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SOIL EROSION ASSESSMENT, LIMITS AND INDICATORS DEVELOPMENT INCLUDING SOIL DIVERSITY EVALUATION IN SLOVAKIA

Hodnotenie pôdnej erózie, limity a indikátory vývoja vrátane hodnotenia pôdnej diverzity na Slovensku

Pavol BIELEK, Ondrej RYBÁR, Blanka ILAVSKÁ, Jozef VILČEK, Pavel JAMBOR, Bohumil ŠURINA
Soil Science and Conservation Research Institute, Bratislava, Slovak Republic

ABSTRACT

Identification of soil erosion indicators in Slovakia can be as a continuing activity after until now comprehensive soil erosion evaluation by experimental and/or expert methods on national and specific regional levels as well.

Seems to be that indirect indication of soil erosion development would be preferred and adopted into the structure of environmental indicators in Slovakia. Soil use situation will be most important parameter of that.

First of all permanent plant cover development we want to take into consideration. Of course this is relevant mainly to areas of erosion probability (see Map 5). Another indicators we have also under development.

Keywords: soil, water, wind, erosion, indicators, diversity, evaluation, erosion control

ABSTRAKT

Identifikácia indikátorov erózie na Slovensku ako nadväzujúca aktivita po doterajšom všestrannom hodnotení experimentálnymi, alebo expertnými metódami tak na celoštátnej, ako aj na regionálnych úrovniach.

Zdá sa, že nepriama indikácia vývoja pôdnej erózie sa bude prednostne rozvíjať a bude zaradená do štruktúry indikátorov životného prostredia na Slovensku. Situácia vo využívaní pôdy bude pritom najdôležitejším parametrom.

Predovšetkým stály rastlinný kryt prichádza do úvahy ako najúčinnejšie ochranné opatrenie proti erózii. Samozrejme toto je relevantné hlavne v oblastiach výskytu erodibilných pôd. Do úvahy prichádzajú aj iné indikátory.

Kľúčové slová: pôda, vodná erózia, veterná erózia, indikátory, diverzita, hodnotenie, protierózna ochrana

GENERAL SITUATION

Soil erosion is very serious problem in Slovakia. It is due to predominance of the mountains and slopes on Slovakian territory. About 576 th.ha of arable land (43%

of the total) is potentially suffering from soil erosion (water erosion mainly) from that 289 th.ha in medium level, 204 th.ha in high level and 58 th.ha in extreme level. Soil Geographical Information System is enabling to identify all agricultural soils (plots) threatened by soil erosion (using the USLE model). Also remote sensing methods are used as a method for identification of eroded areals by visible arguments. Terrain experiments including rain simulation and electromagnetic susceptibility methods as well are also offering some real data and theoretical backgrounds for soil erosion assessment. By all mentioned methods we have collected database of detailed and generalized knowledge about soil erosion situation in Slovakia.

Negative impacts of soil erosion can be demonstrated by several arguments. For example agricultural profits received from different slopes (arable soil) can be in average as follows: slope 0 – 1° = 838 Sk/ha, slope 1 – 3° = 339 Sk/ha, slope 3 – 7° = 20 Sk/ha, slope 7 – 12° = -213 Sk/ha, slope 12 – 17° = -334 Sk/ha. This is due to different yields achieved. For example winter wheat can bring yields 4.68 t/ha in case of lowland (0 – 3° slope), 4.25 t/ha^{-1} (3 – 7° slope) and 4.05 t/ha (7 – 12° slope) on average. Similar data we have for several crops.

Limits of soil erosion potentials adopted in Slovakia are as follows: 4 t of soil matter lost annually from shallow soils (0.3 m deep), 10 t from medium deep soils (0.3 – 0.6 m deep), 30 t from deep soils (0.6 – 0.9 m deep) and 40 t from very deep soils (deeper than 0.9 m).

No correct land use leads to acceleration of soil erosion in comparison to erosion, which is caused by only slopeness of fields. From 1 331 th.ha of total arable land in Slovakia about 362.8 th.ha is located on slopes where root crops are cultivated. This is unacceptable situation. Generally, areas of arable soils located on extreme slopes we can find more often and on larger territory than is acceptable from soil erosion protection point of view. Using the soil GIS we identified about at least 50 th.ha of this different areas. Simply decrease and/or increase of arable land areas in mountainous region of Slovakia could be adopted as a significant indicator of soil erosion potential development.

From the data base focused on land use development in Slovakia we received data about change of arable land to grasslands. From 1999 to 2002 it was about 18.8 th.ha. This is increase of grassland areas about 2.2% what can lead to decrease of the total soil erosion potentials in Slovakia from 4 172 th.tons to 4 016 th.tons (2.66%) per year (calculated by USLE).

In Slovakia we have programme for change of about 50 th.ha of arable soils what will increase the grassland areas about 6% and soil erosion potential will be decreased about 27%.

With help of developed PEDOPT model we can calculate optimal soil use (from erosion protection point of view) for arbitrary field, farm and region in Slovakia. Concrete real and optimum data of soil use structure we can present on example of district Prešov (31 688 ha of arable land) as follows (optimum in brackets): cereals 41.7% (42.8%), oil plants 15.4% (5.4%), sugar beet 0.4% (0.2%), potatoes 5.3% (1.2%), forage 15.4% (26.3%). Move of numbers to optimal percentage we can accept as an indicator of soil erosion decrease, and vice versa.

From climatic factors mainly heavy rains and severe winds can make very critical influence on soil erosion situation. From the statistical data we have information that during the years from 1990 to 2002 within of 4 years at least have been registered an extreme heavy rains (more than 30 mm of precipitation per hour). Simply, it has 3 years frequency (in average). In case when frequency is shorter - we can expect soil erosion intensity increase and vice versa.

In Slovakia we have carried out relatively detailed soil survey of agricultural soils. Density of the data set is less than 14 ha. On the soil maps 1:5 000 we have identified 21 soil types and 210 subtypes, forms and variets. In the soil map 1:500 000 we can find 1 823 classified soil smaller or larger areas. When we combine most important soil parameters we can identify so called 6 752 soil-ecological units. Simply, relatively high heterogeneity we can find on soil cover of Slovakia.

Large-scale farming has problems with soil diversity. In opposite, from soil cover stability point of view it is very good phenomenon. Also human impacts on soil can positively or negatively affect the soil cover heterogeneity.

Soil erosion indicators in theory and practice

Soil erosion is accidental phenomenon in the nature. It depends from conservative parameters (geomorphology, soil properties, and others) and from induced affects (natural and human) formed by driving forces where soil use and agricultural practice are dominating. Mainly induced factors must be taken into consideration as indicators of soil erosion development.

How to indicate the soil erosion potentials development? This is question of the need related to decision level ambitions.

When we need more detailed evaluation and when smaller territory is evaluated – after we can use all models, which are able to calculate the soil erosion potential for each slope or field of targeted territory. Soil and soil erosion GIS is needed and permanent actualization of inserted data must be carried out before each temporary evaluation. For example USLE model can be used in this case. Three simulated situations are presented on Figure 1 (a, b, c).

Figure 1a Soil erosion potential under real plant cover of tested area

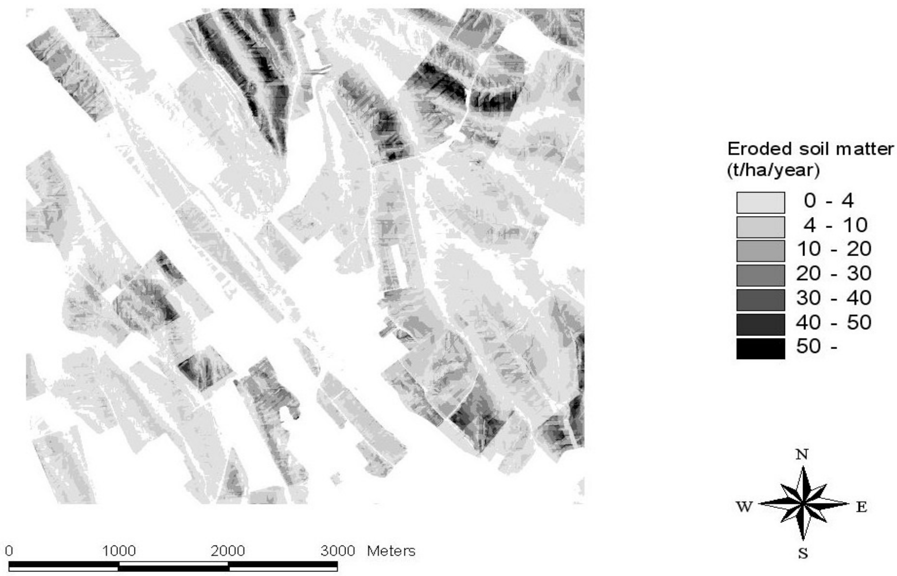


Figure 1b Soil erosion potential in case of no plant cover in all over the tested area

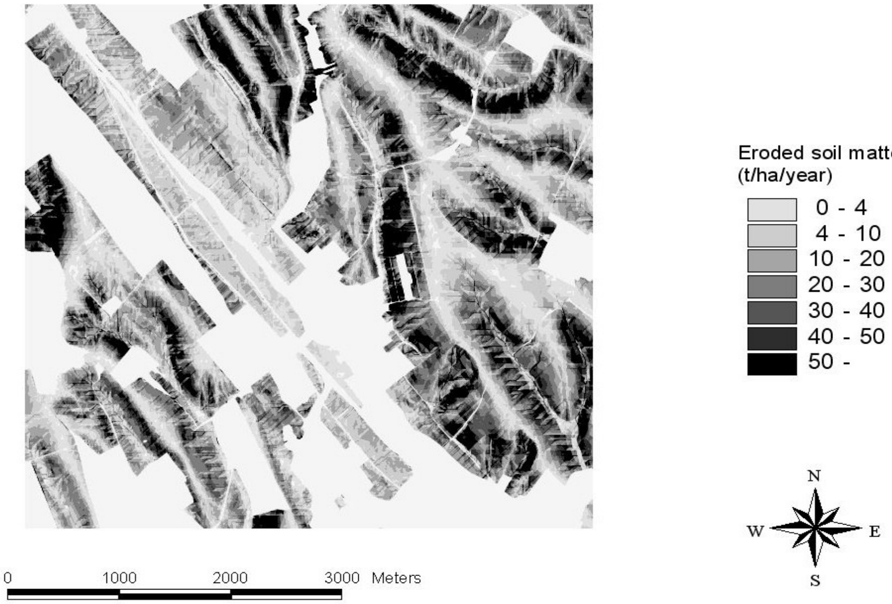


Figure 1c Soil erosion potential when all over the tested area is covered by grass plants

The tested area is 2.5 th ha, from that about 1 776 ha is territory where soil erosion can be expected (by USLE calculation). From the maps can be identified the visual evidence about different soil erosion potentials under different soil cover situation. Is clear that no plant cover is very catastrophic situation form soil erosion point of view.

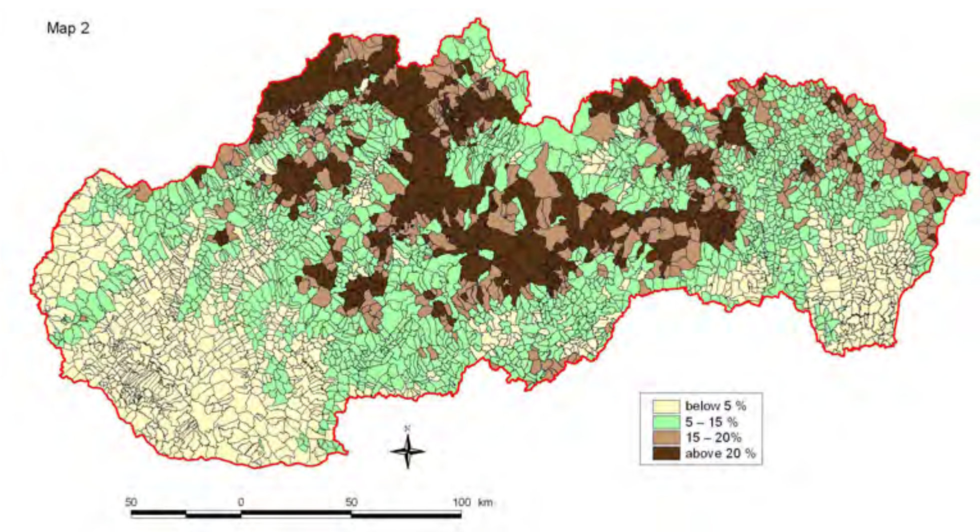
Contrary a grass plant cover is very well protecting soil against erosion. Concrete data about it are presented in Table 1.

Table 1 Soil erosion potentials under different soil cover types.

Category of erosion	% of total potentially affected land		
	Real soil cover situation	**No plant cover**	**Total grass cover**
Low	60.0	18.2	100.0
Medium	33.4	44.1	—
High	5.2	22.8	—
Extreme	1.4	14.8	—

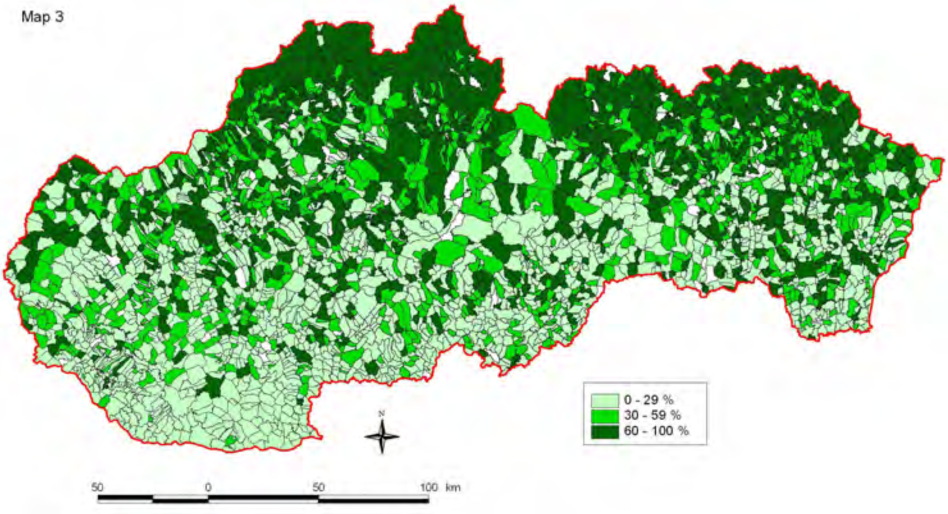
On the level of the state or each larger territory a simplified (indirect) approaches are more suitable for soil erosion indication. Here is structure (steps) of approach which is suitable (maybe) to be used in Slovakia. Five steps of this approach following:

1. Identification of average sloppiness of all Slovakian cadastres (Map 2). This map was created using the digital terrain model.



2. Identification of permanent plant cover areas (mainly grasslands) in % from the total soil area of each cadastre (Map 3). This information is available from statistical data of the Slovak Republic.

Map 3



3. Soil erosion vulnerability areas identification by common evaluation of sloping (Map 4) and plant cover situation (Table 2)

Map 4

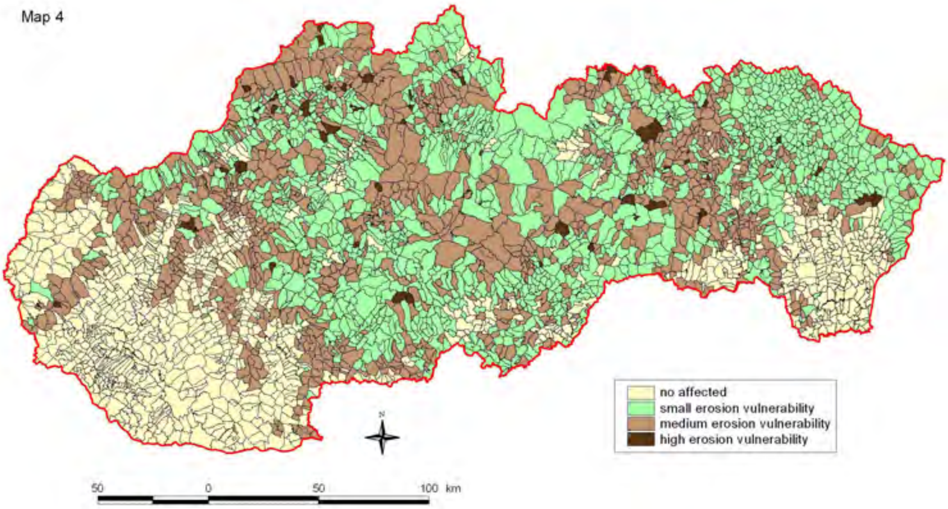
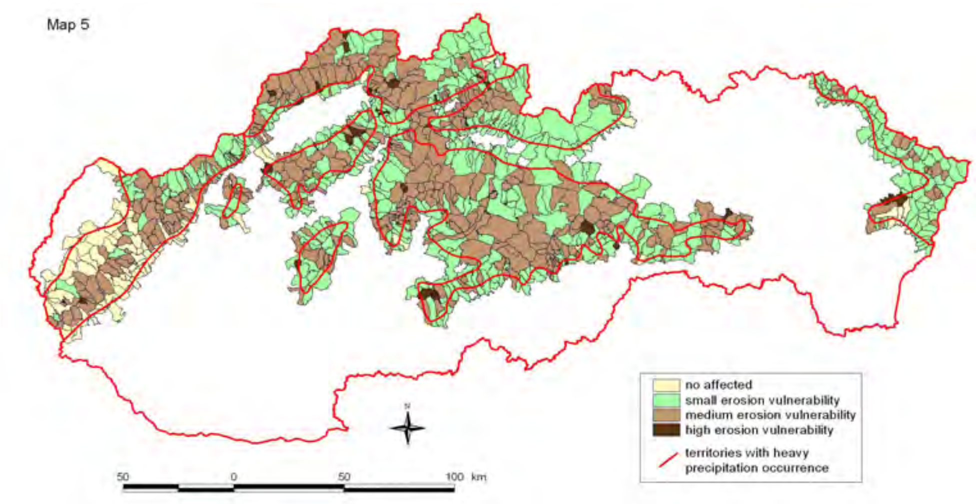


Table 2 Soil erosion vulnerability on levels of cadastres

Average slopenes	Plant cover		
	below 30 %	30 – 60 %	over 60 %
less than 5 % x	x	x	x
5 – 15 % xx	xxx	xx	xx
15 – 20 % xxx	xxxx	xxx	xx
over 20 % xxxx	xxxx	xxxx	xxx

x – no affected
xx – small erosion vulnerability
xxx – medium erosion vulnerability
xxxx – high erosion vulnerability

4. Identification of main heavy rain areas where intensity over 30 mm of rain per hour have been fallen down accidentally within the last 50 years) – Map 5. Those data are available from hydro-meteorological observations.



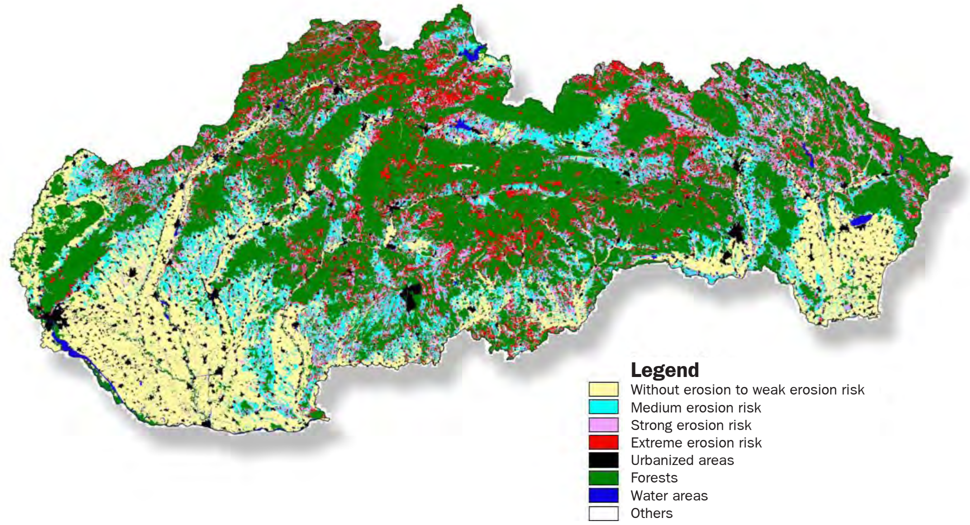
5. Identification of main erosion probability areas by all above (1, 2, 3, 4) parameters and/or factors (Map 5).

As main the indicators of this approach we can choose percentage of permanent plant cover areas in cadastres belonging to the main erosion risk areas. This information is regularly available from statistical yearbooks of Slovakia edited each year in very comprehensive versions. Is clear that larger acreage of permanent plant cover leads to decrease of soil erosion intensity. Of coarse it is relevant mainly (only) to areas of slopes and heavy rains occurrence.

Those cadastres we already identified and are presented in Map 5.

The procedure of soil erosion potential indication comprises a development of permanent plant cover extent in concrete cadastres during the concrete time (e.g. 5 years). When the extent of permanent plant cover is increased, soil erosion potential can be decreased and vice versa.

Map 6 Potential water erosion risk in Slovakia



CONCLUSIONS

Identification of soil erosion indicators is Slovakia can be as a continuing activity after until now comprehensive soil erosion evaluation by experimental and/or expert methods on national and specific regional levels as well.

Seems to be that indirect indication of soil erosion development would be preferred and adopted into the structure of environmental indicators in Slovakia. Soil use situation will be most important parameter of that.

First of all permanent plant cover development we want to take into consideration. Of course this is relevant mainly to areas of erosion probability (see Map 5). Another indicators we have also under development.

REFERENCES

BIELEK, P. 1999: Soil degradation in Slovakia. European Society for Soil Conservation, Paulus and Partner GmbH, Manschnow, Germany, 30 p.

ILAVSKÁ, B. 2003: Potential water erosion risk in Slovakia (map) Bratislava VÚPOP, 1 p.

VILČEK, J. 2003: Model of production-ecological Farmland use and arrangement. VP VÚPOP, 10 p.

WISHMEIER, W. H., SMITH, D. D. 1978: Predicting rainfall erosion losses. Maryland, SEA SDA, Hyatswille, 58 p.

SPATIAL VARIABILITY OF SELECTED SOIL AGRO-CHEMICAL PARAMETERS AND ITS UTILISATION WITHIN PRECISE NUTRIENT APPLICATION

Priestorová variabilita vybraných agrochemických parametrov pôdy a jej využitie v rámci presnej aplikácie živín

Radoslav BUJNOVSKÝ[1], **Klára HORNIŠOVÁ**[2], **Daniel MIKLOVIČ**[1], **Stanislav TORMA**[1]

[1] *Soil Science and Conservation Research Institute, Bratislava*

[2] *Comenius University, Faculty of Natural Sciences, Bratislava*

ABSTRACT

In paper are presented the results of estimation of selected soil agrochemical parameters variability (pH_{KCl}, available P, available K, available Mg) by means the basic geostatistical methods and its evaluation with regard to precise nutrient application within a field. Spatial dependence the values of individual parameters was estimated through approximation of empiric semivariogram by suitable model. Following prediction the values of agrochemical parameters on whole field area was calculated by point kriging method with estimated semivariogram model. Range values for selected parameters on field Chmeľnica III fluctuated in range 68.9 do 95.5 m and between 87.4 and 269.7 m on field Nad mlynom. Recommended sampling density for needs of precise fertilization – one sample per hectare, that is considered as some compromise between reaching spatial dependence agrochemical parameters and soil analysis costs, is still enough demanding on cost analysis and not always adequate for objective definition of spatial variability the concrete parameters.

Keywords: soil reaction, available phosphorus, available potassium, available magnesium, spatial variability

ABSTRAKT

Príspevok prezentuje výsledky odhadu priestorovej variability vybraných agrochemických parametrov pôdy (pH_{KCl}, prístupný fosfor, prístupný draslík a prístupný horčík) základnými geoštatistickými metódami a hodnotenie jej vzťahu k presnej aplikácii živín v rámci honu. Priestorová závislosť hodnôt jednotlivých parametrov sa odhadovala aproximáciou empirického semivariogramu vhodným teoretickým modelom. Následná predikcia hodnôt agrochemických parametrov na celé územie honu sa vypočítala metódou bodového krigingu s odhadnutým modelom semivariogramu. Zo štatistického spracovania nameraných údajov vyplýva že na hone Chmeľnica III hodnoty dosahu vybraných agrochemických parametrov sa pohybovali v rozpätí od 68,9 do 95,5 m, zatiaľ čo na hone Nad mlynom to bolo vo väčšom rozpätí 87,4 – 269,7 m. Odporúčaná hustota odberu pôdnych vzoriek pre potreby presného hnojenia – jedna vzorka na hektár, považovaná za určitý kompromis medzi dosiahnutím priestorovej závislosti agrochemických parametrov pôdy a nákladmi na analýzy pôd, je stále značne náročná na počet pôdnych analýz a nie vždy postačujúca pre objektívne vymedzenie priestorovej variability sledovaných parametrov.

KĽÚČOVÉ SLOVÁ: pôdna reakcia, prístupný fosfor, prístupný draslík, prístupný horčík, priestorová variabilita

INTRODUCTION

From view-point of utilization of soil test results it is important as objectiveness and precision of soil parameters determination as well as question of area of validity with respect to spatial variability within a field. According to literary findings (e.g. Larson, Robert, 1991; Bouma, Fincke, 1993) variability has natural as well as anthropogenic origin. Information on variability of soil agrochemical parameters expressed through classical statistical tools is well documented in many papers (e.g. Wilding et al., 1994; Mulla, McBratney, 2000), but such type of information does not find practical utilization in agriculture as far as areas of different status of agrochemical soil parameters is necessary to define.

The definition the spatial variability of soil parameters within a field represents starting point for subsequent differentiated fertilizer application within precision farming. Problem the statistical processing of spatial data and interpretation their variability is described in several publications (Cressie, 1991; Goovaerts, 1997; Webster, Oliver, 1990). Starting moment at variability evaluation through geostatistical methods represents semivariance estimation. Semivariogram value $\gamma(u,v)$ for pair of points (u,v) in considered area is defined as half the variance of difference of values at these points of realization of random process Z in question

$$\gamma(u,v) = 0{,}5 \text{ Var } [Z(u) - Z(v)] \qquad [1]$$

If some assumptions about the mean of random process Z are fulfilled, the knowledge of variogram is sufficient for determining the best (in the sense of the least mean square prediction error) unbiased linear prediction of the values of realization of Z in considered area (Cressie, 1991). If the random process Z is intrinsically stationary, i.e. if the value $\gamma(u,v)$ depends only on the difference vector u-v, semivariogram may be treated as a function of one vector variable:

$$\gamma(u,v) = \gamma(h), \text{ where } h = u\text{-}v \qquad [2]$$

Some of the semivariogram values is possible to estimate from obtained data with help of formula:

$$\gamma\hat{}(h) = 0{,}5\, \Sigma\{z(x_i) - z(x_i + h)\}2 \,/\, N(h) \qquad [3]$$

where $\gamma\hat{}(h)$ – so called empirical semivariogram in point h

$N(h)$ – number of pairs of data points with the difference vector h

$z(x_i)$ – measured value of quantity Z in data point x_i

At the next stage the obtained set of points $(h, \gamma\hat{}(h))$ is fitted by curve of some of the theoretical model semivariogram. Then, the estimated model of semivariogram is pluged-in in the general equations of linear interpolation (kriging). Appropriateness of the selected model of spatial dependence is evaluated not only by the quality of the fit of the empirical variogram by theoretical, but also by method of crossvalidation (Cressie, 1991).

MATERIAL AND METHODS

The aim of paper was to obtain information on spatial variability of soil pH values, available P, K and Mg content within field and its relation to strategy of soil sampling and fertilization. Problem was solved on example of two fields: Chmeľnica III [acreage 8 ha, medium heavy (silty loam) Haplic Luvisol on loess] on farm Kočín, district Piešťany, and Nad mlynom [acreage 17 ha, medium heavy (clay-loam) Stagnic Cambisol on Carpathian flysh] on farm Osikov, district Bardejov.

Soil samples were taken up in spring 2000 in grid 25 × 25 m on field Chmeľnica III and on field Nad mlynom in grid 50 × 50 m from topsoil layer 0 – 0.3 m. Composite sample was created from three sub-samples that were taken approximately from area with diameter 3 metres by soil auger. In composite soil samples was determined available P, K, and Mg content by Mehlich II method as well as soil reaction values in 1M KCl (Fiala, 1999).

Point coordinates of sampling places and field borders, expressed in S-JTSK system, were obtained from vectored field maps in scale 1:5 000. For vectorisation was used Topol 2.5 software. For interpolation of spatial data was used point kriging method with estimated semivariance, as a model of spatial dependence. There were used available and most used theoretical models (spherical, exponential, power function and gaussian model).

For geostatistical analysis of data were used especially free accessible software packages, when Variowin (Pannatier, 1996) was used at finding the suitable model of spatial dependence and GSLIB software (Deutsch, Journel, 1998) for crossvalidation and interpolation of data. Maps of interpolated data were created by Surfer 7.0 software.

RESULTS AND DISCUSSION

Statistical evaluation of available nutrient content and pH_{KCl} values on fields Chmeľnica III and Nad mlynom are introduced in Tables 1 and 2. Spatial variability of individual parameters is illustrated on Figures 1 – 8.

Table 1 Statistical characteristics of individual data sets from field **Chmeľnica III**

Statistical characteristics	**pH_{KCl}**	**P**	**K**	**Mg**
minimal value	7.2	36	200	210
maximal value	8.1	149	745	415
average	7.39	99.84	357.80	269.30
coefficient of variation	1.53	22.21	30.62	15.39
model for semivariogram estimation	exponential	spherical	spherical	spherical
nugget	0.0009	0	0	0
direction of anisotropy	0	0	0	0
range	68.9	80	95.5	84.4
sill	0.013	520	13 000	1 800
mean of standardized reziduals from cross-validation	-0.014	-0.0009	-0.018	-0.00515
root mean square error of standardized reziduals	0.88	0.90	0.92	1.03
equation of best regression line describing dependence of data on values in the same points predicted by cross-validation	y = -0.72+1.098x	y = -2.82+1.028x	y = -13.27+1.042x	y = -2.22+1.01x
correlation coefficient between data & values predicted by cross-validation	0.62	0.81	0.83	0.77

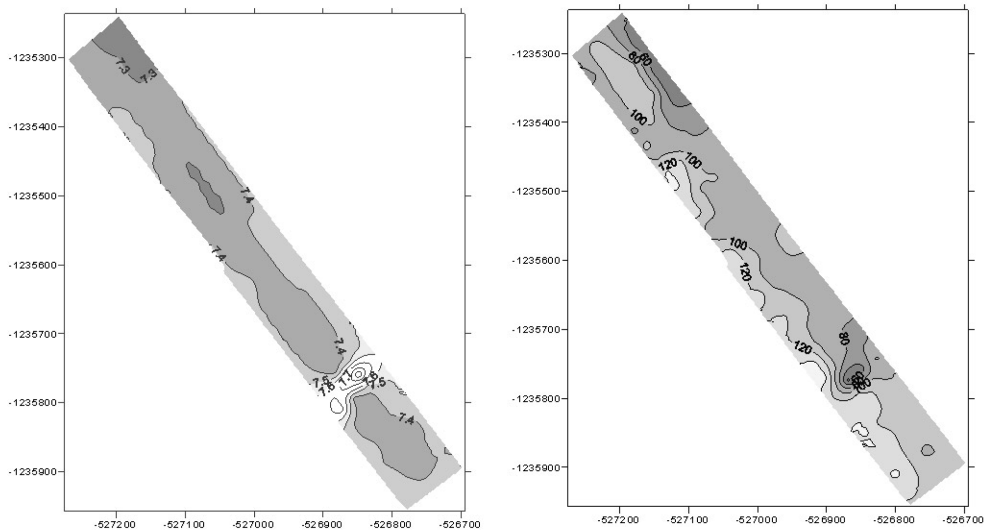
From view-point of IGF (indicative goodness-of-fit) criterion, implemented in Variowin software (Pannatier, 1996), was for examined parameters selected spherical or exponential model. As follows from Table 1 and 2 range values of semivariogram models fluctuated in range 68.9 to 95.5 m on field Chmeľnica III and between 87.4 and 269.7 m on field Nad mlynom. Values of range are not in coherence with classical variability indicators (e.g. coefficient of variation) because increasing values of variation coefficient do not correspond with increase of range values. With regard to considered statistical characteristics, the crossvalidation results are satisfactory for all agrochemical parameters at field Chmeľnica III and in less satisfactory for pH_{KCl} and available K at field Nad mlynom.

Soil sampling density is still the object of discussion. As introduce Mulla and McBratney (2000), spatial dependence of soil agrochemical parameters, expressed through range values, fluctuates from 20 to 428 m. Used grid of sampling is in coherence with that one (40 – 70 m × 40 – 70 m) advised by many authors (e.g. Franzen, Peck, 1994; Oliver, Frogbrook, 1998). Range values should indicate sampling density. However, prior to sampling, the range value is rare to be known. According to Oliver and Webster (1998) soil sampling in grid 165 × 165 m was from view of finding the spatial dependence insufficient.

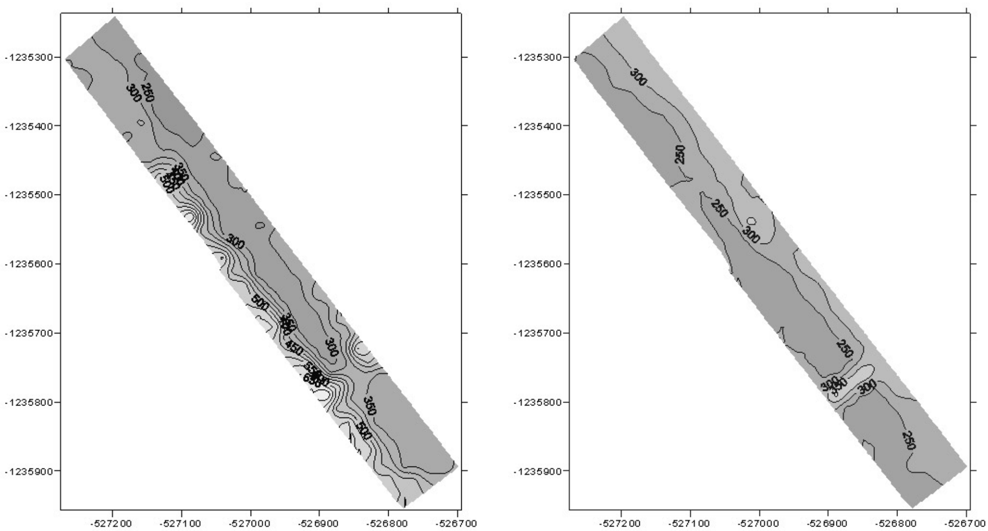
Table 2 Statistical characteristics of individual data sets from field Nad mlynom

Statistical charactristics	**pH_{KCl}**	**P**	**K**	**Mg**
minimal value	3.9	11	95	60
maximal value	7.1	104	360	265
average	5.15	48.76	180.67	148.51
coefficient of variation	14.2	45.06	26.82	38.14
model for semivariogram estimation	exponential	exponential	spherical	exponential
nugget	0	0	0	0
direction of anisotropy	0	0	0	0
range	130.0	156.0	87.4	269.7
sill	0.61	470	2 700	4 125
mean of standardized reziduals from cross-validation	0.0075	0.0305	0.01676	-0.0416
root mean square error of standardized reziduals	1.00	1.01	0.99	1.06
equation of best regression line describing dependence of data on values in the same points predicted by cross-validation	y = 0.61+0.88x	y = -2.62+1.04x	y = 56.45+0.68x	y = 29.64+0.82x
correlation coefficient between data & values predicted by cross-validation	0.38	0.52	0.32	0.57

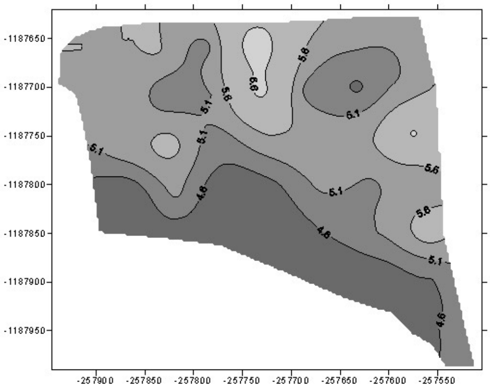
Figures 1 & 2 Spatial variability of pH/KCl values and available P content (ppm) on field Chmeľnica III.

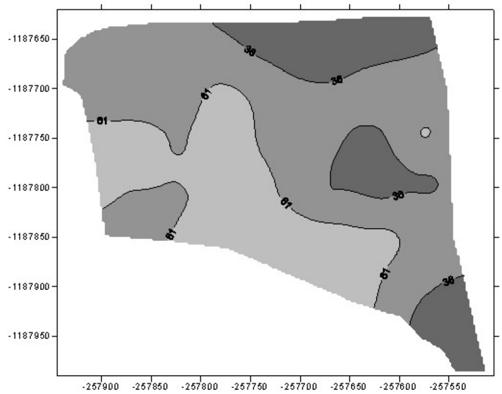


Figures 3 & 4 Spatial variability of available K and Mg content (ppm) on field Chmeľnica III

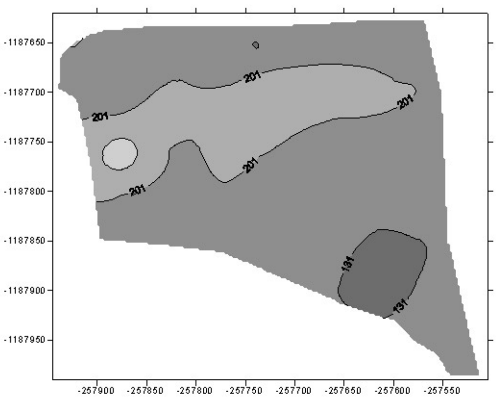


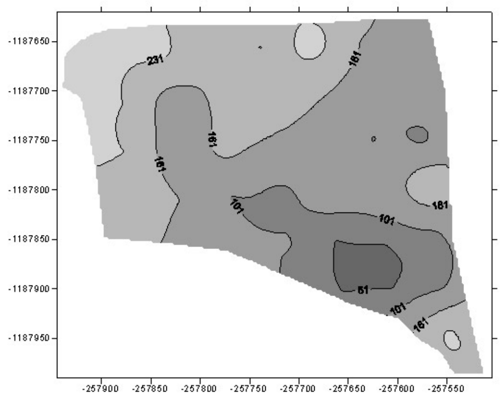
Figures 5 & 6 Spatial variability of pH/KCl values and available P content (ppm) on field Nad mlynom





Figures 7 & 8 Spatial variability of available K and Mg content (ppm) on field Nad mlynom





Soil sampling in grid 100 × 100 m can be considered as some compromise between number of soil samples & analysis and reaching the spatially dependence of examined parameters (Schnug et al., 1994; Robert, 2001). Mentioned density of soil sampling and corresponding number of soil analysis seems economically problematic and as follows from statistical data range values are often under 100 m. It means that sampling density should be denser. Accuracy of range estimation depends on number of samples and sampling density. Insufficient number of soil samples (Burrough, 1991; Cressie, 1991; Mulla, McBratney, 2000) may fudge accuracy of semivariogram estimation and subsequently definition the variability of observed soil parameters especially on fields with small acreage, the fields with non-regular or extreme shape while the sampling network will be not concentrated. Thus, reaching satisfactory soil parameter maps on small fields requires increasing sampling density to for instance 4 composite samples per 1 ha. Despite this even this sampling density cannot serve enough precise maps (namely in the case of pHKCl and available K on field Nad mlynom).

By many authors (e.g. Colvin et al., 1994; Pierce et al., 1994; Schnug et al., 1994; Sylvester-Bradley, 1999; Wollenhaupt et al., 1997) solving of strategy soil sampling and high number of soil samples consists in knowing the reason of spatial yield variability. When there are significant other factors than nutrients there is possible to exclude some field parts from cropping. Next tool at reduction of soil samples number is creating of zones. As introduce Mulla and Bhatti (1997) at definition of zones within field is purposeful to combine information on soil types variability with information on yield variability and soil organic matter, respectively.

On the base of existing knowledge is possible to state that creating of within field zones is coming into question at all agrochemical soil parameters in consequence of respecting the calibration schemes of evaluation and/or the system of nutrient rate calculation. For example soil texture as additional parameter is necessary to take into account at creation the K and Mg fertility maps. By calibration scheme for Mehlich II (Anonymous, 1995) valid in Slovakia for creating fertility map for phosphorus it is necessary to consider as soil texture as well as pH_{KCl} categories. Mehlich III calibration scheme for available P (Anonymous, 1999) requires only soil texture categories.

It is necessary to mention that identification of spatial variability of soil agrochemical parameters not always leads to utilization this information at fertilizer application due to objective reasons. As example is possible to mention field Chmeľnica III where soil liming is not actual due to relative high pH_{KCl} values (between 7.2 and 8.1). Undoubtedly, costs connected with soil sampling, providing soil tests and precise fertilizer application are (will be) higher in comparison with classical system. But, as introduce Lowenberg-DeBoer and Swinton (1997) profitability of precision farming as well as traditional farming is significantly influenced by product value.

CONCLUSIONS

From statistical treatment of measured data follows that range values of semivariogram models fluctuated in range 68.9 to 95.5 m on field Chmeľnica III and between 87.4 and 269.7 m on field Nad mlynom.

Advised soil sampling in grid 100 × 100 m or one sample per hectare, considered as some compromise between reaching the spatial dependence of agrochemical soil parameters and costs on soil testing. This density is still enough demanding on number of soil analysis and not always sufficient for obtaining satisfactory maps of parameters variability within a field. So, strategy of creating zones within field is necessary examine considering spatial variability of soil parameters and crop yield.

REFERENCES

ANONYMOUS: Agronomical criteria for soil test evaluation since 1995. Central Agricultural Inspection and Testing Institute, Bratislava – Zvolen, 1995 (in Slovak)

ANONYMOUS: Unified work procedures for agrochemical soil testing in years 2000 to 2004 (XIth cycle). I. part – sampling in terrain. Central Agricultural Inspection and Testing Institute, Bratislava – Zvolen, 1999 (in Slovak)

BOUMA, J., FINCKE, P.A.: Origin and nature of soil resource variability. In: ROBERT, P.C., RUST, R.H., LARSON, W.E. (eds.), Soil specific crop management - a workshop in research and development issues. ASA-CSSA-SSSA, Madison, 1993, pp. 3 – 13.

Burrough, P.A.: Sampling designs for quantifying map unit composition. In: Mausbach, M.J., Wilding, L.P. (eds.), Spatial variabilities in soils and landforms. SSSA Spec. Publ. No 28, Madison, WI, 1991, pp. 89 – 125.

Colvin, T.S., Karlen, D.L., Ambuel, J.R., Perez-Munoz, F.: Yield monitoring for mapping. In: Robert, P.C., Rust, R.H., Larson, E.E. (eds.), Site specific management for agricultural systems. Proc. 2nd Int. Conf. ASA-CSSA-SSSA, Madison, WI, 1994, pp. 3 – 14.

Cressie, N. A. C.: Statistics for spatial data. J. Wiley, New York, 1991.

Deutsch, V.D., Journel, A.G.: GSLIB – Geostatistical software library and user's guide. Oxford University Press, New York, 1998.

Fiala, K. (ed.): Prescriptive methods of soil testing for partial monitoring system soil. VÚPOP, Bratislava, 1999 (in Slovak)

Franzen, D.W., Peck, T.R.: Sampling for site-specific application. In: Robert, P.C., Rust, R.H., Larson, W.E. (eds.) Site-specific management for agricultural systems. Proc. 2nd Int. Conf. ASA-CSSA-SSSA, Madison, WI, 1994, pp. 535 – 551.

Goovaerts, P.: Geostatistics for natural resources evaluation. Oxford University Press, New York, 1997.

Larson, W.E., Robert, P.C.: Farming by soil. In: Lal, R., Pierce, F.J. (eds.), Soil management for sustainability. SWCS – SSSA, Ankeny, 1991, 103 – 112.

Lowenberg-DeBoer, J., Swinton, S.M.: Economics of site-specific management in agronomic crops. In: Pierce, F.J., Sadler, E.J. (eds.), The state of site – specific management for agriculture. Proc. Symp. ASA-CSSA-SSSA, Madison, WI, 1997, pp. 369 – 396.

Mulla, D.J., Bhatti, A.U.: An evaluation of indicator properties affecting spatial patterns in N and P requirements for winter wheat yields. In: Stafford, J.V. (ed.), Precision agriculture 97. Proc. First European Conf. on precision agriculture. Bios Scientific Publ., Oxford, 1997, pp. 145 – 153.

Mulla, D.J., McBratney, A.B.: Soil spatial variability. In: Sumner, M.E. (ed.), Handbook of soil science. CRC Press Boca Raton, 2000, pp. A321 – A352.

Oliver, M.A., Webster, R.: Combining nested and linear sampling for determining the scale and form of spatial variation of regionalized variables. Geograph. Anal., 18, 1986, pp. 227 – 242.

Oliver, M.A., Frogbrook, Z.L., Res, M.: Sampling to estimate soil nutrients for precision agriculture. Proc. Int. Fert. Soc., No. 417, 1998.

Pannatier, Y.: Variowin. Software for spatial data analysis in 2D. Springer, Berlin, 1996.

Pierce, F.J., Warncke, D.D., Everett, M.W.: Yield and nutrient variability in glacial soils of Michigan. In: Robert, P.C., Rust, R.H., Larson, E.E. (eds.), Site specific management for agricultural systems. Proc. 2nd Int. Conf. ASA-CSSA-SSSA, Madison, WI, 1994, pp. 133 – 150.

Robert, P.: Precision agriculture: A challenge for crop nutrition management. In: Horst, W.J. et al. (eds.), Plant nutrition – Food security and sustainability of agro-ecosystems. Proc. 14th Int. Plant Nutrition Colloquium. Kluwer Acad. Publ., Dordrecht, 2001, pp. 692 – 693.

Schnug, E., Haneklaus, S., Murphy, D.: Equifertiles – an innovative concept for efficient sampling in the local resource management of agricultural soils. Aspects Appl. Biol., 37, 1994, pp. 63 – 72.

SYLVESTER-BRADLEY, R., LORD, E., SPARKES, D.L., SCOTT, R.K., WILTSHIRE, J.J.J., ORSON, J.: An analysis of potential of precision farming in northern Europe. Soil Use Manag., 15, 1999, pp. 1 – 8.

WEBSTER, R., OLIVER, M.A.: Statistical methods in soil and land resource survey. Oxford Univ. Press, Oxford, 1990.

WILDING, L.P., BOUMA, J., GOSS, D.W.: Impact of spatial variability on interpretive modelling. In: BRYANT, R.B., ARNOLD, R.W. (eds.), Quantitative modelling of soil forming processes; Proc. of SSSA Symp., Spec. Publ. No 39, SSSA, Madison, 1994, pp. 61 – 75.

WOLLENHAUPT, N.C., MULLA, D.J., CRAWFORD, C.A.G.: Soil sampling and interpolation techniques for mapping spatial variability of soil properties. In: PIERCE, F.J., SADLER, E.J. (eds.), The state of site-specific management for agriculture; Proc. Symp. ASA-CSSA-SSSA, Madison, 1997, pp. 19 – 53.

SPATIAL VARIABILITY OF SOIL NITROGEN CONTENT IN REGION TRNAVA HILLY LAND (Case Study with Regard on Anisotropic Variation)

Priestorová variabilita obsahu pôdneho dusíka v záujmovom regióne Trnavská pahorkatina (Prípadová štúdia so zreteľom na anizotropnú variabilitu)

Vladimír HUTÁR
Soil Science and Conservation Research Institute (SSCRI), Bratislava

ABSTRACT

Spatial variation relation of soil conditions represents reality of interactions and relationship within soil properties. Geostatical methods, based on theory of regionalized variable, allow determine appropriate count and location of neighbouring sample to estimate value in known, unsampled point using kriging interpolation method. Analyse of obvious spatial anisotropy variation in case study of spatial variability of soil nitrogen content in region Trnava hilly land was analysed. Semivariogram modelling with basic characteristic (sill, nugget, range) was used in kriging interpolation method to create categorised map of soil nitrogen content in study area. An anisotropy variation relation corresponds with geographical theory of foothill soil zonality, represented with following soil series: Chernozems, Luvisols and Gleysols.

