 as well as in Fig. 1. Soil on the plots differs first of all in texture, especially in portion of fraction less 0.001 mm, when its content increase with depth on VP plot more rapid. This fact influenced probably other physical properties pertinent of soil water-holding capacity. For example, maximum capillary water capacity on the VP plot increasing with soil depth and its values are higher on LVP plot. On the conditions of higher soil moisture as well as porosity and lower bulk density can influence also soil layer with weak water permeability in depth of 0.6 – 0.7 m.

Figure 1 Texture curves of single layers on the LVP and VP plots



Climate characteristics in studied period refer to that problem in regard to air temperature and rainfall was about long-term normal in this time.

Soil moisture course during measured period was relative even-tempered on the VP plot and less equable with more expressive July minimum on LVP plot (Figure 2). Next more important difference between soil profiles of plots was in more rapid increase of soil moisture with depth on the VP plot opposite LVP plot where the slight decrease has been observed. Significant difference of soil moisture was in 0.30 m layer and very significant in 0.40 and 0.50 m (Table 2). From whole soil profile point of view, soil of VP was more humid.

Table 1 Basic soil physical properties on the LVP and VP plots

Research plot		**Plot LVP**				
Depth of soil layer (m)		**0.1**	**0.2**	**0.3**	**0.4**	**0.5**
	(mm)	**(%)**				
Texture	< 0.001	11.92	11.67	12.37	12.82	13.39
	< 0.01	36.94	36.90	37.67	37.84	35.88
	0.01 – 0.05	25.14	25.18	24.78	21.22	20.16
	0.05 – 0.25	21.76	21.42	21.23	22.13	22.39
	0.25 – 2.00	16.16	16.50	16.32	18.81	21.57
Skeleton (%)		< 30	< 30	< 30	< 30	< 50
Particle Density (g.cm^{-3})		2.67	2.71	2.73	2.73	2.74
Bulk density (g.cm^{-3})		1.051	1.146	1.175	1.185	1.225
Porosity (%)		62.6	60.6	56.8	56.6	55.1
Max. capillary water capacity (% of weight)		36.0	30.6	28.7	30.7	27.0
Humus content (%)		2.88	2.05	1.73	1.47	1.18

Table 1 Basic soil physical properties on the LVP and VP plots (continue)

Research plot		Plot VP				
Depth of soil layer (m)		**0.1**	**0.2**	**0.3**	**0.4**	**0.5**
	(mm)	**(%)**				
Texture	< 0.001	10.68	15.16	20.12	21.60	27.25
	< 0.01	39.64	39.08	40.12	38.96	40.36
	0.01 – 0.05	34.80	30.44	34.00	22.40	25.28
	0.05 – 0.25	16.51	16.50	12.64	26.26	23.66
	0.25 – 2.00	9.05	13.98	13.24	12.38	10.70
Skeleton (%)		< 5	< 15	< 20	< 30	< 50
Particle Density ($g.cm^{-3}$)		2.60	2.70	2.71	2.74	2.73
Bulk density ($g.cm^{-3}$)		0.931	1.110	1.177	1.076	1.055
Porosity (%)		64.2	58.8	56.5	60.5	61.3
Max. capillary water capacity (% of weight)		39.7	32.2	33.3	39.6	44.0
Humus content (%)		5.82	2.01	1.33	1.07	0.75

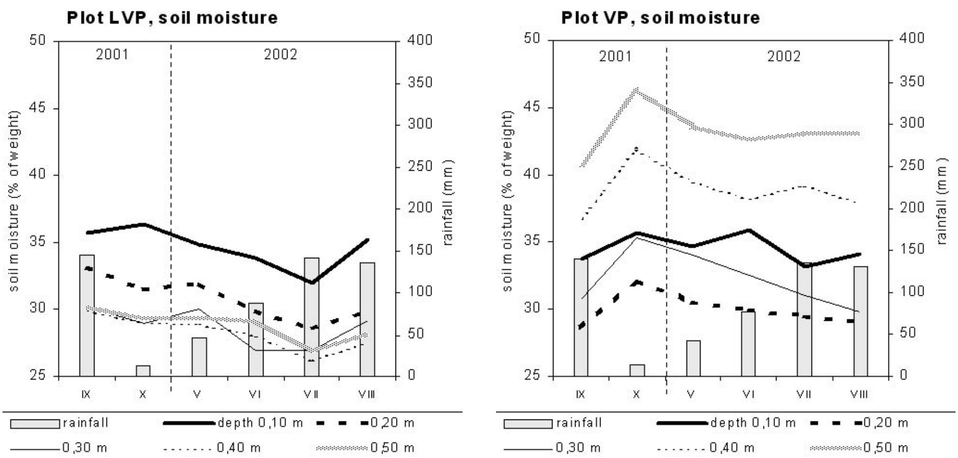
Table 2 Results of t-test and differences of soil temperature, resp. soil moisture between separated soil layers of LVP and VP plots

Soil (air) temperature (°C)			
Level of measurement		**LVP – VP (°C)**	**α**
Air		0.10	0.802
On soil surface		0.22	0.811
Soil depth	0.05 m	-1.18^{x}	0.047
	0.20 m	-0.20	0.332
	0.50 m	-0.18	0.538
Soil profile		-0.37	0.090

Soil moisture (% of weight)			
Level of measurement		**LVP – VP (%)**	**α**
Rainfall		4.82^{x}	0.020
Soil depth	0.10 m	0.15	0.816
	0.20 m	0.83	0.366
	0.30 m	-3.52^{x}	0.016
	0.40 m	-10.63^{xx}	0.000
	0.50 m	-14.32^{xx}	0.000
Soil profile		-5.50^{xx}	0.001

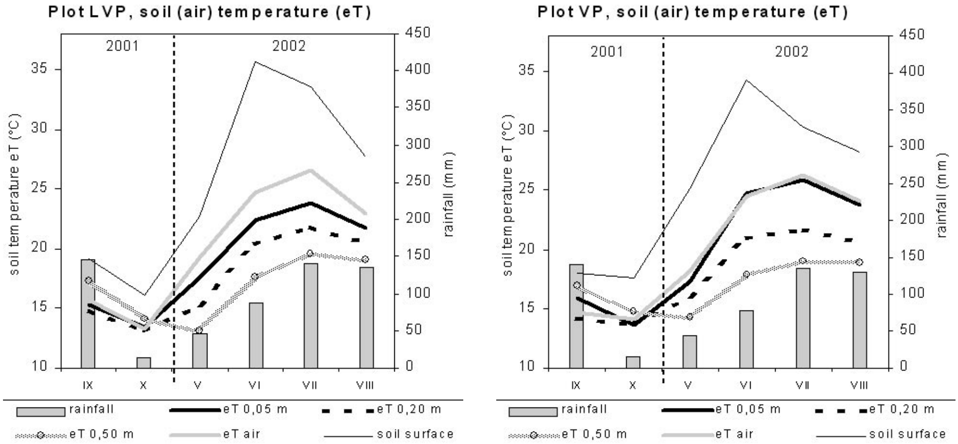
α – level of significance; xx – α = 0.01 ; x – α = 0.05

Figure 2 Course of soil moisture in soil layers during followed period on LVP and VP plots



Course of soil temperature on both plots was very similar (Figure 2). In spite of different soil moisture in deeper layers of LVP soil profile plots were differed from itself significantly in temperature of 0.05 m soil layer, only (Table 2). It is necessary to point out that temperature distinction of air and on soil surface between plots was not expressive. Comprehensively, soil of VP was warmer.

Figure 3 Course of soil temperature in soil layers during followed period on LVP and VP plots



Differences of mean soil temperature as well as moisture among layers of each plot were statistically verified (Table 3). In case of soil temperature and soil moisture, soil profile on the VP plot was more differentiated.