Keywords: spatial variability, geostatistics, kriging, N soil content

ABSTRAKT

Zákonitosti priestorovej variability pôdnych vlastností sú odrazom skutočnosti vzťahov a závislostí medzi pôdnymi vlastnosťami pri mapovaní pôd a pôdnych charakteristík. Geoštatistické metódy, využívajúce analýzu zákonitostí priestorového rozloženia hodnôt náhodnej premennej umožňujú určiť vhodný počet a polohu okolitých hodnôt pre interpoláciu (odhad neznámych hodnôt) a prideliť im príslušné váhy (Borůvka, 2000). V prípadovej štúdii priestorovej variability obsahu pôdneho dusíka v záujmovom regióne Trnavská pahorkatina bola uskutočnená analýza priestorovej závislosti metódami geoštatistiky s výraznou zákonitosťou anizotropnej variability. Na základe tejto analýzy bola vytvorená pôdna mapa krígingovou metódou s výslednou klasifikáciou obsahu pôdneho dusíka v záujmovom regióne. Zákonitosti anizotropnej variability sú vyjadrením rôznorodosti pôsobenia pedologických faktorov príhorskej zonálnosti pôd.

Kľúčové slová: priestorová variabilita, geoštatistika, kriging, obsah pôdneho dusíka

INTRODUCTION

Geostatistical methods of interpolation, popularly known as kriging, start with the recognition that the spatial variation of any continuous attribute can be better described by a stochastic (probabilistic) surface than strictly mathematical function.

Within the geostatical framework, a probabilistic (random function) model based on regionalized variable is used. Theory of regionalized variable assumes that the spatial variation of any random variable can by expressed as the sum of three major components: structural component, having a constant mean; a random, but spatially correlated component, known as the variation of the regionalized variable and a spatially uncorrelated random noise (Burrough P. A, McDonnell R. A, 1998). In the case of x as a position in 1, 2, 3 dimension, the value of a random variable Z at x is given by:

$$Z(x) = m(x) + \gamma(h) + \varepsilon''$$

where $m(x)$ is a deterministic function describing the structural component of Z at x, $\gamma(h)$ is semivariance (which should be equivalent to locally varying but spatially dependent residuals from $m(x)$ [the regionalized variable]) and ε'' is a residual, spatially independent Gaussian noise. Semivariance, which can be estimated from sample data by:

$$\hat{\gamma}(h) = \frac{1}{2n} \sum_{i-1}^{x} \{z(xi) - z(xi + h)\}^2$$

n – number of sample points
z – attribute
h – separating distance

should be equivalent to spatially dependent residual after fulfilling the conditions of intrinsic hypothesis. Stationarity of difference and variance of differences defines the requirements for the intrinsic hypothesis of regionalized variable theory. That means that differences between sites are merely a function of the distance between them.

A plot of $\hat{\gamma}(h)$ against h is known as the experimental variogram and it represents the first step towards a quantitative description of the regionalized variation. Interactive variogram modelling is the tool how regionalized variation (in expression of the experimental variogram) is managed. Basic components, occurring by variogram modelling, are: nugget effect (variance of measurement errors combinated with that from spatial variation at distances much shorter than the sample spacing, which cannot be resolved), sill (maximal semivariance value, reached by bounded models), range (value of distance, in which maximal semivariance is reached (sill)). There are several authorized variograms describing spatial variation (spherical, exponential, Gaussian etc.). Different variograms may occur in different directions (anisotropy) and spatial variation in different (orthogonal) directions must bee therefore investigated. Fitted semivariogram model is used to determine weights needed for local interpolation by weight moving average in ordinary kriging.

MATERIAL AND METHODS

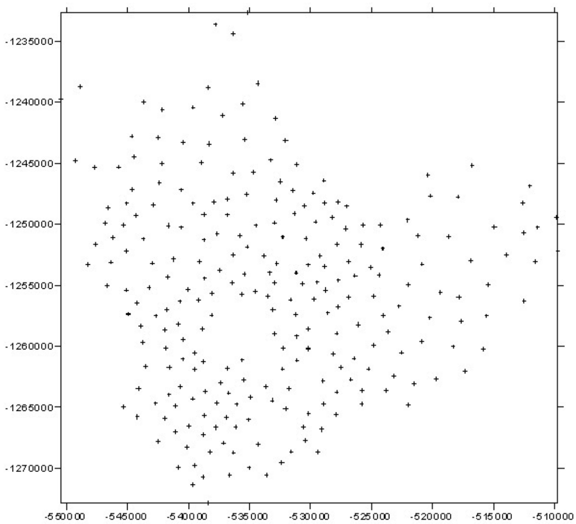
Collection of 250 soil sample set was used for evaluation of spatial variation of soil nitrogen content. Coordinate (spatial) characteristics (S-JTSK, Slovak geodetic system) of each soil sample position were obtained from topological map scale 1:50 000 by paper tablet digitalization. Soil nitrogen content (Kjeldahl content N_t (%)) was determined by SSCRI laboratory (Fiala (ed.) et al., 1997).

Normal (Gaussian) distribution of continuous random variable was fitted for histogram of soil nitrogen content and basic statistic was calculated to satisfy basic geostatistical concepts, such as ergodicity and stacionarity of regionalized variable. Experimental semivariograms in different directions were analyzed in VarioWin software (Pannatier 1996) and significant anisotropic variation was searched. Model parameters from experimental variograms (minor-major range, sill, nugget, anisotropy) were used to determine weights needed for local interpolation (ordinary kriging method). Grid with 200x200 pixel resolution was finalised in Surfer program and a contour map categorized according Bielek (1998) was created to express the spatial distribution of soil nitrogen content in investigated region.

RESULTS AND DISCUSION

Investigated area (100 849 ha) is situated mainly on the Trnava Hilly Land, partly on Nitra Hilly Land and Váh river in the west part of Slovak Republic. During the soil survey, 250 soil probes have been described and classified (Sobocká, J., Šurina, B., Hutár, V., 2000) with respect to the rules of MKSP (Collective 2000). Soil samples, assigned for analysis were sampled from the topsoil (10 cm) of Akp-horizont. Spatial spacing of sample points is assigned on Figure 1.

Figure 1 Soil sample map



The basic nearest neighbour statistic for sample points is calculated as follows: average distance to the nearest neighbour is 1 450 m with distance from 795 m to 3 229 m. Point attributes are sampled in approximately regular net, excluding industrial and urbanized areas.

Soil nitrogen content (Kjeldahl content N_t (%)) was analyzed and categorized according Bielek (1998) in relation to the carbonate content (Fiala, K., 2002). Four category of soil nitrogen content (very low, low, middle and high) are relevant and statistically evaluated in the process of classification (Tab. 1) in investigated area.

Table 1 Evaluation of soil nitrogen reserve in carbonate and noncarbonate soil data file (Fiala, K., 2002)

Evaluation of soil nitrogen reserve (N_t) in carbonate soil data file
(n = 165)

Soil nitrogen (%) content category	**n**	**range**	**average**	**median**	**percentage (%)**
very low (≤ 0.120)	10	0.066 – 0.118	0.101	0.108	6.06
low (0.121 – 0.158)	45	0.120 – 0.158	0.142	0.142	27.27
middle (0.161 – 0.240)	98	0.161 – 0.232	0.187	0.185	59.39
high (0.241 – 0.340)	12	0.242 – 0.329	0.273	0.263	7.27
very high (> 0.340)	0	—	—	—	0.00

Evaluation of soil nitrogen reserve (N_t) in non carbonate soil data file
(n = 85)

Soil nitrogen (%) content category	**n**	**range**	**average**	**median**	**percentage (%)**
very low (≤ 0.120)	7	0,0958 – 0.1110	0.111	0.112	8.23
low (0.121 – 0.160)	34	0.1226 – 0.1601	0.143	0.143	40.00
middle (0.161 – 0.240)	39	0.1629 – 0.2382	0.190	0.180	45.88
high (0.241 – 0.340)	5	0.2427 – 0.3003	0.259	0.251	5.88
very high (> 0.340)	0	—	—	—	0.00

Geostatistical concept assumes ergodic and stationary processes in regionalized variable. In this first step, the expectation over all possible realizations is equal to the average over a single unbounded realization. In second step, the hypothesis of stationarity is related to various degrees of the spatial homogeneity of the fenomenon under study. To assure these two processes, Gaussian random function (normal distribution) is used to infer the probability distribution of a random variable from the histogram of data values (Fig. 2).

Figure 2 Histogram of soil nitrogen content

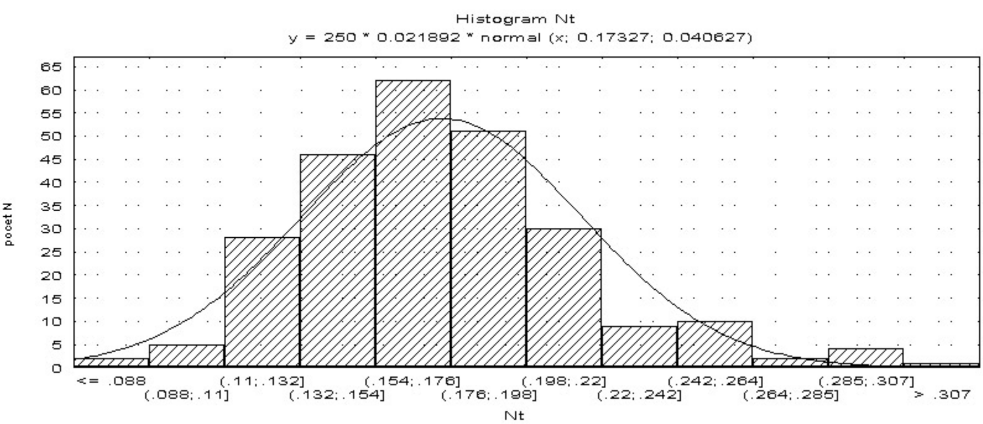


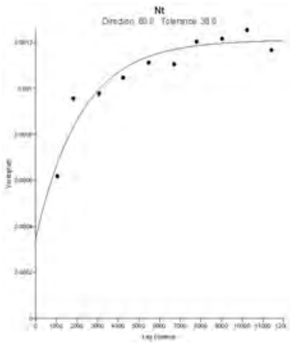
Table 2 Basic statistics of nitrogen soil content

Valid n	Mean	Conf. -95%	Conf. 95%	Sum	Min.	Max.	Range	Var.	Std. Dev.	Standard Error	Skew.	Std. Err. Skew.	Kurt.	Std. Err. Kurt.
250	0.17	0.17	0.18	43.32	0.07	0.33	0.26	0.002	0.04	0.0025	0.72	0.15	1.40	0.31

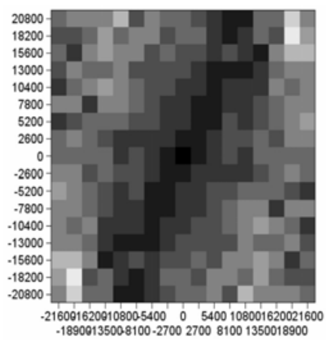
Histogram of soil nitrogen content accounts distribution close to normal (Gaussian) distribution with little left skewness and low kurtosis (Tab. 2).

To calculate combination of spatial variability, a pair comparison file with 31 125 numbers of pairs was created in VarioWin software. Anisotropy variation, calculated by direct variogram surface analyzing, signalizes different variation (Fig. 2) in different directions. Directional variogram in direction 150° attains different basic semivariogram components (nugget, sill, range) contrary to that in direction 60°. Spatial variation in directional variogram 150° rises slowly until sill is reached at length 5 000 m (major range) whereas spatial variation in directional variogram 60° reaches sill much more quickly at length 2 200 m (minor range).

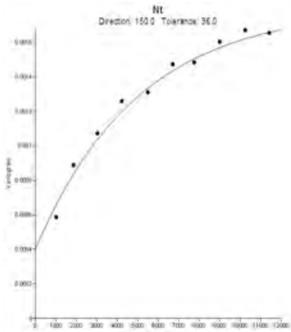
Figure 2 Anisotropy evaluation and semivariogram modelling for kriging interpolation



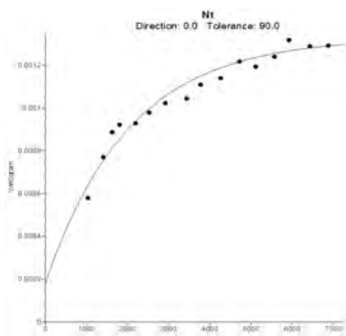
directional variogram, direction 60°



anisotropic variation



directional variogram, direction 150°



directional variogram, anisotropy 1.6

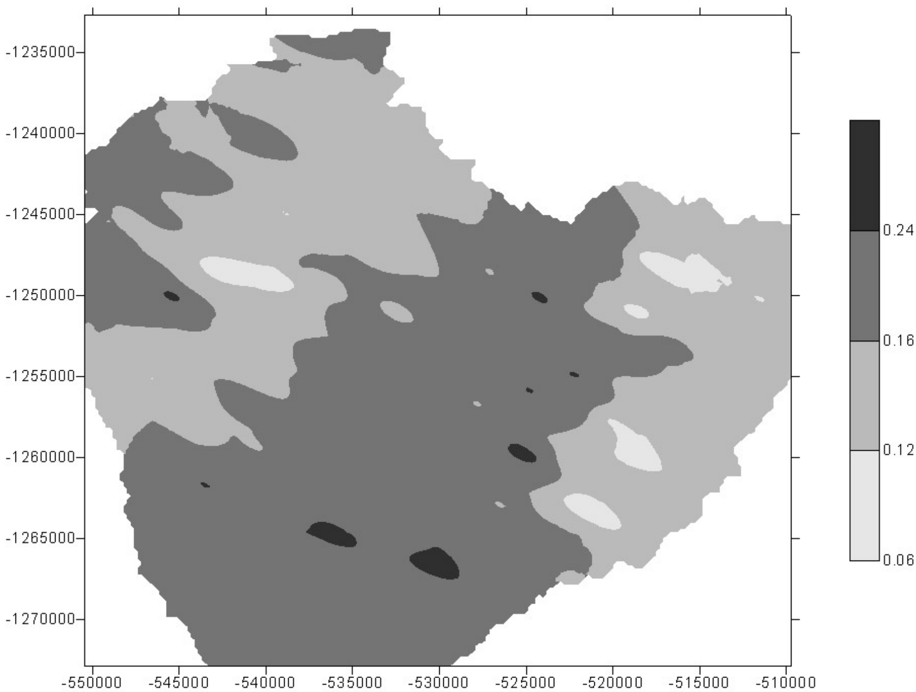
As the spatial variation may be elucidated using only one semivariogram model, anisotropy characteristics (direction, ratio of major/minor range) are therefore included in one result model by kriging interpolation (Tab. 3).

Table 3 Semivariogram model parameters

	Model	Nugget	Sill	Range	Lag direction	Anisotropy Angle	Anisotropy Ratio
N	Exponential	0.00035	0.00086	2 200	60	—	—
N	Exponential	0.0004	0.0014	5 000	150	—	—
N	Exponential	0.00018	0.00115	2 900	—	150	2.27

Contour map (Fig. 3), created by interpolation method – kriging in Surfer software uses all parameters defined with semivariogram. Estimated value at known (unsampled) position is determined by neighbour weighted points, were the weights and range to neighbour points are denoted by variogram. The estimated value in this form is unbiased and the estimation variance is less than for any other linear combination of the observed values.

Figure 3 Contour map of soil nitrogen content N_t (%)



CONCLUSIONS

Geostatistical methods are very useful in many ways, such as optimizing sample network, multivariate geostatistical methods, merging classification with geostatistic and other. In this case study, anisotropy variation was investigated and applied within interpolation framework. Spatial variation in two different directions is very significant feature, which corresponds with geographical theory of foothill soil zonality. Occurrence of basic nutrient macroelement (nitrogen) is bounded to presence of soil carbon content. Presence and content of both elements correspond with main soil units, regionalized with mentioned foothill soil zonality. This theory assumes growth of humid climate towards mountain, which is conditioned by climate influence of mountain zone (barrier). Direction of Malé Karpaty Mountains and soil zone series correspond very closely to direction of soil nitrogen anisotropy variability.

Representative catena, characteristic for middle Europe is assessed with following soil series: Haplic Chernozems, Luvi-Haplic Chernozens, Luvisols, Planosols and Gleysols (Mičian, 1977). High and middle soil nitrogen content is bounded to presence of Chernozems, situated on Trnava Hilly Land and Mollic Fluvisols, situated on right side lowland from river Váh. Occurrence of low and very low soil nitrogen content is bounded on presence of Haplic and Albic Luvisols, situated on Trnava Hilly Land close to Male Karpaty Mountain. Presence of planosols and gleysols is characterized in low depressions, regionalized at the foot of the mountain with middle and partly high soil nitrogen content.

REFERENCIES

Bielek, P., 1998: Dusík v poľnohospodárskych pôdach Slovenska. Bratislava: VÚPOP, 1998. 256 s.

Borůvka, L., 2000: Aplikace geostatistiky v pedologii. In Zb. Konf., Pedologické dny 2000, VUMOP, Praha, p. 19 – 32.

Burrough P.A., McDonnell R.A., 1998: Principles of Georgaphical Information Systems. Oxford University Press, New York.

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

Fiala, K., 1997: Záväzné metódy rozborov pôd. Bratislava: VÚPOP Bratislva, 1999. 142 s.

Fiala, K., 2002: Základné chemické parametre na posúdenie kvality pôd v regióne. Záverečná správa za VE 02. VÚPOP Bratislava, október 2002, 11s. (príloha 13 s.)

Mičian, Ľ., 1977: Všeobecná pedogeografia. Vysokoškolské skriptá. Príf. UK Bratislava.

Pannatier, Y., 1996 Variowin: Software for Spatial Data Analysis in 2D. Springer-Verlag, New York, NY, 1996.

Sobocká, J., Šurina, B., Hutár V., 2000: Typologické členenie pôd regiónu Trnava-Hlohovec a ich základná charakteristika. Záverečná správa za etapu 01. VÚPOP Bratislava, november 2000, 17 s.

COMPARISON OF EROSION DISTRIBUTION MODELLING CALCULATING BY USLE EQUATION AND BONITY PEDO-ECOLOGICAL UNITS

Porovnanie eróznej ohrozenosti modelového územia vypočítanej podľa rovnice USLE a podľa BPEJ

Blanka ILAVSKÁ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

In Slovakian conditions water erosion belongs to most frequent soil degradation processes. Erosion is relevant practically in two thirds of Slovakian territory - typical with undulated relief. They are particularly hilly lands, basins, mountainous and sub mountainous areas. Erosions processes do not cause just only soil productivity reduction, but besides economical loss it is direct reason of water husbandry, energetic and ecological damage. An intensity of water erosion may be calculated by various methods. Spatial analysis of erosion is a time-consuming process. In practice, the best results are achieved by using the Wischmeier-Smith´s equation and by the system of the Bonited Pedo-Ecological Units (BPEU). The comparison result is a finding, by the code use of sloping of the BPEU-system, for erosion risk determination are differences in all the categories. Reduced was the percentile of 2nd category – soils with medium erosion risk, and increased was 1st category % (no erosion risk), and 3rd category – strong erosion risk. From this is resulting interpretation of sloping code in the system of BPEU with aspect on erosion intensity can be considered only for orientational purposes. The work describes the procedures the calculating and assessment of erosion in the territory of agricultural farm PVOD Kočín.

Keywords: water erosion, soil, information system of soil quality, bonited pedo-ecological unit, BPEU, universal soil loss equation USLE

ABSTRAKT

V Slovenskej republike je eróziou postihnutá viac ako polovica výmery poľnohospodárskych pôd. Erózia nespôsobuje len celkové zníženie úrodnosti, ale okrem ekonomickej straty spôsobuje aj vodohospodársku, energetickú a ekologickú ujmu. Preto je určenie intenzity vodnej erózie pôdy v konkrétnom území dôležité z hľadiska posúdenia eróznej ohrozenosti pôdy pri súčasnom využívaní, ako aj pri zmene využívania alebo organizácie pôdneho fondu. Príspevok porovnáva spôsob výpočtu straty pôdy podľa rovnice USLE a podľa bonitovaných pôdno-ekologických jednotiek (BPEJ). Výsledkom porovnania je zistenie, že pri použití kódu svahovitosti z BPEJ – systému pre určenie eróznej ohrozenosti sú rozdiely vo všetkých kategóriách. Znížilo sa percentuálne zastúpenie 2. kate-

górie – pôd stredne erózne ohrozených a zvýšilo sa percentuálne zastúpenie kategórie 1. (bez erózie) a 3. kategórie – pôdy silne erózne ohrozené. Z výsledkov vyplýva, že interpretáciu kódu svahovitosti BPEJ z hľadiska intenzity erózie je možné považovať za orientačnú hodnotu.

Kľúčové slová: vodná erózia, pôda, bonitačný informačný systém, bonitovaná pôdno-ekologická jednotka, BPEJ, univerzálna rovnica straty pôdy USLE

INTRODUCTION

Water erosion negative impacts on soil, country, environment, production height and economics are well known.

In Slovakian conditions water erosion belongs to most frequent soil degradation processes. Erosion is relevant practically in two thirds of Slovakian territory – typical with undulated relief. They are particularly hilly lands, basins, mountainous and sub mountainous areas.

Erosion processes do not cause just only soil productivity reduction, but besides economical loss it is direct reason of water husbandry, energetic and ecological damage. When we want to retard processes of physical soil degradation – erosion included – inevitably we must know eroded areas spatial distribution in the country. Therefore its square extent knowledge can help at erosion control measures implementation and proper farming on soil, whereby to stop or at least to retard soil physical degradation processes. Great problems are caused by erosion, when establishing new crop, whereby by seeds are washed away of the slopes towards lower locations, or blown out of the field. Similar situation used to be at fertilization or chemization measures, this besides economical harm also causes in negligible ecological problems. However crop cover can be damaged by erosion also during vegetation period, particularly by heavy rainfalls in time of summer months. Crop covers on eroded areas have markedly lower vitality and more frequently suffer from pests and diseases that are significantly affecting these areas production. Earth washed out erosion sediments in ponds, ditches along roads, communications, and trouble population. Eroded areas and gullies in slope enable faster outlet out of country, whereby is soil impoverished in moisture. Besides these areas chemical and physical degradation erosion brings about also unpleasant ecological problems in locations, where the earth washed out is accumulated. Therefore urgent is these negative physical degradation processes to be retarded.

MATERIAL AND METHODS

Among the various soil degradation processes, soil erosion is a key policy issue for many countries. One of many definitions of soil erosion risk is following: – the agricultural area subject to water erosion, that is the area for which there is a risk of degradation by water erosion above a certain reference level (OECD, 2001).

Erosion extend is depending on the properties of soil, terrain, and climatic conditions, respectively. Another site conditions act indirectly, via plant cover, its status is linearly dependent on them. This indicator combines information on the inherent vulnerability of soil or specific area (based on physiographic and climatic properties) and information on how agricultural land is being managed.

Global most dangerous period with aspect to erosion is spring, when vegetation cover is not fully developed, and after longer dry period will come either heavier precipitation (water erosion) or high intensity wind (wind erosion). Winter is less risky period, as soil used to be frozen and heavy rainfall occurrence is less likely. However serious risks introduce situations, when thicker snow layer on frozen soil immediately melted.

For potential erosion determination, assessment and modeling various approaches are used in the world.

Risk of soil erosion according to parameters of Bonited Pedo-Ecological Units BPEU)

The concept of soil bonitation (soil quality index) is based on pedo-ecological characteristics parameters for every of the plots. They are indicated by the Bonitation Pedo-ecological Units (BPEU). The BPEUs represent relatively most homogeneous units concerning to soil and its ecological characteristics, it means they consist of the main pedo-climatic units, which are in detail sub-divided according to categorization of slopes, depth, exposition, stoniness content and size-grain distribution in topsoil.

The 7-digital code of BPEU was introduced in the bonitation system in what pedo-climatic properties were presented by this code combination.

In our recent works (1997, 1998) attention was devoted to the topics of soil potential erodibility, whereby fundamental were data derived from the code of the bonited pedo-ecological unit

- textural data
- sloping

Based on mentioned parameters classification of potential water erosion in Slovakia was elaborated and mapped.

Table 1 Categories of water erosion risk

Kat.	Slope (0)	Code of sloping	Characteristic of erosion
1.	0 – 3	0, 1	No erosion
2.	3 – 7	2, 3	Middle erosion
3.	7 – 12	4, 5	Strong erosion
4.	above 12	6, 7, 8, 9	Extreme erosion

Risk of soil erosion according to USLE

For potential erosion determination, assessment and modelling various approaches are used in the world. The most widely accepted method of estimating water induced soil erosion is the so-called Universal Soil Loss Equation (USLE), used extensively in many countries, although the USLE is usually adapted for local conditions.

$$A = R \times K \times L \times S \times C \times P$$

Remark: A – mean annual earth loss in t/ha/y, R – rain factor, K – soil factor, L – factor of slope length, S – factor of sloping, C – vegetation factor, P – erosion control measures factor

From the equation is obvious, soil erosion is phenomenon very complicated and its modeling requires considerable data collection. In professional literature we can meet various variations and modifications of the equation. The USLE equation can complicate terrain; therefore great weight is subscribed to relief effect. Because of it later the equation used to be modified by various authors, their models exacted specially selected factors (mainly S and L) they are usable (unable) in GIS via relief digital models. The farmland acreage damaged by water erosion we have started to verify first on pilot territory including three cadastres, Lančár, Kočín, Šterusy, with total area 1 281 ha of agricultural farm PVOD Kočin. The territory has been intensively farmed; typical crops are cereals, sugar beet, rape and maize. This territory is located on Trnava Hilly Lands of considerably damaged with erosion.

Erosion processes course is expresses by multiplication of two quantitative factors (R and K) and four qualitative factors (L, S, C, P) in mentioned equation by Wischmeier – Schmidt (1978).

- **Factor R** – heavy rain erosion efficacy – under this expression is understood multiplication of total rain kinetic energy and its maximum 30 – minute intensity. The value were read out of the table elaborated, based on ombrographic stations of Slovakia (Malíšek, 1992). In Slovakia are 86 relatively uniformly distributed stations. The R-factor values are in the pilot territory high. For the pilot territory we have chooses R-factor by the station Piešťany with the value 15.40.
- **Factor K** – soil affinity to erosion – was calculated directly from the BPEU to every of main soil units (3rd and 4th position in a code) were associated its numerical value. Factor K highest values are associated to Regosols and eroded Haplic Luvisols (0.72), high values (between 0.3 – 0.4) are typical for Haplic Luvisols, lower for Cambisols, and Rendzinas (at about 0.3 – 0.4). As Haplic Luvisols and Regosols are extended on relatively large areas, the land in the pilot territory has high F-factor values.

Table 2 Value of K-factor in territory of Agricultural farm Kočin

Soil-ecological unit	Soil type	Koef. K
44	Haplic Luvisols	0.51
47	Regosols/eroded Haplic Luvisols	0.72
48	Albi-Haplic Luvisols	0.60
50	Stagni-Haplic Luvisols	0.59
54	Regosols/eroded Haplic Luvisols	0.51
83	Cambisols	0.40
90	Rendzic Leptosols	0.31
97	Lhitic Leptosols	0.72

- **Factor L** – sloping length factor introduces ratio soil loss per area unit of a Whole in standard comparable area d = 22.13 m long (Elena, 1991). It factically is expressed by fall-out curve, it is a line in direction of greatest sloping of relief, and it always is vertical to the contours. As technically was not possible to read and calculate L-factor value, as a risk length we have used slope length 200 m, and L-factor values 3.006.
- **Factor S** – sloping factor is expressed by relationship-ratio of soil loss to the area unit of land, to the soil loss on standard comparative area with length L = 22.13 m

and sloping S = 9%. Factor S was determined to 5th position (sloping) in the BPEU code. S-values were read out of the table mentioned by Mališek (1992) and were divided by the BPEU methodology into five categories, and obtained values were modified by mean values calculation.

Table 3 Value of S-factor of PVOD Kočín

Sloping	S-factor	5 digits of PEU
Non-agricultural soil	0	
0 – 3°	0.31	0, 1
3 – 7°	1.13	2, 3
7 – 12°	2.93	4, 5
12 – 17°	6	6, 7

- **Factor C** – vegetation preservative affect factor expressed agro technical technologies and crop rotation effect on erosion processes initiation and course. Most of the territory is covered by arable land – 1 171 ha (more than 90%) of it. Permanent grassland (105.5 ha), vineyards (4 ha), is on small areas. Cropping structure of the fields were be added by the maps used.

Table 4 Value of C-factor – vegetation factor

Crops	Value of factor C
hope gardens	0.73
Gardens, vineyard without terracing	0.62
potato	0.60
Potato early	0.51
maize	0.58
Ensilage maize	0.49
Sugar beet	0.53
Summer cereals	0.31
Winter cereals	0.18
Gardens, vineyard terracing	0.12
forage crops	0.015
alfalfa	0.002
green grass	0.005

- **Factor P** – erosion control measures factor expresses ratio between soil loss of investigated land (plot) and soil loss on standard plot tilled along sloping curve (vertical to contours). Value of P-factor was addable according real erosion control measures for all piece of land.

Table 5 Value of P factor

Erosion control measures	**Sloping in %**			
	2 – 7	**7 – 12**	**12 – 18**	**18 – 24**
Direct rows	1.00	1.00	1.00	1.00
Contour tillage	0.60	0.70	0.90	1.00
Belt agrotechnics rotation				
– root crops and forage crops	0.30	0.35	0.40	0.45
– root crops and winter cereals	0.50	0.60	0.75	0.90
Combing	0.25	0.30	0.40	0.45
Terracing			0.50 – 0.15	0.05 – 0.20

Factor of slope length will be exaction with adequate value for every slope, based on terrain digital model. By help of satellite images is assumed identification of field crops (or only cultures) and so can be concretized factor – C value. After successful management of these tasks in the modeled area, the method of actual erosion assessment by means of the BPEU data will be applied in whole Slovak republic territory.

RESULTS AND CONCLUSIONS

Highest mean annual soil loss in tons per ha per year is on Regosols, and eroded Haplic or Albi-Haplic Luvisols, Haplic Chernozems, respectively. With extreme and strong erosion, again primarily on Regosols and eroded Haplic Luvisols, Haplic Chernozems, less on Rendzinas and Albic Luvisols. Medium erosion was observed on soils, where were primarily Albic Luvisols and Haplic Chernozems (WRB, 1994)

In the maps outputs is clearly visible that most differences are in the first and second categories, no erosion risk and middle erosion risk of soil. Relationship erodibility: sloping is linear. Soil in the area PVOD Kočín can be categorised in four categories according sloping when used materials of the Bonity Pedo-ecological Units System and in three categories according equation USLE.

Table 7 Categories of water erosion in the Cooperative Farm Kočín

Kateg.	**Characteristic of erosion**	**Erosion risk according BPEU (in %)**	**Erosion risk according BPEU in (%)**
1	No erosion risk	29	59
2	Middle erosion risk	53	19
3	Strong erosion risk	17	22
4	Extreme erosion risk	1	—

Map 1 Water erosion categories in the Cooperative Farm Kočín by the BPEU – system

In practice, the best results are achieved by using the Wischmeier-Smith´s equation and by the BPEU – system. The comparison result is a finding, by the code use of sloping of the BPEU – systems for erosion risk determination are the differences in all the categories. Reduced were the percentile of second category – soils with medium erosion risk, and increased was 1st category % (no erosion risk), and third category – strong erosion risk. From this is resulting – interpretation of sloping code in the system of the BPEU with aspect on erosion intensity can be considered only for orientation purposes.

Map 2 Water erosion categories in the Cooperative Farm Kočín by Wieschmeier-Smith´s equation USLE

REFERENCES

ALENA, F.: Protierózna ochrana na ornej pôde, Metodika, Bratislava, 1991 ISSS-ISRIC-FAO, 1994: World Reference Base for Soil Resources, Draft. Wageningen/Rome.

ILAVSKÁ, B.: Bonitation Soil Information System in the Process of Evaluation and Utilization Farming Land, Proceedings 20/I, VÚPÚ, Bratislava, 1997.

JAMBOR, P., ILAVSKÁ, B.: Metodika protieróznej ochrany, VÚPÚ, Bratislava, 1996.

JAMBOR, P., ILAVSKÁ, B.: Effective Erosion Control via Agro technical Measures 4. Expertentagung Der Arbeitsgruppe Bodenschutz, Osijek, 1997, 6 s.

JAMBOR, P., SOBOCKÁ, J.: Calcic Chernozems and Haplic Luvisol Degradation Caused by Water Erosion in Slovakia, In: Soil Dynamics. Tiberias, Technicin Haifa, 1997.

LINKEŠ,V. a kol.: Informačný systém o pôde, VÚPÚ, Bratislava, 1993.

Linkeš, V. a kol.: Soil Monitoring of Slovak Republic, Present State of Monitored Soil Properties, Bratislava, 1997.

Malíšek, A.: Optimálna dĺžka svahu v závislosti na vodnej erózii, Vedecké práce VÚPÚ, Bratislava, 1992.

Morgan, R.P.C.: Soil Erosion and Conservation, 2th ed., Longman, London, 1996.

Šimonides, I., Kalúz, K., 2001: Vyhodnotenie eróznej ohrozenosti pôdy územia Dolná Malanta, Acta horticulturae et regiotecturae 1/2001.

WATER AND WIND EROSION UPON SLOVAKIAN SOILS

Vodná a veterná erózia na pôdach Slovenska

Pavel JAMBOR
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Water and wind erosion are today serious ecological and agricultural problem wherever, where are larger, consistent land blocks agriculturally used. In Slovakia highest erodibility rate is visible on large consistent land blocks of arable land, which in undulated terrain for long centuries, particularly in recent decades undergo degradation processes of water erosion.

On the other hand serious problem introduces also wind erosion that practically in the same rate jeopardizes soils in lowlands and in sloping terrain. However this risk lasts only for small part of the year. This is a period before/at vegetation period start, when ploughed land is still without vegetation cover. Soil in dry conditions after winter transition is easily detachable and at strong, gusty wind large quantities of most fertile surface layer form dark clouds, from them is soil sedimented in lee.

Most reliable conservation is plant cover – canopy protecting soil cover. Besides are here progressive technologies of conservation tillage system.

The paper is presenting global data within Slovak Republic with aspect to actual need of effective erosion control, particularly in the case of arable land.

Keywords: water erosion, wind erosion, soil, conservation

ABSTRAKT

Vodná a veterná erózia sú v súčasnosti vážnym ekologickým i poľnohospodárskym problémom všade, kde sa poľnohospodársky využívajú väčšie súvislé plochy pôdy. Na Slovensku najvyššiu mieru erodibility predstavujú väčšie súvislé plochy ornej pôdy, ktoré vo zvlnenom teréne už dlhé staročia, ale najmä posledné desaťročia podliehajú degradačným procesom vodnej erózie.

Na druhej strane vážnym problémom je aj veterná erózia, ktorá prakticky rovnakou mierou ohrozuje rovinné i svahové polohy, ale prakticky iba malú časť roka. Je to obdobie pred a na začiatku vegetácie, keď orná pôda je ešte bez vegetačného krytu. Pôda v suchom stave je po prechode zimy ľahko rozpojiteľná, a pri silnom nárazovom vetre veľké množstvá najúrodnejšej povrchovej vrstvy vytvárajú mraky, ktoré sa ukladajú v závetrí.

Príspevok uvádza globálne údaje v rámci Slovenska vzhľadom na aktuálnu potrebu protieróznej ochrany najmä v prípade ornej pôdy.

Kľúčové slová: vodná erózia, veterná erózia, pôda, ochrana

INTRODUCTION

Annual soil loss due to erosion in national scale is enormously high. It is presumposed, water erosion in national extent on average causes total earth runoff 2.8 – 3.2 mil. t out of the territory of Slovakia. In sloping terrain, e.g. is annually washed out up to 60 t earth from area 1 ha. In averaged conditions of medium erosion is earth wash out equal mean yield of winter wheat – 6 $t.ha^{-1}$.

Erosion control measures of agro-technical character do not stop all the erosion. However erosion extent is substantially reduced. Objective is to reduce annual runoff in such rate, so that it equals natural soil surface increase due to dust (sedimentation) and other particles fall out of atmosphere. In our conditions on average tolerable erosion runoff ranges 7.5 – 15 t $earth.ha^{-1}.year^{-1}$ = generally tolerable erosion.

Relatively catastrophic wind erosion occurs in our country mainly on light sandy soils in the regions Záhorie, Hurbanovo (south of western Slovakia) and in southern part of Eastslovakian Lowland, however conservation ecologization measures made mainly within establishment of permanent green belts (wind shelters, wind-breakers) have their great competent grounds whereever upon farmland, where erodible soil urgently needs water and wind erosion control.

MATERIALS AND METHODS

The submitted paper is based on several materials related to the problems of erosion in Slovakia. Primarily they are soil research results – their part related to soil erosion and erosion control.

Further they are publication of experts of the Soil Science and Conservation Research Institute, focused to this problem sphere as well as statistical data. Very important information source was also the standard – STN 75-4500. In our work we also were inspired by several very important sources of world literature.

RESULTS AND DISCUSSION

Within farmland most erodible is ploughed land. In Tab. 4 is presented soil vulnerability to water erosion by the regions of Slovakia. Farmland erodibility categories are presented in Tab. 1 with aspect to the genetic soil types.

At concrete erosion control measures the highest weight of conservation measures should be focused to the erodible soils with highest productivity potential – Haplic Chernozems, Haplic Luvisols and Albic Luvisols.

Table 1 Farmland water erosion risk by main soil units and mean annual runoff (t $earth.ha^{-1}.year^{-1}$)

Soil	medium erosion runoff 4 – 10		severe erosion runoff 10 – 30		extreme erosion runoff 30 – 40	
	ha	%	ha	%	ha	%
Haplic Chernozem	35 594	7.0	7 870	1.8	—	—
Haplic Luvisol	108 762	23.0	45 868	11.0	16 633	4.0
Albic Luvisol	80 395	17.0	28 013	6.6	6 483	2.0
Eutric Regosol	17 046	3.6	9 948	2.0	9 688	2.4

Table 2 Arable land vulnerable by water erosion (Juráň, 1991)

Region	Medium erodible		Strong erodible		Severely erodible		Total	
	ha	%	ha	%	ha	%	ha	%
Eastern Slovakia	108 260	26.8	81 430	20.2	24 710	6.1	214 400	53.1
Central Slovakia	95 660	33.4	58 360	20.4	35 880	12.5	189 900	66.3
Western Slovakia	85 480	10.3	64 170	7.8	22 150	2.7	171 800	20.8
Slovakia	289 400	20.0	203 960	14.1	82 740	5.8	576 100	39.9

In conditions of American NW on arable land Michalson et al. (1999) solved erosion control in complex manner. In current practice we can meet with following measures belonging into a circle of erosion control measures (Uri et al., 1985):

- Contour tillage – usually associated with conventional tillage. However it includes all the current agro-technical measures within the cropping systems. They are made along contours. At ploughing besides contour direction is also required turning the earth in direction against the slope. The measure helps to reduce extent of erosion runoff approximately 50 %. It is suitable for the sloping 3 – 9 degrees. Beneficial effect lasting – depending on texture 1 – 5 months in the order: sandy – loamy – clayey soils.
- Rational crop rotation based on following crop distribution:
  - Perennial fodder crops and grasses with very good conservation effect since consistent canopy formation till its liquidation 1 – 3 years later
  - winter crops with conservation effect duration since autumn end till next year August 10 months
  - springs crops with conservation effect lasting most 5 months
  - row crops with least (lowest) conservation effect duration – not more than 4 months
- **Subsoiling** and **deep tillage** (45 cm) made along contours are one of most effective erosion control measures and prevention of unlimited erosion runoff. Excluded are stony soils
- **Zero – tillage** (no-till) technologies seem to be most progressive erosion (water and wind erosion) control measures, not accepted till now in our country. They are desirable mainly in warmer (semiarid) conditions. Their efficacy however is limited with several factors:
  - **Soil factor** (Suškevič, 1991) – suitable are loamy to sandy soils, deep, with good, stable structure, with neutral, alkaline to weak acid soil reaction. Particularly suitable are warm, permeable, non-compacted soils in regions of more arid character. Mean annual temperature above 9 °C, in vegetation period above 15 – 17 °C. In the conditions of Slovakia these conditions are identical with soil types Haplic Chernozems, Haplic Luvisols.
  - **Weed factor** – at no-till technologies weeds a greatest factor first 4 – 5 years. Their attacks are later reduced.
  - **Factor of moisture** and temperature regimes is particularly great obstacle on acid soils and in case of non stable compact soil structure.

- **Minimum agro-technics** with disking to 7 cm depth seems to be best solution among. All soil conservation technologies in our conditions and could fully compensate convention tillage.
- **Mulching** – in conditions of normal (without extremes) arable land, after small grain cereal is seeded catch crop (e. g. mustard). It after first frosts will form consistent mulch on soil surface. This is practically 100 % erosion control. In spring main crop is directly seeded into the mulch.

• From organizational measures besides rational crop rotation should be mentioned.

• Shape and size of fields:
  - field orientation along contours
  - optimum field length – 400 – 1000 m
  - optimum field width – 200 – 300 m
  - optimum size 10 – 30 ha.

Table 3 The areas of erodible soils by their vulnerability to water erosion (ha)

Soil type	**II. category**	**III. category**	**IV. category**	**Total**
Haplic Chernozem	32 594	7 870	—	40 464
Haplic Luvisol	108 762	45 868	16 633	171 270
Albic Luvisol	80 395	28 013	6 483	114 891
Eutric Regosol	17 046	9 448	9 688	36 182
Total	238 797	91 199	32 804	362 800

Table 4 The area of row crops on erodible soil (ha – mean 1996 – 2000)

Crop	**Ha**
Maize	112 736
Potatoes	31 407
Sugar beet	33 004
Sunflower	54 872
Row crops	232 019

Financial costs invested into erosion control measures are cycled most rapidly on soils with highest productivity potential, i.e. Haplic Chernozems and Haplic Luvisols (Tab. 1). However these soils often are in the complex with mentioned Eutric Regosols. Also Regosol can be successfully treated with the conservation tillage of permanent (annually repeated) measures. It brings substantial improvement.

Table 2 is presenting the review by erosion vulnerability of arable land categories. Problems could be mixed fields with occurrence of several vulnerability categories. This requires field size and shape optimization with aspect to erosion vulnerability classes. Optimum is a field only with one vulnerability class.

Wind erosion (by Streďanský et al., 2003) in Slovak Republic is particularly actual in time of long-term (several weeks) periods of drought at the vegetation period start in cases of strong gusty wind on ploughed land without vegetation cover. Wind erosion initiation was registered at wind velocity 4 – 6 $m.sec^{-1}$.

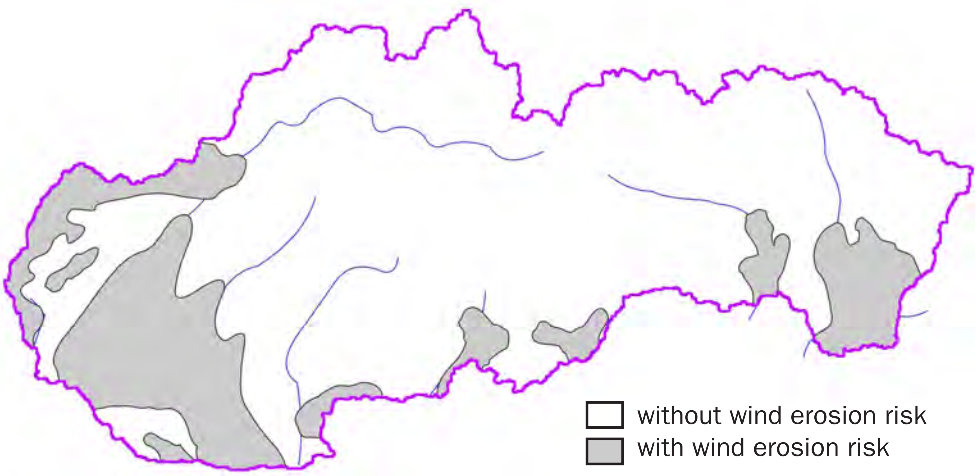
Particularly vulnerable are larger areals (above 10 ha) with texturally lighter ploughed soils without vegetation cover and protection of stable vegetation (windbreakers) or dispersed stable vegetation (trees, bushes).

For extremely jeopardized area considered locations of sandy soils (Záhorie) in total area 39 000 ha. Severe wind erosion risk was observed 210 000 of light soil in South East, South and South West Slovakia (Fig. 1). Here however are included to wind erosion vulnerable soils also immense areas of loamy soils, particularly in dry periods at the end of March and in April until vegetation forms canopy. By runoff is wind erosion categorized into 5 categories (weak – medium – strong – very strong – catastrophic) with runoff 0 - > 280 $t.ha^{-1}.year^{-1}$).

Table 5 Soil vulnerability in Slovakia to wind erosion by textural composition (Streďanský et al., 2003)

Texture	**Farmland ha**	**%**
Light soils	210 000	8.6
Medium heavy soils	1 719 000	53.1

Figure 1 Areals of Slovakia regularly jeopardized by wind erosion



CONCLUSIONS

The principles of effective soil conservation are today focused on:

1. soil conservation against its decreases and use for non agricultural use
2. conservation and sustainability of physical, chemical and biological soil properties and functions
3. conservation against degradation processes (erosion, compactness, etc.).

Generally soil conservation is focused to the sustainability of its capability to produce biomass. However soil protection should fully secure besides biomass production all the five basis soil functions conservation:

– filtration and buffering soil function
– function of biological habitus and gene reserve

- function of the space for man activities
- soil function as a source of geogene energy and raw materials
- soil function as a bearer of cultural hereditary.

Every of the functions requires diametrally diverse approach and substantially differs from soil function as a fruit of man activities.

REFERENCES

BIELEK, P. (1999): Soils and Soil Degradation in the Slovak Republic. ESSC Newsletter, n. 3+4, pp. 3 – 31.

JAMBOR, P., ILAVSKÁ, B. (1998): Metodika protierózneho obrábania pôdy. VÚPOP Bratislava, 70 p.

JURÁŇ, C. (1990): Erózne procesy na území Slovenska a perspektíva protieróznej ochrany pôdy. In: Pôda najcennejší zdroj. VÚPOP Bratislava, pp 61 – 74.

MICHALSON, E.L. et al. (1999): Conservation Farming in the United States. CRC Press, 235 p.

STREĎANSKÝ, J., PARILÁKOVÁ, K. (2003): Miera veternej erózie na Slovensku. Strojopis, 3 s.

SUŠKEVIČ, M. (1991): Vliv intensity zpracovaní půdy na plodiny a půdní urodnost. OZA Hrušovany u Brna, 95 p.

Štatistická ročenka o pôdnom fonde v SR podľa údajov katastra nehnuteľností k 1.1.2001 ÚGKK SR, 155 s.

Štatistická ročenka SR 2001. Štatistický úrad SR, 685 s.

SOIL CONTAMINATION IN MOUNTAINOUS REGIONS OF SLOVAKIA

Kontaminácia pôd v horských oblastiach Slovenska

Jozef KOBZA
Soil Science and Conservation Research Institute, Bratislava, Research working-place Banska Bystrica

ABSTRACT

In the paper is some space focused to the soils that rather are at the margin of interest, particularly with aspect to agriculture and forestry, however with the aspect to environment these soils play important role. Purposefully were selected soils with high altitude (above 900 m a.s.l.) that were included into soil monitoring net of Slovakia, they are more marked influenced by climatic factor (higher annual precipitation sum, wind velocity and frequency), by possible distant pollution transfer, as well as by ground rocks heterogeneity with mottle mosaiclike composition (possibility of geogene influence on soil contamination). Furthermore they are the soils under permanent grass cover, where in the case of anthropogenous contamination risk elements contamination rather takes place (organic matter cummulation in uppermost soil horizon and high soil organic mass level - 15 – 25 %) contrary to ploughed soils, where by regular tillage mineralisation and dilution processes take place in topsoil, i.e. mountainous soils are better indicator of soil contamination in natural environment.

In the paper are used basic methodological principles of soil monitoring in the Slovak Republic. Monitored were following risk elements Cd, Pb, Zn, Cu, Cr and Ni (in leachate 2M HNO_3) in soil profile of main slovakian mountains (High Tatras, Low Tatras, Štiavnické Mountains, Spišská Magura, Slovenské Rudohorie – Volovské Vrchy).

Based on the results was ascertained, practically on all the locations monitored in various mountains were often identified above limit values of Cd, partially Pb and less Zn. Marked above limit values were found in surfacial part of soil profile and showed descending tendency with depth – this is indicating rather anthropogenous effect (obvious distant pollution transfer). At other risk elements (Cu, Cr, Ni) was their concentration markedly under hygienic limit. Temporal shift of risk elements concentrations is more or less variable, this is indicating – non benefitial soil hygienical status in higher positions still is being permanent.

Keywords: soil contamination, soil monitoring, mountainous regions

ABSTRAKT

V príspevku venujem určitý priestor pôdam, ktoré sú skôr na okraji záujmu, najmä čo do poľnohospodárskeho, ale aj lesného využívania, avšak z hľadiska životného prostredia zohrávajú významnú úlohu. Zámerne boli vybrané vysoké polohy (nad 900 m n.m.), ktoré sú zahrnuté v monitorovacej sieti pôd Slovenska a ktoré sú výraznejšie

ovplyvňované klimatickými činiteľmi (vyšší ročný úhrn zrážok, rýchlosť a frekvencia vetra) možným diaľkovým prenosom emisií, ale aj rôznorodosťou podložných hornín s pestrým mineralogickým zložením (možnosť geogénneho ovplyvnenia kontaminácie pôd). Navyše sa jedná o pôdy pod trvalým trávnym porastom, kde v prípade antropogénnej kontaminácie dochádza skôr ku kumulácii rizikových prvkov (kumulácia organickej hmoty v povrchovej vrstve pôd a vysoký obsah pôdnej organickej hmoty 15 – 25 %) na rozdiel od orných pôd, kde pravidelnou kultiváciou dochádza k zrieďovaniu koncentrácie rizikových prvkov v orničnom horizonte, to znamená, že horské pôdy sú aj lepším indikátorom kontaminácie pôd v prírodnom prostredí.

V príspevku sú použité základné metodické princípy monitoringu pôd SR. Sledované boli rizikové prvky Cd, Pb, Zn, Cu, Cr a Ni (vo výluhu 2M HNO_3) v profile pôd v hlavných pohoriach Slovenska (Vysoké a Nízke Tatry, Štiavnické vrchy, Spišská Magura, Slovenské rudohorie – Volovské vrchy).

Na základe dosiahnutých výsledkov bolo zistené, že prakticky na všetkých sledovaných lokalitách v rôznych pohoriach sa nachádzajú často výrazné nadlimitné hodnoty kadmia, čiastočne i olova, menej zinku. Výrazné nadlimitné hodnoty boli zistené v povrchovej časti pôdneho profilu a s hĺbkou mali tieto hodnoty klesajúcu tendenciu, čo indikuje skôr antropogénny vplyv (zrejme diaľkový prenos emisií). Pri ostatných rizikových prvkoch (Cu, Cr, Ni) bola ich koncentrácia výrazne pod hygienickým limitom. Časový posun koncentrácií rizikových prvkov je viac-menej variabilný, čo indikuje, že nepriaznivý hygienický stav pôd vysokých polôh stále pretrváva.

Kľúčové slová: kontaminácia pôd, monitoring pôd, horské oblasti

INTRODUCTION

Soil contamination in mountainous regions (especially in highland) is not often the object of research because transport of heavy metals into the food chain is limited here (no agricultural crops, particularly extensive not utilised pastures, etc.). In addition, hygienic quality of highland including soils is very important from environment conservation point of view.

In this contribution the heavy metal concentrations in sites of various mountainous regions (mostly highland with altitudes more than 900 m above sea level) as well as their soil profile distribution is described. Finally, time development of heavy metal concentrations in soils is also given in this contribution.

MATERIAL AND METHODS

Soil contamination is described in 10 selected monitored sites in some main mountains of Slovakia (High and Low Tatras, Štiavnické vrchy and Volovské vrchy mountains, Spišská Magura Mountain) with altitudes between 940 – 2 024 m. above sea level.

In this contribution the main heavy metals (Cd, Pb, Zn, Cu, Cr, Ni) are evaluated in monitored depth: 0 – 10, 20 – 30 and 35 – 45 cm. Heavy metal concentrations were extracted with 2M HNO_3 and compared with valid hygienic limits (MP SR, 1994). Also the additional analysis (pH/KCl, soil organic carbon according to Tjurin by Nikitin modification, 1972) and calculated on content of humus have been used, too.

Figure 1 Monitoring site under Kriváň (High Tatras) – altitude 1 830 m a.s.l.

All methods are described in more details in the work written by Fiala et al. (1999). Obtained results of heavy metal concentrations are evaluated in space (various sites and mountains), in soil profile (profile distribution) and also with regard to their time development (comparison between 1993 and 1997 years).

RESULTS AND DISCUSSION

Obtained results concerning the heavy metal concentrations in selected soil profiles of some mountainous sites are given in the following Table 1.

Table 1 Concentration of heavy metals in some mountainous sites in Slovakia

N	Site (altitude in m a.s.)	Soil	Depth in cm	pH/KCl	Heavy metals (2M HNO_3) in $mg.kg^{-1}$					
					Cd	Pb	Zn	Cu	Cr	Ni
1	Belianske Tatry pod Hlúpym vrchom (1 850)	KM_m^a	0 – 10 20 – 30 35 – 45	3.55 3.79 3.78	0.35 0.14 0.13	25.30 8.10 6.70	14.43 7.27 8.44	6.47 5.68 4.37	2.70 3.00 3.10	0.60 0.25 0.20
2	V. Tatry – Rovien-ková dol (1 750)	PZ_m	0 – 10 20 – 30 35 – 45	3.28 3.86 4.14	0.44 0.10 0.15	65.50 8.75 13.55	20.80 3.63 9.05	3.59 0.33 0.86	0.20 0.15 1.80	0.20 0.10 0.10
3	V. Tatry – pod Kri-váňom (1 830)	PZ_m	0 – 10 20 – 30 35 – 45	2.85 4.02 4.28	0.49 0.05 0.12	3.96 4.65 6.85	17.51 1.67 4.97	1.00 0.30 0.67	0.45 0.30 3.15	2.78 0.30 0.10
4	Západné Tatry Roháčske plesá (1670)	PZ_m	0 – 10 20 – 30 35 – 45	3.30 3.82 4.26	2.87 0.39 0.25	149.00 19.25 15.55	52.00 6.58 6.06	5.40 0.58 1.07	0.70 0.10 1.55	1.70 0.15 0.15
5	Kráľova hoľa (1948)	PZ_k	0 – 10 20 – 30 35 – 45	3.65 3.54 3.74	0.95 0.17 0.01	88.00 9.50 3.20	24.35 8.25 3.20	5.25 3.25 2.40	1.47 3.14 1.87	2.75 0.85 0.05

Table 1 continues

N	Site (altitude in m a.s.)	Soil	Depth in cm	pH/KCl	Heavy metals (2M HNO_3) in $mg.kg^{-1}$					
					Cd	Pb	Zn	Cu	Cr	Ni
6	Chopok (2 024)	PZ_P	0 – 10 20 – 30 35 – 45	3.33 3.89 4.22	0.43 0.13 0.15	86.50 13.80 16.80	10.30 8.20 8.05	3.40 1.80 1.20	4.00 3.80 3.15	0.90 0.80 0.90
8	Sitno (1 009)	AM_m	0 – 10 20 – 30 35 – 45	4.42 4.22 4.25	0.68 0.32 0.12	100.00 71.00 26.40	32.50 12.10 5.05	6.60 3.90 2.45	1.03 0.98 0.97	0.60 0.30 0.20
9	Spišská Magura pod Pálenicou (1 830)	KM_m^a	0 – 10 20 – 30 35 – 45	3.56 3.96 3.72	0.37 0.12 0.10	17.20 8.00 6.90	10.55 3.70 3.30	3.85 2.20 2.15	1.80 1.40 1.35	2.95 1.85 1.50
10	Kojšovská hoľa (1 246)	LI_m^q	0 – 10 20 – 30 35 – 45	3.40 — —	0.90 — —	67.00 — —	21.35 — —	11.20 — —	1.40 — —	0.60 — —

Values over the valid hygienic limit are given in the bold type (Tab. 1). In the following part the heavy metal concentrations in mountainous soils are evaluated separately.

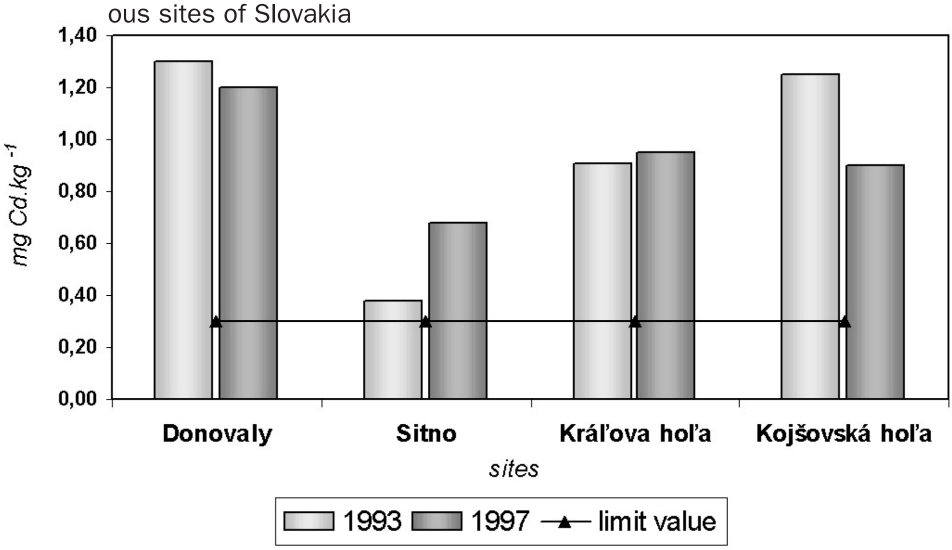
Cadmium

The main sources of cadmium in soil can be occurred in sulphides (sphalerite, wurtzite) where the first one is very numerous mineral in Slovakia. The other source of cadmium in soil is often combined with P-fertilisers (superphosphates) – Zaujec (1999) and finally, the influence of emissions.

Cd-values over hygienic limit occur in all evaluated soils. Concerning Cd-values profile distribution the absolutely highest values were determined in the surface horizon. Consequently, it may be said that the contamination of compared sites has been caused by atmospheric deposition.

Time development of Cd-concentration in some selected sites shows the following Figure 2.

Figure 2 Development of Cd concentration (2M HNO_3) in A-horizon in some mountainous sites of Slovakia



The change of cadmium concentration is more or less significant (large spatial heterogeneity in mountainous soils). It means that unfavourable hygienic state of mountainous soils with Cd lasts also at present. It is very important result.

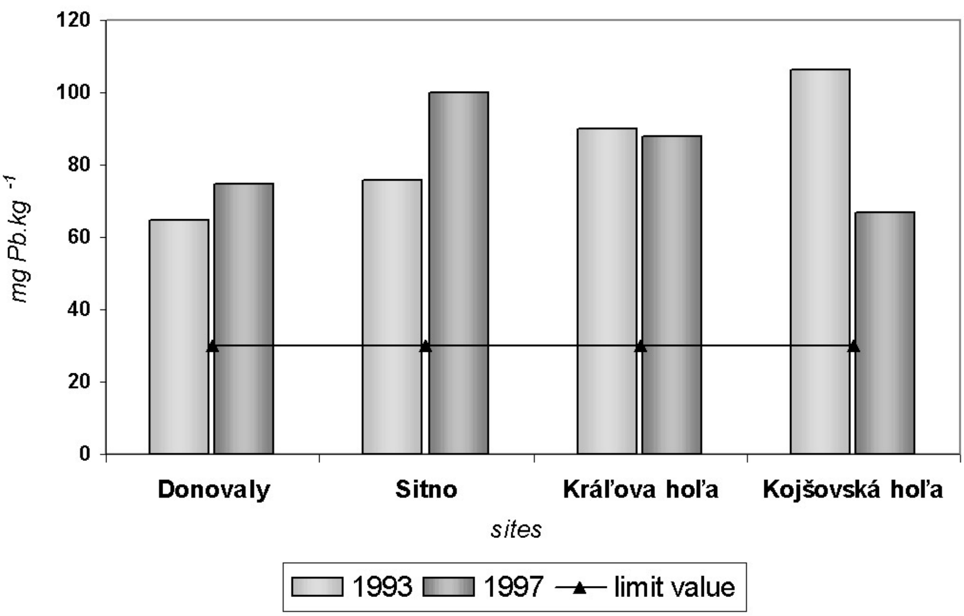
Lead

Natural occurrence of lead is mostly in sulphides (galenite), phosphates (pyromorphite), arsenides (mimetezite) and in some other minerals (Zaujec, 1999). Anthropogenic influence is more important on distribution of lead in soil (e.g. Pb-emissions).

On the basis of obtain results (Tab. 1) it may be said that Pb-distribution in soil profile is similar in comparison with cadmium. The highest concentration is in the surface layer of soil profile. Consequently, it may be said that anthropogenic influence has been indicated (as the influence of atmospheric deposition) here. Finally, it is in relation to our previous results concerning the highest values of lead just in mountainous regions (Kobza, 2003).

Also time development of lead values is more or less variable (Fig. 3) and it means that unfavourable hygienic state of mountainous soils (especially on highland) is actual also at present.

Figure 3 Development of Pb concentration (2M HNO_3) in A-horizon in some mountainous sites of Slovakia



Zinc

The natural Zn concentration of soil may be considered as background Zn concentration and is depending on parent rocks. The Zn is strongly chalcophile, and occurs chiefly as sulphides (ZnS, PbZnS), but also know to substitute for Mg^{2+}, Fe^{2+} in silicates (Polanski, Smulikowski, 1978). Also very significant are the anthropogenic sources. The major anthropogenic sources (atmospheric deposition) have been estimated to 44 % (Alloway, 1990; Beneš, 1994; Wilcke, Dohler, 1995).

On the basis of obtained results (Tab. 1) the most part of compared sites includes the Zn values lower than hygienic limit (MP SR, 1994) except Western Tatras and Donovaly sites. The highest Zn-values have been measured in surface layer of soil profile (atmospheric deposition).

Copper

The regularity in large-scale Cu occurrence in soils indicates that two main factors, parent material ($CuFeS_2$, Cu_2S) and soil formation processes, govern the initial Cu-status in soils (Kabata – Pendias, 1992). The most important statement of Cu contamination of soils is the great affinity to humous soil surface to accumulate this metal.

According to obtain results (Tab. 1), the highest values of Cu are in surface layer, but all values are lower than hygienic limit (MP SR, 1994). In general, it may be said that mountainous soils (highland) are not contaminated with this element in Slovakia.

Chromium

Natural origin of chromium is limited. Increased values of chromium can be measured in regions with ultrabasic rocks in bauxites and in coal (Vostal et al., 1989). Anthropogenic sources of chromium include emissions, influence of metallurgical industry, etc.

According to given results (Tab. 1) Cr-values in all compared soil profiles are significantly lower than hygienic limit (MP SR, 1994). Consequently, it may be said that mountainous soils of Slovakia are not contaminated with chromium, what is in relation to our previous knowledge (Linkeš et al., 1997) referring to concentration of Cr in soils of Slovakia to be low to very low.

Nickel

From among the main sources of nickel can be included steel, galvanic and electric industry, as well. Distribution of nickel in soils has decreased tendency from ultrabasic to basic as far as to acid rocks where the Ni-values are the lowest (Zaujec, 1999).

According to obtained results Ni-values in all compared soils are low to very low. Consequently, it may be said that mountainous soils (highland) are not contaminated with Ni in Slovakia.

CONCLUSIONS

Problem of soil contamination is very important also in mountainous regions (highland, alpine regions). The main object of this contribution is concerning the highest monitoring sites in Slovakia (with altitudes more than 940 m above sea level). It is going mostly about acid to very acid soils (pH-value is often lower than 4.0) with high content of soil organic matter (15 – 25 %). Consequently, the hygienic state of soils in described regions is very important, too.

Referring to obtained results contamination of mountainous soils with cadmium and lead, particularly with zinc has been confirmed. Their highest values in surface layer of soils indicate an atmospheric deposition. Concerning time comparison it may be said that this unfavourable hygienic state of mountainous soils in Slovakia is actual also at present.

REFERENCES

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

Beneš, S.: Obsahy a bilance prvků ve sférach ŽP. MZ ČR, 1994.

Fiala, K., Kobza, J., Matúšková, L., Brečková, V., Makovníková, J., Barančíková, G., Litavec, T., Houšková, B., Chomaničová, A., Váradiová, D.: Záväzné metódy rozborov pôd. VÚPOP Bratislava, 1999, 139 s.

Kabata – Pendias, A. and Pendias, H.: Trace element in soils and plants. London, 1992.

KOBZA, J.: Heavy metal pollution in soils and plants in conditions of Slovakia. In: Innovative Soil-Plant Systems for Sustainable Agricultural Practices. OECD Publication, 75775 Paris-Cedex 16, Printed in France, 2003, 264 – 276 pp.

Linkeš, V., Kobza, J., Švec, M., Ilka, P., Pavlenda, P. et al.: Monitoring pôd SR. Súčasný stav monitorovaných vlastností pôd. VÚPÚ Bratislava, 1997, 128 s.

MP SR: Vestník MP SR, roč. XXVI, čiastka I., Rozhodnutie 3, č. 531/1991 z januára 1994.

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

Polanski, A. and Smulikowski, K.: Geochémia. SPN Bratislava, 1978 (preklad).

Vostál, J. et al.: Hnojení, kvalita produkce a životní prostředí. MZVE ČR, 1989.

Wilcke, W. and Dohler, H.: Schwermetalle in der Landwirtschaft. Arbeitspapier 217, Darmstadt, 1995.

Zaujec, A.: Cudzorodé látky a hygiena pôd. Skriptum SPU Nitra, 1999, 105 s.

Pb AND Cd BIOAVAILABILITY IN SOILS

Biopristupnosť Pb a Cd v pôdach

Marianna KUDRAVÁ, Darina RÚRIKOVÁ
Soil Science and Conservation Research Institute, Bratislava
Faculty of Natural Sciences, Comenius University, Bratislava

ABSTRACT

The measurement of the total content of trace elements provides little information about their bioavailability and potential risk since the toxicity of elements and their environmental mobility are dependent on their chemical forms. To obtain information about the bioavailable fraction of elements in soils a single step extraction procedure is usually used.

Two single extraction procedures validated by BCR (Community Bureau of Reference) are used for assessing bioavailable species in soil: extraction with 0.43 mol/l acetic acid and extraction with 0.05 mol/l EDTA (pH 7). The content of elements in the soil extracts using 0.43 mol/l acetic acid represents the ion-exchangeable forms of elements and bound to the carbonates. EDTA extracts represent the contents of elements sorbed and organically bound in soils.

Keywords: lead, cadmium, soil, bioavailability

ABSTRAKT

Meranie celkového obsahu stopových prvkov poskytuje málo informácií o ich biopristupnosti a potenciálnom riziku, pretože toxicita prvkov a ich mobilita v prostredí sú závislé na ich chemických formách. Aby sme získali informácie o biopristupnej forme prvkov v pôde, obyčajne použijeme postup jednokrokovej extrakcie.

Postupy dvojkrokovej jednoduchej extrakcie schválený BCR (Community Burean of Reference) sa používajú pri hodnotení biopristupných species v pôde: extrakcia 0,43 mol/l kyselinou octovou a extrakcia 0,05 mol/l EDTA (pH – 7). Obsah prvkov v pôdnych extraktoch za použitia 0,43 mol/l kyseliny octovej predstavuje ion – výmenné formy prvkov a väzbu na karbonáty. EDTA extrakty predstavujú obsahy prvkov sorbovaných a organicky viazaných v pôdach.

Kľúčové slová: olovo, kadmium, pôda, biopristupnosť

INTRODUCTION

Man activities caused marked element redistribution in biosphere, particularly their quantitative representation in soil, water and atmosphere. From the of toxicity judgment is necessary to know not total analyte content, but biologically available forms contents; i.e. such forms that can penetrate into food chain. Bioavailable forms are the forms fixed to organic mass and exchangeable forms. European board. "Community Bureau Reference" proposed single step extraction procedures for there forms insulation: 0.43 mol/l CH_3COOH for exchangeable forms of metals and 0.05 mol/l EDTA (pH = 7) for organically fixed metal forms [1].

The work is focused to analytical procedures elaboration and determination lead and cadmium bioavailable forms. Low Pb- and Cd-contents in soils require analytical method used high sensibility. Most often used method for trace quantities determination Pb and Cd is AAS (Atomic Absorption Spectrometry). This method detection limit is approximately 10^{-5} mg/l sample. Today is for Cd and Pb used emission spectrophotometry, AAS and ASV (anodic stripping voltamperometry). Advantage of the method ASV on HMDE (hanged mercury drop electrode) used by us, is the possibility of parallels both elements determinations. Anodic stripping voltamperometry is one of small number analytical techniques, sensitive enough for direct heavy metal determination in environmental samples, it is also useful for study of trace elements speciation. For Pb and Cd it reaches detection threshold in water samples 10 – 10 mol/l [2]. At DPASV (differentially pulse anodic stripping voltamperometry) dissolving step is analyte anodic oxidation, whereby dissolving step is followed by difference pulse voltamperometry. For analyte accumulation is used mercury electrode (HMDE). When this method using accumulation step is amalgams formation of the analytes determined with electrode material.

MATERIAL AND METHOD

As soil samples were used the samples of various soil characteristics. Voltamperometric measurements were conducted on polarographic analyser PAH (Laboratorní přístroje Praha) with the electrode system that consist of static mercury drop electrode in modus HMDE, argentochloride electrode and platinum auxiliary electrode in modus HMDE, argentochloride electrode and platinum auxiliary electrode in linkage with recorder XY 4103.

RESULTS AND DISCUSSION

Determination of total metal content expresses very few about quantity of mobile or really available metal forms. Substantially better information gives heavy metals speciation, i.e. determination of individual forms contents. Water soluble ion exchangeable and organically fixed metal fractions are considered for most dangerous from the view of mobility in soil and their availability for plant root systems.

Exchangeable Pb and Cd forms determination

As real samples soil samples of various characteristics were used.

Analyses experimental results for exchangeable Pb- and Cd-forms are presented in Table 1 and 2.

Table 1 Contents of exchangeable Pb forms in soil samples

Sample	Pb content $\mu g.g^{-1}$	sr/%	Total content Pb/$\mu g.g^{-1}$	Exchangeable b/%
N-1-TT/1	0.174 ± 0.011	2.36	14.6	1.19
N-1-TT/2	0.050 ± 0.009	1.01	12.95	0.39
N-1-TT/3	0.527 ± 0.022	1.98	7.05	7.47
N-3-GA/1	0.200 ± 0.017	3.97	—	—
N-5-ZV/1	0.706 ± 0.045	2.89	21.35	3.72
N-2-LM/2	0.346 ± 0.039	5.07	13.25	2.61

Pb-content of extracted CH_3COOH ranged 0.17 – 0.7 μg.g^{-1}. The highest values were obtained in soils with high carbonate levels (A-1-TT/3 – Haplic Chernozem Calcaric), or in the samples with high total Pb-content (A-5-ZV/1). Pb determinations accuracy in extract CH_3COOH is good. Rel. Standard deviation (Sr) does not exceed 5.1%. Lead belongs to less mobile elements, share of exchangeable forms, fixed to carbonates in leach ate CH_3COOH was very low. Of total Pb-content present in soil it was 0.4 – 7.5%. Total Pb-contents determined by AAS method were cited from the work [3].

Table 2 Contents of exchangeable Cd forms in soil samples

Sample	Cd content μg.g^{-1}	sr/%	Total content Cd/μg.g^{-1}	Exchangeable Cd/%
N-1-TT/1	0.077 ± 0.011	6.15	0.175	44.00
N-1-TT/2	0.033 ± 0.004	5.63	0.14	23.57
N-1-TT/3	0.100 ± 0.005	2.46	0.27	37.04
N-3-GA/1	0.061 ± 0.005	3.67	—	—
N-5-ZV/1	0.102 ± 0.008	3.30	0.165	61.82
N-2-LM/2	0.053 ± 0.009	7.00	—	—

Exchangeable Cd-forms fixed to carbonates contents ranged in analyzed samples 0.03 – 0.1 μg.g^{-1}. Contrary to lead cadmium belongs to very forms extracted CH_3COOH ranges 24 – 62% with aspect to total cadmium amount in given samples. Determination accuracy of very low Cd-contents by the method ASV is good. Rel. Standard deviations ranged 2.5 – 7%.

Soil sample N-1-TT (Haplic Chernozem Calcaric) was analysed in there horizons. From the results comparison in Table 1, 2 is resulting, exchangeable Pb- and Cd-forms level is changing with sampling depth (horizon). A highest Pb and Cd content extracted by 0.43 mol/l CH_3COOH were in third horizon. In this horizon we can find high carbonate amounts and smaller amount of organic matter when compared to other horizons.

For chosen method suitability verification exchangeable forms of Pb and Cd in three standard reference materials (ŠRM) that were also analyzed by other instrumental techniques. Experimentally obtained analyses results are comparable with results obtained by method PGRCH (flow galvanostatic balanced chronopotenciometry) [4], AAS with use the method of calibration curve (AAS_{KK}) and method of several supplements of the standards ($AAS_{MPŠ}$) [5]. By comparison obtained experimental results we can see in given concentration level good harmony, i.e. determined values can be considered as correct.

Determination organically fixed Pb and Cd forms

For every of soil samples were implementer 1 – 3 independent leaching 0.05 mol/l EDTA (pH = 7). Pb- and Cd-contents in extracts were determined by method ASV and evaluated by the technique of several [3] supplements of the standard.

Lead and cadmium were determined directly in extract after suitable dilution and pH modification with solution 1 mol/l HCl in order to eliminate in desirable EDTA effect that was fixing Pb and Cd into stable complexes, in this way i prevented Pb and Cd VA (voltamperometrical) determination.

Experimentally reached analysis results for organically fixed Pb- and Cd-forms are presented in Table 3 and 4.

Table 3 Organically fixed Pb^{2+} forms in soil samples

Sample	Pb-contents µg.g^{-1}	sr/%	Total Pb contents/µg.g^{-1}	Organically fixed Pb/%
N-1-TT/1	5.58 ± 0.35	2.9	14.6	38.22
N-1-TT/2	2.71 ± 0.27	4.3	12.95	20.95
N-1-TT/3	1.25 ± 0.15	5.4	7.05	17.66
N-3-GA/1	5.03 ± 0.27	2.3	—	—
N-5-ZV/1	9.94 ± 0.88	4.1	21.35	46.55
N-2-LM/2	2.98 ± 0.17	2.5	13.25	22.51

Lead belongs to less mobile elements, Pb-level in leach ate 0.5 mol/l EDTA ranged 1.3 – 10 µg.g. Organically fixed forms highest contents were observed in soil samples of 1st horizon, where is occurring highest amounts of organic mass. Share of organically fixed Pb-forms introduced of total Pb-contents (determined by method AAS) present in soil samples 17.5 – 46.5%.

From the comparison results of soil sample N-1-TT is visible, organically fixed Pb share in 1st horizon was approximately double of Pb shares in second and third horizons. Determination accuracy in extract 0.05 mol/l EDTA was good, rel. standard deviation exceed 5.4%.

Table 4 Organically fixed Cd-contents in soil samples

Sample	Cd-content µg.g^{-1}	sr/%	Cd total contents/µg.g^{-1}	Cd organically fixed/%
N-1-TT/1	0.201 ± 0.015	3.55	0.175	114.9
N-1-TT/2	0.085 ± 0.014	6.37	0.14	60.7
N-1-TT/3	0.079 ± 0.013	7.89	0.27	29.3
N-3-GA/1	0.103 ± 0.012	4.72	—	—
N-5-ZV/1	0.132 ± 0.011	3.72	0.165	80.0
N-2-LM/2	0.072 ± 0.007	4.54	—	—

Organically fixed Cd-forms contents ranged in analyzed samples 0.07 – 0.2 µg/g. Determination accuracy of very low Cd concentrations was good, Sr ranged 29 – 115 % with aspect by total Cd amount in given samples. As total Pb- and Cd-levels ire soil samples were determined in 1991, they have not to be so correct, as there can occur metal of atmosphere accumulation. Organically fixed Cd high result in soil sample N-1-TT/1 can be also caused by humine substances interference, their concentration in the sample soil leach ate was markedly higher than at another samples (with exception N-3-GA/1). Applied 40-fold soil solution dilution has not to be enough for humine substances elimination. At Cd determination in soil leachates rich in humine substances could be desirable to compare obtained results with the results after organic substances destruction by UV radiation or heating with mineral acids.

Soil sample N-1-TT at leachates into 0.43 CH_3COOH, as well as at leaching into 0.05 mol/l EDTA, was analyzed in three horizons. From result comparisons in Table 3 and 4 is resulting, determined metals contents with sampling depth decreases. This is caused by the fact, organic matter highest amount is located pint in first horizon, and with depth its amount decreases.

For selected method suitability verification were determined also organically fixed forms of Pb and Cd in referential material. The reference materials were also analysed by the method AAS. Analyses measured by the method DPASV were compared with the results obtained by the method AAS using the method of calibration curve (AAS_{KK}) and methods of several supplements of standards ($AAS_{MPŠ}$), whereby is reached good harmony among the results obtained with various methods. From this is resulting, organically fixed Pb-forms can be reliable determined directly in extract after proper dilution (1:250) and pH modification to the value 1.2.

Cd occurred in soils on markedly lower concentration level. At analysis of soil rich in organic carbon is not possible eliminate inferences determination of organically fixed Cd by humine substances present in extract.

CONCLUSIONS

In submitted paper were detected bioavailable contents of toxic metals Pb and Cd in ŠMR and soil samples of various characteristics. For there forms of metals two simultaneous extractions were used that were recommended by European Community board – BCR: extraction 0.43 mol/l CH_3COOH and 0.05 mol/l EDTA (pH = 7). Metal contents in extracts were determined by the method DPASV and evaluated by technique of supplements of standards.

With aspect to studied problems and marked targets our work conclusions can be summarized into following items:

1. Accredited was effect of soil leach ate patterns on determination Pb^{2+} and Cd^{2+} by the method DPASV. Values of blind experiments were measured for Pb^{2+} and Cd^{2+} in the leachates used by us
2. Optimum pre preparation steps were found for Pb- and Cd-measurement by pilot samples analysis
3. Also by pilot samples analysis were found optimum parameters of Pb- and Cd-signals measurement
4. Analytic procedures elaborated including sample arrangement and proper measurements by DPSAV method were used for determination contents of bioavailable Pb- and Cd-forms in soil samples N-1-TT, N-3-GA/1, N-5-ZV/1 and N-2-LM/2 and ŠRM (S-VM, S-MS, S-SP).
   - Determined were available Pb- and Cd-forms in soil samples and ŠRM. Whereby percentile Pb representation in soil leachates 0.43 mol/l CH_3COOH is 0.4 – 7.5% and Cd 23.5 – 62%. Percentile representation of Pb available forms in ŠRM is 1.5 – 2.5 % and Cd 44.2 – 74%.
   - Organically fixed Pb- and Cd-forms was possible reliably determined after leach ate dilution and pH modification to 1.2 by the solution 1 mol/l HCl before measure itself. Content of organically fixed Pb and Cd in real soil samples ranged 17 – 46.5% for Pb and 29 – 115% for Cd. Contents of organically fixed Pb in ŠRM ranged 14.8 – 30% and for cadmium 50 – 60%.
5. Analytical procedures reliability at bioavailable Pb- and Cd-forms determinations in soils by the method DPASV was accredited by comparison of attained results with the results obtained by other instrumental techniques – ETAAS (atomic absorption spectrometry with electrochemical atomization) and PGRCH.

REFERENCES

[1] Ure A. M., Davidson C. M., Thomas R. P.: in Quality Assurance for Environmental Analysis, Elsevier Science, 1995, s. 505
[2] Batley G. E., Florence T. M.: J. Elektroanal. Chem. 300, 350 (1980)
[3] Žemberyová M., Smirnová L., Vačková M.: Agrochémia 31, 282 (1991)
[4] Bologa P.: Diplomová práca, Bratislava, 2002
[5] Šišoláková M.: Diplomová práca, Bratislava, 1998

LIST OF ABBREVIATIONS USED

AAS – atomic absorption spectrometry
ASV – anodic stripping voltamperometry
BCR – „Community bureau of reference“ = European Board „Community Bureau of Reference“
DPASV – differential pulse anodic stripping voltamperometry
EDTA – acid ethylendiamintetraacedactic
ETAAS – atomic absorption spectrometry with elecrochemic atomisation
HMDE – hanged drop mercury electrode
RGRCH – flow galvanostatic balanced chronopotentiometry
ŠRM – standard reference material
VA – voltamperometrical

TILLAGE EFFECTS ON SOIL EROSION

Vplyv obrábania na eróziu pôdy

Richard LAZÚR
Soil Science and Conservation Research Institute, Bratislava, Slovakia

ABSTRACT

Soil erosion belongs to the most important, most common and most dangerous processes of soil degradation. Apart from decrease in soil fertility, erosion causes also damages on field crops, decreases soil environmental functions potential, downgrades soil resistance to the other degradation factors. Remarkable environmental problems are connected also with the sedimentation phase of the process. According to FAO 50% of soil degradation worldwide is caused by erosion processes.

Soil erosion in general is defined as a process of transport of soil mass within landscape, characterised by soil loss on certain locations, and on the other side, by its accumulation (sedimentation). The process occurs as a result of some external force acting on soil particles, the force moves soil particles, and when the force decreases below certain limit, the sedimentation takes place. In case of water erosion the erosion force is the force of rain drops falling on soil surface with the energy of running water, in case of wind erosion soil particles are removed by energy of wind. Both these processes occur naturally, human activity shall either suppress or increase their intensity, tillage operations are most common practices influencing erosion intensity. In case of tillage erosion soil mass is transported by a force applied on soil through tillage tool (plough or other tillage implement). It is fully human-caused process occurring as a direct result of human activity only on arable land and is limited by field borders.

In our conditions soil erosion by water occurs almost exclusively on arable land, where tillage operations are done regularly. Tillage affects soil erosion both indirectly – by affecting soil erodibility by water (by regulation of soil properties, crop residue management), and directly in the process of tillage erosion. Intensity of tillage erosion is in the same order of magnitude as water erosion. Total soil erosion on arable land in field conditions equals the sum of water and tillage erosion. Erosion risk assessment and effective erosion control must cover both mentioned processes.

- ploughing agrotechnical operations affect intensity of soil erosion indirectly affecting soil erodibility by water erosion by changing soil properties (soil erodibility by water), and through regulation of crop residues on soil surface, anti-erosive tillage practices could decrease soil loss from water erosion by 15 – 80%
- ploughing agrotechnical operations (tillage) contribute to the total soil erosion movement also directly in the process of so-called tillage erosion, when intensity of tillage erosion is well comparable with water erosion, soil loss resulting from tillage erosion on convex slope positions contributes to the total erosion extent by up to 50%
- total extent of soil erosion on arable land in real conditions equals the sum of the two processes – water erosion and tillage erosion

Keywords: soil erosion, tillage erosion, erosion control

ABSTRAKT

Erózia pôdy patrí medzi najdôležitejšie, najrozšírenejšie a najnebezpečnejšie procesy degradácie pôdy, spôsobuje okrem znižovania pôdnej úrodnosti a škôd na poľnohospodárskych kultúrach aj znižovanie potenciálu environmentálnych funkcií pôd, znižuje odolnosť pôdy voči ostatným degradačným faktorom a závažné environmentálne problémy spôsobuje aj sedimentačná fáza erózneho procesu. Podľa FAO 50% degradácie pôdy vo svetovom meradle je spôsobenej eróznymi procesmi.

Erózia pôdy je vo všeobecnosti definovaná ako proces transportu pôdnej hmoty v krajine charakterizovaný na jednej strane stratou pôdy na určitých lokalitách, na druhej strane jej akumuláciou (sedimentáciou). Tento proces nastáva v dôsledku pôsobenia nejakého druhu externej energie na pôdne častice, táto energia dáva pôdne častice do pohybu a keď prestane pôsobiť (resp. keď poklesne pod určitú hranicu), nastáva sedimentácia ako neoddeliteľná časť erózneho procesu. V prípade dažďovej vodnej erózie je touto erózne účinnou energiou energia kvapiek dopadajúcich na povrch pôdy, resp. energia povrchovo tečúcej zrážkovej vody, v procese veternej erózie sú pôdne častice unášané energiou erózne účinného vetra, pričom tieto procesy prebiehajú prirodzene a činnosť človeka môže ich prejavy potlačiť, alebo naopak zintenzívniť. V prípade tzv. orbovej erózie je pôdna hmota premiestňovaná v dôsledku mechanickej energie aplikovanej na pôdu prostredníctvom mechanizmu na obrábanie pôdy (pluh, resp. iný mechanizmus), jedná sa o výlučne antropogénny proces, ktorý prebieha ako priamy dôsledok aktivity človeka len na ornej pôde a jeho prejavy sú obmedzené hranicami honu.

V našich podmienkach prebieha vodná erózia prevažne na orných pôdach, na ktorých sa pravidelne realizujú kypriace agrotechnické zásahy. Agrotechnika ovplyvňuje intenzitu erózie pôdy jednak nepriamo, vplyvom na erodibilitu pôdy vodou (zmenou pôdnych vlastností, reguláciou množstva pozberových zvyškov na povrchu pôdy), jednak priamo v procese tzv. orbovej erózie pôdy. Intenzita procesu erózie pôdy orbou je pritom porovnateľná s vodnou eróziou. Celková erózia na ornej pôde je teda v reálnych podmienkach výsledkom pôsobenia dvoch procesov – vodnej erózie a tzv. orbovej erózie. Posudzovanie erózneho ohrozenia pôdy a protierózna ochrana musia teda brať do úvahy oba spomenuté procesy.

- obrábanie pôdy pôsobí nepriamo na intenzitu erózie pôdy vodou regulovaním pôdnych vlastností určujúcich erodibilitu pôdy a reguláciou množstva pozberových zvyškov, v porovnaní s konvenčnou jesennou orbou môžu pôdoochranné agrotechniky znížiť stratu pôdy vodnou eróziou o 15 až 80%
- priamym vplyvom agrotechniky na stratu pôdy eróziou je proces orbovej erózie pôdy, strata pôdy v dôsledku agrotechniky v podmienkach sprašových pahorkatín je porovnateľná s vodnou eróziou, na celkovom odnose pôdy sa orbová erózia podieľa asi 50%
- celková strata pôdy eróziou na orných pôdach musí byť hodnotená ako suma straty pôdy vodnou a orbovou eróziou

KĽÚČOVÉ SLOVÁ: erózia pôdy, orbová erózia, protierózna ochrana

INTRODUCTION

Erosion of soil mass (releasing soil particles, their transport and sedimentation) in real conditions is result of numerous erosion processes, often occurring simultaneously. These processes influence one another and their intensity and also their relative share on total soil erosion is affected by numerous factors. In field conditions a relative contribution of each single erosion process to the total erosion is difficult (or even impossible) to determine. Although classification of erosion processes is well developed and mechanism of more than 20 different erosion processes is described in literature (see Fulajtár, Janský, 2001), research is focused almost exclusively on sheet and rill rainwater erosion.

Theory, according to which water erosion (over tolerable limit of soil loss) occurs only on agricultural land on slope positions without effective plant cover, is generally accepted. These arable agricultural soils are within plant rotation regularily tilled (plowing, harrowing, disking, cultivation), tillage operations interrupt development of plant cover protecting soil surface from erosion. With tillage operations in sloping relief process of tillage erosion is connected (downslope erosion movement of soil mass caused by difference in the amount of soil translocated by downslope and upslope tillage). We can say that signs of soil erosion in our conditions almost always are the results of two major processes – water erosion, and erosion caused by agrotechnical operations (tillage erosion). Tillage erosion process, although known for long time, was almost ignored in Slovakia and abroad, too. Numerous authors (Kachanoski, 1992a, b; Govers et al., 1999) consider tillage erosion to be dominant process responsible for soil losses on convex parts of hilly relief.

We can find a few causes, why so little attention was paid to the tillage erosion process till today. Signs of tillage erosion are apparent only stepwise after decades of tillage (thinning of humic layer, expose of subsoil on surface) and are often assigned to water erosion. One of the reasons why water erosion was so popular is existence of sophisticated models (USLE) focused on sheet and rill erosion, and also development and common use of standardised techniques for measurement of water erosion (deluometers, rain simulators). Certain change appeared at the beginning of 90-ties, when some works were published dealing with identification, field measurement, quantification and modelling of soil erosion caused by agrotechnical operations – tillage erosion. One of the reasons turning attention of erosion researchers to tillage erosion is existence of method for assessment of total soil loss from certain place, based on the activity of ^{137}Cs in soil. Data obtained by this method showed such spatial distribution of soil loss, which do not respond to the “standard” soil loss models (mostly based on USLE). Experiments showed the highest soil loss on convex upper parts of slopes and sedimentation in concave positions, where according to USLE predicted soil loss should be highest (concentrated surface flow, increasing influence of the slope length). Such spatial distribution of soil loss and accumulation should be best explained by the concept of tillage erosion. Also concept of precision farming pointed importance of spatial variability in soil conditions and showed lower soil fertility in upper convex positions caused by increased soil erosion.

MATERIAL AND METHODS

In order to investigate effects of tillage operations on soil erosion (tillage erosion, tillage translocation) a field experiments were carried out at three selected sites – Smolinske, Hlohovec (two variants) and Lefantovce. All the sites were located at soil type Haplic Luvisol, which represents one of the most intensive agriculturally exploited soil types in Slovakia. At these sites erosive influence of various tillage techniques (moldboard plow, field cultivator) and tillage directions at different slopes were studied. To determine extent of soil erosion caused directly by tillage operations a tillage translocation distance was determined using method based on metallic tracers. Duraluminium tracers (1 cm diameter) were installed into soil in a fixed system of reference in 1 m long line perpendicular to the tillage direction. After tillage operation was done, new position of displaced tracers (translocated by tillage with the soil mass) was detected via in situ measuremnet of soil magnetic susceptibility using the Soil Conductivity Meter EM38. For more detailed description of used method and some experimental results see Lazur (2001).

RESULTS AND DISCUSSION

A tillage operation co-influences the soil erosion process by two ways, in real field conditions acting simultaneously:

- indirectly by affecting soil erodibility by water
- directly in the process of the tillage erosion

Soil tillage as a factor influencing soil erosion by water

Influence of ploughing tillage operations belongs to the external factors affecting soil erodibility by water. In the general Wishmeier soil loss equation – USLE influence of tillage operations is expressed as „P"-factor, the factor of anti-erosion measures, defined as a ratio of soil loss from soil with certain tillage practice to the reference soil loss from soil tilled downslope. Reference tillage is conventional moldboard plowing in downslope direction.

A tillage operation affects soil erodibility by water in following ways:

- By affecting soil structure – tillage affects soil structure, which is an important parameter of soil erodibility. Disintegrated and hoed soil layer has improved infiltration capacity, what is favourable for erosion control. On the other hand, disturbed soil particles are by rain drops or flowing water more easily released and transported. Multiple tillage passes brings soil compaction, what limits water infiltration into soil and such increases surface water flow. Optimal and well-timed tillage passes shall significantly decrease soil losses by water erosion.

Reduction of soil loss compared with autumn plowing (Stone, Moore, 1995)

Tillage	**% decrease in soil loss**
Spring tillage	15
Spring tillage without turning soil	30
Autumn mulch tillage	40
No-till	80

- By regulation of crop residues remaining on soil surface – tillage operations affects soil erodibility by leaving on surface various amount of crop residues having protective effect. Crop residues remaining on soil surface after harvest and stubble acts against erosion by protecting soil surface from direct impact of falling raindrops releasing soil particles, and by slowing down surface flow and increasing infiltration. Conventional ploughing with turning furrow slice buries almost all crop residues and leaves soil surface unprotected. Different tillage practices have different effect on crop residues.

Influence of tillage techniques on soil cover by plant residues

Tillage implement	**% of plant residues remaining on surface after single tillage pass**
Moldboard plow	10
Chisel plow	50 – 70
Discs	50 – 60
Harrows	65 – 95

- By regulation of soil surface roughness – each tillage operation creates rough soil surface, which slows down surface flow and increases infiltration rate. This effect is especially important in the case of contour tillage, when tillage creates rills perpendicular to the gravity directed water flow.

Conservative tillage practices are assumed as effective anti-erosive measures allowing with maintained agricultural utilisation of erodible soil minimise soil loss under tolerable limit. Following anti-erosive tillage techniques are used in our conditions:

Contour tillage – is one of the oldest and best known methods. Realisation of contour tillage is technologicaly more difficult and more time-consuming, and on steeper slopes can not be implemented.

Contour planting – shall follow contour tillage. Rows of crop oriented along the contour also slow surface flow.

Trenching – the aim is to stop gravity drived surface water flow by a few rows of trenches oriented along the contour.

Deep loosening – directly increases soil infiltration rate.

Stubble breaking – as every tillage operation changing soil structure has direct effect on soil erodibility. Protective effect of this measure is under discussion, because stubble breaking leaves rough soil surface slowing surface runoff, but disturbed soil surface is less resistant to the particles release.

No-till planting – is the most perspective and most effective anti-erosion practice utilising protective effect of crop residues. But even this method should not ensure complete anti-erosion protection of soil, especially in case of crops leaving just little residues after harvest. Against high costs of no-till planters and additional costs for weed control popularity of no-till planters grows worldwide.

Soil tillage as a direct erosion agent – tillage erosion

Technologies of soil tillage have beside influence on soil erodibility by natural erosion factors (water, wind) also direct levelling effect on soil surface through soil translocation and redistribution. Tillage translocation is direct transport of soil by tillage tools. Soil is simply moved by tillage tool or translocated by rolling of clods on soil surface. Relative share of these two ways depends on the shape of tillage tool, force applied on soil, slope inclination and the soil parameters. Tillage erosion is soil loss resulting from soil translocation by tillage operations.

Tillage erosion is caused by variation in magnitude of soil translocated during tillage and is characterised by soil loss from convex positions and its accumulation in concave parts (Govers et al., 1999). In the process of tillage soil mass is by tillage tool (plow) elevated and pushed in the tillage direction, and after that falls under gravity force in downslope direction. Result is soil translocation in the tillage direction, amount of translocated soil depends beside tillage translocation distance also on the tillage depth. If suppose, that tillage operations are directed upslope equally as often as downslope, result will be net soil translocation in downslope direction – tillage erosion.

The most important factor, affecting intensity of tillage erosion is the slope inclination (the steeper is the slope, the greather is the difference between amount of soil translocated upslope and downslope – net tillage erosion), but whether soil loss occurs or tot depends primarily on the change in slope inclination (Lindstrom et al., 1992). Other factors, limiting extent of tillage erosion are the size and shape of tillage tool, tillage depth, tillage speed and soil properties.

Tillage of soil with undulated surface with implement on fixed frame has levelling effect on landscape. In microtophographic scale upper parts of surface within the implement frame are tilled deeper – what leads to greather soil translocation- than depression parts. Soil is translocated forward and sideward from the upper parts and forward and sideward to the depression positions. In macrotophographic scale tillage tool on fixed frame translocates soil from convex positions and to concave positions, regardless if the tillage direction is upslope or downslope.

Tillage erosion is limited by the field borders, soil is not lost from the field as in case of water or wind erosion. Result of tillage erosion is soil loss on convex positions and its accumulation in concavities. That leads to successive increase in variability of soil conditions within a field, loss of the most fertile upper part of soil profile in convex positions leading in extreme cases to exposition of parent material on surface (loess, gravels, etc.), and finally decrease in average fertility of the field. Another well known effect of tillage is also excavation of stones from the subsoil.