Table 3 Results of t-test and differences of soil temperature, resp. soil moisture among soil profile (air) layers on LVP and VP plots

Soil (air) temperature (°C)				
Difference of layers	**Plot LVP** $x^1 - x^2$ (°C)	**Plot LVP** α	**Plot VP** $x^1 - x^2$ (°C)	**Plot VP** α
1.0 – 0.0 =	-5.38xx	0.008	-5.27xx	0.004
1.0 – 0.1 =	1.42x	0.026	0.13	0.680
1.0 – 0.2 =	2.77x	0.017	2.47x	0.016
1.0 – 0.5 =	3.63	0.073	3.35	0.091
0.0 – 0.1 =	6.80xx	0.008	5.40xx	0.005
0.0 – 0.2 =	8.15xx	0.007	7.73xx	0.003
0.0 – 0.5 =	9.02x	0.018	8.62x	0.014
0.1 – 0.2 =	1.35x	0.012	2.33x	0.017
0.1 – 0.5 =	2.22	0.119	3.22	0.085
0.2 – 0.5 =	0.87	0.358	0.88	0.392

Soil moisture (% of weight)				
Difference of layers	**Plot LVP** $x^1 - x^2$ (%)	**Plot LVP** α	**Plot VP** $x^1 - x^2$ (%)	**Plot VP** α
0.1 – 0.2 =	3.85xx	0.000	4.53xx	0.000
0.1 – 0.3 =	5.97xx	0.000	2.30x	0.014
0.1 – 0.4 =	6.43xx	0.000	-4.35xx	0.001
0.1 – 0.5 =	5.77xx	0.000	-8.70xx	0.000
0.2 – 0.3 =	2.12xx	0.002	-2.23xx	0.003
0.2 – 0.4 =	2.58xx	0.000	-8.88xx	0.000
0.2 – 0.5 =	1.92xx	0.002	-13.23xx	0.000
0.3 – 0.4 =	0.47	0.293	-6.65xx	0.000
0.3 – 0.5 =	-0.20	0.669	-11.00xx	0.000
0.4 – 0.5 =	-0.67xx	0.003	-4.35xx	0.000

soil profile position of layers in m, α – level of significance; xx – α = 0.01 ; x – α = 0.05

Table 4 Correlation coefficients among soil temperature, soil moisture, soil depth and other soil physical properties on of LVP and VP plots

	Plot LVP			Plot VP		
Analysed parameters	**Soil depth**	**Soil moisture**	**Soil temperature**	**Soil depth**	**Soil moisture**	**Soil temperature**
< 0.001 mm	0.93x	-0.64	-0.72	0.99xx	0.73	-0.87x
< 0.002 mm	0.94xx	-0.83x	-0.83x	0.99xx	0.73	-0.87x
< 0.01 mm	-0.24	-0.18	0.06	0.34	0.37	-0.12
0.01 – 0.05 mm	-0.91x	0.60	0.70	-0.79	-0.70	0.67
0.05 – 0.25 mm	0.65	-0.19	-0.33	0.67	0.81x	-0.41
0.25 – 2.00 mm	0.89x	-0.52	-0.68	0.13	-0.49	-0.62
Skeleton > 2 mm	0.71	-0.29	-0.50	0.97xx	0.83x	-0.78
Particle density	0.91x	-0.98xx	-0.99xx	0.85x	0.36	-0.99xx
Bulk density	0.94xx	-0.94xx	-0.99xx	0.37	-0.28	-0.77
Porosity	-0.96xx	0.92x	0.93x	-0.23	0.42	0.65
Max. capillary water capacity	-0.84x	0.88x	0.94xx	0.51	0.94xx	-0.01
Humus content	-0.96xx	0.94xx	0.99xx	-0.84x	-0.33	1.00xx
Soil moisture	-0.84x	–	0.97xx	0.78	–	-0.36
Soil temperature	-0.92x	0.97xx	–	-0.86x	-0.36	–

Finally, values of mean soil temperature and moisture of five layers on both plots were statistically analysed with several soil physical properties, which were available. Because these data were spatially distributed (profile distribution), their correlation was also in dependence upon soil depth. Obtained results are given in Table 4. We can see that most soil physical properties was relative high correlated with depth what must be taken into the consideration at their evaluation. High negative dependence of soil temperature on depth, fractions < 0.001 mm, and < 0.002 mm, particle density, bulk density, porosity, and humus content was visible in both soil profiles. These properties can influence heat conductance and heat capacity of soil (ŠÁLY, 1998; SCHEFFER, SCHACHTSCHABEL, 1992). Soil moisture must not equal depth but in our case it was significantly correlated with maximum capillary water capacity regardless of relation to soil depth.

CONCLUSIONS

Profile distribution of soil temperature as well as moisture yields different facts. Soil temperature was strong connected with soil depth and till then with other soil properties influencing on soil heat capacity and conductance.

Soil moisture depended on a level of soil sorption capacity. Source of water was true in atmosphere as well as at soil temperature but on the other hand it was depending on gravitation, considerably.

With regard to relation of soil temperature and moisture, more water as good heat accumulator and conductor can be maintained through soil layers with higher sorption capacity. Then, mainly in time beside insolation, these soil layers through their temperature can more or less in uence on temperature of soil layers lying about them.

REFERENCES

ISSS-ISRIC-FAO, 1994: World Reference Base of Soil Resource. Draft. Wageningen, Rome, 161 s.

Kolektív, 2000: Morfogenetický klasifikačný systém pôd Slovenska (Bazálna referenčná taxonómia). VÚPOP, Bratislava, 76 s.

Kubíková, J., 1970: Geobotanické praktikum. UK Praha, 186 s.

Nieplová, E., Faško, P., Lapin, M., 1997: Regionálne scenáre vybraných teplotných a zrážkových charakteristík na Slovensku. Príspevok ku scenárom klimatickej zmeny na Slovensku, NKP SR, Bratislava, s. 7 – 45.

Scheffer, f., schachtschabel, p., 1992: Lehrbuch der Bodenkunde. Ferdinand Enke Verlag, Stuttgart, 491 s.

Střelec, J., 1993: Vybrané prvky mikroklímy v pôde a prízemnej vrstvy vzduchu bukového ekosystému vo vzťahu k ťažbovo-obnovným postupom. Kandidátska dizertačná práca, ÚEL SAV vo Zvolene, 101 s.

Šály, R., 1998: Pedológia. TU, Zvolen, 177 s.

Širáň, M., 2003: Teplota pôdy vo vegetačnom období vo vzťahu k jej vlhkosti. In: Ochrana a využití půdy v nivních oblastech, Sborník referátů, Pedologické dny, Velké Bílovice, s. 112 – 116.

Šmelko, Š., 1988: Štatistické metódy v lesníctve. Učebné texty, VŠLD, Zvolen, 276 s.

Tužinský, L., 1995: Vodný režim lesných pôd s ohľadom na klimatické zmeny. In: Problémy geológie, bioklimatológie a pedológie v súčasných prírodných podmienkach, Zborník referátov, LF TU a ÚEL SAV vo Zvolene, s. 35 – 40.

Zemánek, S., 2002: Variabilita fyzikálních vlastností v půdě – prostorová variabilita vlhkosti ve vztahu k půdní teplotě a ostatním půdním vlastnostem. Ved. konf., Prvé pôdoznalecké dni v SR (diel B), Račkova dolina, s. 386 – 391.

FERTILIZER AND ORGANIC MATTER EFFECTIVITY AT WINTER WHEAT YIELD FORMATION

ÚČINNOSŤ APLIKOVANÝCH PRIEMYSELNÝCH HNOJÍV A ORGANICKEJ HMOTY PRI TVORBE ÚRODY PŠENICE OZIMNEJ

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ABSTRACT

In stationary small plot trial on Haplic Chernozem calcaric in cereal field rotation effect of nutrition on winter wheat yield formation was studied in control as well as in treatments with conventional and ecological systems of cropping. Winter wheat was incorporated in field rotation in seasons 1991/1992, 1995/1996 a 1999/2000.

The stationary trial establishment higher yields of winter wheat apparent at conventional fertilization, when compared to control treatment. In ecological treatment, where nutrient potential was increased by organic matter ploughed in produced on soil plus farmyard manure, yield increase was gradual. Only after ten years of the stationary trial duration difference in yields between the conventional and ecological treatments was reduced to 4%. Smaller grain yields in ecologized treatment were connected particularly with lower levels of available phosphorus. In the case of moderate total nitrogen content, yield formation was positively affected by offer of available potassium in soil.

Keywords: winter wheat, yield, fertilization, treatments – conventional, ecological

ABSTRAKT

V stacionárnom maloparcelkovom pokuse na černozemi kultizemnej čiernicovej karbonátovej sa v obilninovom osevnom postupe študoval vplyv výživy na tvorbu úrody pšenice ozimnej v kontrolnom variante a vo variantoch s konvenčným a ekologickym hospodárením na pôde. Pšenica ozimná bola zaradená do osevného postupu v rokoch 1991/1992, 1995/1996 a 1999/2000.

Hneď od založenia stacionárneho pokusu sa pri konvenčnom spôsobe hnojenia pôdy vykazovali vyššie úrody pšenice ozimnej oproti kontrolnému variantu. V ekologickom variante, ktorého živinový potenciál zvyšovala zaorávaná organická hmota vyprodukovaná na pôde a aplikácia maštaľného hnoja sa zvyšovanie úrod prejavovalo postupne. Až po desiatich rokoch trvania stacionárneho pokusu sa začal zužovať rozdiel v úrodach medzi konvenčným a ekologickým variantom na 4%. Nižšie úrody zrna v ekologickom variante súvisia najmä s nízkym obsahom prístupného fosforu. Pri miernom zvýšení obsahu celkového dusíka sa na tvorbe úrody pozitívne prejavila ponuka prístupného draslíka v pôde.

Kľúčové slová: pšenica ozimná, hnojenie, konvenčná agrochémia, ekologická agrochémia

INTRODUCTION

Winter wheat is in Slovakia included among most spread cereals. It needs fertile soil with good structure, adequate humus and nutrient supply. The crop requires good water regime in soil, the requirements are highest in period of leaf tube formation to blossoming.