In last years in Slovakia and abroad trend of tillage minimisation is apparent. The reason is to decrease expenses for fuel and other machinery operation costs, and also to decrease number of passes on field in order to avoid excessive soil compaction. New mechanisation able to ensure crop production with minimum soil distribution is developed worldwide. This trend significantly helps to combat tillage erosion.

CONCLUSIONS

When evaluating contribution of tillage practices to the soil erosion process we can formulate following statements:

- erosion of soil by water in our conditions occurs almost exclusively on arable soils, on which ploughing agrotechnical operations are done regularily
- ploughing agrotechnical operations affects intensity of soil erosion indirectly affecting soil erodibility by water erosion by changing soil properties (soil erodibility by water), and through regulation of crop residues on soil surface

- ploughing agrotechnical operations (tillage) contributes to the total soil erosion movement also directly in the process of so-called tillage erosion, when intensity of tillage erosion is well comparable with water erosion
- total extent of soil erosion on arable land in real conditions equals the sum of the two processes – water erosion and tillage erosion
- any anti-erosive measures must take into account both water and tillage erosion process

REFERENCES

Fulajtár, E., Janský, L., 2001: Vodná erózia pôdy a protierózna ochrana, VUPOP, Bratislava, 308 s.

Govers, G., Lobb., D.A., Quine, T.A., 1999: Tillage erosion and translocation: emergence of a new paradigm in soil erosion research. Soil and Tillage Research 51, 167 – 1174.

Kachanoski, R.G., Protz, R.D., Gregorich, E.G., 1992a: Management of farm field variability: I. Quantification of Soil Loss in Complex Topography. SWEP/TED report. Centre forSoil and Water Conservation. University of Guelph, Guelph, ON.

Kachanoski, R.G., Miller, M.H., Lobb, D.A., 1992b: Management of farm field variability: II. Soil Erosion Processes on Shoulder slope Landscape Positions. SWEP/TED report. Centre forSoil and Water Conservation. University of Guelph, Guelph, ON.

Lazúr, R., 2001: Soil erosion caused by tillage., Proceedings of the Trilateral Co-operation Meeting on Physical Soil Degradation, VUPOP Bratislava

Lindstrom, M.J., Nelson, W.W., Schumacher, T.E., 1992: Quantifying tillage erosion rates due to mouldboard plowing. Soil and Tillage Research 24, 255 – 264.

Stone, R., P., Moore, N., 1995: Control of Soil Erosion., Factsheet No. 95-089, www.gov.on.ca/OMAFRA/

COMPARISON OF CADMIUM SORPTION ON DIFFERENT SOIL TYPES AND LIGNITE

Porovnanie sorpcie kadmia na rôzne pôdne typy a lignit

Mikuláš MADARAS[1], Gabriela BARANČÍKOVÁ[1], Jarmila MAKOVNÍKOVÁ[2], Martina KLUČÁKOVÁ[3], Miloslav PEKAŘ[3]

[1] *Soil Science and Conservation Research Institute, Bratislava Research Station Prešov*

[2] *Soil Science and Conservation Research Institute, Bratislava Research Station B. Bystrica*

[3] *Faculty of Chemistry, University of Technology Brno, Czech Republic*

ABSTRACT

Cadmium (Cd) batch sorption experiments were realized using samples of 5 topsoils with different physico-chemical properties. Sorption capacity of soil samples was compared with sorption capacity of lignite, which can be potentially used for decontamination of locations polluted by heavy metals. Sorption data were described by linear and Freundlich adsorption isotherm. Cd sorption capacity varied significantly among soil samples: the highest adsorption was observed in case of Chernozem (99.4% Cd adsorbed from the solution) and the lowest in case of Dystric Cambisol (65%). Adsorption capacity of lignite was between capacities of Cambisol and Fluvisol, but the shape of the lignite isotherm was not curved as was observed for soils, but linear in whole range of Cd concentrations. Based on this, it is concluded that adsorption maximum of lignite is much higher than for soils with similar slopes of first linear part of isotherms (Kd). Significant correlation was found between $log\ Kd$ and pH of the samples. On the basis of the experiments, distribution constant for Cd adsorption can be calculated according to the formula: $log\ Kd = -0.18 + 0.484 * pH_{H_2O}$.

Keywords: heavy metals, cadmium, sorption, soil, lignite, pH

ABSTRAKT

V laboratórnych podmienkach bola realizovaná sorpcia kadmia na vzorky povrchových horizontov piatich pôdnych typoch so značne rozdielnymi pôdnymi charakteristikami. Sorpčná kapacita vybraných vzoriek bola porovnaná so sorpčnou kapacitou lignitu, ktorý môže mať potenciálne využitie pri dekontaminovaní lokalít znečistených ťažkými kovmi. Sorpčné experimenty boli vyhodnotené lineárnou izotermou a Freundlichovou adsorpčnou izotermou. Na základe získaných výsledkov môžeme konštatovať rozdielnu sorpčnú kapacitu povrchových horizontov pre sorpciu kadmia. Najvyššia adsorpcia bola pozorovaná na vzorke černozeme (99,4% Cd sorbovaného z roztoku) a najnižšia na kambizemi dystrickej (65 %). Sorpčná kapacita lignitu sa nachádzala medzi kambizemou a fluvizemou, avšak tvar adsorpčnej izotermy lignitu nebol zakrivený ako u pôd, ale lineárny v celom rozsahu rovnovážnych koncentrácií. Z uvedeného vyplýva, že adsorpčné maximum lignitu je oveľa vyššie než pre pôdne vzorky s podobnými hodnotami smernice lineárnej časti izotermy (*Kd*). Pri porovnaní vplyvu vybraných pôdnych vlastností na sorpčnú kapacitu pôd a lignitu bola medzi *log Kd* a pH zistená signifikantná lineárna korelácia. Na základe našich experimentálnych údajov môže byť distribučná konštanta pre kadmium vypočítaná podľa rovnice: $log\ Kd = -0{,}18 + 0{,}484 * pH_{H_2O}$.

Kľúčové slová: ťažké kovy, kadmium, sorpcia, pôda, lignit, pH

INTRODUCTION

Among heavy metals (HM) commonly introduced into soils by different sources, cadmium (Cd) deserves a special attention because of its zootoxicity and relative high mobility with respect to uptake and leaching (Pardo, Guadalix, 1995). In cultivated soils considerable amount of this element can be introduced via anthropogenic pathways, such as the use of fertilizers or waste products used as soil amendments. In recent times, phosphate fertilizers have shown to be a source that contributes to increasing levels of Cd (Aljahi, 1993). Increasing of Cd-content in soil is well documented, e.g. from long term field experiments of Experimental station Rothamsted UK where analysis of archive soil samples since 1840 was realized (Jones et al., 1987).

Great problem in cadmium regulation in soil-plant system is complexity of relationships between accumulation in soil and translocation into plants. Potential mobility and risk of cadmium entry to food chain is not dependent only on total amount of heavy metals in soil. Cadmium transfer is influenced by interaction with soil components, nutrients, other metals, plants, climatic conditions and soil management.

Sorption processes play an important role in soil Cd-fixation. Many of authors (Mestek, Volka, 1993; Borůvka et al., 1997; Schalscha et al., 1999 etc.) estimated the influence of selected soil parameters to mobile and potentially available heavy metal content. It was found that the variation in soil properties such as pH, organic matter content and quality, texture and type of clay minerals, iron and manganese oxides influence quantity and quality of adsorbing sites, and thus significantly influence the distribution as well as availability of Cd to plants.

In this paper we would like to present results of cadmium sorption onto different matrices. Some previous results regarding Cd sorption into soils are presented in earlier papers (Barančíková et al., 1995; Barančíková et al., 1997). However in this paper we would like to compare sorption of different soil types with lignite, which was chosen because of its potential usefulness for treatment of HM contaminated sites. In fact, it is already a basis of some products used for improving soil properties, also with respect to soil contamination (e.g. Ecofert).

In present time (in cooperation with Faculty of Chemistry Brno University of Technology) we are solving project regarding utilization of sorption characteristics of humic acids (HA) isolated from different matrices for environmental purposes. The knowledge of sorption behavior of matrices can be useful for understanding of differences of Cd-sorption onto HA.

MATERIALS AND METHODS

Soil samples were collected from topsoils of five different sites within key monitoring sites of the Soil Monitoring System. They represent common soil types, with wide range of fundamental soil attributes. Lignite was obtained from Hodonín. Basic characteristics of soil samples and lignite are presented in Table 1.

Table 1 Basic characteristics of soil samples and lignite

Sample	pH_{H_2O}	$CaCO_3$ %	Cox (%)	CHK/CFK	fraction < 0.01 mm	Q_4^6
Calcaric Fluvisol	7.8	28	0.97	0.54	25.1	3.73
Gleyic Fluvisol	5.7	0	1.16	0.98	25	3.8
Calcaro-haplic Chernozem	7.9	1.25	1.09	0.68	20.9	4
Haplic Luvisol	6.05	0	1.43	0.55	39.7	4.8
Dystric Cambisol	4	0	3	0.54	8.5	6.1
lignite	4.55	0	27.5	—	—	—

— not measured

On the basis of kinetic studies and in an agreement with literature data (Christensen, Huang, 1999; Christensen, 1984), an interaction time between a soil and cadmium solution was 1 hour. We used soil-solution ratio of 1:25, with starting Cd-concentrations 1 – 50 mg Cd/l in a background solution 0.01 M $NaNO_3$. pH of the stock Cd-solution was set to 4.0. Sorption experiments were done under laboratory conditions. Cd concentrations were determined in a centrifuged solution (10 min., 4 500 rpm), concentrations in soil were calculated from the difference between starting and equilibrium concentration. For analytical determination of Cd anodic stripping voltammetry is used (Kozáková, 1993). Cadmium concentration was measured by Electrochemical Processor EP 100. Indicators of measurements for determination of cadmium concentration can be found in previous paper (Barančíková et al., 1997).

The sorption data were fitted by Freundlich adsorption isotherm (all points) and linear isotherm (*Kd*) based on first linear part of an isotherm (2 – 4 points).

RESULTS

Among the investigated samples, wide range of Cd-sorption was observed, as can be seen from Figure 1 and Table 2. In almost all samples, high affinity of Cd to soils and lignite was found (Tab. 2, S (%)), some of the samples were very effective sorbents of Cd.

The highest sorption capability was observed in carbonate soils Calcaro-haplic Chernozem and Calcaric Fluvisol. As indicated by *Kd* of these soils, linear part of sorption isotherm of Chernozem was steeper then for Calcaric Fluvisol, despite that Freundlich constant (A) is lower for Chernozem. Sorption capability of Haplic Luvisol and Gleyic Fluvisol were simillar and much lower then for above mentioned couple. Again, *Kd* and Freundlich constant are in opposition – *Kd*-indicates better sorption properties for Luvisol and Freundlich constant for Gleyic Fluvisol. The lowest adsorption was observed in a case of Dystric Cambisol.

For lignite, adsorption of Cd was low, between Gleyic Fluvisol and Cambisol. From Figure 1 the different shape of lignite adsorption isotherm can be seen – while soil isotherms of Cambisol and Gleyic Fluvisol are curved in higher Cd-concentrations, isotherm of lignite is linear in whole range of Cd-concentrations used in experiment. Different shape of lignite isotherm in comparison to soils should be caused by unlike chemical structure of lignite matrice (in opposite to soils, lignite contents 10-times higher amount of Cox).

At consideration of influences of selected soil parameters to sorption capacity of soils and lignite, significant linear dependence between *log Kd* and pH was found (Fig. 2). Based on this, it appears that despite different origin and composition of samples, pH is an universal "master" variable, which controls sorption reactions of Cd even in such different matrix as lignite.

Figure 1 Measured adsorption isotherm

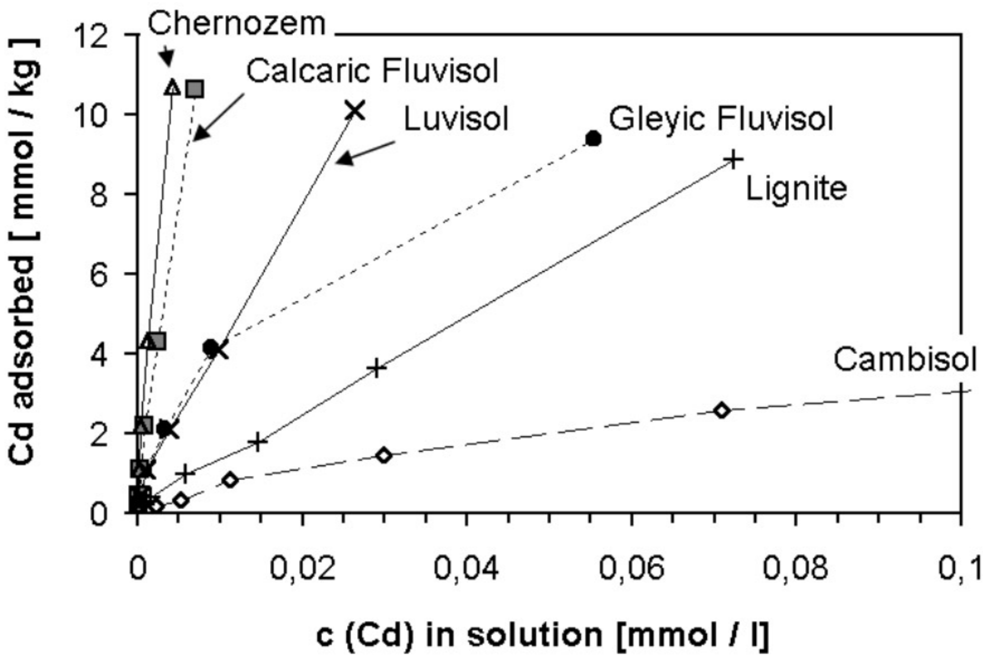
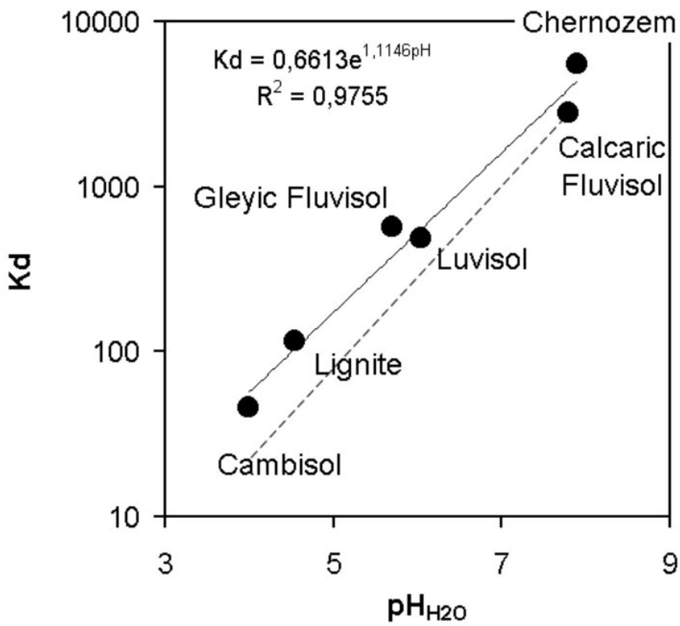


Table 2 Parameters of adsorption isotherms
(*Kd* – slope of linear isotherm, A, n – Freundlich constant and an exponent, S – averaged amount of Cd sorbed from the solution)

Sample	Kd	A	n	S (%)
Calcaric Fluvisol	2 787	1 359	0.947	98.7
Gleyic Fluvisol	564	75	0.642	95.4
Chernozem	5 549	894	0.790	99.4
Luvisol	487	125	0.716	96.3
Cambisol	46	18	0.752	65.4
lignite	115	65	0.806	86.6

Figure 2 Dependence of distribution coefficient *Kd* on pH of samples (dotted line – regression according to Christensen, 1989)



DISCUSSION

Several authors reported (see review McLaughlin et al., 1996) that trace metal concentrations in soil solutions are likely to be controlled by adsorption-desorption equilibria at low metal concentrations, whereas precipitation-dissolution reactions became important only at higher heavy metal concentrations, when adsorption sites are limited. According to the study of Christensen (1989), who measured adsorption characteristics of Danish soils, regresion analysis of *Kd* against various soil parameters showed that 72 % of *Kd* variations could be explained by variations of pH. The second most important parameter was content of organic carbon, but after its introduction correlation was only 7 % higher. Author reported, that *Kd* can be obtained from equation

$$\log Kd = -0.738 + 0.529 * \mathrm{pH} \quad [1]$$

where pH is measured in 0.001 M $CaCl_2$.

As can be seen on Figure 2, our observations are in a good agreement with proposed regression equations. Our results lead to an equation

$$\log Kd = -0.18 + 0.484 * \mathrm{pH}_{H_2O} \quad [2]$$

The slopes of both regression lines are nearly the same. Different constant (-0.738 vs. -0.18) lead to higher *Kd*-predicted from our observations. However, regression [1] is based on more soil samples (21 sites and 3 depths) and all our points are in range of variability observed in the study of Christensen (1989). Also, experimental conditions were different in above-mentioned experiments (100-times lower Cd concentrations, different equilibration time).

A surprise for us was a finding, that sorption behaviour of lignite, despite its so different composition and origin, was governed by the same parameter (pH) then is observed for soils. Lignite used for experiments contained more than 27% of organic carbon, represented by humic acids and fulvic acids, which should provide lot of adsorption sites for heavy metals. The shape of lignite isotherm seems to support this theoretical expectations – even in high Cd concentrations the isotherm is still linear, what means that adsorption sites are not limited in this Cd concentration range.

High content of adsorption sites of lignite makes it usefull for decontamination purposes, but more reasearch has to be done if it is possible to increase affinity of Cd with respect to lignite adsorption sites (e.g. by alteration of pH of lignitic material).

CONCLUSIONS

Based on experimentally determined adsorption isotherms for 5 different soil types and lignite we can conclude, that:

- investigated soil types had different capability for Cd adsorption. The highest adsorption was found in case of Chernozem, which can act as very effective immobilizer of Cd (99.4% adsorbed), as opposed to Dystric Cambisol, where only 65% of Cd was adsorbed.
- affinity of Cd for lignite was between the level of Dystric Cambisol and Luvisol. The shape of adsorption isotherm was linear in whole range of Cd concentrations, which suggests that adsorption maximum of lignite is much higher then for soils with simillar slopes of first linear part of isotherms.
- distribution constant *Kd* of all matrices (soils and lignite) was significantly correlated with soil pH measured in distilled water. Thus, *Kd* can be calculated according to the equation $\log Kd = -0.18 + 0.484 * pH_{H_2O}$. This finding is in a good agreement with data reported in literature.

REFERENCES

Alhaji, S.J., Bal, R.S.: Partition and distribution of cadmium and zinc in selected cultivated soils in Norway. Soil Science, 1993, 156, pp. 240 – 250.

Barančíková, G., Brečková, V., Dluhoš, J.: Cadmium sorption on selected soil types. Vedecké práce VUPU,19/1, 1995, pp. 129 – 133.

Barančíková, G., Brečková, V., Dluhoš, J.: Retencia kadmia pôdami a humínovými kyselinami. Rostlinná Výroba, 1997, 43, pp. 107 – 112.

Borůvka, L., Krištoufková, S., Kozák, J., Huan Wei, Ch.: Speciation of Cd, Pb, and Zn in heavy polluted soils. Rostlinná Výroba, 1997, 43, pp. 187 – 192.

Christensen, T.H.: Cadmium soil sorption at low concentrations: I. Effect of time, cadmium load, pH and calcium. Water Air Soil Pollut., 1984, 21, 105 – 114.

Christensen, T.H: Cadmium soil sorption at low concentrations: VIII. Correlation with soil parameters. Water Air Soil Pollut., 1989, 44, pp. 71 – 82.

Christensen, T.H., Huang, P.M.: Solid phase cadmium and the reactions of aqueous cadmium with solid surfaces. In: McLaughlin, M.J., Singh, B.R. (eds.): Cadmium in soils and plants. Kluwer Academic Publishers, 1999

Jones, K.C., Symon, C.J., Johnston, A.E.: Retrospective analysis of an archived soil collection. II. Cd. Sci. Total Environ., 1987, 67, 75 – 89.

Kozáková, E.: 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, 1993, pp. 137 – 143.

McLaughlin et al.: Review: The behaviour and environmental impact of contaminants in fertilizers. Aust. J. Soil Res., 1996, 33, 1 – 54.

Mestek, O., Volka, K.: Interakce těžkých kovů s půdními složkami. Chemické Listy, 1993, 87, pp. 95 – 806.

Pardo, M.T., Guadalix, M.E.: Cadmium sorption by two acid soils as affected by clearing and cultivation. Communication in Soil Science and Plant Analysis, 1995, 26, pp. 289 – 302.

Schalscha, E.B., Escudero, P., Salgado, P., Ahumada I.: Chemical forms and sorption of copper and zinc in soils of Central Chile. Communication in Soil Science and Plant Analysis, 1999, 30, pp. 497 – 507.

ACTUAL STATUS AND DEVELOPMENT OF pH-VALUE AND ACTIVE ALUMINIUM-CONTENT IN MAIN SLOVAKIAN SOIL TYPES

Aktuálny stav a vývoj pôdnej reakcie a obsahu aktívneho hliníka v pôdach Slovenska

Jarmila MAKOVNÍKOVÁ
Soil Science and Conservation Research Institute, Bratislava, Research Station B. Bystrica

ABSTRACT

Active and exchange soil reaction determination in a set 305 soil samples enabled us to compare differences among the determinations. Active soil reaction highest mean value expressed as pH/H_2O in depth 0 – 0.10 m (7.86) and 0.35 – 0.45 m (8.06) was measured in the group of Mollic Fluvisols on carbonatic alluvial materials. Soil was used as ploughed land, lowest mean value of active soil reaction in depth 0 – 10 m (3.93) and 0.35 – 0.45 m (4.42) was determined in soil group Haplic Podzols, Skeletic Leptosols and Lithic Leptosols used in the form of permanent grassland. According the Z-criterion of Wilcoxon Ordinal Test were the soil reaction changes in 1993 and 1997 evident only in the case of Eutric Cambisols (arable land, depth 0 – 0.10 m) and Dystric Planosol (arable land, depth 0.35 – 0.45 m).

Active aluminium-level in depth 0 – 0.10 m) ranged 0.49 to 835.0 $mg.kg^{-1}$ with average value 62.11 $mg.kg^{-1}$. Median in the set given was significantly lower -6.32 $mg.kg^{-1}$. Active aluminium-mean level in studied groups of soils in 1997 was ranging 2.40 to 518.80 $mg.kg^{-1}$, the highest mean value was registered in depth 0 – 0.10 m -518.80 $mg.kg^{-1}$ was determined in the soil group Haplic Podzols, Skeletic Leptosols and Lithic Leptosols. The lowest value was registered in the soil group Mollic Fluvisols upon non-carbonatic alluvial sediments -2.40 $mg.kg^{-1}$. Between active aluminium-level and pH/KCl was determined high significant negative multiplicative correlation dependence with r-value = -0.88 (in depth 0 – 0.10 m) and r = 0.91 in depth 0.35 – 0.45 m).

Keywords: soil reaction, active aluminium content, acidification, active aluminium content in main soil types SR

ABSTRAKT

Stanovenie aktívnej a výmennej pôdnej reakcie v súbore 305 pôdnych vzoriek nám umožnilo porovnať rozdiely medzi jednotlivými stanoveniami. Najvyššia priemerná hodnota aktívnej pôdnej reakcie vyjadrená v pH/H_2O v hĺbke 0 – 0,10 m (7,86) a 0,35 – 0,45 m (8,06) bola nameraná v skupine čiernic vyvinutých na karbonátových aluviálnych substrátoch využívaných ako orná pôda, najnižšia priemerná hodnota aktívnej pôdnej reakcii v hĺbke 0 – 0,10 m (3,93) a 0,35 – 0,45 m (4,42) bola nameraná v skupine podzoly, rankre a litozeme využívaných ako trvalý trávny porast. Podľa Z-kritéria Wilcoxonovho poradového testu boli zmeny pôdnej reakcie v rokoch 1993 a 1997 preukazné len v prípade kambizeme (orná pôda, hĺbka 0 – 0,10 m) a pseudogleja (orná pôda, hĺbka 0,35 – 0,45 m).

Obsah aktívneho hliníka v hĺbke 0 – 0,10 m sa pohyboval v rozsahu od 0,49 do 835,0 $mg.kg^{-1}$, s priemernou hodnotou 62,11 $mg.kg^{-1}$, medián v danom súbore bol výrazne nižší, a to 6,32 $mg.kg^{-1}$. Priemerný obsah aktívneho hliníka v sledovaných skupinách pôd sa v roku 1997 pohyboval v rozsahu od 2,40 do 518,80 $mg.kg^{-1}$, najvyššia priemerná hodnota v hĺbke 0 – 0,10 m 518,80 $mg.kg^{-1}$ bola stanovená v skupine pôd podzoly, rankre a litozeme, najnižšia bola nameraná v skupine pôd čiernice na nekarbonátových aluviálnych sedimentoch a to 2,40 $mg.kg^{-1}$. Medzi obsahom aktívneho hliníka a pH v KCl bola stanovená vysoko preukazná záporná multiplikatívna korelačná závislosť, s hodnotou r = -0,88 (v hĺbke 0 – 0,10 m) a r = -0,91 (v hĺbke 0,35 – 0,45 m).

KĽÚČOVÉ SLOVÁ: pôdna reakcia, obsah aktívneho hliníka, acidifikácia, obsah aktívneho hliníka v hlavných pôdnych typoch SR

INTRODUCTION

Acidification of soil is caused by natural processes in the agro-ecosystem (acid bedrocks, leaching of base cations with precipitating, nitrification, redox processes, production of weak acids in the soil) and anthropogenic factors. Anthropogenic sources of soil acidification are mainly acid atmospheric deposition, acidifying fertilizers together with incorrect agricultural operations, industrial and municipal wastes (Kanianska, 2000). Actual value of soil reaction determines the main processes in the agro-ecosystem dependent on pH. Acidification of soil caused changes in the buffering processes, availability of nutrients, different metal forms, increase of heavy metal mobility and active aluminium content (Makovníkova, Kanianska, 2001). Aluminium mobility is considered as one of the most adverse effects of acidification. Aluminium impacts on live organisms are high toxic. Aluminium in higher levels is acting toxically both on plats and animals (Makovníková, Kanianska, 1996). P uptake is inhibited at plants, as well as growth of root hairs negatively is effected plant capacity for uptake Ca, Mg, Mn and Zn, this has negative impact on total health condition and plant development.

Primary functions in the development of pH-value play natural barriers against acidification–buffer systems of soils. Three dominant buffer systems control soil acidification in Slovak soils: carbonate, silicate and cation exchange, aluminium (Kanianska, 2000). Soil buffer system determined the resistance of soil acidification. The soils can by separated in three groups (Bedrna, 1994) according to acidification resistance: resistant, weakly resistant and non-resistant. Chernozems, Luvisols, Mollic Fluvisols on calcaric sediments, Eutric Fluvisols and Rendzic Leptosols with carbonate and silicate buffer system are resistant. Mollic Fluvisols and Eutric Fluvisols on non-calcaric sediments, Cambisols, Gleyic Stagnosols and Eutric Andosols with silicate and cation exchange systems are weakly resistant and Podzols, Skeletic Leptosols, Regosols and Dystric Cambisols with aluminium buffer system are non-resistant.

The capacity of buffer system is reflected in actual pH-value of soil. The value of pH with cation exchange capacity and active aluminium content belong to main indicators of soil acidification. This paper is showing the actual status and development of pH-values and active aluminium content in main Slovakian soil types.

MATERIAL AND METHODS

Status and development of pH-values agricultural land of Slovakia have been observed in the frame of Partial monitoring system – Soil (1993 and 1997 year) including 292 soil samples from depth 0 – 0.10 m, 0.20 – 0.30 m, 0.35 – 0.45 m that represent all of the most frequent soil types and subtypes of main regions of Slovakia (Kobza, 1999). In the soil samples were analysing following parameters: active pH-value pH/H_2O (potentiometric analysis, proportion between soil and water 1:2.5), exchangeable pH-value pH/$CaCl_2$ (potentiometric analysis, proportion between soil and 0.01 $mol.l^{-1}$ $CaCl_2$ 1:2) and pH/KCl (potentiometric analysis, proportion between soil and 1 $mol.l^{-1}$ KCl 1:2.5) (Fiala, 1999). In the samples with pH in KCl lower than 6.0 active aluminium (Al) was determined by Sokolov (soil is extracted with 1N KCl, Al is precipitated with NaF). The statistical program STATGRAPHICS 5.0 was used.

RESULTS AND DISCUSSION

Actual pH status (in 1997 year) and statistical distribution in depth 0 – 0.10 m and 0.35 – 0.45 m for arable land and in depth 0 – 0.10 m, 0.20 – 0.30 m, 0.35 – 0.45 m for permanent grassland are presented in Table 1 (arithmetic mean, minimum and maximum).

The highest average pH/H_2O value in the depth of 0 – 0.10 m (7.86) and in the depth of 0.35 – 0.45 m (8.06) was measured in Mollic Fluvisols calcaric (arable land) (Tab. 1). The lowest average pH/H_2O value in the depth of 0 – 0.10 m (3.93) and in the depth of 0.35 – 0.45 m (4.42) was measured in Haplic Podzols (permanent grassland). The differences between pH-value in all depth are caused by natural factors (acid or alkaline bedrocks, redox processes) and anthropogenic factors (anthropogenic acidification, agricultural operation, arable land or permanent grassland). The presence of carbonate is more expressive in pH-values in depth 0.35 – 0.45 m in soil groups on carbonated or non-carbonated sediments, for example in Fluvisols group on carbonated sediments is arithmetic mean of pH in H_2O 7.89 and in Fluvisols group on non-carbonated sediments 6.80 in depth 0.35 – 0.45 m and in Mollic Fluvisols group on carbonated sediments is arithmetic mean of pH in H_2O 8.06 and in Mollic Fluvisols group on non-carbonated sediments 6.66 in depth 0.35 – 0.45 m.

The development of active pH-value in H_2O in main Slovakian soil representative show Figure 1 (in depth 0 – 0.10 m) and Figure 2 (in depth 0.35 – 0.45 m).

Table 1 Actual status of pH-value, arithmetic mean, minimum and maximum

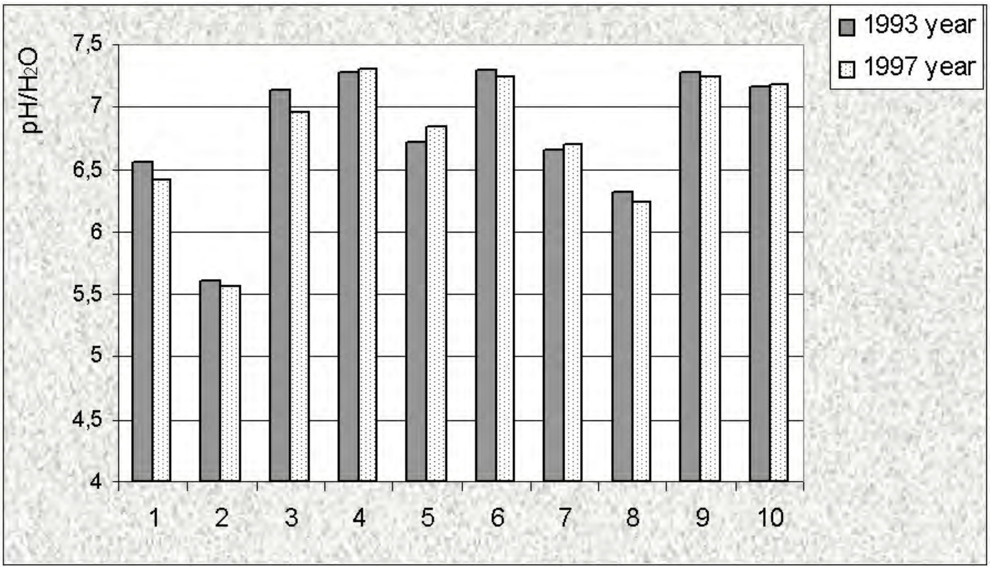
Soil group		Depth in m	pH in H_2O			pH in KCl			pH in $CaCl_2$		
			x_{min}	x_{max}	x	x_{min}	x_{max}	x	x_{min}	x_{max}	x
Podzols, Dystric Leptosols, Leptosols	PG	0 – 0.10	3.66	4.11	3.93	3.30	4.62	3.42	3.23	4.80	3.48
		0.20 – 0.30	3.28	4.74	4.18	3.54	4.14	3.75	3.53	4.28	3.76
		0.35 – 0.45	3.14	4.83	4.42	3.74	4.29	4.07	3.72	4.40	4.12
Rendzic Leptosols	PG	0 – 0.10	5.96	7.60	7.18	5.20	7.98	6.75	5.53	7.70	6.79
		0.20 – 0.30	6.15	7.87	7.11	5.23	7.29	6.46	5.52	7.80	6.87
		0.35 – 0.45	6.37	8.05	7.57	5.34	7.20	6.86	5.23	7.64	6.96
Rendzic Leptosols	AL	0 – 0.10	6.28	7.62	7.25	5.37	7.18	6.67	5.67	7.58	6.93
		0.35 – 0.45	6.70	7.87	7.49	5.81	7.53	6.86	6.19	7.66	7.17
Mollic Fluvisols on carb. sediments	AL	0 – 0.10	7.30	8.50	7.86	6.65	7.59	7.33	7.03	8.14	7.67
		0.35 – 0.45	7.67	9.05	8.06	7.04	7.88	7.53	7.33	8.02	7.81
Mollic Fluvisols on non-carb. sediments	AL	0 – 0.10	5.83	6.99	6.43	5.06	6.64	5.83	5.23	6.55	5.95
		0.35 – 0.45	5.45	7.82	6.66	4.25	7.09	5.86	4.57	7.45	6.12
Fluvisols and Gleyic Fluvisols on carbonated sediments	AL	0 – 0.10	6.86	8.11	7.66	6.06	7.66	7.13	6.34	7.98	7.38
		0.35 – 0.45	7.31	8.35	7.89	6.27	7.96	7.29	6.93	7.94	7.55
Fluvisols and Gleyic Fluvisols on non-carbonated sediments	AL	0 – 0.10	4.56	7.63	6.65	3.67	6.88	5.87	3.59	7.30	5.90
		0.35 – 0.45	4.70	7.62	6.80	3.73	7.26	5.91	3.83	7.60	6.08
Cambisols on vulkanitoch	GL	0 – 0.10	4.63	6.45	5.19	3.65	6.09	4.59	4.00	6.05	4.88
		0.20 – 0.30	5.15	5.66	5.43	3.90	4.44	4.42	4.38	5.08	4.79
		0.35 – 0.45	5.35	6.35	5.72	3.93	5.54	4.63	4.46	5.80	5.08
Cambisols on vulcanites	AL	0 – 0.10	5.79	7.09	6.40	5.22	6.40	5.68	5.22	6.52	5.84
		0.35 – 0.45	5.17	7.00	6.21	4.17	6.01	5.21	4.63	6.38	5.61
Cambisols on flysch	GL	0 – 0.10	4.49	7.24	5.64	3.56	6.93	4.88	4.01	7.13	5.14
		0.20 – 0.30	4.39	7.50	5.77	3.47	7.12	4.76	3.77	7.34	5.20
		0.35 – 0.45	4.55	7.52	5.89	3.69	7.07	4.68	3.92	7.25	5.21

Table 1 Actual status of pH-value, arithmetic mean, minimum and maximum (continues)

Soil group		Depth in m	pH in H_2O			pH in KCl			pH in $CaCl_2$		
			x_{min}	x_{max}	x	x_{min}	x_{max}	x	x_{min}	x_{max}	x
Cambisols on flysch	AL	0 – 0.10	4.54	7.59	6.29	3.94	7.17	5.64	4.19	7.56	5.89
		0.35 – 0.45	5.28	8.00	6.51	4.13	7.23	5.45	4.56	7.65	6.03
Cambisols on acidic substrares	GL	0 – 0.10	4.11	6.20	5.33	3.52	5.65	4.44	3.71	5.46	4.56
		0.20 – 0.30	4.45	6.66	5.63	3.79	6.31	4.83	3.81	6.27	4.88
		0.35 – 0.45	4.46	6.68	5.75	3.78	5.59	4.57	3.85	6.12	4.87
Cambisols on acidic substrares	AL	0 – 0.10	5.61	7.09	6.36	4.92	6.64	5.67	5.11	6.75	5.81
		0.35 – 0.45	5.46	7.01	6.28	4.50	6.48	5.38	4.89	6.67	5.76
Cambisols on limestones calcites	GL	0 – 0.10	5.70	7.22	6.80	5.02	6.80	6.32	5.35	7.12	6.60
		0.20 – 0.30	6.63	7.48	7.19	6.20	6.99	6.74	6.27	7.35	6.96
		0.35 – 0.45	7.24	7.57	7.42	6.35	7.08	6.73	6.85	7.24	7.12
Cambisols on limestones calcites	AL	0 – 0.10	6.75	7.60	7.18	6.01	6.86	6.44	6.22	7.21	6.61
		0.35 – 0.45	7.00	7.72	7.36	6.02	6.95	6.49	6.35	7.25	6.83
Gleyic Stagnosols on loess loams	AL	0 – 0.10	5.30	7.95	6.70	4.47	7.42	6.05	4.65	7.68	6.17
		0.35 – 0.45	4.65	7.91	6.45	3.81	7.21	5.48	4.13	7.42	5.86
Gleyic Stagnosols on loess loams	GL	0 – 0.10	5.41	7.20	6.24	5.00	6.55	5.69	4.88	7.31	5.98
		0.20 – 0.30	5.55	6.96	6.17	4.82	6.38	5.42	4.91	6.95	5.74
		0.35 – 0.45	5.59	7.32	6.34	4.44	6.49	5.44	5.02	6.93	5.86
Haplic Luvisols on loess	AL	0 – 0.10	4.99	7.98	6.85	3.89	7.28	6.19	4.26	7.73	6.55
		0.35 – 0.45	4.52	8.21	6.88	3.36	7.46	5.99	3.86	7.96	6.48
Chernozems on loess	AL	0 – 0.10	5.38	8.01	7.31	4.52	7.53	6.71	4.82	7.67	6.81
		0.35 – 0.45	5.41	8.19	7.69	4.51	7.74	6.93	4.95	7.84	7.07

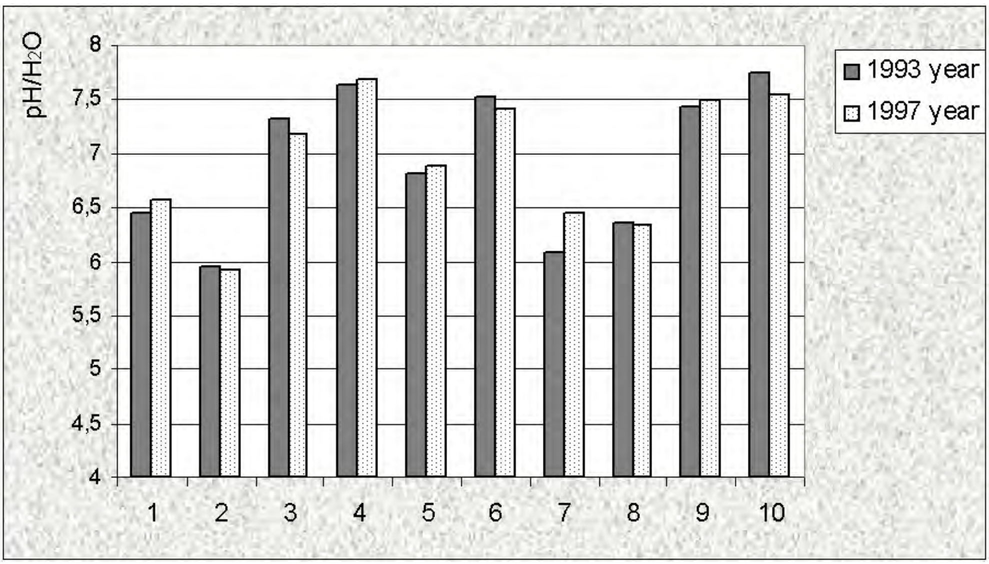
AL – arable land, GL – permanent grassland, x_{min} – minimum, x_{max} – maximum, x – arithmetic mean

Figure 1 Development of active pH-value in H_2O in main Slovakian soil representative in depth 0 – 0.10 m



1 – Eutric Cambisol, 2 – Dystric Cambisol, 3 – Fluvisol, 4 – Chernozem, 5 – Orthic Luvisol, 6 – Phaeozem, 7 – Planosol, 8 – Planosol, 9 – Rendzina, 10 – Rendzina

Figure 2 Development of active pH-value in H_2O in main Slovakian soil representative in depth 0.35 – 0.45 m



1 – Eutric Cambisol, 2 – Dystric Cambisol, 3 – Fluvisol, 4 – Chernozem, 5 – Orthic Luvisol, 6 – Phaeozem, 7 – Planosol, 8 – Planosol, 9 – Rendzina, 10 – Rendzina

Changes in pH/H_2O values between 1993 and 1997 years were statistically significant, according to Z-parameter of Wilcox ranks test, (Z lower than 0.05) in the case of Planosol (arable land, in the depth of 0.35 – 0.45 m) and Cambisol (arable land, in the depth of 0 – 0.1 m) (Table 2).

Table 2 Wilcox on ranks test of pH/H_2O in 1993 and 1997 years

Z-parameter											
Soil representative		**1 AL**	**2 GL**	**3 AL**	**4 AL**	**5 AL**	**6 AL**	**7 AL**	**8 GL**	**9 AL**	**10 GL**
depth (m)	0 – 0.10	0.02	0.48	0.52	0.79	0.16	0.59	0.53	0.52	0.62	0.72
	0.35 – 0.45	0.57	0.64	0.66	0.48	0.34	0.22	0.01	0.10	0.36	0.72

1 – Eutric Cambisol, 2 – Dystric Cambisol, 3 – Fluvisol, 4 – Chernozem, 5 – Orthic Luvisol, 6 – Phaeozem, 7 – Planosol, 8 – Planosol, 9 – Rendzina, 10 – Rendzina
AL – arable land, GL – permanent grassland

Changes of pH-value in Cambisol in the depth 0 – 0.10 m can be influenced with decrease of agricultural operation to optimalization of pH-value, witch is very important for soil types developed on acid bedrocks.

Al-substance becomes more mobile in conditions with acid and very acid soil reaction. Up to boundary pH in KCl lower than 6.0 dominant form Al in soil solution is ion Al^{3+} surrounded with six water molecules. With increasing pH-value Al-ions are gradually changed to insoluble aluminium hydroxide (Kanianska, Makovníková, 1997). Active aluminium content (1997 year) and statistical distribution in depth 0 – 0.10 m and 0.35 – 0.45 m for arable land and in depth 0 – 0.10 m, 0.20 – 0.30 m, 0.35 – 0.45 m for permanent grassland are presented in Table 3 (arithmetic mean, minimum and maximum).

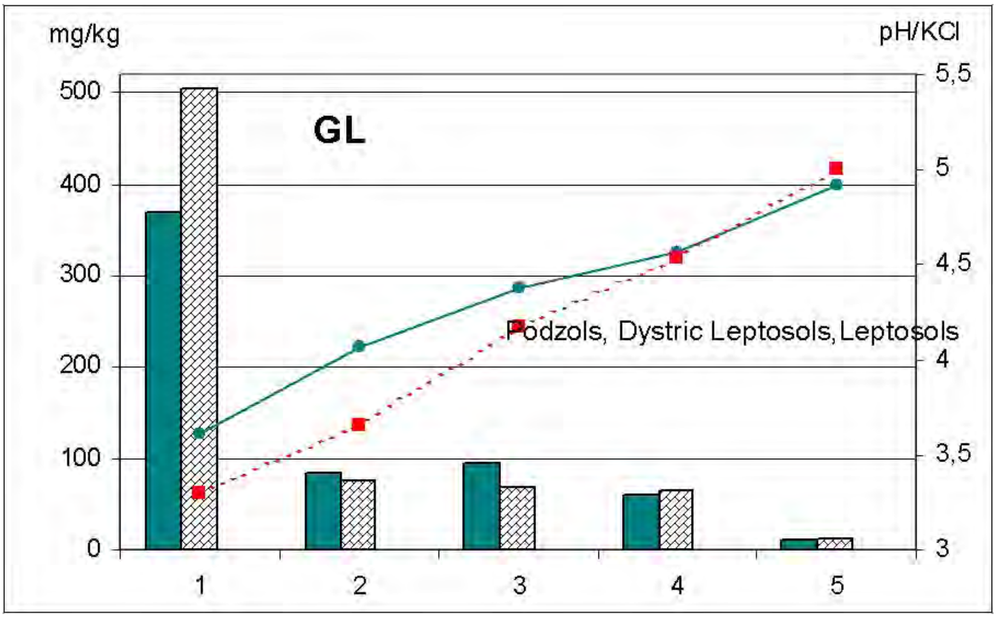
Al active content was in the range 0.49 – 835.0 mg.kg^{-1} in the depth 0 – 10 cm, average value was 62.11 mg.kg^{-1} and median 6.32 mg.kg^{-1}. Measured average value of active Al was highest in the group Podzols, Lithic Leptosols and Skeli-Dystric Leptosols (518.80 mg.kg^{-1}) and lowest in the group Mollic Fluvisols non-calcaric (2.40 mg.kg^{-1}). The values measured are processed by correlation analysis with shows negative multiplication between Al content and pH in KCl in depth 0 – 10 cm (r = -0.88) and in depth 35 – 45 cm (r = -0.91) too. This finding is in agreement with Kozák, Boruvka (1989).

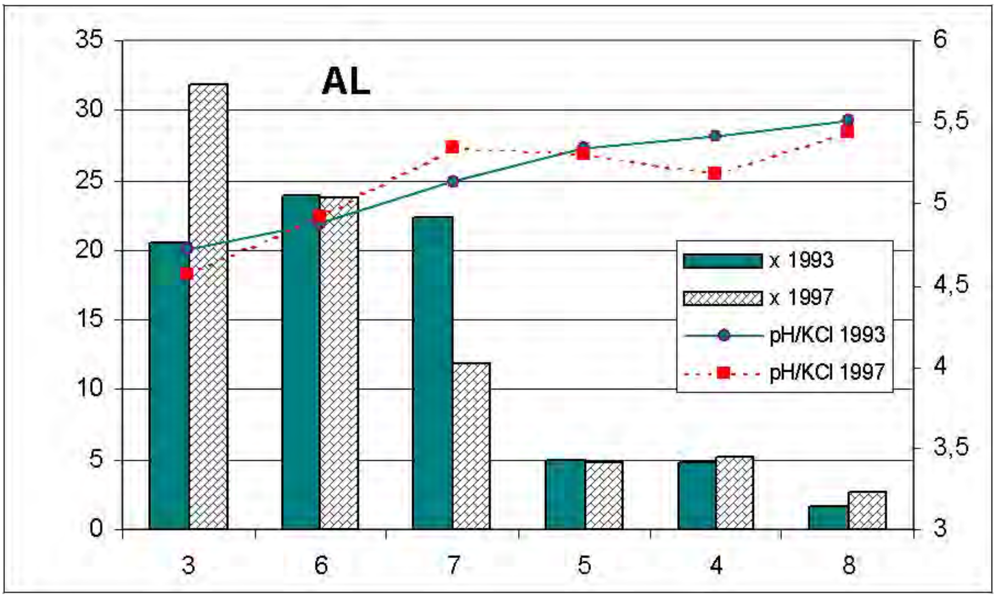
The development of active aluminium content in main Slovakian soil representative in depth 0 – 0.10 m shows Figure 3 for permanent grassland and for arable land. Changes in active aluminium-content between 1993 and 1997 years were not statistically significant. The more expressive increase we can see in Podzols, Dystric Leptosols and Leptosols group with is combined with decrease of pH-value in this group. Active aluminium contents in arable lands are lower than in permanent grassland groups, gentle decrease of active aluminium content is determined in Haplic Luvisols group.

Table 3 Actual status of pH-value, arithmetic mean, minimum and maximum

Soil group		Active aluminium content mg.kg^{-1}			
		Depth	Arithmetic mean	Minimum	Maximum
Podzols, Dystric Leptosols, Leptosols	GL	0 – 0.10 m	518.80	211.50	835.00
		0.10 – 0.20 m	347.70	153.80	560.80
		0.35 – 0.45 m	154.20	67.10	250.20
Cambisols on acidic substrares	GL	0 – 0.10 m	107.11	2.70	490.80
		0.10 – 0.20 m	63.40	1.80	442.40
		0.35 – 0.45 m	85.10	0.90	437.80
Cambisols on acidic substrares	AL	0 – 0.10 m	5.20	3.60	12.32
		0.35 – 0.45 m	6.85	2.07	14.40
Cambisols on flysch	GL	0 – 0.10 m	70.30	0.97	257.40
		0.10 – 0.20 m	127.90	1.03	532.40
		0.35 – 0.45 m	114.70	1.49	416.50
Cambisol on vulcanites	GL	0 – 0.10 m	78.10	0.90	266.40
		0.10 – 0.20 m	49.20	3.60	148.80
		0.35 – 0.45 m	39.40	1.80	109.80
Gleyic Stagnosols on loess loams	GL	0 – 0.10 m	9.83	0.9	38.70
		0.10 – 0.20 m	11.40	0.9	36.90
		0.35 – 0.45 m	0.74	0.31	1.89
Gleyic Stagnosols on loess loams	AL	0 – 0.10 m	4.13	0.49	21.60
		0.35 – 0.45 m	28.49	0.46	238.10
Fluvisols and Gleyic Fluvisols on non-carbonated sediments	AL	0 – 0.10 m	66.10	0.90	240.30
		0.35 – 0.45 m	60.50	0.45	179.10
Haplic Luvisols on loess	AL	0 – 0.10 m	9.83	0.49	60.33
		0.35 – 0.45 m	39.47	0.90	374.80
Mollic Fluvisols on non-carb. Sediments	AL	0 – 0.10 m	2.40	0.98	3.60
		0.35 – 0.45 m	20.80	0.10	99.80

Figure 3 Development of active aluminium in soil representative





x – 1993, 1997 – arithmetic average in 1993 and 1997 years, GL – grassland group, AL – arable land group

1 – Podzols, Dystric Leptosols, Leptosols, 2 – Cambisols on vulcanites, 3 – Cambisols on flysch, 4 – Cambisols on acidic substrates, 5 – Gleyic Stagnosols on loess loams, 6 – Fluvisols on non-carb. Sediments, 7 – Haplic Luvisols on loess, 8 – Mollic Fluvisols on non-carb. Sediments

CONCLUSIONS

The highest average pH/H_2O value in the depth of 0 – 0.10 m (7.86) and in the depth of 0.35 – 0.45 m (8.06) was measured in Mollic Fluvisols calcaric (arable land). The lowest average pH/H_2O value in the depth of 0 – 0.10 m (3.93) and in the depth of 0.35 – 0.45 m (4.42) was measured in Haplic Podzols (permanent grassland). Changes in pH/H_2O values between 1993 and 1997 years were statistically significant, according to Z-parameter of Wilcox ranks test, in the case of Planosols (arable land, in the depth of 0.35 – 0.45 m) and Cambisol (arable land, in the depth of 0 – 0.1 m). Al active content was in the range 0.49 – 835.0 $mg.kg^{-1}$ in the depth 0 – 10 cm, average value was 62.11 $mg.kg^{-1}$ and median 6.32 $mg.kg^{-1}$. Measured average value of active Al was highest in the group Podzols, Lithic Leptosols and Skeli-Dystric Leptosols (518.80 $mg.kg^{-1}$) and lowest in the group Mollic Fluvisols uncalcaric (2.40 $mg.kg^{-1}$) in the depth 0 – 0.10 m. In arable lands is very important higher content of active aluminium in the depth 0.35 – 0.45 m, where inhibited growth of root, and is negatively effected water regime of plants. The measured values are processed by correlation analysis with shows negative multiplication between Al-content and pH in KCl in depth 0 – 10 cm (r = -0.88) and in depth 35 – 45 cm (r = -0.91), too.

The way how to prevent active aluminium into food chain and underground waters is optimalization pH-value in soil through liming, whereby soil reaction regulate soil chemismus and is initiator of increase of heavy metal mobility and active aluminium content in soil.

REFERENCES

BEDRNA, Z.: Resistibility of Landscape to Acidification, Ekológia, 13, 1994, s. 77 – 86.

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

KANIANSKA, R., MAKOVNÍKOVÁ, J.: Mobil Al actual status in Slovakian soils. Vedecké práce 20/II., VÚPÚ Bratislava, 1997.

KANIANSKA, R.: Acidifikácia vplyvom kyslých atmosférických polutantov. Pedo-Disertationes. Bratislava, 2000, 96 s.

MAKOVNÍKOVÁ, J., KANIANSKA, R.: Changes in soil reaction and active aluminium content induced by simulation of acid precipitation. Rostlinná výroba, 42, 1996, s. 155 – 159.

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

KOBZA, J. a kol.: Monitoring pôd Slovenska. Priebežná správa, VÚPOP Bratislava, 1999, s.180.

KOZÁK, J., BORUVKA, L.: Species of Al ions as related to some characteristics of both agricultural and forest soils of the Šumava region. Rostlinná výroba, 44, 1998 (9), s. 419 – 426.

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

POLLUTION IMPACT ON SELECTED BIOLOGICAL SOIL PROPERTIES IN CENTRAL SPIŠ

VPLYV ZNEČISTENIA NA VYBRANÉ BIOLOGICKÉ VLASTNOSTI PÔD STREDNÉHO SPIŠA

LIBUŠA MATÚŠKOVÁ, JÁN VOJTÁŠ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

The research was focused on pollution identification and its impact on microorganisms and biological processes in soils of Central Spiš. Our objective was soil biological properties characterisation in pedogeochemically contamined soils, to verify contamination impact on biological property changes as soil pollution indicators. The farmland, where pollution level ranged from A-limit level (0.3 mg.kg^{-1}) to C-value (above 20 mg.kg^{-1}), was sampled. The results showed, mercury was not a typical case of heavy metals affect on soil microorganisms and soil biological processes, as Hg in natural environment can be active in various forms, from there is dependent Hg-bioaccumulation and impact on environment.

KEYWORDS: pollution, biological soil properties, microorganisms

ABSTRAKT

Výskum bol zameraný na identifikáciu znečistenia a jeho vplyv na mikroorganizmy a biologické procesy v pôde v pôdach stredného Spiša. Cieľom riešenia bolo charakterizovať biologické vlastnosti pôd na pedogeochemicky kontaminovaných pôdach, overiť dopad kontaminácie na zmeny v biologických vlastnostiach ako indikátorov znečistenia pôd. Vzorky pôd boli odobraté z poľnohospodárskych pôd, kde úroveň znečistenia sa pohybovala od hodnoty na úrovni A limitu (0,3 mg.kg^{-1}) po hodnotu C (nad 20 mg.kg^{-1}). Výsledky výskumu ukázali, že ortuť nie je typickým prípadom vplyvu ťažkých kovov na pôdne mikroorganizmy a biologické procesy v pôde, nakoľko ortuť sa v prírodnom prostredí môže vyskytovať v rôznych formách, od ktorých závisí jej bioakumulácia a účinky na prostredie.

KĽÚČOVÉ SLOVÁ: znečistenie, biologické vlastnosti pôdy, mikroorganizmy

INTRODUCTION

Decisive role for soil ecological functions conservation belongs to microorganisms, they are responsible for biological cycle of nutrients, decomposition and heterogenous chemical substances detoxication in soil. First observations of heavy metals impact on soil microbial processes were dated on 20th century beginning (Lipman, Buges, 1914; Brown, Minges, 1916). Till in years 1960 – 70, when was observed extensive harmful effect of heavy metals pollution from mine-resources on surrounding ecosystems. Also was observed soil microbial processes disturbtion by increasing heavy metals (HM) concentration. Extreme HM concentrations round exploiting mines and preparation plants for ore materials canted visible impact on HM accumulation in organic mass through soil organisms activities and soil fauna inhibition (Tyler, 1975; Stojan, 1978; Freedman, Hutchinson, 1980).

Toxic elements are moving in environment in natural conditions via "geocycles", where the elements become available for plants and animals. Human activity offers new sources of toxic elements affecting "geocycle" and gradually the elements availability for biological processes (Wood, 1974).

MATERIALS AND METHODS

Our research territory of interest is located in Volovské Vrchy mountains and part of transition into Hornadska Kotlina basin on the estuary of deep and narrow Rudňavský Potok valley. Main share on atmosphere pollution had Železnorudné Bane Rudňany and Kovohuty Krompachy (metalurgy).

Investigation of mercury load effect on soil biological properties was started in October 1999 (Tab. 1). Based on the load of given territory by Hg were selected four sampling locations, where pollution level ranged between A-limit level (0.3 mg.kg^{-1}) and C-value (above 20 mg.kg^{-1}).

Table 1 Mercury pollution (mg.kg^{-1})

Date sampling	**20. 10. 1999**
Site	Content Hg (mg/kg)
Poráč	21.230
Olšo	10.730
Markušovce	1.990
Lieskovany	0.353

Figure 1 Hg (sampling 20. 10. 1999)

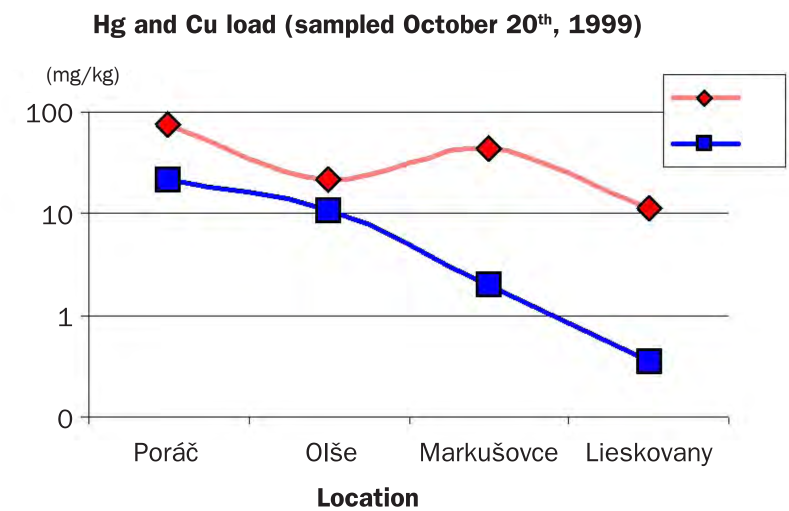


Table 2 Agronomy – hygienical characteristics of sampling locations

Site	Soils type	pH/KCl	Cox %	Contamination	Utilisation
Poráč	RNk – ranker kambizemný stredne ťažká	4.95	2.4	Hg	Pasture
Olšo	KMg – kambizem pseudoglejová stredne ťažká	4.80	2.3	Hg	Arable soils
Markušovce	PG – pseudoglej stredne ťažký	6.75	2.0	Hg	Arable soils
Lieskovany	PG – pseudoglej stredne ťažký	7.32	2.2	Hg	Arable soils

Soil sampling and processing

For soil biological soil properties investigation sampling depth was 0.05 – 0.1 m. After it followed sieving through 2 mm sieve. Before proper determination were soil samples pre incubated (7 days).

Parameters investigated

Moisture, respiration, soil microorganisms biomass, dehydrogenase activity, nitrification, total and sporuling bacteria, cellulolythic and N_2 fixing bacteria. actinomycetes, pseudomonades, fibric fungi, oligotrophic bacteria, humus, total nitrogen (Filip, 1995).

RESULTS AND DISCUSSION

Mercury takes particular position among heavy metals. In natural environment Hg can be active in different forms, from them is depending Hg-bioaccumulation and impacts on environment. Recent studies are dealing in metal toxicity effect on microbial process in relationships to soil properties. Generally these indicate higher effect on light soils, than on the soils with high clay contents or organic matter (Doelman, Haanstra, 1984; Malissewska, 1985; Hattori, 1992).

Sampling sites investigated belonged among medium heavy soils with approximately the same humus contents. Significant difference among the locations was in soil reaction, whereby the sites most loaded with mercury (Porač, Olšo) had acid reaction (4.95 or 4.8 pH) that was more suitable for methylmercury synthesis in laboratory and natural conditions.

By literature data, mercury substances added into soil in high concentrations have inhibitory effect on CO_2 production (biological activity), dehydrogenase activity as well as nitrification processes.

In Tables 3 and 4, Figures 2 and 3 is presented effect of mercury load on biological activity after 24 hours and 27 day incubation. From mentioned is resulting, the highest biological activity values were observed in the least loaded area Lieskovany.

Table 3 Biological activity (µg/g per 24 hours)

Site/Date	20.10.99	17.3.00	25.5.00	7.7.00	19.9.00	25.10.00
Poráč	60	70	42	30	88	60
Olšo	52	46	50	16	58	34
Markušovce	142	118	176	50	56	96
Lieskovany	182	222	176	206	198	210

Figure 2 Mean biological activity (µg/g per 24 hours)

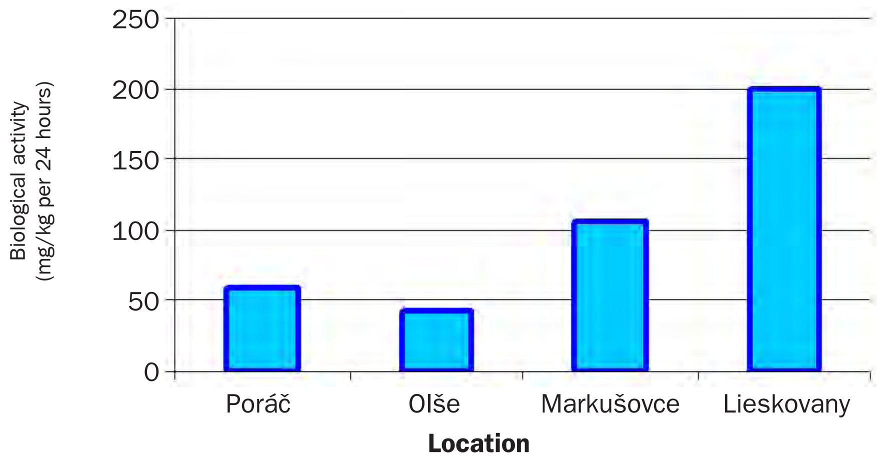


Table 4 Biological activity (µg/g per 27 days)

Lokalita	20.10.99	17.3.00	25.5.00	7.7.00	19.9.00	25.10.00
Poráč	748	790	776	458	844	670
Olšo	576	492	416	206	636	552
Markušovce	1 696	1 060	1 024	462	396	580
Lieskovany	1 166	1 130	1 072	1 186	1 010	1 102

Similar course we have registered also after balance of microbial biomass (after 24 hours and 27 days). The highest values were observed in the least loaded locations, whereby the most loaded Porač is the exception from trend again.

Figure 3   Mean biological activity (μg/g per 27 days)

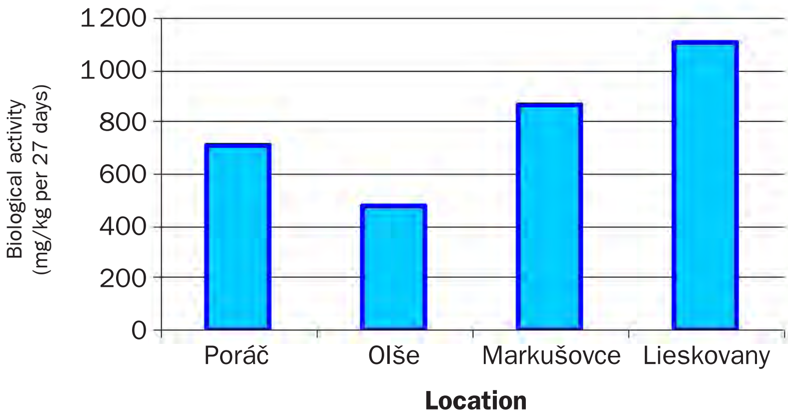


Table 5   Microorganisms biomass values (μg/g per 24 hours)

Lokalita	20.10.99	17.3.00	25.5.00	7.7.00	19.9.00	25.10.00
Poráč	30.3	141.24	505.9	355.4	375.8	446.6
Olšo	69.9	78.1	303.5	251.7	260.5	344.8
Markušovce	19.0	342.5	207.2	373.4	380.1	341.2
Lieskovany	121.3	394.8	219.9	616.1	451.5	560.7

Figure 4   Mean microorganisms biomass values (μg/g per 24 hours)

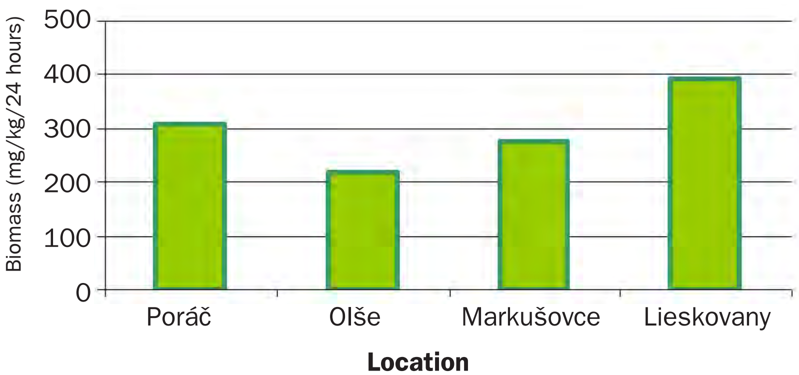


Figure 5 Mean values of microorganisms biomass (μg/g per 27 days)

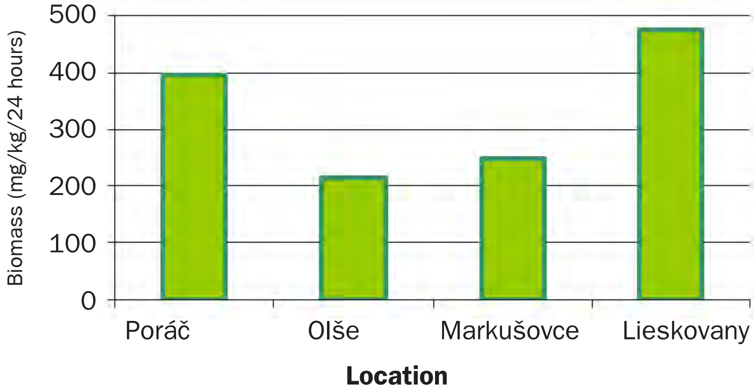


Table 6 Microorganisms biomass values (μg/g per 27 days)

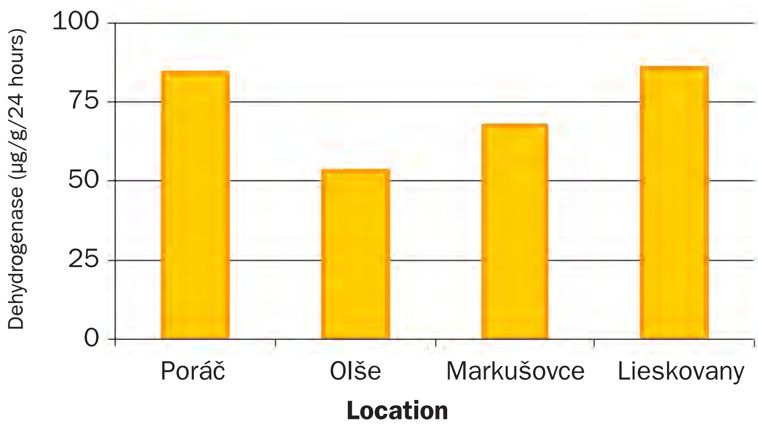
Lokalita	20.10.99	17.3.00	25.5.00	7.7.00	19.9.00	25.10.00
Poráč		480.6	242.1	333.7	464.8	460.9
Olšo		60.5	206.8	234.1	220.8	355.7
Markušovce		162.6	255.8	275.7	185.2	358.7
Lieskovany		459.4	416.5	421.5	389.2	691.8

By literature data dehydrogenase activity belongs to significant indicators of soil pollution. Similar result was registered also at our observations. However dehydrogenase value in the most loaded location Porač (21.2 Hg mg.kg^{-1}) were in the level of dehydrogenase value in the least loaded area Lieskovany (0.353 mg.kg^{-1}). Baath (1989) summarized data of laboratory and field conditions, where at high HMs concentrations in soil was observed no their influence on biological processes, however at low concentration was this influence registered.

Table 7 Dehydrogenase (μg/g per 24 hours)

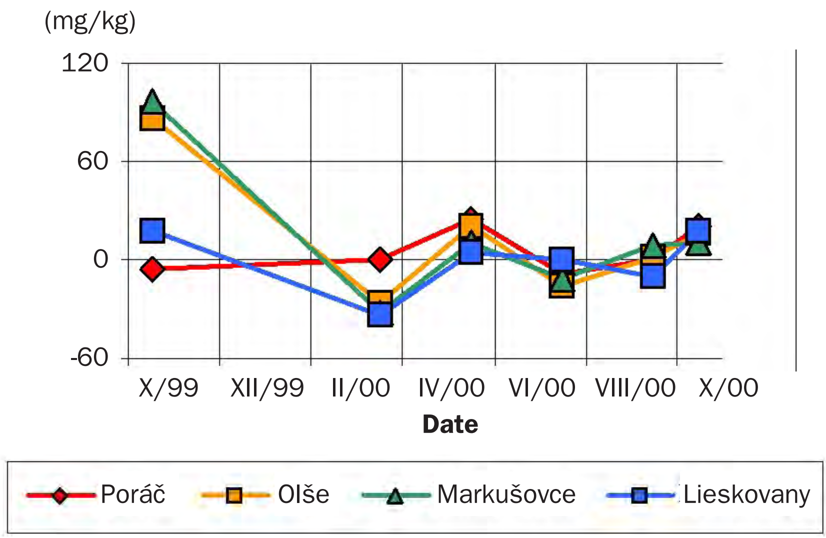
Lokalita	20.10.99	17.3.00	25.5.00	7.7.00	19.9.00	25.10.00
Poráč	40.3	69.2	68.7	81.7	121.5	123.1
Olšo	39.6	36.0	25.2	50.4	73.7	92.8
Markušovce	31.2	44.4	39.6	91.2	79.7	120.1
Lieskovany	71.6	44.3	55.9	102.4	137.1	103.7

Figure 6 Mean dehydrogenase values (µg/g per 24 hours)



Mineral nitrogen accumulation with aspect to its sensibility to environmental properties is limited rather with soil type and its site. Soil type influence and of the site are probably dominating ones soil load effect. Influence of pollution on nitrification and ammonification processes is not evident.

Figure 7 Nitrification (mg/kg)



Effect of mercury pollution on soil organisms was not evident (Figures 8, 9, 10, 11, 12, 13).

Figure 8 N_2 – fixing bacteria

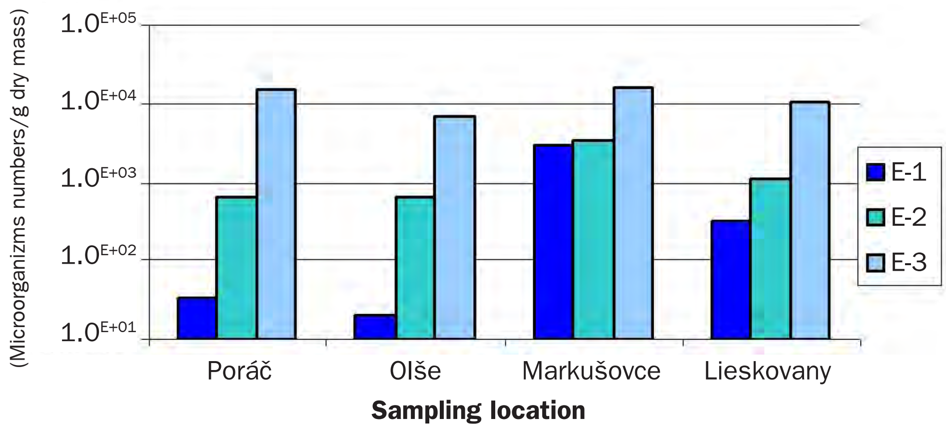


Figure 9 Oligotrophic bacteria

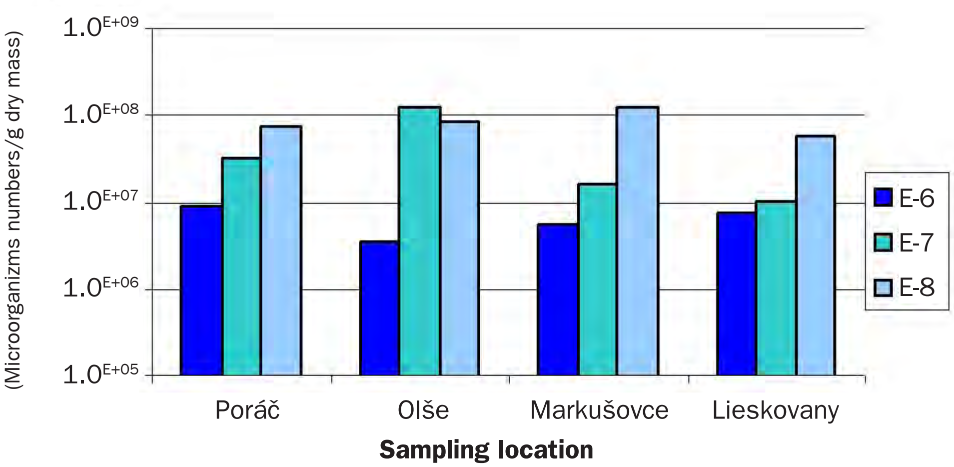


Figure 10 Pseudomonades

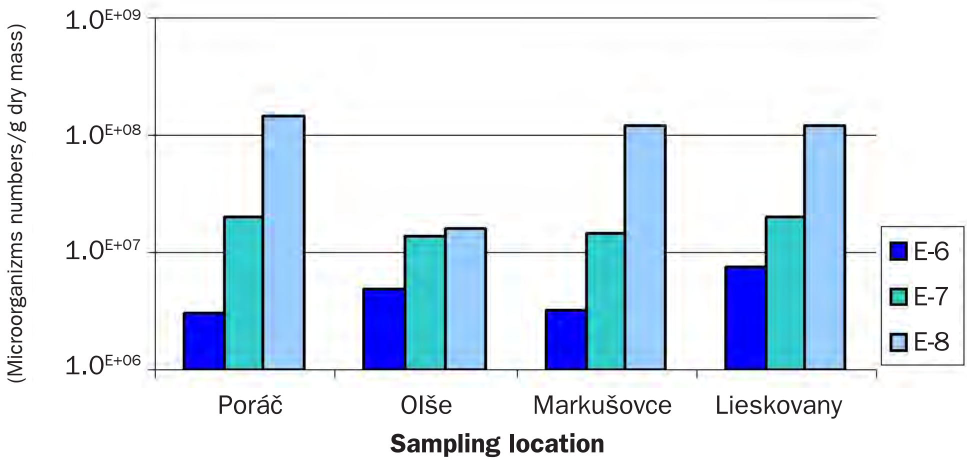


Figure 11 Cellulolythic bacteria

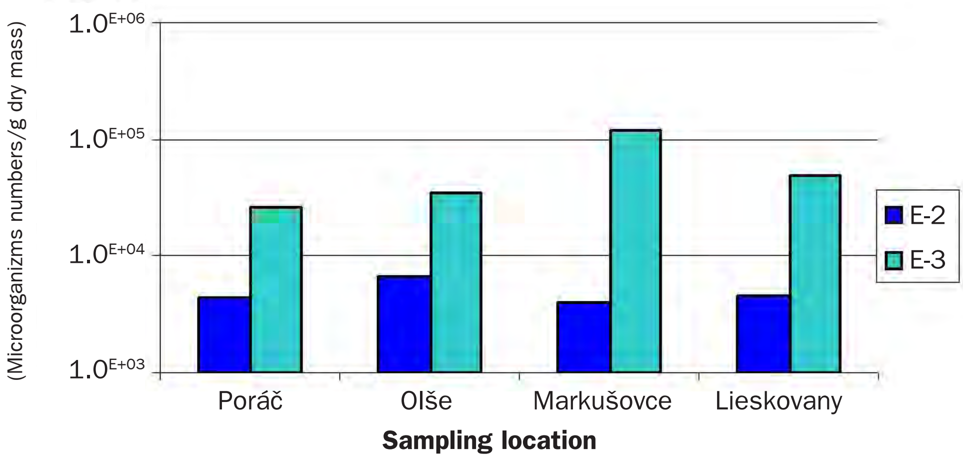


Figure 12 Fibric fungi

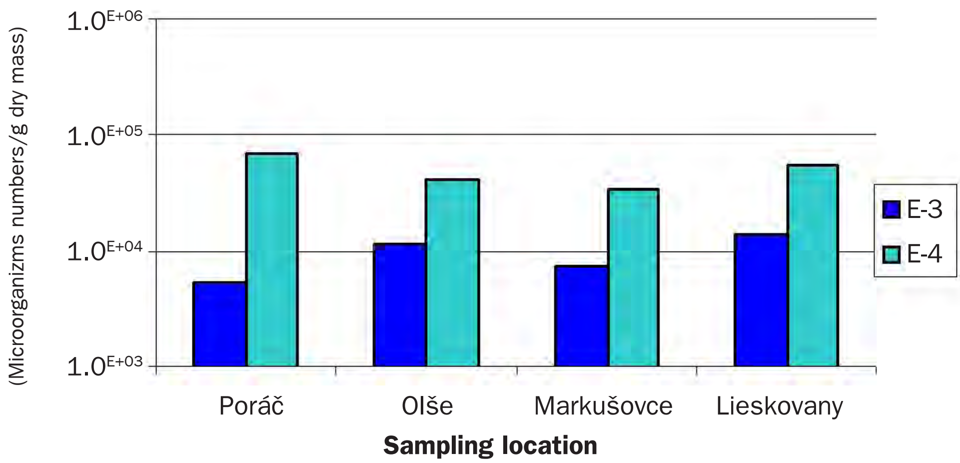
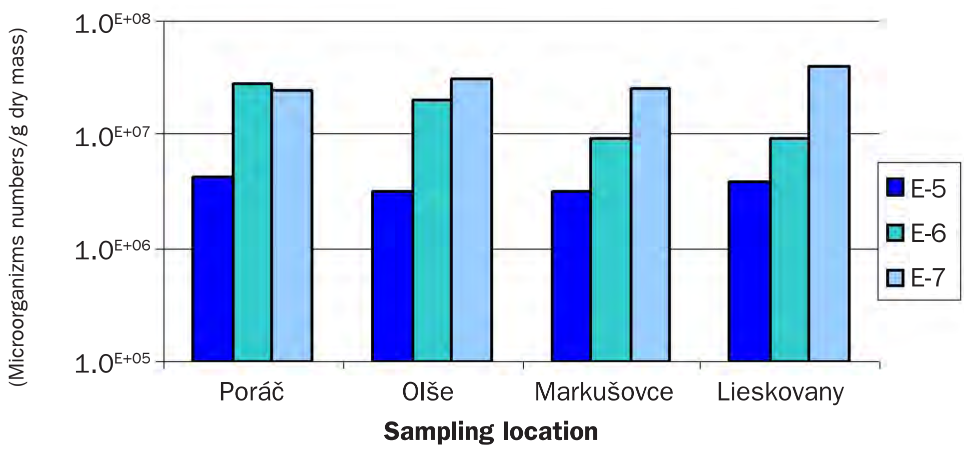


Figure 13 Bacteria total



CONCLUSIONS

The results are in harmony with further authors observations (van Fassen, 1973; Stadelmann, 1984; Dahlin, 1997; Hattori, 1992; Filip, 1997 and others). Mercury compounds added to soil in high concentrations inhibited $C0_2$ production (biological activity), dehydrogenase activity as well as nitrification processes. Microorganisms number reduction due to mercury load was not registered.

Mercury is not typical case of load impact on soil microorganisms. Some bacteria release mercury out of environment by volatilisations (Silver, Mistra, 1988). The factors, influencing microbial activity in soil-moisture, temperature, pH, significantly effect also Hg-transformation in soil. As in there sampling locations was also detected contamination by copper, it is not possible unambiguously to say, how much contributed this fact to our results.

Present research activities are focused to pollution identification and its effect on microorganisms and biological processes, running in soil. Many works (mainly foreign ones) defined concrete biological changes of soil biological properties due to pollution (Filip, 1996, 1997; Anderson, 1982; Tesařova et al., 1988 and others). Sorrowfully, no final conclusions in this topics were not published, whereby are mentioned large differences among the results in laboratory and terrain conditions.

REFERENCES

Doelman P., Haanstra L.: Short term and long term effects of cadmium chromium, copper, nickel, lead and zinc on soil microbial respiration in relation to abiotic soil factors. Plant and Soil 79, pp. 317 – 327, 1984.

Filip, Z.: Entwicklung und Bewertung Biologischer Untersuchungsverfahren zur Kennzeichnung des Naturlichen Boden zustastandes und der Anthropogenen Bodenbelastungrn. Langen, Germany, 1997.

Filip, Z.: Methods of soil analysis. Federal env. Agency, Langen, 1995, Germany.

Freedmann, B., Hutchinson, T.C.: Effect of smelter pollutants on forest litter decomposition near a nickel copper smelter. Canadian Journal of Botany, 58, pp. 1722 – 1736, 1980.

Giller, K.E., Witter, E., Grath, S.P.: Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils. Soil. Biol. Biochem. Vol. 30, No 10/11, pp. 1389 – 1414, 1988.

Hattori H.: Influence of heavy metals on soil microbial activities. Soil Science and Plant Nutrition 38, pp. 93 – 100, 1992.

Maliszewska W. et al.: The influence of various heavy metal compounds on the development and activity of micro-organisms. Environmental Pollution (Series A) 37, pp. 195 – 215, 1985.

Tesařová, M.: Microorganisms and the carbon cycle in terrestrial ecosystems. In: Vancura Soil microbial associations, Elsevier,Amsterdam, 1988.

Tyler G.: Effect of heavy metal pollution on decomposition and mineralization rates in forest soil. Heavy metals in the Environment. Ed. T.C. Hutchinson, Toronto, Canada, pp. 217 – 226, 1975.

Wood, J.M.: Biological cycles for toxic elements in the environment. Science 183, pp. 1049 – 1052, 1974.

Hg BALANCE IN THE SYSTEM CONTAMINED SOIL – WINTER RYE

Bilancia Hg v systéme kontaminovaná pôda – ozimná raž

Miroslav MEDVEĎ, Ján VOJTÁŠ, Libuša MATÚŠKOVÁ
Soil Science and conservation Research Institute, Bratislava

ABSTRACT

In vegetation experiments was studied Hg balance in the system contamined soil – winter rye. Results showed from the mercury present in soil at the beginning of experiments winter rye resorbed 0.05 to 0.12% Hg. 96.6 to 99.3% Hg remained in soil and 0.64 to 3.28% were Hg losses. From Hg amount resorbed by winter rye 89 – 94% Hg was found in roots of rye, 5.3 – 11% in straw, and only 0.05 – 0.23% in grain.

Determined Hg contents in rye did not introduce any risk of the limit exceeding in rye – floor, nor Hg transfer risk into foods of animal origin. Potential danger appear mercury losses from soil into atmosphere. There can introduce several tens – fold Hg amounts than is Hg amount located in overhead parts of winter rye.

Keywords: mercury, contamined soil, winter rye, Hg balance

ABSTRAKT

Vo vegetačných pokusoch bola študovaná bilancia Hg v systéme kontaminovaná pôda – ozimná raž. Výsledky ukázali, že z ortute prítomnej v pôde na začiatku pokusov odčerpala ozimná raž 0,05 až 0,12% Hg, 96,6 až 99,3% Hg zostalo v pôde a 0,64 až 3,28% tvorili straty Hg. Z množstva ortute, ktorá odčerpala ozimná raž na 89 až 94% Hg nachádzalo v koreňoch raže, 5,3 až 11% v slame a len 0,05 až 0,23% v zrne.

Stanovené obsahy Hg v raži nepredstavovali žiadne riziko prekročenia záväzného limitu Hg v ražnej múke ani riziko transféru Hg do potravín živočíšneho pôvodu. Potenciálnym nebezpečím sa javia straty ortute z pôdy do ovzdušia. Tieto môžu predstavovať niekoľko desiatok krát väčšie množstvá Hg ako je množstvo Hg nachádzajúce sa v nadzemnej časti ozimnej raže.

Kľúčové slová: ortuť, kontaminovaná pôda, ozimná raž, bilancia Hg

INTRODUCTION

Soil contamination with mercury can take place in surroundings of plants processing mercury or using it in the manufacturing technologies. In Slovak Republic as contamined soils are considered soils with Hg content above 0.3 $mg.kg^{-1}$ soil sampled from A-horizon (Vojtáš, 2000). Generally soil Hg availability is low for plants with trend to be accumulated in roots. Plant overhead parts however adsorb Hg directly from atmosphere. Some authors mentioned, on total Hg content in plant air deposition can have 90% share. Besides solid phase, in which mercury can be fixed, and Hg occurs also in solved and volatile forms, including inorganic mercury vapours. Beneš (1993) mentioned, metallic Hg in the form of vapours can form even 30% total mercury content in soil.

In order to obtain and disseminate data on Hg transport in cropping ecosystem, exact vegetation experiments were established on contamined soil, and within the experiment was studied Hg balance in the system soil – winter rye.

MATERIALS AND METHODS

The problems were solved in vessel experiment in the research base Macov of Soil Science and Conservation Research Institute. Contamined soil (top soil) studied was transported from selected location of cadastral territory Markušovce – field Olšanské pole. Soil was thoroughly homogenised, sieved and analysed on basic agrochemical and hygienical parameters. Results – main nutrients contents, pH, humus and heavy metals contents are presented in Table 1, 2.

Table 1 Total nitrogen available nutrients (Mehlich II), pH and humus in soil for vessel experiments

(mg*kg^{-1})						%
N-total	**P**	**K**	**Ca**	**Mg**	**PH/KCl**	**Humus**
1 443	76	200	440	80	5.1	2.6

Table 2 Heavy metal contents in soil for vessel experiments

Leachate	**Cd**	**Pb**	**Zn**	**Cu**	**Cr**	**Ni**	**Co**	**Mn**	**As**	**Hg_{tot}**
Aqua regia	0.15	20.1	65.4	41	19.1	13.6	8.8	670	21.5	10.7
$2MHN0_3$	0.12	10.2	7.1	23.9	1.65	1.1	1.82	259	4.8	—

Vessel experiments had the tank to test various agrochemical measures effect on soil containing above limit content Hg with the objective to reach highest possible Hg immobilisation in soil and reduce Hg-availability for plants. Good physiological rye status had to be guarantee that agrochemical measures should have no negative effect on crop status.

Vessel experiments had 7 treatments – agrochemical measures with 5-fold repetitions (Tab. 3).

Agrochemical measures were implemented in 35 vessels filled with 10.4 kg contamined soil on September 11th, 2000. Rey drilling was implemented on September 29th, 2000 and rey harvest on July 4th, 2001. After winter rye harvest was soil and plants sampled and analysed on Hg-contents.

Table 3 Agrochemical measures treatments

Treatment	Agrochemical measures
1	Liquid ammonium application in rate 120 kg N.ha^{-1}
2	Application liquid ammonium in rate 120 kg N.ha^{-1} and natrium sulphide in rate 533.5 kg Na_2S.ha^{-1}
3	Calcium nitrate application in rate 120 kg N.ha^{-1}
4	Application (CaO + MgO)* in rate 1.5 t.ha^{-1} and natrium sulphide in rate 533.5 kg Na_2S.ha^{-1}
5	Application (CaO + HgO)* in rate 1.5 t.ha^{-1}
6	Natrium sulphide application in rate 533.5 kg Na_2S.ha^{-1}
7	Control without agrochemical measures + 85% CaO + 15% MgO

RESULTS AND DISCUSSION

Winter rye stand was from physiological aspect O.K. Average production of winter rye in vessels is presented in Table 4.

Table 4 Average winter rye production in vessels

Treatment	Mean drymass yield in g/vessel			
	Straw	Roots	Grain	Whole plant
1	117.8	21.6	55.7	195.1
2	113.1	20.6	54.4	188.1
3	105.9	19.5	46.3	171.7
4	79.6	15.4	31.0	126.0
5	83.7	14.7	34.3	132.7
6	84.8	17.1	34.5	136.4
7	79.0	17.7	32.5	129.2

Average Hg contents in soil and winter rye after harvest are presented in Table 5.

Table 5 Mean Hg content in soil and main rye parts after experiment finish

Treatment	Mean Hg content in mg.kg^{-1}					
	Soil	Winter rye				
		Straw	Roots	Grain	Overhead part	Whole plant
1	10.0	0.04	3.8	0.002	0.028	0.45
2	10.0	0.09	4.7	0.001	0.058	0.41
3	10.1	0.06	3.8	0.001	0.044	0.36
4	10.3	0.11	4.9	0.001	0.083	0.70
5	10.1	0.06	3.0	0.002	0.045	0.25
6	10.2	0.10	4.1	0.001	0.072	0.27
7	10.3	0.05	3.7	0.001	0.033	0.67

From Table 5 is resulting, mean Hg content in whole rye plant ranged 0.25 – 0.70 mg Hg.kg^{-1}, of it in straw Hg concentration ranged 0.04 – 0.11 mg Hg.kg^{-1}, in roots 3.0 – 4.9 mg.kg^{-1}, and in grain 0.001 – 0.002 mg Hg.kg^{-1}. Hg concentration in overhead biomass of rye ranged 0.033 – 0.083 mg Hg.kg^{-1}. From this is resulting, highest Hg concentration was determined in rye roots, i.e. 27 – 123 times higher than in straw, and 1500 – 4900 times higher than in grain. As highest acceptable Hg concentration for flour is 0.005 mg Hg.kg^{-1}, can be stated, determined Hg-levels in grain of winter rye in range 0.001 – 0.002 mg Hg.kg^{-1} do not introduce any risk of obligatory Hg risk exceeding in this food – staff. Similar also Hg-content in rye straw does not introduce any risk from the view of Hg transfer into food of animal origin.

Hg transfer from soil into main rye parts is presented in Table 6.

Table 6 Hg transfer from soil into main winter rye parts

Treatment	Hg transfer coefficients				
	Straw	Roots	Grain	Overhead part	Whole plant
1	0.004	0.380	0.0002	0.0028	0.045
2	0.009	0.470	0.0001	0.0058	0.041
3	0.006	0.376	0.0001	0.0044	0.036
4	0.011	0.476	0.0001	0.0081	0.068
5	0.006	0.297	0.0002	0.0045	0.025
6	0.010	0.402	0.0001	0.0071	0.026
7	0.005	0.359	0.0001	0.0032	0.065

From Table 6 is resulting, mean transfer Hg coefficients for whole rye plants ranged 0.025 – 0.68 for straw 0.004 – 0.011, roots 0.297 – 0.470, and for grain 0.001 – 0.002. Hg transfer coefficients for overhead rye part ranged 0.0028 – 0.0081. Hg balance in main winter rye parts is presented in Table 7.

Table 7 Hg balance in winter rye

Treatment	Hg share in main rye parts (%)***		
	Straw	Root	Grain
1	5.33	94.44	0.23
2	8.69	91.12	0.19
3	8.14	91.74	0.12
4	10.97	88.99	0.04
5	10.32	89.48	0.20
6	10.40	89.55	0.05
7	5.58	94.28	0.14

***) Hg-content in whole rye plant = 100 %.

From Table 7 can be judged Hg distribution in winter rye. It can be stated, with aspect to Hg-contents in whole rye biomass in straw was registered 5.3 – 11 % Hg (mean 8.5 %), in roots 89 – 94 % Hg (man 91.4 %) and in grain 0.05 – 0.23 % Hg (mean 0.14 %).

Hg balance in system soil – winter rye is presented in Table 8.

Table 8 Hg balance in system soil – winter rye

Treatment	Percent Hg balance of contamined soil		
	Hg remaining in soil	**Hg resorbed by winter rye**	**Non determined Hg amount (loss)**
1	96.634	0.089	3.277
2	97.901	0.118	1.981
3	96.795	0.086	3.119
4	97.791	0.090	2.119
5	97.710	0.054	2.236
6	99.274	0.088	0.638
7	97.753	0.086	2.161

From Hg balance in system contamined soil – winter rye studied in vessel experiment can be stated that from mercury of soil was by winter rye resorbed 0.05 – 0.12%, and 96.6 – 99.3% remained in soil and 0.64 – 3.28% Hg can be charged up mercury loss of soil during vegetation period of winter rye. From the results of contamined soil testing in vessel experiment is resulting, from mercury of soil was by winter rye, including roots, resorbed only 0.05 – 0.12% Hg. It is considered another fact, of whole Hg amount in rye biomass on average 91.4% was registered in ground plant part – roots 8.5% in straw, only 0.14% in grain, then can be stated that contamined soil shared only with small share on rye overhead part.

From informative recalculation can be stated that from 1 ha area can into area volatile 0.09 – 9.43 kg Hg from contamined soil. It in the treatment with highest Hg "loss" of contamined soil is taken Hg concentration in overhead port of rye and informatively is added yield of overhead rye of 1 ha, we can find that rye overhead part contains totally only less than 0.007 kg Hg. From this is visible, how large and potentially dangerous source of contamination for fodder crops and plant products can be Hg located in atmosphere. This fact is serious reason for principal consideration to grow crops for food and fodder crops on contamined soil, or they could be grown only in some conditions, of them main condition can be Hg level in yielded crops principal control.

The agrochemical measures used on Hg contamined soil did not bring expected evident results as far as Hg transfer reduction into rye is concerned.

From the results can be stated, contamined soil of Markušovce – field Olšanské pole studied, will be long-term Hg reservoir. Through technical crops growing however will be possible to reduce Hg contents gradually, but in the case at such high Hg-level in soil and low Hg transfer into plants, this will be very long way with very distant target. However here are the problems that should be solved immediately. They are the losses Hg from contamined soils into atmosphere, their share on plant contamination (non resorbed share) and responsible attitude to losses elimination. There problems solution is topic for further research.

CONCLUSIONS

From the mercury present in the soil studied at the experiment start, winter rye resorbed only 0.05 – 0.12% Hg. In soil remained 96.6 – 99.3% Hg and 0.64 – 3.28%

Hg was lost. From Hg amount resorbed by rye 89 – 94% was determined in roots, 5.3 – 11% in straw and only 0.05 – 0.23% in grain.

Overhead rye part contamination by Hg of contamined soil was low. Hg-levels determined in rye did not introduce any risk of exceeding obligatory Hg threshold in flour of rye, neither the risk of Hg transfer into food of animal origin. Potentially more dangerous appeared Hg losses from soil into atmosphere that can be tens time higher, when compared to Hg amounts in over ground rye. This fact is serious reason and motivation for research activities to be focused to Hg losses into atmosphere and their share at contamination of plants by aerial deposition (non sorbed share).

REFERENCES

Beneš, S.: Obsahy a bilancie prvku ve sférach životného prostředí, MZ ČR, 1993.

Hronec: Habilitačná práca.

Vojtáš, J.: Analýza hygienického stavu pôd na Slovensku a návrh doplnenia kódu bonitovaných pôdno-ekologických jednotiek pre kontaminované pôdy. Kandidátska dizertácia. VÚPOP, Bratislava 2000.

WHEAT AND CORN MAIZE YIELDS DEVELOPMENT IN THE TERRITORY OF THE WATER-WORK GABČIKOVO WITH ASPECT TO SOIL WATER REGIME

Vývoj úrod pšenice a zrnovej kukurice na území vodného diela Gabčíkovo z aspektu vodného režimu pôd

Dušan MIKLOVIČ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

In period 1996 – 2002 was in the territory of the Žitný ostrov, in the area touched by the Hydro-work Gabčíkovo monitored yields of wheat and corn maize. The yields were registered in the cultivated arable land, where were installed monitoring areas (Mp) serving for monitoring of changes: soil water regime, soil moisture, ground water levels.

The results reflected, winter wheat yields generally showed in this period gradual decrease, when compared to starting point status – they were more than 1 t/ha lower. On the other hand corn showed increase from 6 more than 9 t/ha in the monitored period.