Soil nutrient supply and balanced nutrient ratio in preemergent period play substantial role at formation optimum conditions for wheat development in autumn. In case of nutrient deficience and drought in this period tillering is significantly retarded. Increased requirements for nitrogen in time of generative organs initiation and in time of grain filling. Phosphorus is most necessary from germination to harvest maturity. Potassium is accepted from first growth days to blossoming. Increased requirements are in period of leaf tube formation to earring.

Conventional management of winter wheat growing in case of P and K fertilization is determined by their levels in soil, in case of nitrogen by standards published in adequate plant nutrition methodologies. The normative for wheat prescribes N-rate approximately 120 kg $N.ha^{-1}$ that should be divided for basic, regenerative, production and qualitative fertilization respectively. For the normative rate precision serves inorganic nitrogen determination in soil in given growth phase.

Ecological way of wheat growing excludes industrial fertilizers use and is based only on nutrient supplementation into soil by farmyard manure application and ploughing in the precrop organic remains.

Fertilization effect on wheat yield studied many of authors. From their findings is resulting, the nutrients applied need not be annually optimum used for main product formation. Soil nutrient availability is depending from soil moisture and its use. Hydrometeorological factors regulate nitrogen substances dynamic in soil, fixation processes and nutrient release into soil solution. In our work we concentrated our attention to judgment of various cropping methods on winter wheat yields.

MATERIAL AND METHODS

Winter wheat (cvs. SO-928 in 1991 and Ilona in 1995, 1999) was grown in cereal field rotation in three fertilization treatments (non fertilized control – C, ecological treatment – ECO and conventional fertilization – CONV).

Stationary small-plot trial was established on Haplic Chernozem calcaric, in maize production belt, Danubian Lowland. Soil $CaCO_3$ content = 25%, humus = 3.2%, pH/KCl = 7.9, pH/H_2O = 8.3.

The trial was established by the method of randomized square blocks in autumn 1991. Experimental plot size of each treatment was 200 m^2 with four replications. Winter wheat was incorporated into field rotations in 1991/1992, 1995/1996 and 1999/2000.

Cereal field rotation:

winter wheat (catch crop: California bluebell) – sunflower – spring barley (catch crop: Sorghum) – pea – winter wheat (catch crop: California bluebell) – sunflower – spring barley (catch crop: Sorghum) – pea – winter wheat

Fertilization treatment:

CONTROL	non fertilizer control	
ECOLOGIZED	farmyard manure and organic matter produced on soil	
CONVENTIONAL	farmyard manure and NPK-fertilization in rates:	
	r. 1991/1992	82 – 42 – 126 kg.ha^{-1}
	r. 1995/1996	119 – 42 – 126 kg.ha^{-1}
	r. 1999/2000	119 – 42 – 126 kg.ha^{-1}

Phosphorus in form of granulated superphosphate (19.4% P) potassium in the form of potash (49.8% K) were applied in autumn 1991 and 1995 before winter wheat sawing. Nitrogen was supplied in the form of ammonium nitrate (35% N) in spring 1992, 1996 and 2000.

Farmyard manure in convention and ecologized treatments was applied in autumn, under winter wheat in rate 15 t.ha^{-1}, under sunflower 20 t.ha^{-1}, under sugar beat 40 t.ha^{-1} and under maize 40 t.ha^{-1}. In the ecologized treatment after main product harvest was ploughed in only organic matter produced on soil.

In autumn 1991, at the trial establishment and in 1992, 1996 and 2000 after harvest was soil (0 – 0.30 m depth) sampled for determination total nitrogen by the method by Jodlbauer, available P and K by Mehlich II. More detailed information concerning soil nutrient regime balance in the trial were presented in the final report – Bujnovský et al. (3).

RESULTS AND DISCUSSION

The values of available nutrient levels and yields in Figs. 1, 2 and 3 are arithmetic mean of every treatment four repetitions. The stationary trial results enable to judge dynamics of nutrients at concrete cropping method and its impact on yield formation in given hydrometeorological conditions of the year.

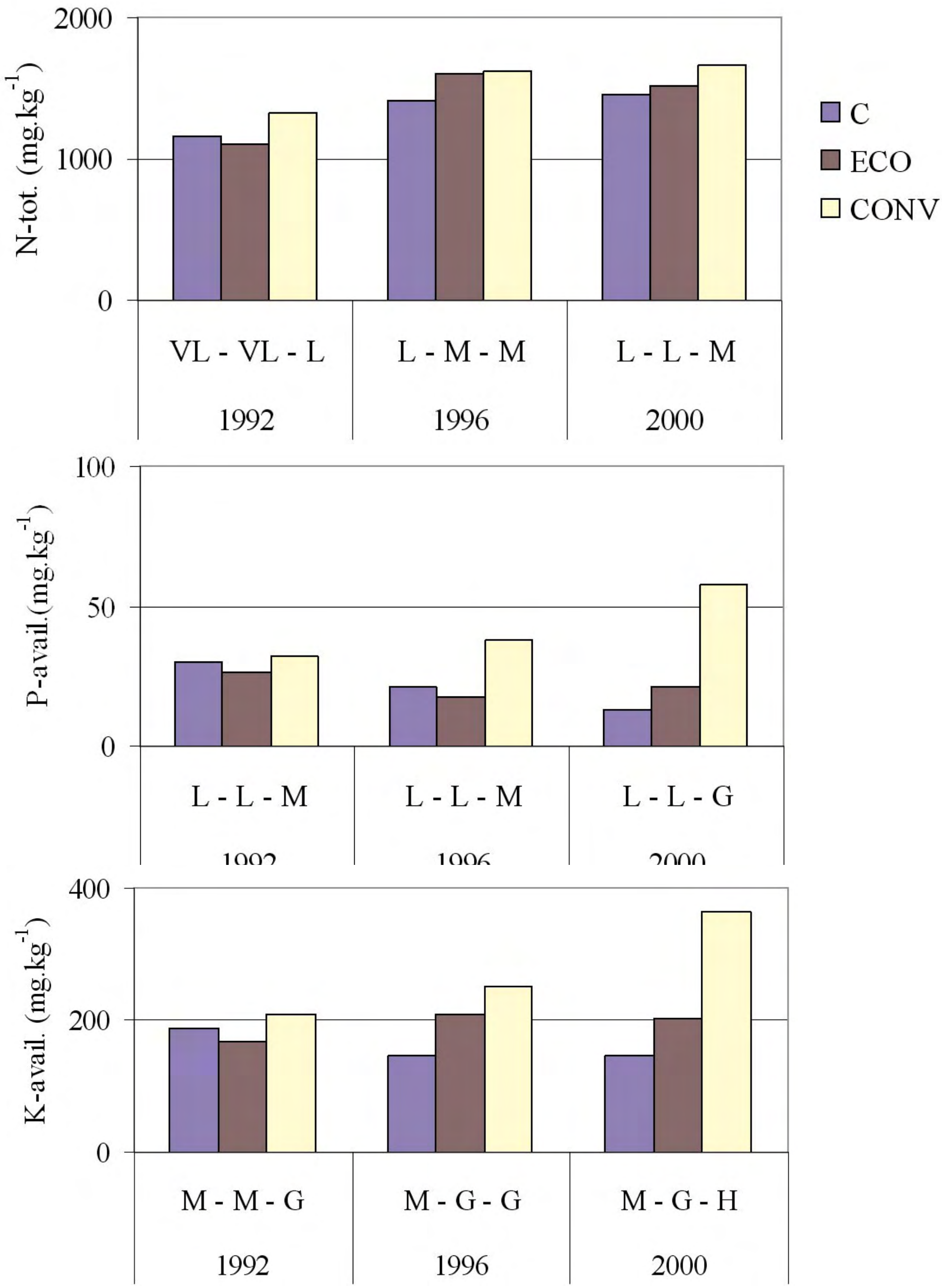
From Fig. 1 resulting, total nitrogen level in first year was most low to very low. Only after five years it was increased most by one category of balance criterion by Bielek and Kudličková (2). In time of the stationary trial only after five years medium level of total nitrogen cumulated at conventional cropping, and similar tendency was registered also at the ecologized treatment with farmyard manure and organic matter ploughed in (1996).

As well known, inorganic nitrogen is approximately 1,5% of total nitrogen (Hudcová, Procházdka, 1990), whereby this N-form is main source of nitrous nutrition of plants. Farmyard manure applied and ploughed in and byproduct are the sources for soil nitrogen supply. At conventional fertilization, N-fertilizers help at farmyard manure decomposition, in this way they help to increase soil inorganic N offer.

Available P and K balance in leachate Mehlich II was made by use Agronomical criteria for agrochemical soil analyses balance (Anonymus, 1995). At conventional treatments was found medium to good phosphorus level. In remaining treatments was available P level low.

In time of 10-year stationary trial duration soil available K-supply was increased. In conventional treatment good supply was increased to high, and in ecologized treatment from medium supply to the category good. In control was K-supply medium.