From the aspect of water regime type, the highest wheat yields, total phytomass and energetic units were registered on hydromorphic soil type, i.e. the soils with constant ground water effect of elevated moisture (from 120 to 150 % rel.), corn similarly, however uniformly in all of mentioned features in the level of 120 %, when compared to automorphic water regime type (without ground water effect).

Keywords: soil water regime, main product yield, wheat, corn maize, total phytomass, energetic units

ABSTRAKT

V období rokov 1996 až 2002 bola na území Žitného ostrova v oblasti dotknutej výstavbou Vodného diela Gabčíkovo sledovaná výška dosahovaných úrod pšenice a zrnovej kukurice. Úrody boli zaznamenávané na prevádzkových plochách, na ktorých sú vybudované monitorovacie plochy (Mp) slúžiace na sledovanie zmien: vodného režimu pôd, vlhkosti pôdy, výšky hladiny podzemnej vody.

Výsledky ukázali, že úrody ozimnej pšenice všeobecne vykazujú v tomto období postupný pokles a v porovnaní s východiskovým stavom sú nižšie o viac ako 1 t/ha. Úrody zrnovej kukurice naopak ukazujú za monitorované obdobie nárast zo 6 na viac ako 9 t/ha.

Z aspektu typu vodného režimu boli najvyššie úrody pšenice, úrody celkovej fytomasy a energetických jednotiek dosahované na hydromorfnom pôdnom type – pôdy so stálym vplyvom podzemnej vody na vodný režim (od 120 po 150 % rel.), úrody zrnovej kukurice podobne avšak vyrovnané vo všetkých uvedených znakoch na úrovni 120 % oproti automorfnému typu vodného režimu (bez vplyvu podzemnej vody).

Kľúčové slová: vodný režim pod, úroda hlavného produktu, pšenica, kukurica, celková fytomasa, energetické jednotky

INTRODUCTION

The Hydro-work Gabčíkovo belonged among large-scale water-economy investment actions not only in Slovak Republic, but also in Central Europe. With its size and technical parameters has been this construction considerable interference into natural environment as well as into agricultural production itself in the region of Žitný ostrov. Therefore no wonder, significant attention was focused to the territory monitoring, also with the aspect to determination of so called "zero status" of crop yields before the Hydrowork getting into operation. This status should characterize comparable level for possible changes that were provoked by the Hydrowork and its operation.

Žitný ostrov territory was/is belonging to most productive agricultural regions of Slovakia. With aspect to fertility and productive capability most of soils belong to the categories of high productive land (Džatko, 1979). Besides from the view of the task objective is land productivity conditioned mainly by technical configuration of the Hydrowork (part of the dam, derivation channel, discharge channel) and natural phenomena of the territory (Žitný ostrov territory is natural whole typical with several rarities – soil types diversity, textural diversity, ground water levels diversity, occurrence of strongly mineralized waters, saline soils, etc.).

Crop production monitoring and assessment before the Hydrowork Gabčíkovo setting into operation was finished in 1991 (Antalík et al., 1991).

This paper target is subsequent assessment of the Hydrowork Power Station operation effect on soil productivity capacity change, particularly with aspect to water regime predicted changes.

MATERIAL AND METHODS

For the study of yields height change net of monitoring objects system was used (Mp of the sites). They were built up by the Soil Science and Conservation Research Institute. The observations were made in period 1996 (four years after the Hydrowork setting into operation) to 2002 on the following sites:

Monitoring areas distribution

Site	Locations	Characteristics
Mp-1 Mp-2 Mp-3	Kalinkovo Hamuliakovo Šamorín	region of the dam (region of ground water level elevation)
Mp-4 Mp-5, 6 Mp-7 Mp-9	Rohovce Horný Bar Jurová Gabčíkovo	area of derivation channel (practically without any changes)
Mp-10 Mp-11	Gabčíkovo Pataš	discharge channel (ground water levels fluctuation)
Mp-12 Mp-14	Čiliž. Radvaň Trávnik	preservation sealing walls
Mp-16 Mp-18	Zlatná na Ostrove Hadovce	saline soils occurrence

Monitoring net structure and distribution in terrain enables to control all the predicted effects of the Hydrowork that could markedly positively/negatively affect soil development and fertility (Fulajtár et al., 1991).

In linkage with the ground water levels predictions following areas were itemized in the monitored territory:

- area with permanent ground water elevation
- area with more or less stabilized ground water levels, and
- area with the change of natural inner drainage of danubian waters.

From the view of soil types, in given territory are located following soil representatives: Eutric Fluvisols, Arenic Fluvisols (22% monitored soils area), Haplic – Gleyic Chernozems (14%), Chernozemic, calcaric Mollic Fluvisols (64%). By clay particles contents – decisive for texture all basic soil types were registered here (light, medium heavy and heavy soils).

From agrochemical view dominating is here alkaline soil reaction and very diverse levels of available nutrients (P and K).

Stationary monitored areas are located in the fields with intensive agriculture. Just this reality was used for this work purposes, i.e. for observation of yields, when given crop was grown on neighbouring field in standard way. For proper yield height observation were the plants sampled in time of harvest from square meter area in four repetitions. Annually in the spring was sampled soil for basic agrochemical parameters determination (soil reaction in KCl, available phosphorus and potassium in leachate by Mehlich II). Monitoring includes longterm data collections on soil properties dynamics and their assessment in linkage on starting point status and new conditions brought about by the Hydrowork operation (Fulajtár et al., 2002).

RESULTS AND DISCUSSION

In Table 1 are presented main crops average yields in period 1985 – 1990 in Slovakia on selected pilot farms distributed in the Žitný ostrov territory.

Table 1 Mean yields of wheat, barley, and maize in Slovakia and Žitný ostrov (t.ha^{-1})

	Data source					
	Slovakia*			**Žitný ostrov****		
Year	**wheat**	**barley**	**maize**	**wheat**	**barley**	**maize**
1985	4.88	4.05	5.55	6.97	5.62	6.49
1986	4.42	4.24	4.87	5.51	4.83	6.18
1987	5.40	4.49	5.80	6.60	5.38	7.03
1988	5.80	4.60	5.55	7.34	5.62	6.54
1989	5.53	4.70	5.55	7.26	6.00	5.82
1990	5.00	4.82	3.56	6.04	4.83	4.29
Mean	5.17	4.48	5.15	6.62	5.38	6.06
Mean rel. (%)	100	100	100	128	120	118

* Statis. yearbooks SR, ** Antalík (1991)

The results are clearly documenting facts mentioned in introduction, given territory includes most productive region of Slovak Republic, where relative yields of wheat, barley and maize longterm are in the level 118 – 120% Slovakian mean.

The Hydrowork Gabčíkovo setting into operation in 1992 presupposed changes in ground water levels, particularly in ground water levels in area of Čunovo Dam. The measurements confirmed, in reality ground water levels were changed from former depths 5.5 – 7.0 to 3 – 2 m under terrain (Fulajtár et al., 2002).

In the area of derivation and discharge channels ground water levels have been moderately elevated, while in the locations Mp 14, 16 and 18 was elevation more visible. Mean wheat, barley and maize yields in given area (approximately 117 000 ha ploughed land) are clearly documenting the land high productivity capacity.

Cropping system structure presented in Table 2 was in period 1996 – 2002 relatively constant. Most uniform crop system was in cropping structure 1998 and 2002, when cereals were representing 93%.

Table 2 The crops grown percentile presentation at the Mp

Year	Cereals	Oil crops	Fodder crops
1996	79	7	14
1997	72	14	14
1998	93	7	0
1999	72	14	14
2000	67	27	6
2001	86	7	7
2002	93	7	0
Mean	80	12	8

Within cereals most stable position is fixed to wheat and after it is maize. Generally are in monitored area dominating cereals (67 – 93%), relative stable position have fodder crops (on average 12%) and alternating are oil crops (7 – 27%, Tab. 3).

Table 3 Average yield of main product, dry phytomass and energetical units of wheat and maize in sites studied during the years 1996 – 2002

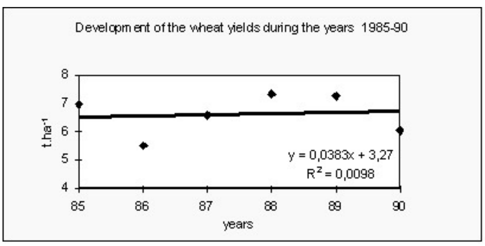
Water regime type	Site	Main product yield			
		wheat		maize	
		t.ha^{-1}	%	t.ha^{-1}	%
automorphic	Mp 3, 4	4.15	100	7.9	100
semihydromorphic	Mp 1, 2, 6, 10	4.85	116	8.4	106
hydromorphic	Mp 5, 7, 9 – 12	5.00	120	9.8	124
hydromorphic*	Mp 14, 16, 18	5.17	124	8.4	106

Water regime type	Site	Phytomass			
		wheat		maize	
		t.ha^{-1}	%	t.ha^{-1}	%
automorphic	Mp 3, 4	10.44	100	18.4	100
semihydromorphic	Mp 1, 2, 6, 10	11.72	112	19.6	106
hydromorphic	Mp 5, 7, 9 – 12	15.70	150	22.8	124
hydromorphic*	Mp 14, 16, 18	13.29	127	20.0	109

Water regime type	Site	Energetical units			
		wheat		maize	
		GJ.ha^{-1}	%	GJ.ha^{-1}	%
automorphic	Mp 3, 4	192	100	328	100
semihydromorphic	Mp 1, 2, 6, 10	232	120	346	105
hydromorphic	Mp 5, 7, 9 – 12	287	149	405	123
hydromorphic*	Mp 14, 16, 18	243	126	346	105

* – solonetsing

Figure 1 Development of winter wheat, barley and corn maize yields on area studied during the years 1996 – 2002 comparing them with initial stage (1985 – 1990)



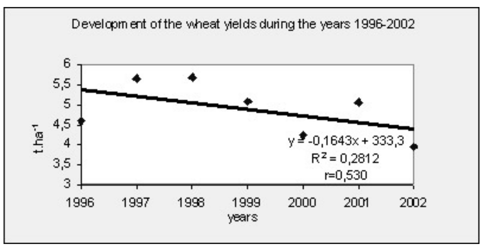


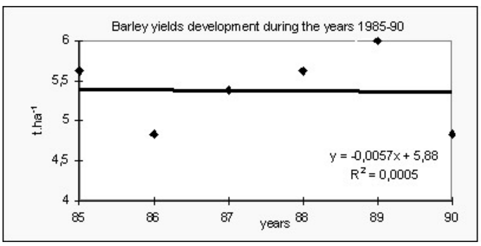
Figure 1 is presenting winter wheat yields development in period 1985 – 1990 (so called starting point situation) and contemporarily the same crop yields development in period 1996 – 2002. It is clear that wheat yields in 1985 – 1990 were stabilized with moderate increase in the level higher than 6 t.ha^{-1}. Wheat yields in period 1996 – 2002 after the Hydrowork was started, however show decreasing tendency. This fact is in direct relation to present situation in agriculture – fertilization level decreased to mean rate NPK nutrients 57 kg per hectare (1996/97 report of Statistical Office SR), whereby this rate substantial part was covered by fertilizer nitrogen form. And yield decrease was also caused by non beneficial climatic conditions (too high temperatures, water deficiency, pests and diseases).

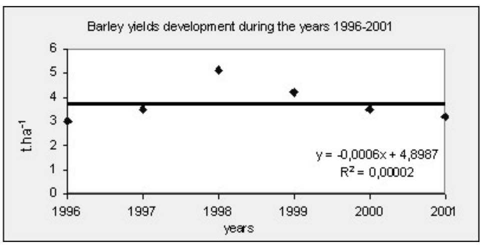
When balancing cereals yields trends in Slovakia Miština (1996) came to similar conclusion – in period of transformation cereal yields were decreasing in period 1989 – 1996 almost linearly – annually 0.2 t per hectare. By the author this was consistent not only with non beneficial weather conditions, very important is also level of inputs.

Similarly in the conclusions of 19th seminar on plant nutrition and preservation was mentioned that strong reduction of energo-material inputs, particularly fertilizers and pesticides caused strong decrease of soil productivity (Anonym, 1999). This is documented on the fact that in this period wheat yields decreased by 1 t.ha^{-1}, when compared with five years mean (1987 – 1991), where mean wheat yield was within Slovakia 5.4 t.ha^{-1} and fertilizer rates ranged 220 – 230 kg pure nutrient NPK per hectare. As a main reason of this loss in the monitored years we can indicate the wrong situation in application of industrial fertilizers, their imbalanced (absence of P and K fertilizers, there is overweigh of N fertilizers) and the last but not at least presence of climatic unfitting years for wheat growing.

Similar situation can be observed in Figure 2 with spring barley yields data in balanced years. Desirable situation in yields during period is corresponding with much more lower, although gradually growing yields in period 1996 – 1999. In 1996 was registered record with lowest spring barley yield – 3.02 t.ha^{-1}. Mentioned is in close harmony with data by Kulik and Líška (1997), who for mentioned year published national mean 3.18 t.ha^{-1}.

Figure 2 Development of barley yields on area studied during the years 1996 – 2002 comparing them with initial stage (1985 – 1990)



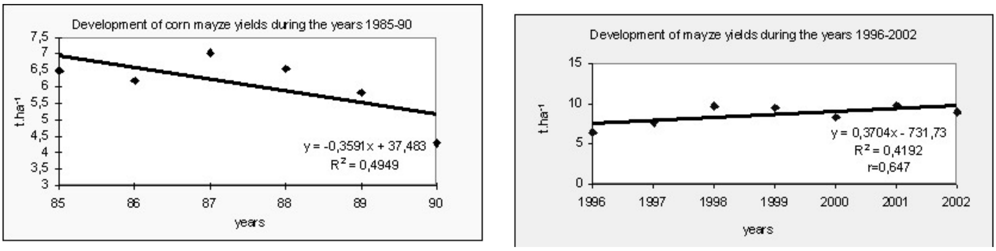


By their opinion, barley, though not very requiring crop, yet it requires some growing parameters fulfilment. Particularly important is water and air regime optimisation.

Other situation is at corn maize yield development (Fig. 3). Maize shows gradual yield increase in period 1985 – 1990 from 7 tonnes to yield negligibly higher than 4 t.ha^{-1} on average. While in recent period (1996 – 2002) there is clear tendency of yield increase from 6 to 9.5 t.ha^{-1}. In other words this means – climatic conditions have been better and are corresponding with maize requirements.

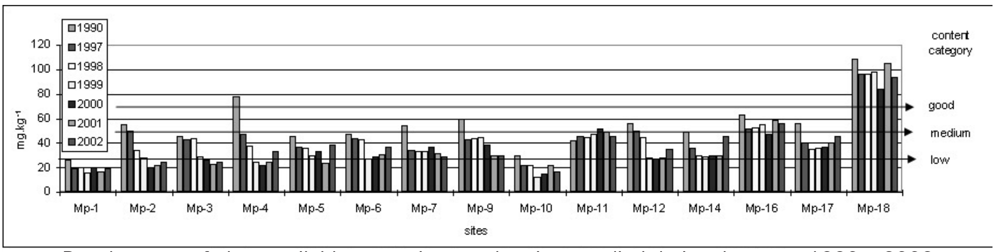
According Fulajtár et al. (2002), from recent hydrowork Gabčíkovo monitoring results is obvious that the affects soils and agriculture primarily via ground water level regime changes, whereby changed water regime effects also on another soil properties.

Figure 3 Development of corn maize yields in area studied during the years 1996 – 2002 comparing them with initial stage (1985 – 1990)

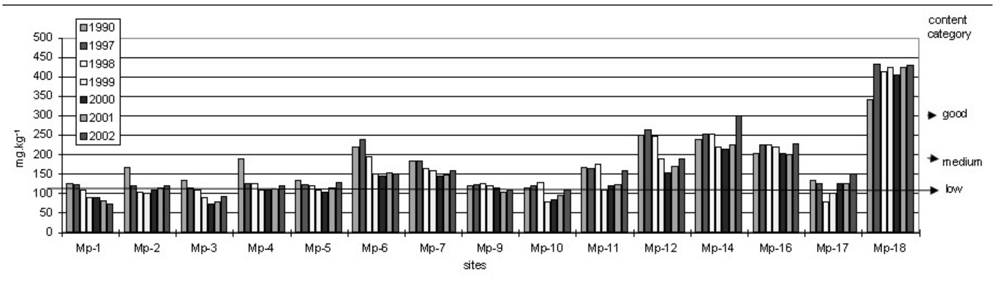


In Figure 4 is presented development of plant-available P and K levels in soil that was monitored during mentioned years in fields surrounding monitored locations to the agrochemical properties status: it can be stated, in most cases, in monitored areas was visible some stagnation or evident main nutrient levels decrease. In this way is reflected fact – fertilization radical reduction after 1989 has not been stopped and so inevitably comes gradual soil nutrient supplies gradual decrease and still is duration not adequate compensation of the nutrient resorbed away from soil by yields.

Figure 4 Development of plant-available phosphorus on the sites studied during the years 1990 – 2002 (mg.kg^{-1})



Development of plant-available potassium on the sites studied during the years 1990 – 2002



From the view of soil moisture regime in given territory that are decisive factor of the yields Fulajtár (1998) recognizes three types of basic soil water regime:

- *automorphic type:* typical with soil water content direct dependence from atmospheric precipitation. Ground water due to its higher depths, occurrence of sandy and gravelish layers, does is not elevated into soil profile. This water regime type was registered at the locations Mp-3 and 4

- *semihydromorphic type:* is typical with partial ground water influence that seasonally or permanently is being capillary elevated into rhizosphere of soil profile. This type of soil water regime was registered at Mp-1, 2 and 6
- *hydromorphic type:* typical with constant ground water effect that by capillary elevation is effecting dominant part of rhizosphere in soil profile. This type of water regime was registered at Mp-5, 7, 9, 10, 11, 12, 14, 16 and 18 (whereby Mp 14, 16 and 18 can be distinguished by the type hydromorphic sodic soils - occurring in the areas of mineralized ground water, where alkalinization takes place (sodization), i.e. reduction of soil water availability for plants.

Wheat and maize analyses for the study period 1996 – 2002 confirmed ground water marked effect on yield height and stability. On this are witnessing the wheat and maize yields, obtained on soils with water regime supplied by capillary rise, although there was lower nutrient supply and climatically drier yields.

More detailed data on wheat yield, total phytomass dry mass production and energetic units on soils with various water regime types are presented in Table 3.

From the table is resulting:

- lowest yields used to be reached on soils with automorphic water regime type – without ground water influence
- on soils with sporadic ground water influence, i.e. semihydromorphic type, yield mean is 15% higher, dry mass 10%, and energetic units 20% higher
- on soils with permanent ground water influence, or soils with hydromorphic water regime type were wheat yields 20% higher.

CONCLUSIONS

Soil fertility and yield height changes six year study in given territory showed following:

- in given territory cropping system structure were overwhelming cereals (the period mean – 78%, and oil crops relatively constant 13% and changeable fodder crops 6 – 14% (mean 9%))
- most frequently grown crops – wheat, maize
- winter wheat yields showed gradual tendency of slow decrease, when compared with starting point status, registered yield decrease was higher than 1 $t.ha^{-1}$ (r = 0.530)
- on the other hand corn maize yields showed in the period 1996 – 2002 increase on the level higher than 9 $t.ha^{-1}$ (r = 0.647)
- from the aspect of water regime type highest results of wheat yield, phytomass dry mass production and energetic units production were in given period attained on hydromorphic water regime type (rel. interval 120 – 150%), when compared to automorphic type (100%)
- from the aspect of basic agrochemical soil properties development (available P and K) can be stated either stable status, or in most cases, these nutrients gradual decrease in soil. Radical fertilization lowering after 1989 still was not stopped and situation associated with non-adequate compensation of resorbed nutrients durates.

REFERENCES

Anonym: Konal sa 19. seminár o výžive a ochrane rastlín., Agrochémia 3, 1999, 2, s. 24

Antalík, A. a kol.: Dlhodobé sledovanie a hodnotenie rastlinnej výroby pred uvedením do prevádzky vodného diela Gabčíkovo.

Záverečná správa, Výskumný ústav rastlinnej výroby, Piešťany, 1991, 59 s.

Džatko, M. a kol.: Hodnotenie relatívnej produkčnej schopnosti pôd ČSSR. Rostlinná výroba 25, 1979, s. 693 – 698.

Fulajtár, E. a kol.: Monitoring vplyvu vodného režimu aluviálnych pôd na výšku a kvalitu produkcie poľných plodín. Výročná správa, VÚPÚ Bratislava, 1998, 8 s.

Fulajtár, E. a kol.: Súhrnné hodnotenie monitorovania východiskového stavu pôd a poľnohospodárstva na území dotknutom výstavbou VD Gabčíkovo, Monitorovaná informácia, Výskumný ústav pôdnej úrodnosti, Bratislava, 1991, 86 s.

Fulajtár, E. a kol.: Súhrnné hodnotenie monitoringu poľnohospodárskych pôd v oblasti vplyvu VD Gabčíkovo za obdobie 1989 – 2002. Súhrnná hodnotiaca správa, VÚPOP Bratislava, 2002, 50 s.

Kulík, D., Líška, E.: K problematike pestovania jačmeňa jarného na Slovensku. Zborník referátov: Obilniny, šľachtenie, pestovanie, ekonomika, marketing, využitie a poradenstvo. Nitra, 1997, s. 18 – 20.

Miština, T.: Perspektívy pestovania obilnín v integrovaných systémoch rastlinnej výroby. Zborník referátov: „Využitie integrovanej rastlinnej výroby v podmienkach Slovenska“, Nitra, 1996, s. 7 – 15.

PRODUCTIVITY POTENTIAL OF THE TEXTURALLY MEDIUM HEAVY CALCARIC MOLLIC FLUVISOLS, HAPLIC CHERNOZEMS AND EUTRIC FLUVISOLS

PRODUKČNÝ POTECIAL STREDNE ŤAŽKÝCH KARBONÁTOVÝCH ČIERNÍC, ČERNOZEMÍ A FLUVIZEMÍ

BOŽENA PECHOVÁ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Within the partial task of the project "Soil Nutrient Potential in Relationship to Yield Formation and Fertilization Strategy" relationships of yield forming parameters and their effect on yield formation were balanced.

From the balance of soil reaction, humus contents and quality (HA:FA), total nitrogen, available P and K resulted following order of medium heavy modal-calcaric soils from the view of productivity potential: Chernozems – Mollic Fluvisols – Eutric Fluvisols.

Of course also in these fertile soil types some agrochemical parameters imbalance was registered. Besides variability and humus quality in Mollic Fluvisols occurred also P and K nutrients lower level, in Haplic Chernozems total nitrogen was lower, and in Eutric Fluvisols were typical defficiencies of all the factors of mentioned scale conditioning soil nutrition potential.

Soil productivity potential studied was in correlation with all the point values of the Soil Ecological Unit of Land Evaluation (BPEJ). From the practical view was positive, at point evaluation increase of calcaric soils was ascertained particularly statistically evident clay particles fraction smaller than 0.01 mm, water retention capacity increase, total porosity, humus, HA/FA ratio, total cation exchange capacity increase, respectively.

KEYWORDS: soil reaction, humus, humine acids and fulvoacids ratio (HA:FA), N, P, K in soil, medium heavy soils, Mollic Fluvisols Calcaric, Haplic Cernozem, Eutric Fluvisol Calcaric

ABSTRAKT

V rámci čiastkovej úlohy „Potenciál pôdnych živín vo vzťahu k tvorbe úrod a stratégii hnojenia“ sa vyhodnocovali vzťahy úrodutvorných parametrov a ich vplyv na tvorbu úrod.

Z hodnotenia pôdnej reakcie, humusu, kvality humusu (HA:FA), celkového dusíka, prístupného fosforu a draslíka vyplýva poradie stredne ťažkých modálne-karbonátových pôd z hľadiska produkčného potenciálu: černozeme, čiernice a fluvizeme.

Samozrejme aj v týchto úrodných pôdnych typoch sa zaznamenáva kvalitatívna nevyváženosť niektorých agrochemických parametrov. Popri variabilnosti v kvalite hu-

musu sa v čierniciach vyskytoval nižší obsah prístupných P, K živín, v černozemiach aj celkového dusíka a vo fluvizemiach nedostatočnosť celej hodnotenej škály faktorov podmieňujúcich potenciál pôdnej výživy.

Sledovaný produkčný potenciál pôd koreloval s bodovými hodnotami (BPEJ). Z praktického hľadiska je pozitívne, že pri zvyšovaní bodového ohodnotenia karbonátových pôd zisťujeme najmä štatisticky preukazný nárast frakcie ílovitých častíc < 0,01 mm, retenčnej vodnej kapacity, celkovej pórovitosti, humusu, pomeru HA:FA, celkového dusíka a celkovej katiónovej výmennej sorpčnej kapacity.

Kľúčové slová: pôdna reakcia, humus, pomer humínových kyselín a fulvokyselín (HK:FK), N, P, K v pôde, stredne ťažké pôdy, čiernica modálna karbonátová, černozem modálna karbonátová, fluvizem modálna karbonátová

INTRODUCTION

Soil productivity potential is defined by Džatko (1997) as optimum possible level of soil productivity in concrete space and presumposed time that will be demonstrated by concrete crop optimum production, without serious disturbtion of factor balance and environment biological stability. Contemporarily from this definition is resulting soil productivity potential use ecological bearability.

Within the set of soil productivity assessment are also included terms like soil bonitation, soil quality, soil appraisal, soil productivity potential assessment and others. Soil productivity potential is indicated by land cover macroindicators, physical, chemical and biological soil properties (Demo, Bielek, 2000).

Recently has been in fertilizer consumption dominating N-fertilizers that in most cases are covering a crop N-need in given year. Requirements for phosphorus, potassium has been almost one decade covered by soil reserves gradually formed in the past. Due to it soil nutrient supplies are getting to be exploited (Bujnovský et al., 2002).

Because of mentioned, in period 1999 – 2001 we have recalculated Slovakian soils productivity potential. We were focused to assessment on soil reaction changes, i.e. deviation from the assuptions given by development, humus cumulation, its quality assessment, NPK -nutrient supplies. Soil productivity potential was also judged based on biomass formation in different soil types, subtypes and varieties (Pechová et al., 2002). This paper will touch calcaric soil nutrient potentials assessment.

MATERIAL AND METHODS

Farmland productivity potential assessment within partial task "Soil nutrient potential in relationship to yield formation and fertilization strategy" was based on the selected sites of the Slovakian Soils Monitoring (Linkeš et al., 1997).

Within the project was in period 1999 – 2001 balanced productivity potential of texturally medium heavy Mollic Fluvisol Calcaric, Haplic Chernozem and Eutric Fluvisol Calcaric.

Soil samples-depths 0.30 m, every sample was mean of 5 samples sampled. Total site number – 17. Soil sampling was determined by the crop (24% sites was sampled 1x, 41% 2x, 35% 3x).

We focused to assessment of yield-bringing soil potentials at growing cereals, row crops and oil crops.

Soil samples analyses (Fiala et al., 1999): pH/KCl, total nitrogen, available phosphorus (Mehlich II, Olsen), available potassium (Mehlich II).

Data of humus and HA (humic acid), FA (fulvic acids), carbonates, total cationic exchangeable sorption capacity and physical soil properties (clay particles fraction under 0.01 mm, bulk density, retention water capacity, total porosity) – their calculations were made by B. Houšková, Soil Science and Conservation Reseasrch Institute database (Kobza, et al., 1997).

RESULTS AND DISCUSSION

The results are presented in Figures 1 – 6.

Abbreviations used in Figures 1 – 6:

pH/KCl: SAC-strongly acid, AC-acid, SLAC-slightly acid, N-neutral, A-alkaline, SA-strongly alkaline soil reaction

Humus contents: L – low, M – medium, G – good, VG – very good

Humus quality: H – humic, F – fulvic, H-F – humic-fulvic, F-H –fulvic-humic humus type

Soils contents (N, P, K): VL – very low, L – low, M – medium, G – good, H – hight, VH – very hight.

Table 1 Correlation relationships among soil parameters is resulting (n = 36)

N_{tot} = 431.79 Humus + 898.41	R = ^{xxxx} 0.598
P-M2 = -62.595 pH/KCl + 543.52	R = ^{xx} -0.384
P-M2 = -2.7511 $(CO_3)^{2-}$ + 122.96	R = ^{xx} -0.369
P-M2 = 48.503 (HA:FA) + 10.317	R = ^{xxxx} 0.538
K-M2 = -177.22 pH/KCl + 1 579.3	R = ^{x} -0.323
K-M2 = -9.1051 $(CO_3)^{2-}$ + 405.05	R = ^{xx} -0.363
K-M2 = 171.9 (HA:FA) + 13.899	R = ^{xxxx} 0.567

Statistical evidence levels: ^{xxxx}(0.001), ^{xxx}(0.01), ^{xx}(0.05), ^{x}(0.1)

Concentrational expression of the soil parameters: humus (%), N, P, K ($mg.kg^{-1}$).

In Figures 1 – 6 are verbally balanced soil properties with relationships to plant nutrition (Anonymus, 1995; Bielek, Kudličková, 1990). Verbal balance of the results makes vizually transparet dark columns emphasizing (at weak acid soil reaction, lower humus contents, low total N-levels, and for low to medium available phosphorus and potassium levels).

From these data is resulting, modal calcaric soils differs among them more or less in the properties assessed.

Soil reaction of Mollic Fluvisols is unambigously alkaline, Haplic Chernozems most neutral to alkaline, and Eutrich Fluvisols alkaline. To the pH/KCl is fixed available phosphorus assessment (Mehlich II, because of transparency is presented without numeric indexes). Phosphorus contents showed marked concentration variability.

From the view of crop nutrition suitable is fixation on good level. This criterion was not truth at 27% Mollic Fluvisols, 31% Chernozems and even 75% Eutric Fluvisols. If soil solution reaction is under influence of calcium hydrogencarbonate, soil solution has neutral to weak alkaline reaction. Soil solution pH upper limit is up to 8. Strong alkaline soil reaction is in the soil solution prevailingly influenced by sodic hydrogen carbonate, in such case pH is higher than 8 (Fecenko, Ložek, 2000). Two strong alkaline soils studied by us had soil reaction values up to pH 7.8.

Available P and K contents (Mehlich II) is statistically significant dependent from soil reaction, given particularly by Ca and Mg carbonates. In texturally medium heavy modal carbonatic soils are these elements fixed, this was reflected by negative linear correlation (Tab. 1). The negative linear correlation was confirmed also at available P determination by Olsen method (alfa = 0.1).

Humus quality (HA:FA) in carbonate soils has positive effect on soil available P and K levels. Highest P and K levels occur in Chernozems, where is more often registered humate type of humus.

Chernozems 15%, Mollic Fluvisols 36% and up to 83% Eutric Fluvisols showed K-level under necessary good supply. Nitrogen linkage with humus was confirmed also at prevailing alkaline soil reaction, typical for most carbonate soils. Lower total nitrogen contents occurred both, in Calcaric Eutric Fluvisols (25%), and Haplic Chernozems (23%).

Soil Ecological Unit of Land Evaluation (BPEJ) system elaborated by Džatko (2002) characterizes soil and its possi- bilities to be used for farming. When increasing carbonatic soil point evaluation based on the BPEJ system, we can see particularly: clay (under 0.001 mm) fraction increase (%) (n = 36, R= ^{xxxx}0.694), water retention capacity (vol. %) (R = ^{xxx}0.494), total porosity (R = ^{xx}0.358), humus (%) R = ^{xxx}0.435), HA:FA (R = ^{xxxx}0.526), total nitrogen ($mg.kg^{-l}$) (R = ^{xx}0.369) and total cationic exchangeable sorption capacity "T" (cmol (+).kg^{-1}) (R = ^{xxx}0.445).

Carbonate soils textural variability (clay particles under 0.001 mm, in %) statistically significant affected the same soil parameters as BPEJ characteristics.

Yield-bringing soil potential was increased by both, concentration (Figs 1 – 6) and soil parameters relative linkage (Tab. 1). Relationships affecting soil-forming development, as well as agrotechnics used in the sites.

Nutrient offer in texturally medium heavy modal calcaric soils at given soil reaction, humus contents and quality, affects statistically significant nutrient resorption by yield, biomass yield formation and subsequently also main product (Pechová et al., 2002).

CONCLUSIONS

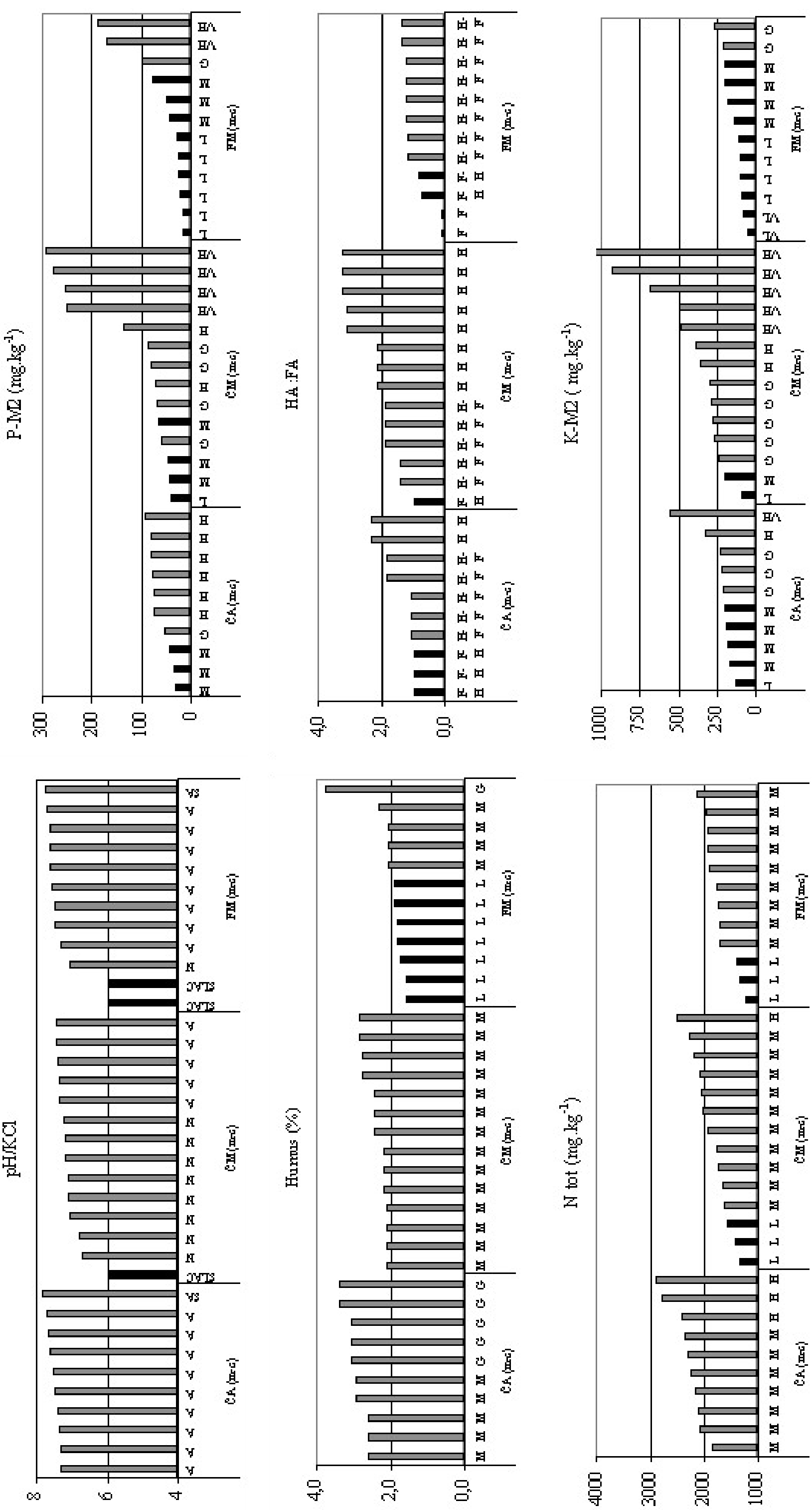
From soil reaction values, humus amount and quality and nutrient offer of texturally medium heavy modal calcaric soils is resulting that most Chernozems and Mollic Fluvisols have accumulated up high productivity potential. For its implementation they need respecting all agrotechnical terms and moisture stability.

Calcaric Eutric Fluvisols on the other hand have evidently lower productivity potential. This is visible in lower humus contents and its quality, available P and K levels, as well as nitrogen.

Among mentioned soil parameters were found statistically significant correlations objectivizing biomass and main product yields conditions.

Bonitational soil productivity assessment is in harmony with carbonatic soil assessment.

Figures 1 – 6 Valorization agrochemical soil parameters



REFERENCES

ANONYM: Jednotné pracovné postupy pre ASP, ÚKSÚP, Bratislava, 1989, 25 s.

BIELEK, P., KUDLIČKOVÁ, J.: Bilancia a potenciály dusíka v poľnohospodárskej krajine. Záver. Syntetická správa, VÚPU, 1990, s. 59.

BUJNOVSKÝ, R., MIKLOVIČ, D., PECHOVÁ, B., TORMA, S.: Strategické aspekty hnojenia poľnohospodárskej pôdy a plodín. VÚPOP, Bratislava, 2002, 26 s.

DEMO, M., BIELEK, P.: Regulačné technológie v proukčnom procese poľnohospodárskych plodín. SPU, Nitra, VÚPOP, Bratislava, 2000, 648 s.

DŽATKO, M.: Hodnotenie produkčného potenciálu poľnohospodárskych pôd a pôdno-ekologických regiónov Slovenska. VÚPOP, Bratislava, 2002.

DŽATKO, M.: Sustainable land use modelling and agricultural landscape managing in Slovakia. In: Landscape Ecology: Things to do. Proccedings WLO Amsterdam, 1997, 27 p.

FECENKO, J., LOŽEK, J.: Výživa a hnojenie poľných plodín. SPU v Nitre a Duslo, a.s., Šaľa, 2000, 442 s.

FIALA K. a kol.: Záväzné metódy rozborov pôd. Čiastkový monitorovací systém – Pôda. VÚPOP v Bratislave, 1999, 139 s.

KOBZA, J. a kol.: Monitoring pôd Slovenskej republiky - súčasný stav monitorovaných vlastností pôd. VÚPÚ, Bratislava, Lesoprojekt, Zvolen, ÚKSÚP, Bratislava, LVÚ, Zvolen, 1997, 128 s.

LINKEŠ, V. a kol.: Monitoring pôd SR. Výsledky čiastkového monitorovacieho systému – pôda. VÚPÚ, Bratislava, SČMSP pri VÚPÚ, Bratislava, Lesoprojekt, Zvolen, ÚKSÚP, Bratislava, LVÚ, Zvolen. Vydal VÚPÚ v Bratislave, 1997, 128 s.

PECHOVÁ, B. a kol.: Potenciál živín v pôdach SR z hľadiska možnosti formovania úrod plodín a potreby hnojenia. Syntetická správa za VE 01. VÚPOP v Bratislave, 2002, 50 s.

SOIL PARAMETERS RELATIONSHIPS AND THEIR EFFECT ON SOIL PRODUCTION FUNCTIONS

VZŤAHY PÔDNYCH PARAMETROV A ICH VPLYV NA PRODUKČNÉ FUNKCIE PÔDY

Božena PECHOVÁ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Within the partial task „Soil Nutrient Potential in Relationships to Yield Formation and Fertilization Strategy“ yield forming parameters relationships were balanced, as well as their effect on yield formation.

Statistically significant correlations among soil parameters, i.e. soil reaction, humus and its quality (HA:FA), total nitrogen, available phosphorus and potassium, is objectivizing yield forming potential. Soil yield forming potential was increased by concentration and relationships linkage of soil parameters. This is a consequence of these soils longterm evolution and the form of their use respectively.

Soil productivity potential was particularly beneficial in Calcaric Mollic Fluvisols, Chernozems, Eutric Fluvisols, and some Haplic Luvisols. Acid soil reaction, lower nutrient and humus (most of lower quality) levels decrease fertility of Dystric Planosols and Cambisols.

Keywords: soils reaction, humus, humine acids an fulvoacids ratio (HA:FA), N, P, K in soil, Mollic Fluvisol, Chernozem, Haplic Luvisol, Fluvisol, Cambisol, Pseudogley, Rendzina, Cambisol

ABSTRAKT

V rámci čiastkovej úlohy “Potenciál pôdnych živín vo vzťahu k tvorbe úrod a stratégii hnojenia“ sa vyhodnocovali vzťahy úrodutvorných parametrov a ich vplyv na tvorbu úrod.

Štatisticky významné korelácie medzi pôdnymi parametrami t.j. pôdnou reakciou, humusom, kvalitou humusu (HK:FK), celkovým dusíkom, prístupným fosforom a draslíkom objektivizuje hodnotenie úrodnostného potenciálu. Úrodnostný potenciál pôd sa zvyšuje koncentračným a vzťahovým prepojením pôdnych parametrov. Je to dôsledok dlhodobého vývoja týchto pôd a spôsobu ich využívania.

Dobrý produkčný potenciál bol najmä v karbonátových čierniciach, černozemiach, fluvizemiach a v niektorých modálnych hnedozemiach. Kyslá pôdna reakcia, nízky obsah živín a humusu, prevažne nižšej kvality znižuje úrodnosť pseudoglejov a kambizemí.

Kľúčové slová: pôdna reakcia, humus, pomer humínových kyselín a fulvokyselín (HK:FK), N, P, K v pôde, čiernica, černozem, fluvizem, hnedozem, kambizem, pseudoglej, rendzina, regozem

INTRODUCTION

Agrochemical soil parameters, particularly for plant available nutrient levels, introduce summarized factor, which by nutrient of fertilizers applied assistance is significantly participating at soil productivity potential formation (Bujnovský et al., 2002; Fecenko, Ložek, 2000), as well as abroad (King, 1990; Boysen, Oehring, 1992; Bujnovský, Fotyma, 2001). Low fertilization intensity (particularly P and K) is in last decade demonstrated in their supplies gradual lowering, this is considered for soil degradation demonstration, also called soil fatigue (Lal, 1998; Isherwood, 2000).

Soil reaction has substantial effect on plant growth, soil microorganisms and on soil biological processes. In acid soil are markedly lowered levels of available nitrogen, phosphorus, potassium, magnesium and trace elements. Soil liming therefore belongs to basic measures for soil quality conservation. Soil processes heterogeneous conditions in the natural regions affect humus formation. Soil organic matter levels and quality are depending mainly from soil type, textural composition and agricultural land use. Composition and chemical structure of soil organic matter (SOM) – one of most important soil property, HA (humic acids) are depending predominantly on soil type. HA chemical structure enables relative exact indication of SOM maturity status and some its physical chemical parameters can play important role at soil type classification (Barančíková, 1997; Wegner, 1999).In lowland warmer regions is danger of humus losses higher than in cooler mountainous zones (Bedrna, 1998).

Characteristics and soil type productivity potential were in our country assessed by Bielek et al., 1998. From their works is resulting, Chernozems and Mollisols were most productive soil types. High productive arable soils include Haplic Luvisols, Fluvisols, and Cambisols Dystric Planosol and Rendzinas were productive topsoils. Eutric Regosols were less productive topsoils.

The findings obtained are presenting soil productivity potential qualitative development, contemporarily they are background for fertilization strategy and nutrient rates projection.

MATERIAL AND METHODS

Farmland productivity potential assessment within partial task "Soil nutrient potential in relationship to yield formation and fertilization strategy" was based on the selected sites of the Slovakian Soils Monitoring (Linkeš et al., 1997).

The study in period 1999 – 2001 was oriented to following soil types, subtypes and varieties: Mollic Fluvisols (modal, modal-calcaric), Chernozem (haplic-calcaric, modal-calcaric, luvi-haplic), Fluvisol (arenic, modal, modal-calcaric), Haplic Luvisol (modal), Cambisol (modal-saturated), Dystric Planosol (luvic-saturated, modal-saturated), Rendzina (modal), Calcaric Arenosol.

Mollic Fluvisols occurred in textural categories of light and heavy soils, Chernozems and Cambisols were medium heavy, Eutric Fluvisols, Haplic Luvisols and Dystric Planosols were medium heavy.

Soil samples-depths 0.30 m, every sample were mean of 5 samples sampled. Total site number – 105 (samples – 184). Soil sampling was determined by the crop (43 % sites was sampled 1 x, 39 % 2 x, 18 % 3 x). We focused to assessment of yield-bringing soil potentials when growing winter wheat, spring barley (in stage of milk maturity), ensilage maize (immediately before harvest), cabbage rape right (after blossoming) and sunflower annual (at the end of blossoming) (Pechová et al., 2002).

Soil samples analyses (Fiala et al., 1999): pH/KCl, total nitrogen, available phosphorus (Mehlich II), available potassium (Mehlich II). Data of humus and HA, FA (fulvic acids) were obtained from Soil Science and Conservation Research Institute database (Kobza et al., 1997).

RESULTS AND DISCUSSION

Main nutrition soil potential consists of N_{tot}, P and K available in soil. It in some circumstances is utilisable for yield formation. High level of total nitrogen in soil creates assumptions for higher offer of N-inorg. Its content has considerable dynamics resulting from the conditions enabling nitrogen changes in soil.

N_{tot} content is released into soil by SOM mineralisation. Humus is presenting soil organic matter, which passed through long development process. Ratio HA:FA is important for humus quality. Conditioning factors for implementation of N, P, K – potential in soil are soil reaction and moisture regime. Moisture fixation and possibilities of its utilisation by crops are dependent on soil physical parameters. All this parameters (with direct mediation effect on yield formation) can be called-soil plant nutrition parameters for their relationships linkage.

Soil types differed by their properties within the same soil category, subtype and variety. We have evaluated them by the Agronomic Criteria (Anonymous, 1995; Bielek, Kudličková, 1990).

The results obtained are presented within Table 1. Mean values within soil type (subtype, variety) at higher number of processed data are objectivized by percentile occurrence of beneficial properties. In optimum case these two assessments are offering the same qualitative information. We register it particularly in the case of texturally heavy Calcaric Haplic Chernozems and Mollic Fluvisols, as well as by heavy Mollic Fluvisols, Calcaric Eutric Fluvisols, and Haplic Luvisols.

Table 1 Mean value of soil parameters and positive soil properties occurrence

Soil type	Subtype-variete	pH/KCl		Humus (%)		HA:FA		N_{tot}. (mg.kg^{-1})		P-Mehlich II (mg.kg^{-1})		K-Mehlich II (mg.kg^{-1})	
		Mean	Positive (%)	Mean	Positive (%)	Mean	Positive (%)	Mean	Positive (%)	Mean	Positive (%)	Mean	Positive (%)
Light soils													
RM	a	6.3	57.0	1.6	0	0.97	71	1 233	0	144	71	246	100
Loamy soils													
ČA	m	5.8	0	2.9	100	1.32	73	1 825	100	123	73	278	64
	m-c	7.5	100	2.9	75	1.52	88	2 267	88	65	38	245	63
ČM	č-c	7.3	100	3.4	100	1.97	100	2 280	100	86	67	306	50
	h	6.2	29	2.1	100	1.40	92	1 736	77	105	69	370	85
	m-c	7.1	92	2.4	57	2.29	71	1 882	79	132	57	467	79
FM	m	6.0	60	2.4	80	1.48	80	1 783	60	68	20	183	20
	m-c	7.3	83	2.1	42	0.97	67	1 733	75	64	25	143	17
HM	g	5.9	0	1.6	0	0.65	0	1 674	75	68	0	260	75
	m	6.7	71	1.7	21	0.72	14	1 562	50	102	57	418	79
KM	m-n	5.8	17	2.4	83	0.63	33	1 406	0	47	17	126	0
PG	l-n	6.4	33	1.7	0	0.57	0	1 499	17	53	0	139	17
	m-n	6.2	43	2.0	43	0.65	0	1 348	14	73	29	256	71

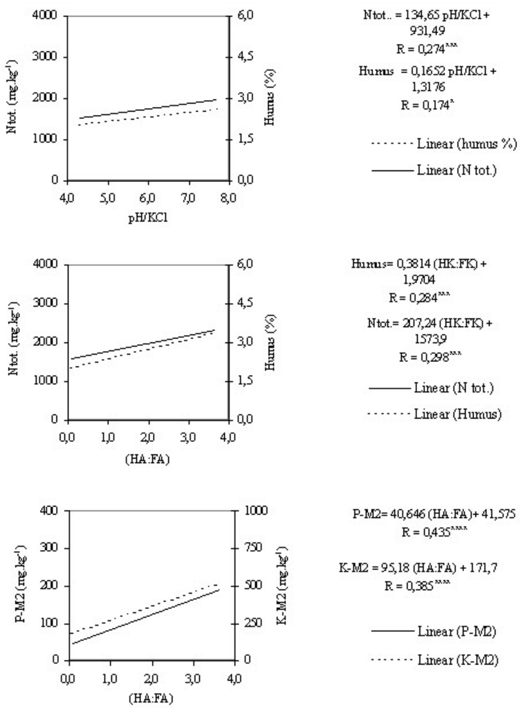
Table 1 continues

Silty soils													
ČA	m-c	7.4	100	3.7	100	1.33	100	2 808	100	36	22	143	22
FM	G	6.2	75	3.3	100	0.73	0	2 569	100	36	0	223	25
	m-c	7.2	100	3.4	100	0.67	0	2 212	100	97	67	247	50
HM	m	5.4	0	2.6	100	1.31	75	1 692	75	120	100	428	100
PG	l-n	5.2	0	1.8	40	0.66	0	1 572	40	49	20	162	20
	m-n	4.9	25	2.0	25	0.61	25	1 538	25	23	0	210	25

Abbreviations:
Soil type: RM – Regosol, ČA – Mollic Fluvisol, ČM – Chernozem, FM – Fluvisol, HM – Haplic Luvisol, KM – Cambisol, PG – Dystric Planosol
Soil subtype: a – arenic, č – mollic, chernozemic, g – pseudogleyic, h – luvic, m – modal, l – luvisol
Soil variety: c – carbonatic, n – saturated
Positive factors: pH/KCl: neutral > 6.6 – alkaline soil reaction
Humus: medium > 2.0 % – very good
Humine acids: fulvoacids: humic-fulvic > 1.0 – humic types
N-contents: medium > 1 610 $mg.kg^{-1}$ – very hight
P-contents: good – very hight (according to pH/KCl and soils sort)
K-contents: good – very hight (according to soils sort)

From the Figures 1 Correlation relationships among soil parameters is resulting conception zone of multiple correlations ascertained among soil fertility parameters studied. Statistically significant positive linear correlations of humus – total nitrogen and soil reaction, humus, total nitrogen, available phosphorus, potassium, humus quality (HA:FA), objectivizes yield-bringing potential assessment. Proved is soil reaction and humus quality significance from the view of plant nutrition.

Figure 1 Multiple correlation relationships among soil parameters (n = 105)



Furthermore also among the parameters on Y axis (Fig. 1) were registered statistically significant correlations (n = 105, humus/nitrogen: R = 0.637^{xxxx}, humus/(HA:FA): R = 0.284^{xxx}, P-M2/K-M2: R = 0.610 ^{xxxx}). In soil reaction acid region was detected positive linear correlation between available phosphorus and humus (n = 51, R = 0.416^{xxx}) (statistical evidence levels: ^{xxxx} (0.001), ^{xxx} (0.01), ^{xx} (0.05), ^{x} (0.1).

Soil yield-bringing potential is increased by the concentration and relationship linkage of soil parameters.

As it is presented in Table 1, it is depending from the soil type, subtype and variety. Relationship between available phosphorus and potassium is under influence of their dependence from soil organic mass, tillage and multicomponent fertilizer dressing, respectively. Nutrient offer at given soil reaction, humus content and quality significantly influences nutrient resorption by yield, biomass production and subsequently main product yield. This is also confirmed by correlation of biomass and soil reaction, humus and its quality. These soil parameters are also significantly forming both, yield-bringing and crop qualitative properties (Pechová et al., 2002).

CONCLUSIONS

Among soil reaction values, humus amount and quality and nutrient offer of medium heavy and heavy soils is being detected natural concentration variability.

Based on percentile positive/negative soil properties expression, with aspect to their yield-formation potential is stated that most of Calcaric Mollic Fluvisols, Chernozems, Haplic Fluvisols and Haplic Luvisols were keeping their high yield-forming with aspect to humus amount and quality and nutrient levels. Less fertile are Dystric Planosols and Eutric Cambisols.

Among mentioned soil parameters were determined statistically significant correlations that were objectivizing the conditions for biomass and main product formation.

REFERENCES

Anonym: Jednotné pracovné postupy pre ASP, ÚKSÚP, Bratislava, 1989, 25 s.

Barančíková, G.: Obsah a zloženie humusu v pôdach SR. In: Monitoring pôd SR, 1997, 81 s.

Bedrna, Z.: Enviromentálne vlastnosti pôdy a ich význam v poľnohospodárstve; Poľnohospodárstvo 44, 1998, č. 11, s. 809 – 819.

Bielek, P.: Zachovanie pôdnej úrodnosti – základný princíp trvalo udržateľnej sústavy hospodárenia na pôde. In: Trvalo udržateľná úrodnosť pôdy a protierózna ochrana. VÚPÚ v Bratislave, 1998 s. 13 – 16.

Bielek, P., Šurina, M., Ilavská, B., Vilček, J.: Naše pôdy (poľnohospodárske). Kompendium o pôdach Slovenska, Príručka pôdoznalca, vysokoškolský učebný text. VÚPÚ v Bratislave, 1998, 80 s.

Bielek, P., Kudličková, J.: Bilancia a potenciály dusíka v poľnohospodárskej krajine. Záver. Syntetická správa, VÚPÚ, 1990, s. 59.

Boysen, P., Oehring, M.: Richtwerte für die Düngung. Landwirtschaftskammer Schleswig--Holstein, 1992, 41 s.

Bujnovský, R., Fotyma, M.: Fertilizer recommendation schemes officially used in Czech Republic, Latvia, Poland, Slovak Republic and United Kingdom. Nawozy i Nawozenie 3, 2001, No. 1, 5 – 31.

Bujnovský, R., Miklovič, D., Pechová, B., Torma, S.: Strategické aspekty hnojenia poľnohospodárskej pôdy a plodín. VÚPOP, Bratislava, 2002, 26 s.

Fecenko, J., Ložek, J.: Výživa a hnojenie poľných plodín. SPU v Nitre a Duslo, a.s., Šaľa, 2000, 442 s.

Fiala K. a kol.: Záväzné metódy rozborov pôd. Čiastkový monitorovací systém - Pôda. VÚPOP v Bratislave, 1999, 139 s.

Isherwood, K. F.: Minerala fertilizer and the enviroment. Int. Fert. Ind. Assoc., Paris, 2000, 51 p.

King, L.: Sustainable soil fertility practices. In: Francis,Ch.a., Flora,C.B., King,L.D. (eds.), Sustainable agriculture in temperate zone. J. Wiley and Sons, New York, 1990, 144 – 177.

Kobza, J. a kol.: Monitoring pôd Slovenskej republiky - súčasný stav monitorovaných vlastností pôd. VÚPÚ, Bratislava, Lesoprojekt, Zvolen, ÚKSÚP, Bratislava, LVÚ, Zvolen, 1997, 128 s.

Lal, R.: Soil quality and sustainability. In: Lal.,R., Blum,W.H., Valentine,C., Stewart,B.A. (eds.), Methods for assessment of soil degradation. CRC Press, Boca Raton, 1998, 17 – 30.

Linkeš, V. a kol.: Monitoring pôd SR. Výsledky čiastkového monitorovacieho systému – pôda. VÚPÚ, Bratislava, SČMSP pri VÚPÚ, Bratislava, Lesoprojekt, Zvolen, ÚKSÚP, Bratislava, LVÚ, Zvolen. Vydal VÚPÚ v Bratislave, 1997, 128 s.

Pechová, B. a kol.: Potenciál živín v pôdach SR z hľadiska možnosti formovania úrod plodín a potreby hnojenia. Syntetická správa za VE 01. VÚPOP v Bratislave, 2002, 50 s.

Wegner, K., et al.: Parameters of humic acids as diagnostic features of the soils. In: Gonet, S.S., Zaujec, A., Debska, B. (eds): Humic substances in ecosystems 3, Proc. 3rd International Conference Humic Substances as Factor of the Terrestrial and Aquatic Ecosystems, 1999, p. 117 – 124.

DIGITAL DATABASE OF SELECTED SOIL PROFILES OF THE COMPLETE AGRICULTURAL SOIL SURVEY OF SLOVAKIA (KPP-DB)

Digitálna databáza výberových sond komplexného prieskumu poľnohospodárskych pôd Slovenska

Rastislav SKALSKÝ[1], Juraj BALKOVIČ[2]

[1] Soil Science and Conservation Research Institute, Gagarinova 10, 827 13 Bratislava, tel: +421/2/482 06 901, e-mail: skalsky@vupu.sk

[2] Department of Pedology, Faculty of Natural Sciences, Komenius University, Mlynská dolina 1, 842 15 Bratislava, Slovakia, tel. +421/ 2/ 602 96 574, balkovic@fns.uniba.sk

ABSTRACT

This paper deals with actualization of selected soil profile digital database of the complex agricultural soil survey, which is especially focused on creation of the project: Digital database of selected soil profiles of the Complete Agricultural Soil Survey of Slovakia (KPP-DB) version 1.0. We describe basic rules of KPP-DB building as well as historical preview of data collection and digitalization as a basic assumption for its sufficient actualization. This paper also describes an algorithm for elimination of some insufficiencies as well as for actualization of used soil classification and some analytical fields of the original version of database (PC-AISOP). It also gives information on data structure and field contents of KPP-DB. The contribution defines the positions of KPP-DB within the soil information systems, which is handled and build up by SSCRI and it also focuses on some fields of KPP-DB using in soil and landscape evaluation.

Keywords: KPP-DB version 1.0, soil information system, complete soil survey, soil classification

ABSTRAKT

Predkladaný príspevok sa zaoberá problematikou aktualizácie digitálnej databázy výberových sond komplexného prieskumu pôd, výsledkom ktorej bolo spracovanie samostatného databázového produktu: Digitálnej databázy výberových sond komplexného prieskumu poľnohospodárskych pôd Slovenska (KPP-DB) verzia 1.0. Popisuje základné východiská budovania KPP-DB, tiež históriu zberu a digitalizácie údajov ako základného predpokladu jej úspešnej aktualizácie. Príspevok ďalej popisuje algoritmus eliminácie zistených nedostatkov a aktualizácie použitej klasifikácie pôd a niektorých analytických položiek pôvodnej verzie databázy (PC-AISOP). Informuje o spracovanej dátovej štruktúre a náplni položiek KPP-DB, definuje jej postavenie v rámci informačného systému o pôde

budovaného v rámci Výskumného ústavu pôdoznalectva a ochrany pôdy, poukazuje tiež na niektoré perspektívne oblasti využitia KPP-DB pri hodnotení pôdy a krajiny.

Kľúčové slová: Komplexný prieskum poľnohospodárskych pôd – digitálna databáza 1.0, informačný systém o pôde, komplexný prieskum pôd, klasifikácia pôd

INTRODUCTION

Digital database KPP-DB v. 1.0. 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 documentation. 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. Since 1982, some efforts for digitalization of basic documentation of the Complete Soil Survey have been emerged. Because of huge amount of basic documentation it was impossible to process all data and only so-called ‘selected soil profiles' were digitalized therefore. Selected soil profiles by their number (nearly 18 000 records) and information value (morphologic information, basic chemical and physical information) satisfy the idea of pedological database with sufficient information level (in geographical as well as in general meanings).

Also data digitalization required a routine and challenging work and without efforts of many people, soil scientists as well as people from other brunches, it should be never finished.

KPP-DB version 1.0 has been finalized by a staff of workers in final three years. It is proposed to enable soil information and to make data using easier and more tabular to all people who need soil information for their work. Our efforts do not finish by the first version of soil database and we have ambition to make this data fund more quality in the future.

Nowadays, KPP-DB belongs among basic databases of agricultural soils and it creates one of the basic spatial and attribute unit of geographical information system of agricultural soils in Slovakia. This database is able to provide efficient information for the whole area of agricultural landscape.

MATERIAL AND METHODS

We used the original database of selected soil profiles of the Complete Agricultural Soil Survey in database format (dbf). In the process of data actualization and manipulation, we used edit and query tools of MS ACCESS program. Transformation modules were realized in environment of Visual Basic for application.

RESULTS AND DISCUSION

The results of original database actualization and KPP-DB building are divided into several individual items:

- historical aspects of database building
- identification and elimination of database insufficiencies
- actualization of database structure
- actualization of soil classification and some analytical fields

Historical aspects of database building

Geographical information system of agricultural soils of Slovakia began to develop in 1981 as a separate (central) module PEDMO, which summarized pedon information within the frame of the branch information system of soils AISOP (automated information system of soils) – Linkeš et al., 1987. AISOP entered the process of management rationalization of various activities on soil fund and it was especially designed to provide higher data quality and higher efficiency of data using therefore (Linkeš et al., 1988).

The conversion of original analogue data about individual profiles into digital form (creation of PEDMO module) was realized by alphanumerical encoding based on numerical converters (IM module in AISOP). General information about soil profiles and analytical values for all horizons were recorded by using special encoding forms (Linkeš et Šimonyová 1982, Linkeš et al. 1988). Topological coordinates of individual soil profiles were adopted from operating maps of KPP, which were based on the Official State Maps (OSM) – scale 1:5 000 (1:10 000) (Šurina, Juráni 1997). Moreover, individual pedons were ranked into relevant natural, administrative (cadastral area, municipality) and cartographical categories (map sections of OSM 1:5 000, map number) (Linkeš et al., 1984).

Current KPP-DB results from transformation of original database platform – MS--DOS operation system (PC-AISOP) – into a platform of MS WINDOWS, where MS ACCESS is used. PC-AISOP, as a PC software product proposed for soil data storage and manipulation, was created by data transferring from original PEDMO module (part of information system AISOP), which was running on EC computers.

Identification and elimination of database insufficiencies

Some formal as well as fundamental problems of the original database PC-AISOP were summarized by Sobocká (1998). She identifies following insufficiencies of the original PC-AISOP version:

- insufficiencies resulting from software solution – problematical data preview and querying
- formal errors in analyses (missing measurement units of some database fields)
- nominal form of data (except of analytical values), which are unsuitable for numerical processing

Foregoing failings have to be accompanied also by following:

- insufficiencies in some used values
- incorrect topological location of some soil profiles

Insufficiencies resulting from the original software environment of PC-AISOP database were solved by data transferring into database software MS ACCESS and by proposing the new database field structure. The improvements are as follows:

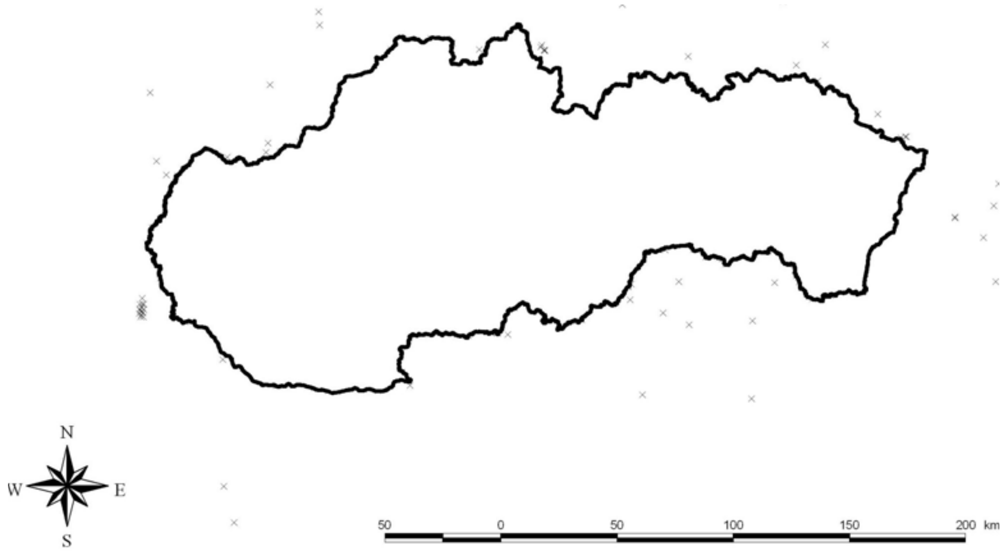
- editing and adding records
- data querying
- using of spatial information by GIS

Majority of formal errors, such as doubled records, incorrect analytical values (shifts in decimal points etc.), were eliminated in KPP-DB.

The problem of field encoding in KPP-DB still remains due to its complexity. Mainly morphogenetic properties of horizons of individual pedons are recorded in nominal form.

These fields have only string character ant they do not allow mathematical-statistical analyses. It is necessary to develop a system of field encoding and to propose the code scales, which reflect the ranges of properties for individual fields (quantification of fields – signs).

Figure 1 Incorrect location of soil profiles in KPP-DB



Some insufficiencies in used field values (ranges), especially those for tables of morphologic values, occurred when database structure and classification had been actualized. We especially mean insufficiencies resulting from systematic errors caused by digitalization of analogue data for PEDMO module, in process of so-called "algorithmic calculations" (Linkeš et al., 1988). It means that some table fields of general and profile information were automatically filled (Fig. 2) based on created algorithms when database PEDMO was built up (Linkeš et al., 1984). However, we are not able to eliminate these insufficiencies and they have to be accepted in KPP-DB therefore.

KPP-DB is also influenced by a random error resulting from incorrect topological location; however, we are not able to identify its real weight (Fig. 1). Coordinates x and y were read from operative maps of KPP by using triangle method. Totally 110 soil records (from 17 743 records) lie outside Slovak boundaries, but the number of soil profiles with incorrect location inside Slovak boundaries were not found out. It will be necessary to develop specific algorithm for elimination this random error.

Actualization of database structure

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

Soil profile data were divided into two datasets and six tables in original PC AISOP:

- dataset of general information (Table of general information)
- dataset of profile information (Tables for horizons 1 – 5)

In the new proposal, the original number of datasets was kept, however, the number and thematic content of tables (four tables) was changed as shown by Figure 2. All soil profile data were divided into two datasets: dataset of general information (i) and dataset of profile information (ii).

(i) dataset of general information

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 (separate tables for these groups were not proposed due to small number of data fields):

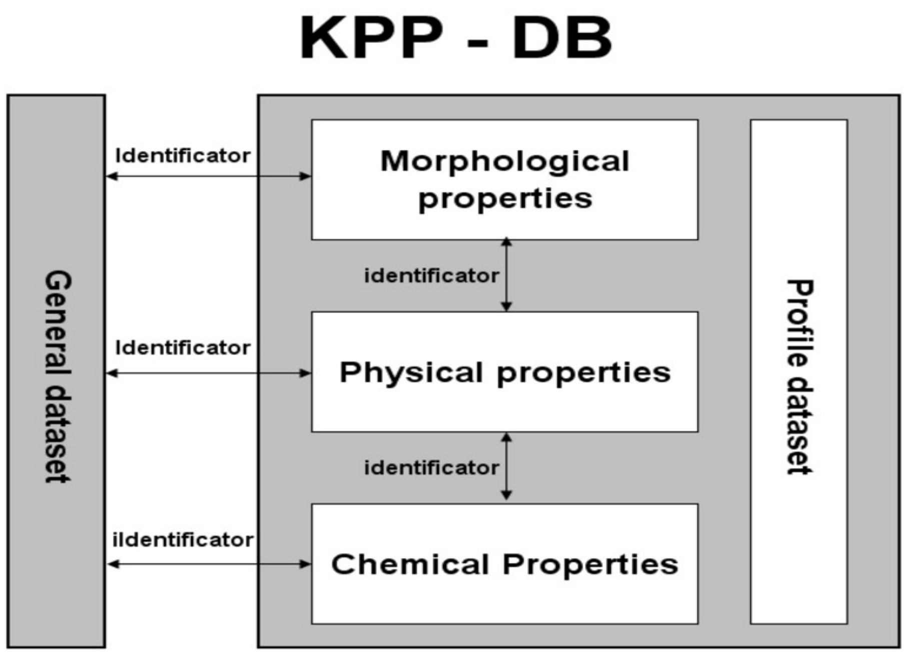
- information about profile identification
- information about profile location
- information about natural conditions
- pedological information

(ii) dataset of profile information

This dataset provides information about basic pedological properties of individual soil profiles. Pedological characteristics are presented for individual genetic horizons. A real number of table fields for the concrete record depends on number of recognized horizons in the concrete pedon. This dataset of profile information is divided into three individual tables as follows:

- table of morphologic properties
- table of physical properties
- table of chemical properties

Figure 2 Proposed structure of database KPP-DB



All records in individual tables of both datasets are connected by a primary key (identification number of soil profile) and possible mistake in querying for the concrete record is excluded therefore. Tabular preview of current fields of KPP-DB is attached in Appendix 1.

Actualization of soil classification and some analytical fields

The necessity for actualization of soil classification resulted from following reasons:

- soil classification used in the original database was based on genetic and agronomical soil classification (Něměček et al., 1967), which was consecutively modified in sense of Něměček (1973) and it does not fulfill any official classification system and its using is difficult therefore
- insufficient encoding of classification soil units and genetic horizons
- codification of new morphogenetic soil classification system of Slovakia (STAFF, 2000) as a basal reference taxonomy

Actualization of used soil classification was originally aimed to realize in direction form genetic horizon to soil units, however, this method was impossible to realize because of:

- absence of some important diagnostic signs for genetic horizons in KPP-DB (humus quality, content of water-soluble salts)
- some morphologic features were recorded in limited rate during the field survey (quality of hydromorphic process signs)
- because of finical and time-demanding work during analogue data encoding, some morphologic signs important for classification were filled automatically on the base of known correlations in process of so-called ‘algorithmic calculation’ (notice above)

Therefore, different procedure was chosen. It follows these rules:

- soil profile classification as well as classification of genetic horizons underwent a multiple control treatment and we can suppose that they are right therefore
- however, multiple manipulation with data in process of digitalization is weighted by a random error and, in practice, we are unable to eliminate this random error.

Used algorithm of actualization was realized on the base of comparison of the original classification units in the original database with MSCS (STAFF, 2000) on the taxonomic level of soil subtype and we used some analytical characteristics for this purpose. The elimination of a random error in soil classification of the original database was assigned by a comparative matrix, which was used to eliminate records with impossible combination of genetic soil horizons in the concrete soil unit (totally 1 266 records). These records were excluded from database into an independent dataset for incorrect records.

Also actualization of substrate classification was done as a part of actualization of soil classification. Soil substrate was actualized with respect to Morphogenetic Soil Classification System (MSCS, 2000). Specific numerical converters were used to fill new categories: particle size category less then 0.002 mm, some physical parameters based on original calculations, particle size evaluation according to triangle classification by MSCS, 2000 instead of USDA triangle classification. World Reference Base (WRB, 98) classification (ISSS-ISRIC-FAO, 1998), as international reference taxonomy, is preferred in KPP-DB v. 1.0 instead of FAO legend, which was used in original database.

In the process of automated actualization of soil classification, transformation tables for soil units, soil substrates and genetic horizons were created and these transformation algorithms, together with those of automated control of field content, were accomplished using 'Visual Basic for application' environment. The data structure was enriched by information about soil unit in the dataset of general information and by some information indirectly connected with soil unit in the dataset of profile information (table of morphologic and chemical properties) – Appendix I.

Moreover, the transformation table for genetic horizons was created with aim to compare used horizon signature and classification with MSCS 2000. This transformation is not directly applied on database structure because of high finicalness of transformation algorithm.

CONCLUSIONS

KPP-DB belongs among basic databases of agricultural soils nowadays and it creates one of the basic spatial and attribute foundation of GIS of Slovak agricultural soils. This database is able to provide efficiency information for the whole area of agricultural soil fund in Slovakia.

KPP-DB is the forward-looking database with huge information potential, which can be used especially by the modern interpolation techniques based on mathematical--statistical processing in GIS applications. Diffuse soil map creation by fuzzy k-mean algorithm combined with geostatistical methods is one of the examples of such using of KPP-DB (Balkovič et al., 2002). KPP-DB was also used for e.g. map building of some basic and derived soil properties in small scales (Bielek et al., 2002).

REFERENCES

Balkovič, J., Hutár, V., Skalský, R., 2002: Continuous soil classification and diffuse soil map creating by methods of fuzzy k-means. Phytopedon, Vo. 2, (in press).

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. konf. Prvé pôdoznalecké dni v SR, (17. – 19. jún 2002, Račkova dolina), VÚPOP, Bratislava, p. 405 – 406.

ISSS-ISRIC-FAO, 1998: World Reference Base for Soil Resources. World Soil Resources Reports, 84, Rome, 88 p.

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

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), VÚPVR, Bratislava.

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

Linkeš V., Poliak P., Krieková A., 1984: Pedologické moduly v československom informačnom systéme o pôde – ich charakteristika a perspektíva využitia. In: Bedrna Z. et al. (ed.): Vedecké práce VÚPVR No. 14. Príroda, Bratislava, p. 9 – 21.

Linkeš V., Gromová A., Lupták D., Poliak P., 1988: Informačný systém o pôde. Príroda, Bratislava.

Linkeš V., Búlik D., Došeková A., 1993a: Informačný systém o pôde. Záverečná správa, VÚPÚ, Bratislava.

Němeček J., 1973: Přehled nejnovějších klasifikačních systémů půd. Studijní správa, Úst. věd. inf., Praha.

Němeček J., Damaška, J., Hraško J., Bedrna Z., Zuska V., Tomášek M., Kalenda M., 1967: Průzkum změdělských půd ČSSR - souborná metodika, díl 1., Min. zem. a výž., Praha.

Skalský R., Rybár O., 2001: Digital Database of Agricultural Soils of Slovakia – A Central Conception. In: Proceedings of SSCRI, vol. 24, SSCRI, Bratislava, p. 95 – 101.

Sobocká J., 1998: Návrh na archiváciu a aplikáciu pôdoznaleckých máp a pôdoznaleckých databáz s využitím GIS vo výskumnom ústave pôdnej úrodnosti. Záverečná správa (21-60-10), VÚPÚ, Bratislava.

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

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 1:5000
N		c_mapy	map number	map number of official state map 1:5000
N		x	x - coordinate	coordinates read from operating maps of CSS (based on official state map 1:5000)
N		y	y - coordinate	coordinates read from operating maps of CSS (based on official state map 1:5000)
N		nadm_v	altitude (meters)	altitude read from operating maps of CSS (based on official state map 1:5000)
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
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
W		hlbka_p	soil depth	assigned according to field forms CSS in four categories (shallow, moderately deep, deep, very deep)
W		FAO	reference soil classification	generated, based on comparation of used classification of original database and soil legend according .FAO
W		BPEJ	PEU	code of pedoecological units assigned by automatic procedure from relevant fields of original database

Appendix 1 Structure and field description of KPP-DB (continues)

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
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	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 P2O5
N	p_dras_h	available potassium	assigned according to field forms CSS, in mg.kg-1 K2O

Appendix 1 Structure and field description of KPP-DB (continues)

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 %
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 %
data_form		field name	field description	notes/data origin
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:
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
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

CARDINAL AND MARGINAL PROBLEMS OF THE SOIL RESEARCH IN SLOVAKIA

Nosné a marginálne problémy výskumu pôd na Slovensku

Rastislav SKALSKÝ[1], Mladen KOLÉNY[2], Vladimír FALŤAN[3]
[1] *Soil Science and Conservation Research Institute, Gagarinova 10, 827 13 Bratislava, tel. +421/2/482 06 901, e-mail: skalsky@vupu.sk*

[2] *Comenius University, Faculty of natural sciences, Department of physical geography and geoecology, Mlynská dolina 1, 842 15 Bratislava, Slovakia, tel. +421/2/602 96 265, e-mail: koleny@fns.uniba.sk*

[3] *Comenius University, Faculty of natural sciences, Department of landscape ecology, Mlynská dolina 1, 842 15 Bratislava, Slovakia, tel. +421/2/602 96 265, e-mail: faltan@fns.uniba.sk*

ABSTRACT

Article deals with part of theoretical soil science. We go into short history and position of soil science in Slovakia including the science structure and provision of soil research. In various chronological times was different main research problem. We do not have explicit paradigms of soil science yet. Diversification of soil research in to several departments has reflection also in its practical application. The advantage is permanent monitoring of some data and information by agriculture and forestry research. These results can be available also for civil engineers, naturalists and environmentalists. The disadvantage is unequal of the development of various disciplines. Some soil disciplines do not have strict methods. We try to concern some main problems and also marginal problems, which can become cardinal (or dominant) later. We inform about natural calamity and catastrophe impact to soil cover. Cardinal and marginal problems of the soil research in Slovakia

Keywords: theoretical soil science, paradigms of soil science, the discipline structure of soil science, cardinal problems of soil science, marginal problems of soil sciences, natural calamity and catastrophe, metamorphose of the soil cover, pedometrics

ABSTRAKT

Príspevok je z oblasti teoretickej pedológie. Zaoberá sa stručnou históriou a postavením pedológie na Slovensku. Z uvedeného vyplýva aj štruktúra samotnej vedy, ako aj organizačného zabezpečenia výskumu pôd. V jednotlivých obdobiach je v popredí záujmu pôdneho výskumu vždy iná oblasť. Napriek uvedenej skutočnosti neboli doteraz explicitne formulované paradigmy pedológie. Rozdrobenosť pôdneho výskumu vo viacerých rezortoch sa odráža aj v preferovaní využiteľnosti výsledkov pre prax. Výhodou je permanentný odber získaných údajov a informácií o pôde praxou nielen poľnohospodárskou a lesníckou, ale výsledky využívajú i iní (stavební inžinieri, prírodovedci, environmentalisti a pod.) Istým handicapom sa ukazuje nerovnomernosť vývoja všetkých disciplín. Mnohé oblasti slovenskej pedológie nemajú jednotnú metodiku, nevenuje sa im dostatočná pozornosť. V príspevku sa snažíme vytipovať isté nosné problémy, ako aj zatiaľ marginálne, ktoré však v zmenených prírodných a spoločensko-ekonomických podmienkach môžu sa stať dominantnými. O jednej z takýchto marginálnych oblastí, ktorej sa nevenuje zatiaľ dostatočná pozornosť – t.j. vplyvu prírodných kalamít a katastrof na pôdny pokrov – podávame stručnú informáciu.

KĽÚČOVÉ SLOVÁ: teoretická pedológia, paradigmy pedológie, štruktúra disciplín pedológie, nosné problémy výskumu pôd, marginálne problémy výskumu pôd, prírodné kalamity a katastrofy, zmeny pôdnej pokrývky, pedometrika

INTRODUCTION

In Antics, Middle Ages and early New Ages people, similar as today, were interested in soil and its most important function – fertility. Soil was/is and still for long time will be basic mean for food production. Till the period of Dokuchaev soil information was concentrated to its ownership, situation, extent, and selected physical properties (particularly texture and stoniness). Soil information resulted from practice needs to increase soil fertility. Till today such pragmatic approach has been typical, since Maria Teresia sovereign, for geodesy and land officials. Even the genetic soil science founder himself was forced to more detailed soil survey by pragmatic reasons – the farms owned by him were not as productive as he needed. Therefore he started more detailed study besides soil system itself also the surroundings – factors and conditions of its initiation, development and soil evolution. His ideas gradually found way also into Slovakia.

Static soil science period (soil was defined as revived weathering material) was substituted by period of dynamic soil science (soil is considered as natural phenomenon originated by evolution of terrestrial crust by organisms affect on rock, by coactivity of water, air, solar radiation, time, later also man). Also in periods of land-use start, farmers knew how to prepare soil properly, they cleared forests (by grubbing and firing), they obtained soil nutrients (by fallowing and later ploughing in farmyard manure), ploughed, tilled, weeded, and in dry periods irrigated. Information on agricultural land use were transferred orally and were coming into heredity.

Already in Middle Ages was in Slovakian space great interest in soil, conditioned by the problems of evidence. It was caused by need of food. Later landlords needed also financial means. They showed increased interest for land acreage and yield-forming potential. Already in XVth century used to be elaborated reviews about farm numbers in the estates. In 18th century Maria Teresia emperor established cadastres (Grundbuch) with parcel description and geometric survey. This was the fundament of land-use central evidence. In transition 19th to 20th century land evidence was enriched in soil quality. Horusitszky, Hungarian geologist and cartographer from Royal Geological Institute in Budapest, in the way of questionnaire ascertained soil quality on various rocks by the results of farming. He got information about soil quality and he created soil maps. That material was able for the soil taxation.

SOIL SCIENCE BEARING PROBLEMS IN SLOVAKIAN TERRITORY IN PERIOD SINCE BEGINNING OF 20TH CENTURY

In Czechoslovakia Agropedological and bioclimatological Institutes were created in 1921 in Bratislava and Košice. After Vienna arbitrage Institute from Košice was moved to Spišská Nová Ves.

After Czecho-Slovakia establishment was started systematical soil survey, particularly soil texture. In forties was implemented genetic soil science and at Spišská Nová Ves city was established soil laboratory headed by Dr. Kožuch. After 1949 was established three-pit system of soil survey and resulting terrestrial division of Slovakia into four agricultural production zones. Lowland warmest parts belong to maize-type. Remaining lowland parts with low located basins is zone of sugar beet. Most carpathian basins and valleys belong into potato and fodder crop type. This territorial division has been lasting till now. In 1959 (Randuška et al.) was completed atlas of site forest conditions with soil map of scale 1:200 000 with 6 of old regions.

In period 1960 – 1971 was implemented modern Complete Soil Survey of the agricultural soils (KPP). This resulted in series of soil maps in scales 1:5 000, 1:10 000 and 1:50 000 and Soil Map of Czechoslovakia 1:500 000. Complex soil research method was draw first time in 1962 in Czech language (Němeček) and its modified translation was in 1966.

In 1975 – 1977 was running farmland pedo-ecological mapping in scales 1:5 000 and 1:50 000 with numeric coding of soil quality. In this way were formed approximately 1 000 types of pedo-ecological units (PEU). Subsequently were PEU evaluated and consecutively were used for application moduls creating. The matter was acceptable soil integration into fields, optimum land-use for cultures and crops, fertilization, investment and non investment soil reclamation and after 1990 basal soil appraisal and soil price at its definite delimitation out of biomass production, further here is land rent and land situation rent (till now solved only for urban – built up soils).

Similar mapping was implemented in period 1975 to 1985 upon woodland in scale 1:10 000 with fair copy for forest economical wholes in scale 1:25 000. For the purposes of Atlas of Slovakia was formed soil map block in scale 1:500 000 and in smaller scales. In 1990 was finished mapping of whole Slovakian territory in scale 1:200 000 according newest nomenclature. In 1996 was elaborated Soil Map of Slovakia in scale 1:400 000.

In recent period were developed soil physics, chemistry and mapping, cartography, respectively. Partially was developing also soil mineralogy, less soil biology. Among application branches developing have been agro physics, agrochemistry, plant nutrition, soil remediation, partially also hydropedology and forest soil science. Elaborated were also methodologies for soil survey in terrain (Němeček et al., 1966) and for laboratory analyses (Hraško et al., 1962) and these publications were recently innovated (Čurlik, Šurina, 1998; Fiala et al., 1999). Since 1983 team of authors has been continually working in the field of soil nomenclature and taxonomy. In 2000 the stuff of soil scientists issued 4th newest version of the Morphogenetic Soil Classification System. If we do not mentioned about 3rd disown version of Morfogenetical Classification Soil System (Hraško, 1996), Morfogenetical Classification Soil System (2000) is 3rd version.

Since 1985 have been running works on general soil monitoring (part of state monitoring system of environment), and since 1990 has been also running special soil monitoring of the soils influenced by the Gabčíkovo Hydro-power Plant. General soil monitoring has more than 600 profiles.

Since 1993 has been running systematic anthropogenous soil research, and Soil science Department Faculty of National Sciences at Commenius University in collaboration with Soil Science and Conservation Research Institute Bratislava have been organizing 6th scientific international conference. To bearing problems of soil research was included also soil hygiene. Since 1980 has been concentrated attention to soil nitrate and heavy metals at some risk crops. Mentioned review formed bearing topics of Slovakian soil research, perhaps here are also included also erosion control, as well as farmland conservation. To our sorrow, here can be stated just only permanent farmland decrease.

MARGINAL PROBLEMS OF PRESENT SOIL SCIENCE AND SOME PROGRESSIVE AREAS OF ITS DEVELOPMENT

Besides bearing problems in soil research also appeared its aberations (temporal marginalities). One of them is detailed soil survey based on relief micro- and mezzo--forms, also on the base remote sensing. Mentioned is also soil cover structure, studied partially on soil patterns.

Today we also can speak about rapid development of pedological disciplines corresponding with informatics development and GIS-technologies that still more are in centre of attention. Pedologhical data processing options thanks to computing technique and GIS tools development in recent decades significantly increased. They enable to analyze pedological data by quantitative procedures. Here is reduced rate of subjective decision, when assessing soils.

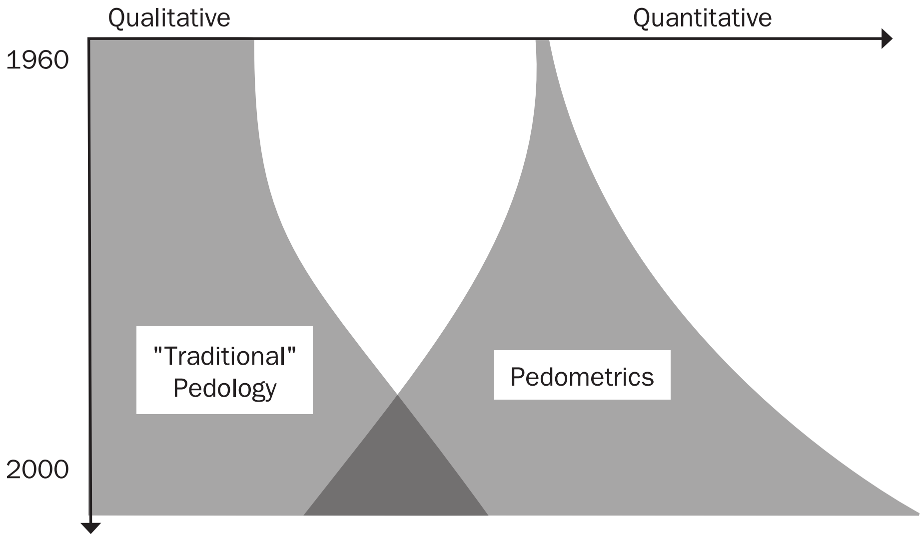
This process share is also transition from qualitative research procedures to quantitative ones and effort for insecurity rate expression at soil models formation. Many of today used quantitative methods were elaborated for soil research in 20th century 60 – 70ies (e.g. numerical taxonomy, geostatistical methods) that in spite of their progressivity were developed with aspect to information technologies level that time only marginally (Mc Bratney et al., 2000).

Quantitative procedures elaboration and their application in soil science resulted in nineties of 20th century into formation of soil science region named pedometrics. Webster (1994) is defining this term as formal neologism formed of greek roots „pedos“ – soil, earth and „metros“ – to measure. The pedometrics definition as a pedological discipline brings McBratney and he considers it for:

„That area of science concerned with description, classification, formation and distribution of soil by quantitative mathematical and statistical techniques.“

Many pedometrics methods development have been continued since 60ies of 20ies century, however still recently was pedometric considered as independent discipline and it was recognized from classic soil science. Only by penetration computing technique almost into all human activity regions classic soil science and pedometrics started in some areas to be overlapping (Fig. 1) (Mc Bratney et al., 2000).

Figure 1 Classic soil science and pedometrics relationships development in time (fitted by McBratney et al., 2000)



Pedometrical procedures are heterogeneous, they apply wide spectrum of general, as well as specialized mathematical and statistical methods used in various modifications and mutual combinations. Pedological data are often proceeded in combination with data obtained, e.g. by remote sensing data interpretation, as well as terrain digital models (DTM) in GIS environment.

The procedures classification using pedometrics is proceeded by the work McBratney et al. (2000) and McBratney (www.usyd.edu.au):

1. Numerical taxonomy methods introducing a group of quantitative approaches to soil and lanscape classification. The numerical methods are share of this group using approaches based on principles fuzzy sets and fuzzy logics.
2. The methods of spatial variability modeling introduce a group of interpolation methods that can be divided by their character in two groups:
    - geostatistical methods – introducing the methods of data spatial analysis for soil properties description and prediction, based on theory of spatially dependent random variables.
    - The methods included under title environmental correlation introduce a group of methods using standard statistical procedures: variability analyses, regression and multidimensional data analysis. These methods by their idea most often are based on soil empiric-deterministic model as a function of environmental properties, first time defined by Jenny (1941).
3. Soil quality assessment methods in sense of numerical description and soil propertiers assessment in the level of so called fine-scale (under I m) and formation of processional oriented models characterizing soil properties (e.g. Pedotransfer--function quantification via modeling soil pore medium by use of image analysis and fractal geometry).

In soil science progressive seems to be also effort for continual soil model application respecting natural, very often soil properties character in comparison to conventionally used non- continuous model (with less frequented occurrence) that defines soil properties (units) both, in geographic and taxonomic space, limited crisp – so called „double crisp model“ (Borough et al., 1997).

The problem, still not sufficiently in centre of soil scientist's attention, is possible soil properties changes due to predicted climatical changes. Sorrowfully it should be stated, also the problem of pure food production on relatively least contaminated soils also are not in the centre of soil research. Alternative agriculture and agro tourism still are branches that only are searching their groundeness. To these problems also are included natural catastrophes affects on soils. We would like to highlight these problems more detailed.

Under natural catastrophes should be understood considerable and sudden negative changes in country space causing catastrophe in biota and death to people.

By the term – calamity can be understood a natural catastrophe – without any loss on human lives. The changes are caused by natural danger element – uncontrollable natural power with extraordinally destructive impacts. Soil processes are relatively slow, in case of negative tendencies, their affect is not catastrophic. Soil catastrophic phenomena are caused by the forces active out of soils. The forces are geomorphological (erosion, slides, murs, avalanche), hydrological (floods, tsunami), meteorological (catastrophic rainfalls, hailstorm, tornados, extreme droughts, fires, extreme frosts, ice formation), and biological (diseases, insect over multiplication, extension of introduced varieties without natural competition).

The forces, their initiation causes, the course itself and consequences of their catastrophic activities with associated space quality changes – these all are the objects of geographical research. Geography has enough information about background status (i.e. status before catastrophe), it knows how to forecast these phenomena, based on recent history, it knows how any of the spaces will react on concrete catastrophe type and in prediction – planning level can propose suitable measures against a calamity and catastrophe in therapeutic level. Proper recovery measures oriented to consequences compensation are to be proposed in any case of natural catastrophe.

First should be mentioned some institutions professionally involved in natural catastrophes. Soil institutions solving „classic“ researches were mentioned in the cases of soil monitoring. Monitoring of the calamities or catastrophes with harmful effect on soil solve the problems not systematically with exception of the producers (however their duty is not publication of damages). Perhaps insurance offices or Ministry of Agriculture have been regularly registering all the events, here also are directed requirements for damage elimination. Slovak Hydrometeorological Institute (SHMU) has in his agenda floods, storms, extremely high and low temperatures, droughts, hailstorms as the forces predicted in some time and some spaces. As rule negative consequences are not their research activities domain, however they are dominating at the damages objectivisation. Geofond is oriented to slides, debris avalanche, particularly to earthquakes and their consequences. Exceptionally is Genofond also involved in snowslips. In other parts of the world take place also volcanic activities and tsunami

Risk and predictiones of avalanches in some areas are domain of the Mountain Service (is active in all slovakian higher mountains). Plant preservation against diseases or abundant animal pests is in the centre of activities of Central Control and

Testing Agricultural Institute, Bratislava and Forest Economy Research Institute, Zvolen. Fire negative impact preservation in country secures Assembling of Firemen that has been registering naturally and artifitially originated fires, their extent or catastrophic consequences.

Besides the research project Vega the System of Monitoring Research and Information of Natural Catastrophe in Slovak Republic (for needs of ecological management and country optimization), responsible authors Hreško - Minár. Natural forces catastrophic effect on soils is not covered by any special system. Within basic monitoring are studied particularly relatively slow changes, including soil erosion. Special form of monitoring is linked with every soil contamination including that one connected with natural forces. Recently is attention attracted to climatic changes (Slovak Hydrometeorological Research Institute, Slovak Technical University, Slovak Agricultural University and Soil Science and Conservation Research Institute). The matter are particularly weather anomalies and total aridisation trend. In 2075 mean annual temperature will be increased in range 2 – 5 Centigrades. For first phases of complex monitoring system of natural catastrophes this means (Minár, 2001) a catastrophe monitoring before its start, this in case of real catastrophe significantly helps by natural environment reconstruction. By special procedures application (past phenomena study) is possible to prevent or eliminate negative impacts on minimum possible rate. Second phase is a catastrophe course. In the research of damaged region characteristics, first is necessary geodetically determining extent. Ideally could be to use ortophotomaps before/during or immediately after a catastrophe. The maps can be used in the case of the territory flooding and its delimitation out of production function by detection sediments and erosion, etc. For contamination is necessary sampling and sample analyses in laboratories. For permanently contaminated soils and their products was established Agricultural Production Quality Board, also controlling small selling quality. Special team can help by proper parameters measurement. Third phase after a catastrophe should solve given country detriment by geoecological mapping and data elaboration and deposition into GIS. Special research should be focused to recovery measures and assessment conditions of the catastrophic process as well as possible repetitions. If the territory could not be secured enough against repetitive impact of destructive forces, or the recovery could be economically not bearable, given activity should leave the space and new functions should be proposed. Can be stressed, man causes greatest calamities and catastrophes. He is degrading soils, causes escalated erosion and contamination and takes away farmland for non-production purposes.

CONCLUSIONS

We would like to present short scheme of soil science structure with several aspects (Tab. 1), as well as review of bearable topics in present Slovak soil science:

- Conservation area and farmland quality
- Soil and production contamination
- Farmland degradation (compaction, escalated soil erosion)
- Soil monitoring, insurance of soil data situation exactness
- Soil information maintenance and actualisation and GIS formation
- Nutritional and reclamation measures in new economical conditions

- Farmland use optimisation includind land remediation
- Problems connected with global warming
- Soil classification and systemization (taxonomization)
- Anthropogenous soils
- Methodologies precisation and unification in terrain and laboratory activities
- BIS and its optimum use
- PEDOKONZULT – permanent service for practice in region of soil topics.

Mentioned review could not be complete without this time marginal problems of present Slovak soil science:

- Pedometrics development and remote sensing methods use
- Soil determination key formation
- Paleosoil system creation
- Soil natural scientific system formation without purposefulness
- Investigation of all relevant fixations in soil and soil – environment
- Soil biota research
- Soil regularities, their formulation
- Exaction of point interpolation information into area
- Soil cover structure
- Monitoring of negative natural and anthropogenous soil calamities and catastrophes.

Table 1 Soil science disciplines structure scheme

1. SUBJECT POINT OF VIEW		
A – by soil components and research methods	soil physics	
	soil chemistry	
	soil mineralogy	
	soil biology	
	soil ekology	
B – according knowledge character general	soil science	
	systematic soil science	
C – according to findings collection and use	empirical	terrain laboratory
	theoretical applied	
2. TEMPORAL POINT OF VIEW		
	present soil science	
	historical soil science	
	paleopedology	
3. SPATIAL POINT OF VIEW		
	pedogeography	
	soil kartography	

We regard as important also missing paradigms in soil science in Slovakia estimation. It is mainly:

- idiographic soil science – as static soil science
- nomotetic soil science – as dynamic soil science
- locational soil science – (reduced in Slovakia only to soil mapping)
- synergic soil science – as ecological soil science
- exactional soil science – as pedometrics s.s. and parametrisation, logisation and formation (maintence) of soil information systems

Finally should be stated, theoretical soil science back warded behind empiric and applied soil science that are substantially better reworked. One of Slovakian soil survey marginal problems was also natural catastrophes affect on soils.

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REFERENCES

Agenda 21 a ukazovatele trvalo udržateľného rozvoja. Vyd. Min. Životného prostredia SR, Bratislava, 1996. 520 s.

Burough P.A., Gaans van P.F.M., Hootsmans R., 1997: Continuous Classification in Soil Survey: Spatial Correlation, Confusion and Boundaries. Geoderma 77, p. 115 – 135.