Figure 1 Fertilization and organic matter effect on nutrient offer in soil



Note: VL – very low, L – low, M – medium, G – good, H – high nutrient content in soil

From Fig. 1 and its supplementing tables (1, 2) can be judged wheat grain yields obtained in 1992, 1996 and 2000 in three fertilization treatments in cereal field rotation.

Figure 2 Effect of cropping method on winter wheat yields

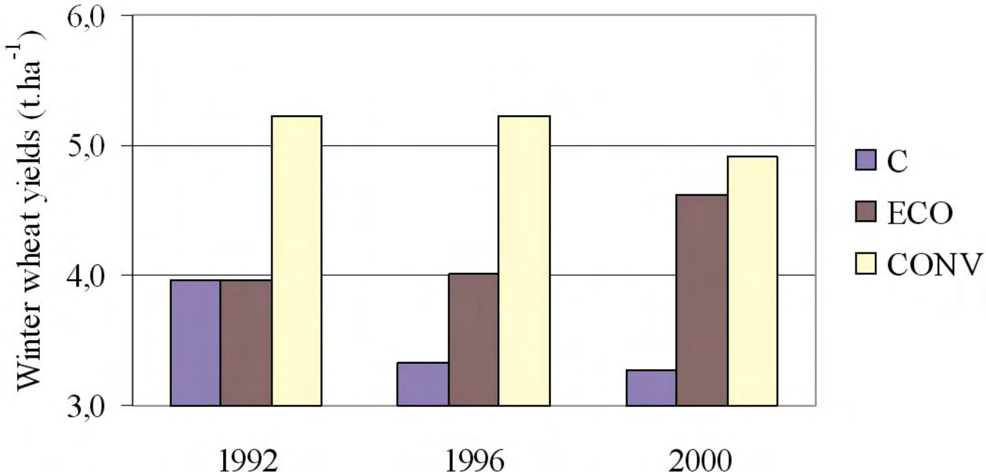


Table 1 Yield differences among experimental treatments (%)

Treatments	**1992**	**1996**	**2000**
CONV-C	24.0	36.4	33.1
ECO-C	-0.1	17.4	29.0
CONV-ECO	23.9	19.0	4.1

Table 2 Yield comparison in experimental treatments by Lord's test (calculated values – u)

Treatments	**1992**	**1996**	**2000**
CONV/C	0.615	0.950	2.229
ECO/C	-0.003	0.400	1.091
CONV/ECO	0.573	0.490	0.190

Note: Every treatment has 4 repetitions: u crit. (0.01) = 0.618, u crit. (0.05) = 0.406

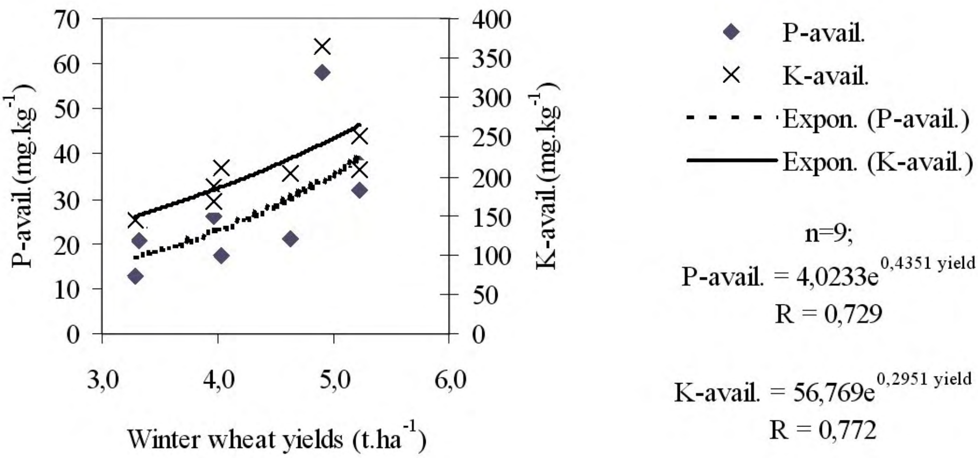
In the years of experiment dominant were higher yields at conventional cropping. Yield increase was also registered in ecologized treatment with farmyard manure and organic matter ploughed in. These changes were statistically significant (Tab. 2).

At the nutrition offer mentioned and moisture conditions were registered increases in wheat grain yields: 36% after 5 years, and 33% after 10 years in the conventional treatment, when compared to control. In ecologized treatment were these increases: 17% after 5 years and 29% after 10 years. Can be concluded that only after 10 years of stationary trial yield differences started to be lower, when compared conventional and ecologized cropping systems – 4% (Tab. 1). Lover yields in ecologized treatment are in correspodence particularly with available P low supply. In case of total N moderate increase was visible effect of available K offer in soil.

Winter wheat lower yields in organic fertilization systems in comparison with conventional treatment registered also KARABÍNOVÁ, PROCHÁZKOVÁ (7) and KOVÁČ (8).

Winter wheat yield formation was given by conditions (moisture) affected by nutrient offer in soil and precrop, respectively. In calcaric soil available P and K increase in soil caused exponential increase of winter wheat grain yields, Fig. 3 ($n = 9$, R_{crit} (0.05) = 0.666).

Figure 3 Available P and K effect on winter wheat grain yields formation



From various types of experiments is resulting, at optimum moisture conditions winter wheat production of high quality depends primarily from nutrition, precrop within field rotation, soil preparation, seed quality and seeding (IVANIČ et al., 1982; KANDERA, 1982; PRUGAR, KOSTKANOVÁ, ČERNÝ, 1982; ĽAHKÝ, 1987; HUDCOVÁ PROCHÁZKA, 1990; KOVÁČ, 1995; MIKLOVIČ, PECHOVÁ, 1997; BUJNOVSKÝ et al., 1998; PECHOVÁ, KUBICOVÁ, FALŤANOVÁ, 1998). These findings confirmed, and in given conditions concretized the results of our stationary trial.

CONCLUSIONS

From our balance is resulting, winter wheat height can be affected by the methods of cropping. Consequence was gradual change of nutrient offer that was demonstrated by statistically significant differences in wheat yields.

During the stationary trial in cereal field rotation, with aspect to control, higher yields were registered particularly in the case of conventional fertilization (in first year 24%, in fifth o 36% and tenth 33%). In ecologized treatment, nutritional potential of which was increased by organic matter produced on soil and farmyard manure application, lower yield increase was registered in comparison with control (in first year 0%, in fifth 17% and tenth 29%). Resulting is, only after ten years difference in yields started to be lower up to 4% in comparison of conventional and ecologized cropping.

Lower yields in ecologized treatment correspond particularly with available P lower supply and its some stabilization due to zero P-fertilization. In the case of moderate N-total supply available K-offer in soil positively affected yield formation.

REFERENCES

ANONYM, 1995: Agronomické kritériá pre hodnotenie agrochemických rozborov pôd od roku 1995; ÚKSÚP, Zvolen, 14 s.

BIELEK, P., KUDLIČKOVÁ, J., 1990: Bilancia a potenciály dusíka v poľnohospodárskej krajine (syntet. záver správa), VÚPÚ, Bratislava, 59 s.

BUJNOVSKÝ, R. a. kol., 1998: Vplyv rôznych pestovateľských opatrení a hnojárskych zásahov na agrochemické vlastnosti pôdy, výšku úrod a kvalitu plodín (záver.správa),VÚPÚ, Bratislava, 29 s.

HUDCOVÁ, M., PROCHÁZKA, F., 1990: Agrochemické vlastnosti půdy v závislosti na organickém hnojení. Agrochémia (Bratislava) 30, č. 3, s. 76 – 80.

IVANIČ, J. a kol., 1982: Výživa rastlín a hnojenie; Príroda, Bratislava, 328 s.

KANDERA, J., 1982: Vplyv hnojenia dusíkom na úrody a kvalitu úrod ozimnej pšenice; Polnohospodárstvo 28, č. 1, s. 13 – 24.

KARABÍNOVÁ, M., PROCHÁZKOVÁ M., 1995: Ekologické aspekty pri pestovaní hustosiatych obilnín. In: Trvalo udržateľné hospodárenie v kultúrnej krajine. Zborník referátov. Nitra, s. 253 – 257.

KOVÁČ, K., 1995: Vplyv konvenčného a ochranného obrábania pôdy pri obmedzených vstupoch hnojív na produkciu biomasy ozimnej pšenice. Rost. Výr. 41, č. 2, s. 41 – 54.

ĽAHKÝ, J., 1987: Vplyv hnojenia dusíkom na zmeny obsahu aminokyselín v zrne ozimnej pšenice; Agrochémia (Bratislava) 27, č. 2, s. 33 – 36.

MIKLOVIČ, D., PECHOVÁ, B., 1997: Úroda a kvalita pšenice ozimnej pri vysokom obsahu fosforu a draslíka v pôde; Vedecké práce Výsk. Úst. Pôd. Úrod. (Bratislava), 20 /II, s. 199 – 208.

PECHOVÁ, B., KUBICOVÁ, Z., FALŤANOVÁ, N., 1998: Vplyv výživy na úrodu a kvalitu pšenice ozimnej; Vedecké práce Výsk. Úst. Pôd. Úrod. (Bratislava), 21, s. 215 – 224.

PRUGAR, J., KOSTKANOVÁ, E., ČERNÝ, V., 1982: Vliv stupňovaného hnojení dusíkem na výnos a jakost zrna ozimé pšenice; Rost. Výr. 28, č. 7, s. 735 – 743.

CROP YIELD PREDICTION IN YEAR 2003

ODHAD ÚROD PRE ROK 2003

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ABSTRACT

The European Union (EU), through its Common Agricultural Policy (CAP), attemps to regulate the common agricultural market, secure food supplies and provide food at reasonable prices. Behalf adaptation the common agricultural market of Slovak Republic with other EU member states markets, it is neccessary to carry out the preliminary yield predictions of strategic agriculture crops during their vegetation period. Consequently, the EU member states collect agrometeorological data and consecutively use them for agrometeorological estimating and predicting crop yield on national scale.

The submitted article attends to describe process of yield prediction for strategic agriculture crops using remote sensing methods (data from NOAA-AVHRR satellite system) and agrometeorological models (WOFOST) for Slovak Republic in 2003 campaign. Obtained results are compared with the results predicted by others institutions and the real yield. The article also refers to the possibilities of precising the results in the future.

Results of crop yield estimations combined with regional inventory enable to predict general yield for required crops.

KEYWORDS: Normalized Difference Vegetation Index (NDVI), crop yield estimate, satellite system NOAA-AVHRR, WOFOST, Geographical Information System (GIS)

ABSTRAKT

V záujme prispôsobenia stratégie trhu s poľnohospodárskymi plodinami Slovenskej republiky trhom krajín Európskej únie (EÚ), je dôležité vykonávať priebežný odhad a predpoveď úrod strategických poľnohospodárskych plodín priebežne počas vegetačného obdobia. Je to zároveň v súlade so spoločnou poľnohospodárskou politikou (CAP) členských krajín EÚ, v rámci ktorej sa zbierajú a využívajú informácie pre tvorbu agro-meteorologických odhadov a predpovedí úrod hlavných poľnohospodárskych plodín pestovaných v jednotlivých členských krajinách.

Článok je zameraný na objasnenie procesu odhadu úrod vybraných poľnohospodárskych plodín pomocou metód DPZ (s využitím údajov zo satelitného systému NOAA-AVHRR) a agrometeorologických modelov (program WOFOST) pre územie Slovenskej republiky (pre rok 2003). Zároveň sme sa pokúsili porovnať dosiahnuté výsledky s predpoveďami vypracovanými inými inštitúciami ako aj so skutočne dosiahnutými úrodami a zároveň poukázať na možnosti spresnenia odhadov.

Kombináciou odhadu úrod s regionálnou invertarizáciou je možné predpovedať aj celkovú produkciu poľnohospodárskych plodín.

KĽÚČOVÉ SLOVÁ: vegetačný index (NDVI), odhad úrod, satelitný systém NOAA-AVHRR, WOFOST, geografický informačný systém (GIS)

INTRODUCTION

For effective operation on common European Union (EU) agriculture market, as well as in individual states, it is very important to carry out the preliminary yield prediction of strategical agriculture crops during their vegetation period. Detail data and precise methods of their processing by remote sensing (RS), geographical information system (GIS) and global position system (GPS) are using to obtaine precise crop yield forecast.

History

A base for the common market that ensures free movements of goods, services, capital and people over EU member states markets is supplied by the Common Agriculture Policy (CAP). Since 1988, according the CAP, the EU project Monitoring Agriculture with Remote Sensing (MARS) has been realized by the Space Application Institute at the EU Joint Research Centre (JRC) Ispra, Italy. The MARS projects are based on principles of the extend use of remote sensing within the EU member states, monitorig the agriculture and estimating and predicting of crop yield as precise as it is possible.

Slovak Republic as a candidate country, started with MARS activities in 1994 and since 1998 SSCRI solves problem of regional inventory and yield forecasting on the basis of the contracts with Ministry of Agriculture (MoA) of Slovak Republic.The project is divided into 2 main tasks:

1. regional inventory: presents quantitative estimation of the planted area of various crops. It is based on interpretation of high resolution satellite data (LANDSAT, IRS, SPOT) using crop signatures obtained by field survey with GPS measurement
2. crops yield prediction: using agro-meteorological model (WOFOST) and statistical methods on NDVI values and historical crop yield data

The results were calculated for both national and regional (administrative districts and main geomorphological units) scales.

MATERIALS AND METHODS

The 2003 campaign was based on combination of the data obtained by interpretation of satellite data (NOAA-AVHRR satellite system), field survey data (mainly data of crop conditions) and statistical data.

Materials

In the process of crop yield prediction several various data sources were used:

1. Satellite scenes: NOAA-AVHRR satellite system was used to obtain NDVI values (refered to state of crop development). The maximal weekly values of the same or adequate weeks of vegetation seasons in 2001, 2002 and 2003 were compared.
2. Agro-meteorogical data:
   2.1. Meteorological data: parametres of daily records of irradiation, maximum a minimum temperature, wind speed, precipitation, early morning vapour preasure were measured on individual meteorological stations (Slovak Hydrometeorological Institute (SHI))

2.2. Phenological data: date of crop sowing and harvest over individual observation stations (SHI)

3. Databases: required for WOFOST program.
   3.1. Soil data: physical soil characteristic as water retention, hydraulic conductivity and workability (WOFOST dataset)
   3.2. Crop physiological data: phenology, assimilation, respiration, partitioning of assimilates to plant organs, water use, nutrients parameters (WOFOST dataset)

The crop and soil data acquired from the WOFOST dataset, which represents soil and crop conditions of EU member states. The database was built on the basis of long-term observations over the Europe and some data were retrieved from literature.

4. Statistical data: average values for Slovak Republic and for administrative districts were used (Statistical Office of the Slovak Republic - SOSR).
   4.1. Yield data: for 2001 and 2002 seasons
   4.2. Sown area data: for 2001 and 2002 seasons

Methodology

Based on criteria of MoA and European Commision (EC) the yield predictions for strategical agriculture crops as winter wheat, spring barley, oilseed rape, grain maize, sunflower and sugar beet were carried out.

For the process of yield prediction two types of models were used:

1. effective models based on principle of estimating biomass from vegetation indexies. The indexies are based on difference spectral reflextance of vegetation in red and infrared light spectrum. In this study NDVI (Normalized Difference Vegetation Index) and NOAA – AVHRR satellite system as source (with 1.1x1.1 km pixels and scene width 2700 km) were used.

In 2003 crop yield campaign we used the satellite scenes from 2001, 2002 and 2003. The NDVI maximal weeks values of defined weeks in vegetation season were processed by statistical methods. The crop predictions were carried out for at national scale (whole SR) as well as for regional scale (districts).

2. functional models based on agrometeorological (soil-crop-weather) modelling.

In this study we used WOFOST 6.0. environment. WOFOST allowed to estimate potencial (radiation and surface temperature were taken into account) and *water limited* (soil and plant water balance were included) crop growth and crop yield.

The input data (meteorological and phenological data collected by SHI) as well as the WOFOST results were presented as points. For that reason the extrapolation method was used to assure the spatial validity and accuracy of results Geomorphological units, which are climatically homogenous, were used to present WOFOST predictions.

The final predictions were carried out by effective model with WOFOST precising and for accurating the results, predictions were compared with real yield of previous years. The final crop predictions were represented both at national scale (SR), or at regional scale (administrative units), respectively.

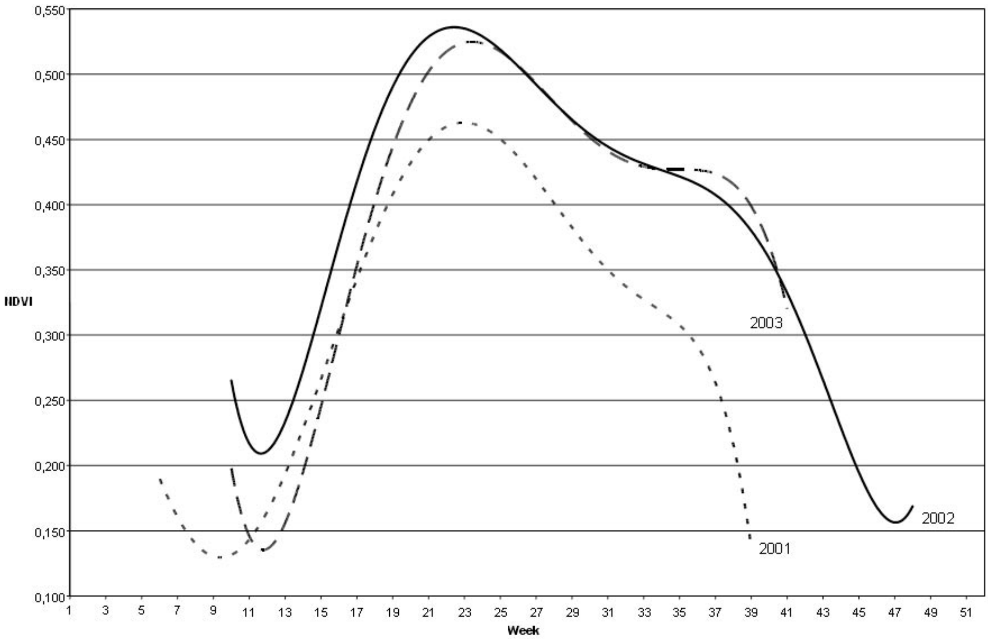
RESULTS AND DISCUSSION

Crop yield prediction

The yield predictions were carried out for winter wheat, spring barley, oilseed rape, grain maize, sunflower and sugar beet at regional scale (districs) We used the effective model (based on NDVI) with WOFOST precising of resusuts to obtain yield predictions.

Fig. 1 presents comparison of NDVI values continuances in 2001, 2002 and 2003. The NDVI values in 2002 and 2003 are similar and both are, in comparing with 2001, higher.

Figure 1 NDVI indexies for Slovak Republic



Comparing SSCRI results with predictions of other institutions

To appreciate valididy of our predictions we compared SSCRI preliminary estimates with estimates prepared by JRC (published in MARS Bulletin). In Bulletin, predictions for EU member states as well as for east Europe countries (Russia, Ukraine and Belarus), Turkey and some North African mediterian states are presented. SSCRI and JRC used methods are similar, though our predictions were presented at larger scale and they are more detailed.

In Table 1 the comparison of yield predictions (in % of change) carried out by SSCRI, SOSR, JRC and MoA are presented.

The results found that the predictions are similar, but SSCRI predictions are more various (better predictions, but worse predictions, too).

The advantage of SSCRI predictions is the fact that it is able to present preliminary predictions (during vegetation season).

Talbe 1 Comparison of different crop yield predictions between institutions (in 2003)

administrative unit	Winter wheat				Spring barley				Oilseed rape			
	SSCRI	SOSR	JRC	MoA	SSCRI	SOSR	JRC	MoA	SSCRI	SOSR	JRC	MoA
Slovak Republic	2.60	-5.22	-5.00	-21.64	-13.67	-3.92	-16.80	-19.95	1.91	-37.02	-3.80	-53.24
Bratislava district	11.89	4.74		-8.39	-12.53	1.45		-8.72	8.47	-32.99		-35.05
Trnava district	-4.63	-2.66		-15.45	-16.76	-2.91		-12.39	-4.14	-39.42		-51.70
Trenčín district	-0.60	-0.06		-13.41	-7.53	-2.10		-10.10	-4.19	-31.16		-43.81
Nitra district	-3.35	-12.17		-22.16	-19.00	-16.94		-25.74	-5.18	-44.64		-51.11
Žilina district	-5.57	-9.57		-16.96	-8.67	3.05		-5.41	-7.91	-44.20		-53.21
Banská Bystrica district	-11.56	-2.58		-22.80	-21.90	2.16		-17.28	-16.72	-37.85		-56.81
Prešov district	-16.98	-7.42		-31.32	-14.78	9.69		-9.05	-13.41	-26.00		-60.75
Košice district	-14.95	-6.67		-32.62	-27.31	7.69		-17.57	-1.78	-30.48		-56.71

SSCRI 22.6.2003 SOSR 20.6.2003 JRC 8.7.2003 MoA 25.8.2003

administrative unit	Grain maize				Sunflower				Sugar beet			
	SSCRI	SOSR	JRC	MoA	SSCRI	SOSR	JRC	MoA	SSCRI	SOSR	JRC	MoA
Slovak Republic	3.47	-17.13	-30.70	-23.47	1.60	6.95		-0.48	-2.96	-15.56		-16.20
Bratislava district	1.21	7.58		-8.99	-2.34	33.66		25.94	-5.77	-2.95		-8.91
Trnava district	3.96	-13.26		-16.71	-3.81	9.62		7.47	-0.81	-15.63		-15.40
Trenčín district	2.04	-24.74		-30.38	0.08	12.23		4.96	1.65	-13.30		-17.86
Nitra district	-6.29	-21.79		-24.31	-3.30	-3.28		-6.92	-0.08	-20.54		-20.92
Žilina district	4.01	13.76		3.61					0.81	-20.13		-26.70
Banská Bystrica district	1.79	-12.91		-20.07	-4.53	10.20		6.51	-1.61	-23.36		-34.37
Prešov district	3.27	-9.38		-15.67	-1.91	3.58		-0.23	-0.85	-6.18		-0.29
Košice district	7.41	-7.87		7.15	-3.24	20.14		57.51	-1.44	-0.94		3.48

SSCRI 12.10.2003 SOSR 15.10.2003 JRC 18.11.2003 MoA 24.11.2003

Accuracy possibilities

To achieve more precise predictions in next years the following arrangements will be neccessary:

1. using longer time series of NDVI values. The use of longer time series could provide more objective predictions. For these purpouses SSCRI ensured NDVI data from 1998 which will be used in next year already
2. integrating and considering the winter period character (temperature variances, freezing) and other critical conditions of crop growth (for example floods, precipitation deficit, temperature over the crop threshold) to achieve more precise crop yield predictions especially of winter crops
3. calibration of WOFOST soil and crop files on the conditions of Slovak Republic.

CONCLUSIONS

The crop yield estimation were based on combination of the data obtained by interpretation of satellite data (NOAA-AVHRR satellite system), data from field survey (meteorological, phenological, agronomic data) and statistical data. All mentioned data input to the process of modelling and evaluating. The yield prediction obtained by using agrometeorological model in WOFOST environment filled up and corrected the estimates predicted by effective model. The both effective and functional models differ in the character of spatial units, to which the results refered (administrative units, resp. geomorphological units).

In comparation SSCRI crop yield predictions with the predictions of several other institutions (MoA, JRC and Statistical Office of the Slovak Republic) we didn't note significant differencies.

The predictions carried out by SSCRI have several advantages:

- the JRC, Ispra presents the results of crop forecasting at European scale, while SSCRI at national and regional scale (the results are more detailed)
- the Statistical Office of the Slovak Republic provides the crop yield predictions about the harvest, while SSCRI predicts preliminary crop yield during vegetation season.

In 2003 crop yield campaign some tasks contribute to accure and approarch SSCRI preliminary predictions to the real crops yield were found. They have to be solved in next years.

REFERENCES

HIJMANS, R.J., GUIKING-LENS, I.M., VAN DIEPEN, C.A., 1994: User's guide for the WOFOST 6.0. crop growth simulation model. Technical Document 12, DLO Winand Staring Centre, Wageningen.

Mars Bulletin, European Commission, Directorate General JRC, Join Research Centre, Institute for the Protection and Security of the Citizens, MARS Unit

SUPIT, I., 2000: An exploratory study to improve predictive capacity of the Crop Growth Monitoring System as applied by the European Commission. Treebook 4, ISBN 90-804443-5-9, 180 pp.

SUPIT, I., VAN DER GOOT, E.: Updated system description of the WOFOST crop growth simulation model as implemented in the crop growth monitoring system applied by European Commission.

SVIČEK, M., SHOLTZ, P., NOVÁKOVÁ, M., FENDEKOVÁ, M., KEBÍSKOVÁ, L., 2003: Odhad úrod a regionálna inventarizácia. VÚPOP, 11 pp.

LANDSCAPE SUITABILITY FOR SPRING BARLEY (HORDEUM SATIVUM L.) GROWING

VHODNOSŤ POĽNOHOSPODÁRSKEJ KRAJINY PRE PESTOVANIE JARNÉHO JAČMEŇA (HORDEUM SATIVUM L.)

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ABSTRACT

The work objective is to differentiate rural land of Slovakia with aspect to the possibility of effective spring barley growing. The differentiation is based on pedo-climatic and production economic parameters. At soil categorization, correlation relationships between the site properties (soil and climatic conditions) and crop biological and agrotechnical requirements were considered. Spring barley requirements were included into yield databases using the software filters in the way that the given site property excluded or limited barley growing, what was reflected in predicted production. The prediction was subsequently interpolated into four suitability categories: soils not suitable for spring barley growing, less suitable soils, suitable soils and very suitable soils. The database was formed and each of the Bonited Pedo-Ecological Unit (BPEU) was added in it as well as particular category of suitability for barley growing. By mediation of the Geographic Information System on BPEU distribution in Slovakia, the map of categories of soil suitability for spring barley growing was also generated. In Slovakia, there is 20% of farmland very suitable for spring barley growing, 24% suitable, 24% less suitable and 32% non suitable soils for spring barley growing according to our calculation. In the paper, these categories are characterized in details and specified from the view of geographic, soil, climatic, productivity, economic and energetic parameters.

KEYWORDS: spring barley; soil suitability for growing spring barley, agricultural landscape categorization

ABSTRAKT

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

Z výsledkov vyplýva, že na Slovensku je 20% poľnohospodárskych pôd pre pestovanie jarného jačmeňa veľmi vhodných, 24% vhodných, 24% málo vhodných a 32% nevhodných. Tieto oblasti sú v príspevku charakterizované z hľadiska pôdno-klimatických i produkčno-ekonomických parametrov.

KĽÚČOVÉ SLOVÁ: jarný jačmeň, vhodnosť pôd pre pestovanie jačmeňa, kategorizácia poľnohospodárskej krajiny

INTRODUCTION

Recently, spring barley (Hordeum sativum L.) is in Slovakia grown practically in all types of natural sites ranging from lowlands to mountainous regions. Successful growing of barley, as well as of other crops, is fully dependent especially on environmental climatic and soil conditions. These chief factors influence production and economy of the crop assumptions to a great extent. Although not negligible role is played by genetic and breeding measures, with aspect to heterogeneity of soil-climatic conditions and considerable geomorphologic heterogeneity, various regions show different rates of barley growing suitability.

Soil categorization focused on the crop distribution was in the centre of attention of several works. As early as 1921, economical farmland classification was applied and on this basis, the territory of Slovakia was divided in to four production regions. After 1948 the system of so called geonomical production types was established. In 1958, agricultural production zoning was finished, within which zones with different grow suitability were identified for majority of crops. In the same year, production regions and sub-regions were identified for taxation purposes. They are still used, especially for statistical purposes. The system of soil suitability categories for selected crops, elaborated after 1971, is based on more exact pedological background obtained after completion of Complex Soil Survey and subsequently Soil Appraisal. Important works, done in this area, were published by KORBÍNI and FACUNA (1978), DŽATKO (1980), KOVÁČ et al. (2003).

Recently, development of information technologies, especially Geographic Information Systems, enables processing of existing and innovated soil databases and more precise quantification and area division of soil suitability categories for crop growing. The aim of this paper is to show such methods for spring barley as an example.

MATERIAL AND METHODS

For outlining the regions of soil suitability for barley growing, the bases for us were the crop exact and potential data. Because growing suitability is predominantly judged on the basis of really reached production, this factor played decisive role at the categories formation. Particular data of yields and barley growing economics in Slovakia were obtained for period 1990 to 2000 directly from the farms. Data of 281 agricultural subjects were assessed. They have been farming in various natural conditions on total area exceeding 556 thousand hectares of farmland, which is approximately 23% of total acreage of farmland in Slovakia.

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

The dependence of studied indicators on soil production potential in analyzed farms (expressed by average point value in 100-point scale) was tested by non-linear polynomial regression analysis. Subsequently, potentially possible yield of spring barley, its share in cropping system as well as potential economical parameters (yields, costs, profit, or loss) were calculated using the regression equations for each of the BPEU and added to database. Soil rate of suitability for spring barley growing was differentiated and qualified using the Geographic Information System ARC INFO, based on vector bonity maps (scale 1:5 000) and area distribution of studied factors. All economical indices used in the work were calculated without government subsidy.

Used background:

- Soil Science and Conservation Research Institute database of Bonited Pedo-Ecological Unit (BPEU) data and their point evaluation in 100 point scale (DŽATKO, 2002),
- soil categorization by their allegiance to climatic region, sloping category, texture and stoniness (LINKEŠ et al., 1997),
- typological-production farmland categorization (DŽATKO, 2002) and database of production and economical parameters by the BPEU (VILČEK, 1999),
- real spring barley yields, their economical parameters (receipts, yields and costs) and real cropping system structure of arable land,
- energetic equivalents for barley growing energy production, calculated by the methodology of authors STRAŠIL (1987) and PREININGER (1987).

The following codes for the evaluating parameters were chosen:

Soil–climatic regions: *00 – very warm, very dry, plainly, 01 – warm, very dry, plainly, 02 – sufficiently warm, dry, hilly, 03 – warm, very dry, plainly, continental, 04 – warm, very dry, basin–like, continental, 05 – relatively warm, dry, basin–like, continental, 06 – relatively warm, moderately dry, highland–like, continental, 07 – moderately warm, moderately moist, 08 – moderately cold, moderately moist, 09 – cold, moist, 10 – very cold, moist.*

Typological–productivity categories of soils: *01 – the most productive arable soils, 02 – highly productive arable soils, 03 – very productive arable soils, 04 – productive arable soils, 05 – medium productive arable soils, 06 – less productive arable soils, 07 – low productive arable soils, OT1 – medium productive arable soils and very productive grassland, OT2 – medium productive arable soils and medium productive grassland, OT3 – low productive arable soils and less productive grassland.*

RESULTS AND DISCUSSION

Generally, rate of successful spring barley growing is judged by real yields of area unit ($t.ha^{-1}$). This, however, with aspect of unequal real energetic and material inputs into plant production process, can be sometimes confusing. Nowadays, production potential of our soils is used only at 68% by barley growing, as resulted from our previous work (VILČEK, 2001). Considerable reserves are particularly in the crop proper distribution within the conditions that are most suitable for it.

Objective results of the rural country categorization for cropping systems can be reached only by analysis of satisfactory quantity of data and parameters. In spite of statistically sufficient number of respondents, in the case of some parameters there are some exceptions in proposed categories that are not exactly in harmony with the scale chosen.

Starting point for formation of soil suitability categories for barley growing was poly-functional analysis of selected pedo-ecological and economical parameters that remarkably affect the crop successful growing. This analysis showed significant dependence of production and economical characteristics on pedo-climatic conditions.

It is obvious that successful growing is influenced also by other factors that are not included in our analysis. For example, actual soil reaction (pH) was not respected in division of suitability zones. Optimum soil reaction for barley is 6.2 – 7.5 (Hraško and BEDRNA, 1988). Therefore genetically acid soils were classified as less suitable for growing. Similar principle was used in classifying compacted soils and soils with clayey gleyic horizon. Although barley is considered as a crop with lower requirements for soil properties, economical profitability of its growing assumes acceptation of all pedo-climatic factors.

Based on available data and using an inductive method, four regions were identified with respect to suitability for barley growing.

Rural country characteristics with regards to spring barley growing suitability

Soil category – very suitable – covers 20% of total acreage of farmland. Primarily, soils of Danubian Lowland, Danubian Hilly Land, Chvojnická Hilly Land and East Slovakian Lowland. Main soil types are Chernozems (48% of the category area), Fluvisols (35%, the largest area covered by subtype Mollic Fluvisols – 19%) and Orthic Luvisols (14%). Soils are texturally medium heavy (79%), deep (99%), without soil skeleton (98%), mostly on the plane (90%). The category is located within climatic region 00 and 01 (91%). Soil fertility, expressed in 100-point scale, is between 78 and 100 points.

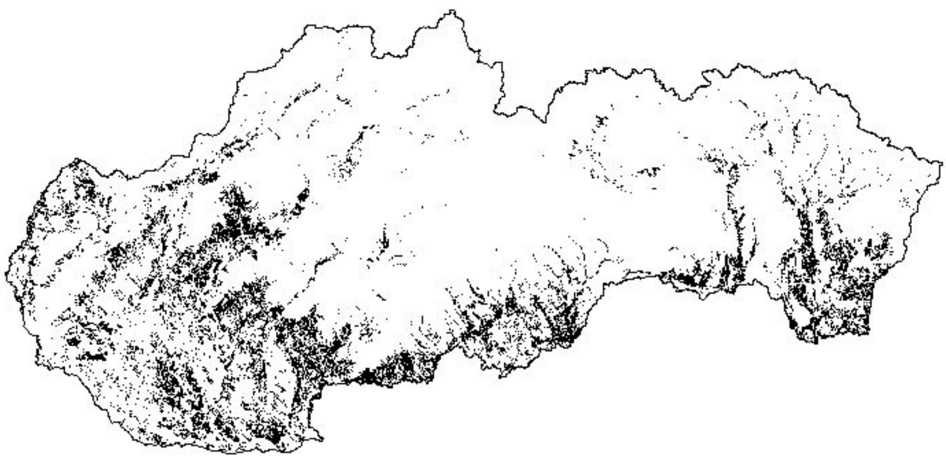
Mean yields were in the level 4.92 $t.ha^{-1}$. Soils with productivity potential is above 4.63 $t.ha^{-1}$ were included into this category. Assumption of rational spring barley sowing on ploughed land in this category is up to 25%. According to typological production categorization of farmland, first five soil production categories (01 to 05) belong to this category. By spring barley growing, profit above 3 170 $Sk.ha^{-1}$ and profitability rate above 25% can be attained. Bioenergy produced by barley ranges from 73 to 83 $GJ.ha^{-1}$.

Soil category – suitable soils – includes approximately 24% of Slovak farmland. Geographically, majority of these areas belong to Nitra Hilly Land, South-Slovak Basin, Košice Basin, East-Slovak Lowland and marginal parts of Danubian Lowland. Dominant soil types are Fluvisols (45%, Mollic Fluvisols cover 14%), Luvisols (25%) and Regosols (15%). As for texture, soils are from medium heavy (61%), without soil skeleton (89%), deep (93%), on medium slopes up to 7° (91%). The region is identical with climatic regions 00 to 05 (94%, the highest proportion belongs to the region 01 – 24%). Soil point value range is 49 – 77 points.

Figure 1 Very suitable soils for spring barley growing

Potential spring barley yields in the region were in the level 3.83 – 4.60 t.ha^{-1}, with mean yield 4.19 t.ha^{-1}. In cropping system structure, spring barley can reach up to 20%. According to typological-production Slovak soils division, the categories located here were identified as high productive arable land to low productive fields (O2 to OT3). The profit obtained by this crop can be assumed in the level 1 300 – 3 200 Sk.ha^{-1} and profitability rate is presupposed within 15 – 25%. Spring barley generates 60 – 73 GJ.ha^{-1} energy.

Figure 2 Suitable soils for spring barley growing

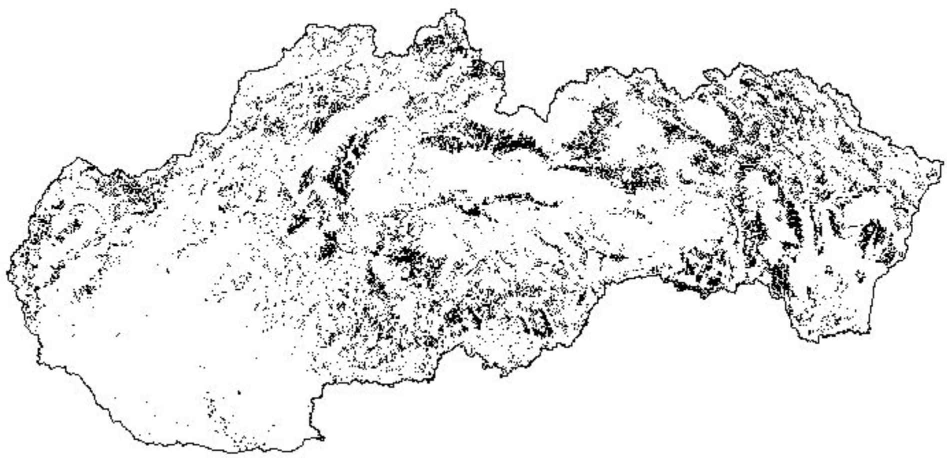


Soil category – low suitable – covers approximately 24% of Slovak farmland. It consists of Slovensko-Moravské Karpaty, Borská Lowland, Middle Beskyde, Basin of Turiec, parts of the Southslovakian Basin, parts of Subtatran Basin, Ondavská and Laborecká Highland, Zvolen and Hornád Basin and marginal parts of East-Slovak Lowland. Dominating soil representatives are Cambisols (55%) and Dystric Planosols (27%).

Texturally soils are ranging from medium heavy (74%) to heavy (18%), from deep soils (63%) to medium deep (35%), with various stoniness, located on plane (21%), slopes 3 – 7° (39%), and slopes 7 – 12° (40%). In this category, climatic regions from 05 to 08 (58% soils) dominate. The soils point value range is 19 – 48 points.

Spring barley ha-yields were ranging 3.01 – 3.80 t.ha^{-1}. Mean yield is 3.44 t.ha^{-1}. Categories of productive arable land to low productive fields (04 to OT3) can be found here according to typological production division of Slovak soils. Spring barley growing economical parameters in this category are following: presupposed profit is under 1 300 Sk.ha^{-1}, and profitability rate up to 15%. 1 ha of spring barley produces 47 to 60 GJ of energy.

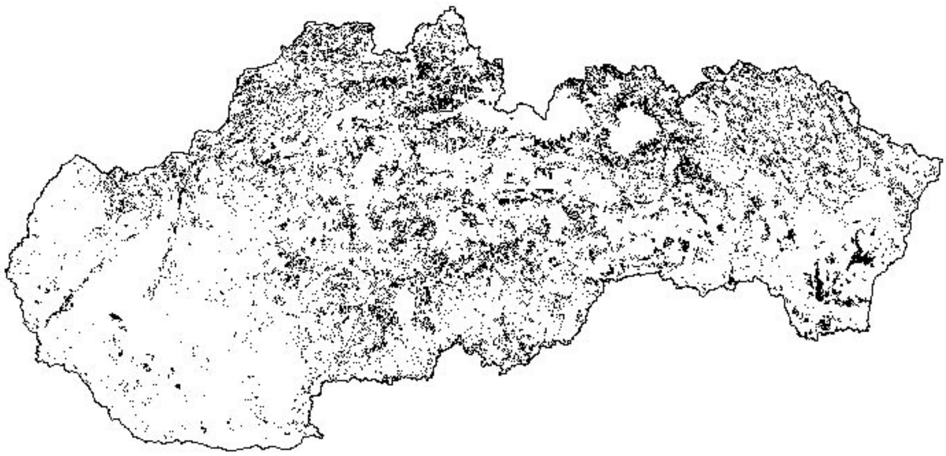
Figure 3 Low suitable soils for spring barley growing



Soil category – non suitable – is spread approximately on 32% of Slovak farmland area. From geographic point of view, it includes particularly Fatra-Tatry region, Eastern Beskyde, Podhôľno-Magurský region, Slovenské Rudohorie and extremely heavy soils of East-Slovak Lowland. From pedological view, soil on slopes above 12°, heavy soils, extremely acid, water-logged soils with non beneficial physical and chemical properties can be found here. Dominant soil types are Cambisols (65%), Rendzinas (11%) and Haplic Gleysols (7%). Texturally soils are medium heavy (76%), with high content of soil skeleton (74%), shallow (74%), on slopes 12 – 17° (35%), on steep slopes above 17° (24%). Absolutely dominating are climatic regions 07 to 10 (73%). The soil point value is lower then 19 points.

Hectare-yield level of soils in this category is lower then 2.95 t.ha^{-1}. Spring barley should not occur in cropping system structure on arable land of this category. According to typological production categorization of Slovak soils, dominating are soils suitable more or less only for use as permanent grasslands and partially also alternating fields (categories OT and T). In mentioned regions spring barley growing is associated with losses, and thus it is not profitable.

Figure 4 Non suitable soils for spring barley growing



CONCLUSION

In comparison with other previously formulated territorial division systems of production regions and zones in Slovakia, this alternative brings more detailed analysis of pedo-climatic conditions of territory (based on BPEJ basic mapping unit) and it associates economical and energetic aspects of the crop growing. Substantial is that the system enables possible detailed area identification of given category for any region of Slovakia by GIS help. It is obvious that in territory identified by this method, further analysis is possible by using other supplementary parameters. Thus, the method is an open system that does not identify sharp borders of each category, but it creates them more or less mosaic-like based on particular conditions of the crop and site, respectively.

REFERENCES

HRAŠKO, J., BEDRNA, Z., 1988: Aplikované pôdoznalectvo. Bratislava, Príroda, 1988, 474 s. ISBN 064-170-88.

DŽATKO, M., 1980: Vypracovanie sústav členenia a hodnotenia agroekosystémov SSR (záver. správa). Bratislava: VÚPVR, 1980, 39 s.

DŽATKO, M., 2002: Hodnotenie produkčného potenciálu poľnohospodárskych pôd a pôdno-ekologických regiónov Slovenska. Bratislava, VÚPOP, 2002, 88 s. ISBN 80-85361-94-9.

KORBÍNI, J., FACUNA, J., 1978: Zóny vhodnosti pestovania hlavných poľnohospodárskych plodín v SSR. Bratislava, Príroda, 1978, 111 s. ISBN 64-223-78.

KOVÁČ, K. a kol., 2002: Všeobecná rastlinná výroba. SPU Nitra, 2002, 335 s. ISBN 80-8069-136-3.

KROMKA, M., 2001: Vplyv predpokladaných klimatických zmien na mineralizáciu pôdnej organickej hmoty. In: Bull. Slov. meteorol. spoloč. SAV, – roč. 12, 2001, č. 2, s. 21 – 25.

LINKEŠ, V., PESTÚN, V., DŽATKO, M. (1996): Príručka pre používanie máp bonitovaných pôdno--ekologických jednotiek. Bratislava, VÚPÚ, 1996, 43 s. ISBN 80-85361-19-1.

PREININGER, M., 1987: Energetické hodnocení výrobních procesů v rostlinné výrobě. In: Met. ÚVTIZ, vol. 87, 1987, v. 7, 29 s.
STRAŠIL, Z., 1987: Bilance energie a efektívnosti vkladů v zavlažovaných a nezavlažovaných ekosystémech půd (závěr. zpráva). Praha-Ruzyňe, VÚRV, 1987, 29 s.
VILČEK, J., 1999: Pôdnoekologické parametre usporiadania a využívania poľnohospodárskej krajiny (záver. správa). Bratislava, VÚPOP, 1999, 113 s.
VILČEK, J., 2001: Využívanie produkčného potenciálu našich pôd. In: Naše Pole, 2001, č. 5, s. 40 – 41.

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