Burton, I., Kates, R., White, G. F.: The environment as Hazard, 2nd Edition, The Guilford Press, New York 1993, 290 s.

Čerňanský, J., Kožuch, M.: Digitálna ortofotosnímka Kočín. M 1:10 000, stav k r. 1998. LMS © Úrad geodézie, kartografie a katastra Slovenskej republiky, 1998, Digitálne ortofoto a DMT – Prírodovedecká fakulta, UK Bratislava, Katedra kartografie, geoinformatiky a DPZ, XI. 2000.

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

Dokučajev, V.,V.: Vybrané práce. Přírodovědecké vydavatelství, Praha, 1951. 240 p.

Drabek, T. E., Hoetmer, G. J. (eds.): Emergency management: Principles and practice for local government. International City Management Asociation. Washington D. C. 1991, 616 s.

Etkin, D., Vasquez, M. T., Kelman, I.: Natural disasters and human activity. A contribution to the North American Commision Environmental Cooperation State of the environment report. Environment Canada 1998.

Fiala, K. a kol.: Záväzné metódy rozborov pôd. Výskumný ústav pôdoznalectva a ochrany pôdy. Bratislava, 1999. 138 p.

Fulajtár, E. a kol.: Vplyv vodného diela Gabčíkovo na poľnohospodárske pôdy. VÚPÚ, Bratislava, 1998. 202 s.

Horusitzky, H.: Über die Anfertigung agrogeologischer Karten. Földtani közlöny, Budapest, 1899.

Hraško, J. a kol.: Rozbory pôd. SVPL, Bratislava, 1962. 342 p.

Hraško, J., Jambor, P.: Dokumenty o pôde. VÚPÚ, Bratislava, 1996. 48 s.
Hreško, J., Minár, J.: Rámcový návrh projektu „Monitorovací výskum a informačný systém prírodných katastrof v Slovenskej republike (pre potreby ekologického riadenia a optimalizácie krajiny). KFGG, PRIF UK, Bratislava, 2001. rkp. 3 s.
Jakál, J.: Extrémne geomorfologické procesy ako prírodné živly. AFSHetN UP, Prírodné vedy, Folia geographica 2, roč. XXX., Prešov, 1998. p. 297 – 304.
Jambor, P.: 5 rokov (1990 – 1995) plodnej spolupráce VúPú a PVOD Kočín modelový podnik. Vyd. VÚPÚ Bratislava, 1996. 20 s.
Jenny H., 1941: Factors of Soil Formation, A System of Quantitative Pedology. McGraw--Hill, New York.
Kolektív autorov: Monitoring pôd SR. VÚPÚ, Bratislava, 1994. 4 s.
Kolény, M.: Propedeutika k monitorovaniu prírodných katastrof Slovenska z hľadiska pôd. Acta Environmentalika Universitatis Comenianae, Supplement, Bratislava 2002. p. 153 – 162.
Kňazovický, L.: Lavíny. Vyd. SAV, Bratislava, 1967. 264 p.
Lukniš, M.: Reliéf Vysokých Tatier a ich predpolia. Vyd. SAV Bratislava, 1973. 375 p.
McBratney A., 1997: Pedometrics Studies of Soil Variation.
URL: http//www.usyd.edu.au/su/agric/acpa/people/summary.htm
McBratney, A., Odeh, I., Bishop, T., Dunbar, M. and Shatar, T., 2000: An overview of pedometric techniques for use in soil survey. Geoderma, vol. 97, 293 – 327.
Mičian, Ľ.: Vývoj pôdoznaleckého výskumu na území ČSSR a jeho súčasný stav. Práca k ašpirantskému minimu. Archív KFG PRIF UK, Bratislava, 1963. 172 p.
Midriak, R.: Morfogenéza povrchu vysokých pohorí. Veda, vyd. SAV Bratislava, 1983. 513 p.
Minár, J.: Prírodné katastrofy – pole pre geografickú syntézu. III. Seminarium polsko--czesko-slovackie: Przestrzen geograficna na przelome wiekow – wyzwania teoreticne i metodicne. 18-22 cerv. 2001, Cierszewo, k. Plocka, 8 rkp. (in print)
Mocik, A. a kol.: Koncepcia bazálneho monitoringu pôd Slovenska. VÚPVR, Bratislava, 1985. rkp.
Nemčok, A.: Zosuvy v Slovenských Karpatoch. Veda, SAV, Bratislava, 1982. 319 p.
Němeček, J. a kol.: Prieskum poľnohospodárskych pôd ČSSR. Súborná metodika A, 3. vyd. Laboratórium pôdoznalectva, Bratislava, 1966. 162 p.
Paulov, J.: Snahy o premenu teoreticko-metodologického modelu geografie. Čas. Filozofia, č. 1, SAV, Bratislava, 1968. p. 55 – 68.
Pianizza, M.: Geomorphological contributions to seizmic risk assesment. Suplementi di Geografia Fisica e dinamica Quaternaria, II. 1989, p. 111 – 114.
Randuška, D. a kol.: Atlas stanovištných pomerov lesov. Mierka 1:200 000 (Kraj bratislavský, nitriansky, žilinský, banskobystrický, košický a prešovský). Bratislava, 1959.
Webster R, 1994: The development of pedometrics. Geoderma, vol. 62, p. 1 – 15.
Zachar, D.: Erózia pôdy. Veda, SAV, Bratislava, 1970. 517 p.

CHARACTERISTICS AND CLASSIFICATION OF SOIL CHANGES INVOLVED BY PHYSICAL DEGRADATION PROCESSES

Charakteristika a klasifikácia premien pôd spôsobených procesmi fyzikálnej degradácie

Jaroslava SOBOCKÁ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Based on the newest references data, affects of soil physical degradation on pedogenetical processes in soil profile were assessed and their significance from the view of soil transformation in present conditions was determined. As the most important problem showed to be sheet water erosion in chernozemic and luvisolic hilly land areas. The erosion – accumulation processes and their expressions were assessed as a classification problem, which was recalculated from the view of international classification systems. The study result is the project of soil associations (sequentions) classification and mapping at the Chernozems and Luvisols damaged by erosion, their comparation with the WRB (World Reference Base) system, as well as the proposal to include new soil type – Colluvisol within the Morphogenetic Soil Classification System (MSCS) of Slovakia. The Colluvisol was defined as a soil type with diagnostic Ck-horizon occurring in lowland or depressional relief forms as a direct consequence of historical erosion – accumulation processes.

Keywords: physical degradation, classification, erosion, Colluvisol

ABSTRAKT

Na základe najnovšej literatúry boli prehodnotené vplyvy fyzikálnej degradácie pôd na pedogenetické procesy v pôdnom profile a určená ich významnosť z hľadiska transformácie pôd v súčasných podmienkach. Ako najzávažnejší problém sa ukázala plošná vodná erózia vyskytujúca sa v černozemnej a hnedozemnej pahorkatinnej oblasti. Erózno-akumulačné procesy a ich prejavy boli hodnotené ako klasifikačný problém, ktorý bol prehodnotený z hľadiska medzinárodných klasifikačných systémov. Výsledkom štúdia je návrh klasifikácie a mapovania pôdnych asociácií (sekvencií) eróziou postihnutých černozemí a hnedozemí, ich komparácia s WRB systémom ako aj návrh na zaradenie nového pôdneho typu – koluvizeme do Morfogenetického klasifikačného systému pôd Slovenska. Koluvizem bola definovaná ako pôdny typ s diagnostickým Ck-horizontom vyskytujúci sa v údolných, resp. depresných formách reliéfu ako priamy dôsledok historických erózno-akumulačných procesov.

Kľúčové slová: fyzikálna degradácia, klasifikácia, erózia, koluvizem

INTRODUCTION

At present physical degradation processes identification in soil profiles has been elaborated only partially, without any complete assessment. Mainly an identification of erosion and compaction processes of agricultural soils is often presented, as direct consequence of human activities, although also other physical degradation factors are not negligible. So, we can meet here primarily anthropically involved physical degradation in all negative impacts on soil profile: i.e. humus horizon thickness reduction, textural changes (fine earth leaching), humus content and nutrient supply decrease, pH change, subsoil pseudo-aggregates formation, etc. Degradation processes and their intensity make a big share on morphological, physical-chemical and biological changes in soil profiles, which can result in different classification taxon. We have stated that diagnostics and classification of soil affected by erosion according to the latest Morphogenetic Soil Classification System of Slovakia (2000) reflect erosion processes at the level of soil type, variety and form. A separated soil horizon was not defined. Similarly situation is recognized in compacted soils where physical characteristics are defined at the level of soil texture (textural triangle) and compacted layer presents directly a part of cultizemic soil horizon description.

MATERIAL AND METHODS

The main goal of physical degradation processes in soil profile was:

- Review and assessment of physical degradation processes in aspect of present pedogenetic development;
- Identification of new physical degradation manifestation and their adequate incorporation in a classification system, or its correction;
- Prediction, or prognosis of future development of this phenomenon mainly in areas intensively used by human;
- Model construction of gradual genetic development of soil units under physical degradation conditions.

For definition of all physical degradation range we have chosen definitions according to Van Lynden (1997). It can distinguish several types of physical degradation more or less occurring in Slovakia.

1. **Water erosion** – loss of topsoil by sheet erosion/surface wash. It means a decrease in depth of the topsoil due to more or less uniform removal of soil material by runoff water. An irregular displacement of soil material (gully and/or rill erosion) can cause clearly visible scars in the terrain. The possible causes can be inappropriate land management in agriculture, forestry or construction activities allowing excessive amounts of unobstructed runoff.
2. **Wind erosion** – loss of topsoil by wind erosion, i.e. a decrease in depth of the topsoil due to more or less uniform removal of soil material by wind action. As terrain deformation can be characterized an irregular displacement of soil material by wind action causing deflation hollows, hummocks and dunes. Possible causes can be insufficient protection by vegetation (or otherwise) of the soil against the wind, insufficient soil moisture, destruction of soil structure.

3. **Soil compaction** – deterioration of soil structure by trampling or the weight and/or frequent use of machinery. As the main causes can be recognized repeated use of heavy machinery, having a cumulative effect on pseudo-aggregates formation. Heavy grazing and overstocking may lead to compaction as well. Factors whose influence are ground pressure (by axle/wheel loads of machinery used), frequency of the passage of heavy machinery; soil texture; soil moisture.
4. **Aridification** – decrease of soil moisture. As possible causes can be: lowering of ground water tables for agricultural purposes or drinking water extraction; decreased soil cover and organic matter content; climate change.
5. **Sealing and crusting** – clogging of pores with fine soil material and development of a thin impervious layer at the soil surface obstructing the filtration of rainwater. As possible causes can be recognized poor soil cover, allowing a maximum "splash" effect of raindrops, destruction of soil structure and low organic matter.
6. **Urban/industrial land conversion** – (soil/land) being taken out of production for non-bio-productive activities, but not possible "secondary" degrading effects of these activities. Possible causes are considered urbanization and industrial activities; infrastructure; mining; quarrying, etc.
7. **Water-logging** – as effects of human induced hydromorphism. Causes are recognized: rising water table (e.g. due to construction of reservoirs/irrigation) and/or increased flooding caused by higher peak-flows.

RESULTS AND DISCUSSION

In conditions of Slovakia among the most serious problems of physical degradation belong sheet water erosion and soil compaction, less there are wind erosion and other types of above mentioned physical degradation. That was a reason, why we have focused on identification and definition of water sheet erosion processes occurring in most affected areas – Chernozem and Luvisol from loess hilly land of Slovakia.

Classification problem of soil compaction

Problem of soil compaction directly connected with grain size fraction of soils, and therefore the classification is considered at the level of soil texture. In textural heavy soils we assume an occurrence of subsoil hardpan or pseudo-aggregates presence, which are described in the cultizemic diagnostic horizon, according to the MSCS (2000). It is very low permeable compacted layer as a consequence of recent soil technologies often used and other non-rational cultivated practices. We do not assume any changes of soil types, subtypes or varieties on the base of subsoil hardpan. However subsoil compacted layer is not presented as stabile feature (e.g. by deep ploughing can be this layer disturbed), so it cannot be considered as direct diagnostic feature.

Classification problem of wind erosion

The problem of wind erosion is serious mainly in areas of sandy and light soils occurrence. Classification interpretation is quite well presented in form of various Regosol types or similar types. An important characteristic of these soils is sand grain size fraction. The surface can be deformed by erosive wind activity. This phenomenon is not so much recognizable in soil profile it can be deduced from landscape, i.e. vegetation cover, anti-erosion measures, deflation dunes, etc. Classification changes can be indicated at the level of form where we recognized eroded and accumulated forms, both. Their occurrence has been is not well evidenced, changes at the level of soil type or subtype were not yet documented. Nevertheless we anticipate a certain development of Cambisols to Regosols in sandy hilly land areas with active wind erosion connected with intensive farming, but also the water erosion has a share in soil degradation.

Classification problem of aridification

The problem of drying of soil profile used to be more difficult detected, because traces of hydromorphism remain in soil profile yet long time after water regime changes. The aridification of soil profile is needed observe in the frame of whole perceiving of land desertification, or to pursue anthropogenic influences on land what is one of degradation factors in land development. From the standpoint of physical degradation we do not assume strong classification change, only change of soil structure and long-term observed moisture conditions can indicate land drying. More expressive manifestation of land drying may be presented in soil chemistry (alkalization, salinization, carbonatizaton, etc.).

Classification problem of sealig and crustig

This problem is negligible in aspect of classification soil unit change. Forming of impervious layer due to rain fall drops effect is many times one of the causes of excessive soil material runoff, but it has only seasonal effect.

Classification problem of urban/industrial land conversion

This problem of physical degradation is very serious and requires individual research at the level of new soil science field. Due to strong and deteriorated impacts of many anthropic factors in land there is presented a strong deformation of soil cover and its reduction for other than agricultural purposes. In this aspect there all natural classification units are changed into Anthrozemic, less Cultizemic soil types. Therefore it may be used wholly new classification of soils occurring in urban, industrial, transport-lines and mining areas.

Classification problem of water-logging

The problem of human-induced hydromorphism in soil profile can be assessed as an effect of water regime change showing in redox features relatively soon. These features are classified at the level soil type and subtype. With > 80 % mottles of soil profile soils incline to Pseudogley. At presence of 10 – 80 % redox features soils are developed at the Pseudogley subtype level. In the case of whole water saturation in soil profile with high level of ground water it can be developed gley soil type, or gley subtype, respectively. This feature is very difficulty evidenced as an indirect effect of anthropogenic activity.

Classification problem of water erosion

This problem is really serious and therefore a great deal of the paper is dedicated it. In Chernozem´s and Luvisol´s areas of Slovakia it can be recognized excessive water erosion, mainly in loess hilly land. This phenomenon is dominant in undulated agricultural hilly land on soils developed from loose and friable loess and loessial loams.

Soils belong to our most fertile ones, therefore their protection is most significant in sustainable land use development.

Literature background review

Already Zachar (1960) used so-called "morphological traces" for soil erosion identification, particularly the presence/absence of diagnostic horizons and their thickness. His scale includes 5 classes: a) runoff of 1/10 original soil profile, b) runoff of 1/10 – 1/3 soil profile, c) runoff of 1/3 – 2/3 soil profile, d) runoff more than 2/3 soil profile, but not whole soil profile, e) runoff of whole soil profile.

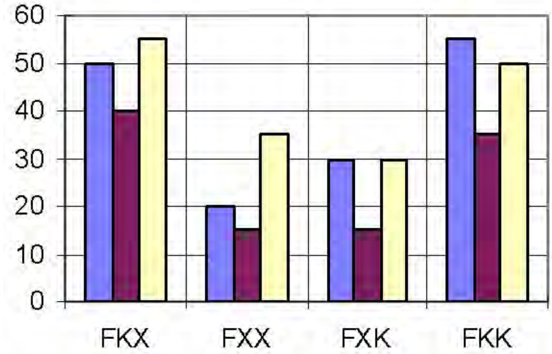
Sobocká, Jambor (1998) tested thickness of humus horizon in Eroded Chernozemic area of the SE-Danubian lowland part by means of so-called micro-catenas (i.e. it does not respect whole slope, only geometric form on slope). For analysis and mapping of area four geometric relief forms were tested: convex-convex (F_{XX}), convex-concave (F_{XK}), concave-convex (F_{KX}) and concave-concave. Individual transects in geometric forms were selected by representative way with approximately unified slope (7 – 10°), unifies slope length (60 m) and pits distance (25 – 30 m). We have tried to find a relation, or dependence of soil unit distribution on morphometric relief parameters. Each micro-catena was characterized by particular soil unit arrangement.

Table 1 Testing of geometric relief form

Geometric relief forms	F_{KX}	F_{XX}	F_{XK}	F_{KK}
Average thickness of A-horizon in top part of micro-catena (cm)	50	20	30	55
Average thickness of A-horizon in middle part of micro-catena (cm)	40	15	15	35
Average thickness of A-horizon in bottom part of micro-catena (cm)	55	35	30	50

Results of our investigations allowed us precise and accuracy mapping of several soil associations in conditions of erosion processes in Chernozemic areas.
F_{XX}, Eroded Chernozem – Calcaric Regosol – Accumulated Chernozem,
F_{XK}, Eroded Chernozem – Calcaric Regosol – Haplic Chernozem,
F_{KX}, Eroded Chernozem – Accumulated Chernozem,
F_{KK}, Haplic Chernozem – Accumulated Chernozem.

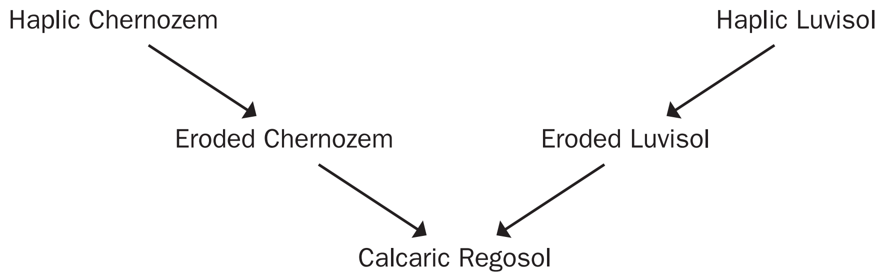
Graph 1 Average thickness of A-horizon in tested micro-catenas (top, middle, bottom part)



Jambor, Sobocká (1997, 1999) observed in transition conditions of Trnavian loess hilly land to Little Carpathian Mountains (cooperative farm Kočín) a development of water erosion processes and its reflection in soil typology. In time of 30 years in depending upon slope, morphology and textural composition of soil profile there was stated change of some Haplic Luvisols to Eroded Luvisols and at last to Calcaric Regosols. Also a marked increase of skeletal soil category was registered.

As a historical genetic process of soil erosion is considered gradual change of Chernozems and Luvisols to their eroded forms what result in Calcaric Regosols formation as shows the graph 2.

Graph 2 Historical genetic process of soil erosion as a cause of gradual soil types change



Lehotský (1999) pursued erosion-accumulation catenas in model hilly land Bzince pod Javorinou (Luvisol). His main findings are:

- in rectilinear (i.e. by erosion most affected catena part) is indicated change of soil profile horizontation, where a typical ochric top horizon is disappearing and the surface is formed by compacted Bt-horizon with compaction values of twice higher than in other parts of soil profile 2x (3 – 5 MPa),
- in rectilinear catena part content of humus is decreasing similarly like T and pH values. Comparing with top catena – part grain size fraction 0.001 – 0.01 is diminished into 56%, 74%, or 75%, respectively.

Fulajtár, jr. (1999) in detail studied changes of soil types due to erosion and mineralization. He registered some transformations of soil profiles in model area of Rišňovce:

- transformation of Leached Chernozem with Bv-horizon presence on Chernozem with s A/C profile which is carbonated from surface;
- transformation of Luvizemic Chernozem to Haplic Luvisol;
- transformation of Chernozem to Regosol.

Besides he described such changes which represent a big deal in soil fertility changes reflecting anthropically conditioned water erosion:

- changes in humus content and quality, (this process affects all transformed soils),
- changes in carbonates
- changes in cation exchangeable capacity,
- changes in water capacity,
- changes in nutrients content.

Soil erosion in classification systems

According to the latest Morphogenetic Soil Classification System of Slovakia (Collective 2000) diagnostics and classification of soil erosion affected soils reflect soil erosion processes at the level of soil type (change of Haplic Luvisol or Chernozem to Regosol), variety (soil reaction change) and form: eroded (e), accumulated (h). Eroded form is defined as a form in what the whole solum was affected by soil erosion and a part of dominant diagnostic horizon was preserved. Accumulated form is defined as thickness increasing of A-horizon by gravitation accumulation of humic material (occurring as a rule in concave relief forms), which is manifested by thickness exceeding limited value of A-horizon, by differentiation in colour (more dark than original humus horizon), respectively in soil structure, texture, consistency, or stratifying.

In the world soil classification systems like World Reference Base (1998), Revised Legend of FAO (1996) a Soil Taxonomy USDA (1998) we have not found any note abut classification of eroded soils. Obviously changes of original soil types on eroded soils are reflected in soil types like Arenosol, Regosol, etc.

Russian Soil Classification (Šišov, Dobrovolskij, 1997) defines soils affected by erosion processes at the high levels like soil type, soil subtype and defined one diagnostic horizon. It is post-erosion diagnostic horizon – homogeneous, in colour is dominating brown, chestnut, red-brown and pale-yellow shades, non-structured or granular. At irrigation there is often clogging of pores with fine soil material and crusting. Humus content is less than 1.5 %. It was formed as result of transformation B-horizons or parent material.

Soil group Abrazems (Erozems) – soils with lacking of topsoil diagnostic horizons due to natural or anthropogenic erosion, deflation or profile truncating. Immediately on surface there is preserved B-horizon (illuvial, textural, metamorphic, calcareous) or transition horizon to parent material.

Soil group Agroabrazems (Agroerozems) – soils with lacking of topsoil diagnostic horizons due to natural or anthropogenic erosion, deflation or profile truncating at surface levelling. Specific feature of these soils is agrogenically transformed horizon, which is a soil transformation result of B-horizons or parent material. This horizon preserves mainly colour of original substrate at low humus content (1 – 1.5 %). Grey colour shades with humus content 1.5 – 2.5 % are remnants of strongly eroded Chernozems which lost 70 – 120 cm humus horizon and only bottom and transition part was conserved (humus content about 2 %).

Soil group Stratozems – are soils with uppermost horizon in their profile has been transported and accumulated. The stratified humus-enriched material layer is more than 40 cm. The formation can be connected with water or wind accumulation and/or with artificial sedimentation (irrigation water, mineral-organic material).

Independent diagnostic horizon – eroded or accumulated was not defined in the Morphogenetic Soil Classification System as in the case of Russian soil classification where was defined post-abrasive horizon for Abrazems or Erozems classification. Similarly consideration about new soil type for accumulated form of erosion affected soils were not respected, as in the cases of soil classification Germany, (Arbeitskreis für Bodensystematik der DBG 1998), Austria (Nestroy, 2000), Russia and Czech Republic (Němeček et al., 2001). With the anthropization feature consideration into the soil system there is a need of detailed distinguishing of naturally conditioned and anthropically conditioned erosion with their intergrades differentiation. These problems solve proposals of USDA Soil Taxonomy where accelerated erosion belongs among anthropically conditioned processes.

Classification of soil sequences

From the view point of classification there is no problem to classify all catena parts.

Soil sequence Chernozem Cultizemic (ČMa) – Chernozem Cultizemic eroded (ČMm^{e}) – Regosol Cultizemic – Chernozem Cultizemic Accumulated (ČMa^{h}) can be generalized on all by soil erosion affected Chernozems and map them in large and middle scales like soil association. Mentioned sequence can be found also in carbonate variety. We point out the use of "cultizemic" adjective (as subtype) because strong soil erosion is running mainly in farmland.

ČMa ⟶ ČMm^{e} ⟶ RMa^{c} ⟶ ČMa^{h}

Soil sequence: Luvisol Cultizemic (HMa) – Luvisol Cultizemic Calcareous Eroded (HMa^{ce}) – Regosol Cultizemic Calcareous (RMa^{c}) – Luvisol Cultizemic Calcareous overlying (HMa^{ch}) is more complicated, as a problem of Luvisol carbonatization have been emerging. At Calcareous Luvisols we can say about secondary carbonatization with long-term historical influence of soil erosion as direct consequence on chemical and physical soil properties.

The second classification problem is consideration of criterion textural differentiation coefficient (> 1.2) as a condition for Luvisol classification. Our findings confirm that many of recent Luvisols do not meet this requirement. This problem is connected with insufficient knowledge of recent Luvisols and their adequate presentation in classification system. Therefore we suggest to not considerate (exclude) this criterion for Cultizemic Luvisol´s subtypes, or find other more acceptable solution, respectively.

HMa ⟶ HMa^{ce} ⟶ RMa^{c} ⟶ HMa^{ch}

This classification problem can be demonstrated by comparison of mentioned sequence with the World Reference System WRB (1998).

LVha(dy) ⟶ LVcc(ha) ⟶ RGca ⟶ LVhac(st)

HMa = LVha(dy) – Cultizemic Luvisol is presented also in acid variety comparable with Haplic Luvisol sometimes dystric

HMa^{ce} = LVcc(ha) – Cultizemic Luvisol Eroded, Calcareous (not generalized) comparable with Calcic Luvisol (in the MSCS Calcic horizon is not diagnostic horizon), also Haplic Luvisol

RMa^{c} = RGca – Cultizemic Regosol Calcareous comparable with Calcareous Regosol (it can be presented also Calcic horizon)

HMa^{ch} = LVhac(st) – Cultizemic Luvisol, Accumulated, (sometimes with redox-features) comparable with Haplic Luvisol, Calcic Luvisol or Stagnic Luvisol.

At last we state that soil erosion and accumulation processes in Chernozem and Luvisol areas are classified at the level of soil type (Regosol), soil variety – carbonate content and soil form – eroded and accumulated. Cultivation processes as a trigger of erosion are not reflected.

Colluvisol description and diagnostics

On the base of review several soil classification systems (FAO, WRB, DBG, Russia, Austria, Czech Republic) we have endeavoured to assess soils called in the world as Colluvisols, Colluvizems, Stratozems, Cumulic Anthrosols. Their uniform characteristic is presence of top horizon (including Akp-ploughing horizon) produced by long-term transport and accumulation of material from humus-horizons due to several soil-forming factors, first of all by erosion-accumulation activity.

In the FAO system (1994) are presented Cumulic Anthrosols (ATc) – showing an accumulation of fine sediments, thicker than 50 cm, resulting from long-continued irrigation or man-made raising of the soil surface.

Cumulic Anthrosols in the WRB (1994) are defined as Anthrosols having a Terric or plaggen Anthric horizon. Terri-cumulic Anthrosols have top horizon > 50 cm made by application of earthy manures, mud and compost, surface raising and homogenization is presented. Plaggi-cumulic Anthrosols have historically conditioned Cumulic horizon formed by application of sod and farmyard manure, surface raising and homogenization.

Stratozems in the Russian classification soil system (Shishov, Dobrovolskij 1998) are incorporated into synlithogenic soil types. They present various soils with one common feature: surface horizon as transported and accumulated, stratified, by humus enriched horizon with the thickness > 40 cm. This horizon is laying on an original soil or parent material. Stratifying is formed by water or Eolic accumulation, or also, but also Artificial sedimentation (e.g. at irrigation processes), or by application organo-mineral materials. This sedimentation can be last long-term period and effects with other pedogenetic processes. They are similar to Alluvial soils, but their classification into the same group cannot be considered, as Alluvial soils have wholly other genetic concept. A subdivision of Stratozems is based on top horizon properties and thickness of accumulated layer. E.g. light-humus Stratozems AY-RY-(/A-B-C/) – have stratified profile > 100 cm thick and light-humus horizon > 40 cm thick forming in conditions of natural vegetation laying on buried soil profile. Buried soil does not show any feature of recent running pedogenetic process.

In the German soil classification system (DBG 1998) Kolluvisols are included among Terestrial Kultisols (terrestrial anthropogenic soils). Soil type Kolluvisols (YK) are defined as soils with Ah/M/II … profile from transported (removed) Humose soil material (humus content corresponds to the Ah-horizon definition). Horizon formed by water runoff from along the slope and consequently by accumulation on toeslopes, in land depressions, or by wind erosion, or it could be formed by local removing due to tillage). In the profile Ah + M > 40 cm there is considered some type of substrate removing (Fluvial, Eolic, or Anthropogenic).

Subtypes: diagnostic horizons

- normal subtype M > 40 cm – normal Kolluvisol (YKn)
- transition subtypes with differentiated feature types:

Podzol-Kolluvisol (PP-YK), at which sequence of Podzol horizons in M < 15 cm
Pseudogley-Kolluvisol (SS-YK) S or transition of S from 40 – 80 cm, Sw-M > 40 cm
Gley-Kolluvisol (GG-YK) Go and transition horizons from 40 – 80 cm.

Němeček et al. (2001) involved Colluvizems in Fluvial soil group. He defined them as soils with stratigraphy Ap-Az-, forming by accumulation of erosion sediments in bottom parts of slopes, concave slope parts and terrain depressions. Thickness of accumulated horizon must be > 25 cm. Diagnostic horizon Az- includes cultural humose horizons and defines as stratifying of material from humus horizons. He notes that delimitation of Colluvisols helps at aforestration date determination and erosion start designation in the history. Subdivision: modal – m, stagnic – g, calcareous – c, arenic – r, pelic – p.

Nestroy (2001) in the frame of Austrian Soil Classification (2000) includes Colluvisols in order: Terrestric soils, grup: Colluvisols and Anthrosols. Colluvisols are soils forming under natural conditions, they are prevailingly deep and consist of accumulated eroded material (transported by wind and water) and with exception of A-horizon it does not show mature genetic horizons. According to soil origin can be Colluvisol from Cambisol, from Chernozem, etc. Soils are occurring in concave sites and due to presence of humus containing material, their thickness and water supply belong to high priced soils. Subdivision is made by carbonate content (Calcareous, non-calcareous) and gleying possibility (Gley, Pseudogley).

Colluvisols (Koluvizems)[1]

Reviewing above mentioned classification systems we hold up an idea to introduce a new soil type – Colluvisols in classification system of Slovakia what demonstrate also several papers of Lehotský (1999, 2001)

As representative pedon we introduce description of Colluvisol Chernozemic observed in village Brestovany (county Trnava)

Description of soil type:

Name proposal:	Colluvisol Chernozemic Calcareous (KLbc)
Location:	Brestovany (county Trnava)
Elevation:	140 m at sea level
Orographic unit:	Trnavian hilly land
Land use:	arable land (wheat)
Relief:	concave part of slight gradient (3 – 5°)
Parent material:	loess

[1] In brackets is introduced Slovak name.

Pedon description:

Akpc 0 – 20 cm – 10YR 4/4-6, slightly moist, loose, loamy, crumb, strong biological activity (animal channels, coprolite), calcareous ploughing horizon, distinct transition to

Ckc 20 – 42 cm – 10YR 6/4, 5/4, 4/4, slightly moist, compacted, loamy, slightly crumb or subangular blocky, medium rooted, calcareous horizon of soil material accumulation enriched by humus, distinct transition to

Amc“ 42 – 68 cm – 10YR 3/2, moist, slightly plastic, loamy, subangular blocky, by mycelium calcareous with medium or strong biological activity, buried relict mollic horizon, distinct transition to

A/Cc 68 – 78 cm – 10YR 4/4, 6/4, moist, plastic, loamy, slightly crumb, mycelium calcareous, rarely worm channels and coprolite, gradual transition to

Cc > 78 cm – 10YR 6/4, 6/7, loess, moist, plastic, loamy, no structure, presence of mycelium carbonates and concretions, slight biological activity.

In discussed classification systems there is not unambiguous including of Colluvisols in higher taxon of soil units. In Russian classification system they create a single taxonomic group in the frame of synlithogenic soils, in Czech classification system are included into Fluvisols. World systems FAO and WRB as well as German and Austrian classification systems include this soil type among anthropogenic soils. Their incorporation is obviously connected with genetic concept of origin what is not defined unambiguously. Because of not only natural factors but also anthropic activities are sharing in forming of these soils.

Indication of diagnostic horizon is also not defined exactly. In most systems soil material is washed down or otherwise removed presents substrate from humus horizon from what can be developed new soil types. In the Czech classification system Az-horizon is characterized as humus horizon formed by overlay of humus material. In the German classification system it is M-horizon – mineral soil horizon forming from sedimentation Holocene soil material (by translocation, fluvial activity, washing up, tillage of soil). In the Russian classification system there is an indicated horizon R what is subdivided in light-humus RY-horizon and dark-humus RU-horizon according to percentage humus content < 3%, or > 3%. Although they have similar soil profile horizontation like Fluvisols their genetic base (provenance of origin) is different.

For Slovakian classification system we propose as a basic diagnostic horizon of Colluvisols Ck-horizon developed by transport and following accumulation of soil material enriched in humus, sometimes stratified, however by colour distinguished. Its thickness is proposed A+Ck > 40 cm. Accompanying feature of Colluvisols is frequent occurrence of buried soils with original soil profile horizontation, or its remnants.

According to definition: COLLUVISOLS (Koluvizems – KL) – soils with mollic or ochric A-horizon from colluvial sediments. As subtypes are suggested: modal, cultizemic, chernozemic, hnedozemic, luvizemic, gleyic, pseudogleyic ones.

Basic sequence of horizons: A-Ck-A“-(B)-C.

Colluvisols are occurred in toe-slope, in concave relief slope parts, in depression forms whereby they must be distinguished from alluvial sediments. Formation of Colluvisols is conditioned by erosion-accumulation water activity, eolic activity or anthropic influence (e.g. tillage). Their including into higher soil taxonomic group is yet discussed.

Although they have very similar soil horizons sequence to Fluvisols, their pedogenetic basis (origin provenance) is other. Therefore their including in higher taxonomic groups is perceived very differently.

CONCLUSIONS

At assessment and characteristics of genetic soil changes caused by physical degradation processes we have endeavoured to find such physical forms which substantially share on gradual soil transformation. The problem of compacted soils is no doubt serious, but does not represent a reclassification problem. At the type of urban/industrial land conversion is the most evident problem, however there is a need to develop an individual research. The most significant and urgent physical degradation problem was defined water erosion presented mainly in hilly land in areas of our most fertile areas – Chernozems and Luvisols. According to our results and interpretations we have gained an option that an imagine of recent Chernozems and mainly Luvisols is different from till this time presented mentions. We have encountered soil units with classification troubles, so we have tried to find an acceptable solution in aspect to reflect recent physical degradation. The outlined starting-points need some development and continue the research

REFERENCES

Arbeitskreis für Bodensystematik der DBG. 1998: Systematik der Böden und der bodenbildenden Substrate Deutschlands. Mitteilungen der DBG, Band 86, 180 s.

FAO-UNESCO. 1997: Soil Map of the World. Revised legend with corrections and updates. ISRIC, Wageningen.

Fulajtár, E. 1999: Vplyv človeka na pôdny kryt sprašových pahorkatín juhozápadného Slovenska In Zbor. “Antropizácia pôd IV.” 29.4.1999 VÚPOP Bratislava, 35 – 43.

Jambor, P., Sobocká, J. 1998: Calcic Chernozem and Haplic Luvisol Degradation Caused by Water Erosion in Slovakia. Proc. Conf. “Soil Dynamics”. Tiberias, Technicon Haifa, 11s.

ISSS-ISRIC-FAO. 1998: World Reference Base for Soil Resources. World Soil Resources Reports, 84. FAO, Rome, 88 s.

Kolektív, 2000: Morfogenetický klasifikačný systém pôd Slovenska. Bazálna referenčná taxonómia. VÚPOP, Soc. Ped. Slovaca, Bratislava, 76 s.

Lehotský, M. 1999: Erózno-akumulačné katény a degradácia pôd. In Zbor. “Antropizácia pôd IV.” 29.4.1999 VÚPOP Bratislava, 72 – 78.

Sobocká, J. 1998. Vlastnosti reliéfu a erodibilita pôdy. In: Zbor. “Ochrana a udržateľný vývoj úrodnosti pôdy v SR, trvalo udržateľná úrodnosť pôdy, protierózna ochrana”. VÚPÚ Bratislava, Agroinštitút Nitra, s. 317 – 322.

Sobocká, J., Jambor, P. 1998: Diagnostics and location of erodible soils and antierosion proposal on example of SE-Danubian lowland part. Landscape and Urban Planning 41, p. 129 – 133.

Soil Survey Staff. 1998: Keys to Soil Taxonomy, Eight Edition. USDA/NRCS, Washington, D.C., 326 s.

Soil Survey Staff. 1975: Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. Soil Conservation Service, U.S.D.A., U.S. Govt. Pr. Off…, Washington, D.C., 754 s.

Šišov, L.L., Dobrovoľskij, G.V. 1997: Klasifikacija počv Rossii. Počvennyj institut imeni Dokučajeva, Dokučajevskoe obščestvo počvovedov pri RAN, Moskva, s. 236.
Van Lynden, G.W.J.1997: Guidelines for Assessment of Human-Induced Soil Degradation in Central and Eastern Europe (SOVEUR Project) Report 97/08, ISRIC Wageningen.

MONITORING OF WATER EROSION INFLUENCE ON SOIL PROPERTIES CHANGES

Sledovanie vplyvu vodnej erózie na zmenu pôdnych vlastností

Ján STYK
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Water erosion processes influence on soil parameters (textural composition, physical properties, pH/KCl, humus content and available phosphorus) changes in time (temporal dynamics) and space (spatial differentiation) were studied in two erosion transects (Voderady – ploughed land, Kečovo – permanent grassland). The work is a part of Partial Monitoring System – Soil net. Based on radioactive isotope ^{137}Cs activity analyses were ascertained that both transects were more or less affected by water erosion. Erosion-accumulation processes intensity was most influenced by land relief, precipitation intensity, land use culture as well as by farming system. More marked influence of water erosion on the soil characteristics studied quantitative changes was demonstrated on intensively cultivated soils of the erosion transect at Voderady. In basal part of slope (toe) was observed marked accumulation of earth mass translocated by erosion. This was demonstrated by relatively high humus contents (almost 3%) in subsoil. On transect at Kečovo (grassland), in the past used as arable land, erosion processes influence was much more intensive than today. This also was confirmed by the analyses ^{137}Cs. Erosion runoff reduction happened due to mentioned transect grassing. Physical properties changes at both of transects were not significant neither in space nor in time. Based on the properties studied balance (temporal dynamics) can be stated that in the period of the study (2000 – 2001) visible trend of their changes (short period of observation) was not registered.

Keywords: water erosion, spatial differentiation, time dynamics

ABSTRAKT

Vplyv procesov vodnej erózie na zmenu pôdnych parametrov (zrnitostné zloženie, fyzikálne vlastnosti, pH/KCl, obsah humusu a prístupného fosforu) v čase (časová dynamika) a v priestore (priestorová diferenciácia) sme sledovali na dvoch eróznych transektoch (Voderady – orná pôda, Kečovo – TTP), ktoré sú súčasťou monitorovacej siete Čiastkového monitorovacieho systému – Pôda. Na základe analýz aktivity rádioaktívneho izotopu ^{137}Cs sme zistili, že obidva transekty sú viac, alebo menej ovplyvnené vodnou eróziou. Intenzita erózno - akumulačných procesov je vo veľkej miere ovplyvnená reliéfom krajiny, intenzitou zrážok, kultúrou využívania ako aj spôsobom obhospodarovania. Výraznejší vplyv vodnej erózie na kvantitatívne zmeny sledovaných pôdnych vlastností sa prejavil na intenzívne obhospodarovanej pôde erózneho transektu vo Voderadoch. V spodnej časti svahu (báza) sme spozorovali výraznú akumuláciu eróziou premiestnenej pôdnej hmoty. Prejavilo sa to pomerne vysokým obsahom humusu (takmer 3%) v podornici. Na transekte v Kečove (TTP) bol v minulosti (keď sa využíval ako orná pôda) vplyv eróznych procesov intenzívnejší ako v súčasnej dobe čo potvrdzujú aj výsledky analýz ^{137}Cs. Zníženie erózneho vplyvu na pôdu bolo dosiahnuté zatrávnením spomínaného transektu. Zmeny fyzikálnych vlastností na oboch sledovaných transektoch v priestore a čase nie sú významné. Na základe vyhodnotenia sledovaných vlastností v čase (časová dynamika) môžeme konštatovať, že za sledované obdobie (roky 2000-2001) nebol pozorovaný zreteľný trend ich zmien (krátky časový úsek sledovania).

KĽÚČOVÉ SLOVÁ: vodná erózia, priestorová diferenciácia, časová dynamika

INTRODUCTION

Soil has relatively a large ability to resist unfavourable conditions of surrounding but it can be degraded if the adverse influence of surroundings is too intense. Soil degradation by processes of water erosion is one of primary problems of agriculture in our country. The result of water erosion influence on soil can be the reduction of natural fertility of soil, pollution of water streams, clog up of water reservoir etc. Monitoring of water erosion influence on agricultural soil has been running since 1993 year (the first three erosive transects were established) a part of Partial monitoring system – Soil. Primary aim of this task is to observe and evaluate quantitative changes of soil properties (physical properties, humus content, available phosphorus, textural composition) on the eight erosive transects (7 on arable soils, 1 on permanent grassland) in the time (time dynamic) and in the space (spatial differentiation). Obtained results help us to specify the method established on measure of radioisotope ^{137}Cs activity. We can find out (using this method) the intensity of water erosion processes for defined time period (30 – 35 years). In this contribution we would like to present the results obtained from two different transects (one is on arable soil and second is on permanent grassland).

MATERIAL AND METHODS

Method of radioisotope ^{137}Cs assessment is established on distribution of ^{137}Cs in the soil profile. Normal depth distribution of ^{137}Cs is determined by depth of topsoil (0.25 – 0.30 m). Content of ^{137}Cs in this layer is relatively homogenous and under this layer its content is markedly lower. This scheme is appropriate only in the soils not influenced by erosion processes. The isotope is strongly bound by colloidal components of the soil, it is hardly releasable by water, its half-life is long (30 years) and so this element is in the soil relatively stable (Fulajtár, Janský, 2001). Water erosion can cause marked changes of this element in the soil profile by translocation and consequential accumulation of soil matter (Linkeš, Lhotský, Stankoviansky, 1992). We can assess a real values of erosive and accumulation factor of erosive process in specifically time period (redistribution of soil for time period 30-35 years). Every analysis for radioisotope ^{137}Cs were realised in laboratories of Nuclear Energy Research Institute at Trnava.

Monitoring of the soil properties changes can help us to specify results obtained by method measuring of radioisotope ^{137}Cs activity. Soil properties were analysed in accordance with standard analytical methods used in laboratories of Soil Science and Conservation Research Institute.

The results presented in this contribution are from two different erosive transects which one was situated on the arable soil (Voderady) and the second one on the permanent grassland (Kečovo). Three pedological sites were located on every erosive transect. First site is in the top of slope (not eroded or slightly eroded soil), the second one is in the erosive part of slope (eroded soil), the last one is in the accumulation part of slope (accumulated soil). Every year (since the year of 2000) we have been taking the soil samples from these sites (sampling depths: 0 – 0.10, 0.20 – 0.25, 0.25 – 0.30, 0.30 – 0.35, 0.35 – 0.40, 0.40 – 0.45 m).

RESULTS AND DISCUSSION

Voderady

For the hilly lands of Podunajska nížina (lowland) is characteristic moderately rolling relief with medium heavy soils originated on the loess. Transect is located on the arable soil with slope inclination 6 – 12°. Haplic Chernozems is situated on the all erosive transect (in the upper, erosive and accumulation part of slope).

On the base of determined values of caesium content we can confirm a presence of intensive occurred erosive-accumulation processes (Tab. 1). Accumulation of soil matter is realized in accumulation part of slope (base) where ^{137}Cs is determined till the depth of 40 cm (accumulation of soil matter transported by erosive processes).

Table 1 Radioisotope ^{137}Cs content in individual parts of erosive transect

Transect	^{137}Cs (Bq.kg^{-1})				
	0 – 0.20 m	0.20 – 0.25 m	0.25 – 0.30 m	0.30 – 0.35 m	0.35 – 0.40 m
Voderady – top	9.0	7.5	5.1	2.7	0.6
Voderady – slope	6.6	6.0	2.5	1.4	0.6
Voderady – base	8.5	10.5	8.9	6.9	6.4

Water erosion influence on the soil can confirm even soil properties results. We found out visible differences especially in humus and available phosphorus content (Fig. 1, 2) in the space (spatial differentiation). There were measured changes these properties in the individual parts of transect and in the soil profile of course (profile differentiation). Uppermost humus content (till the depth of 0.45 m) was measured in the lower part of slope (base). Values of humus content in the top of slope were lower and in the erosive part of slope were lowest. Available phosphorus content has the similar development as the humus content on transect only moderate difference was determined in the erosive part of slope (values of phosphorus content in this part were higher than in the top of slope). Changes of these parameters in the time (time dynamic) for the period of 2000 and 2001 were not significant (short-term period).

Figure 1

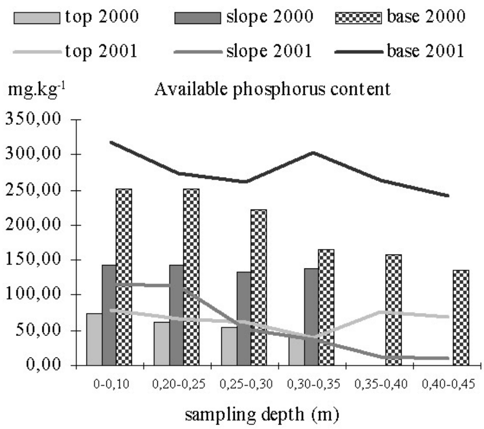
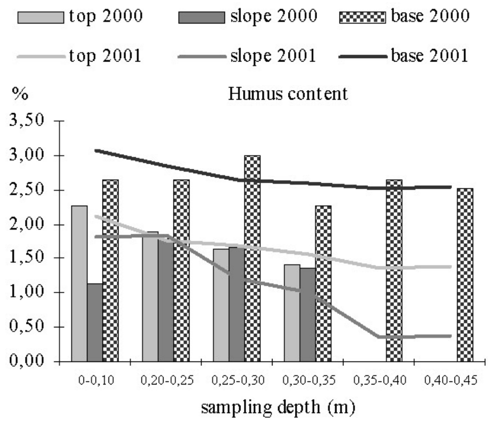


Figure 2



Content of fraction < 0.01 mm is gradually increased from the top of slope toward the accumulation part of slope (Fig. 4). pH value is over 7 on every point of observed transect. Changes of pH value downwards to the base are not significant (Fig. 3).

Figure 3

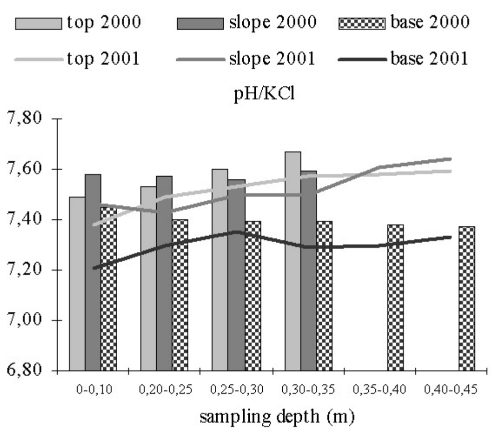
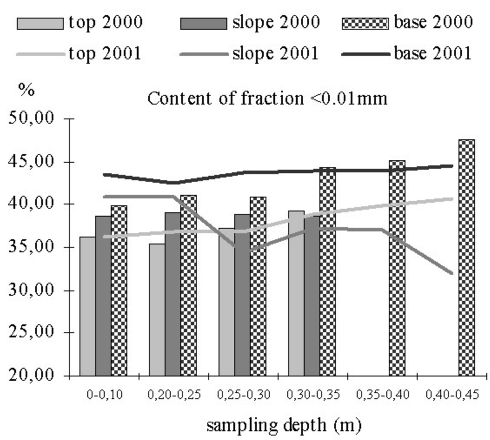


Figure 4



Bulk density and porosity changes in the time (time dynamic) were not significant (Tab. 2). Bulk density was moderate increased in the base of slope. It can be influenced by higher amount of clay particles in this part of slope. It can be said (on the base of bulk density values) that the soil on the all erosive transect is with favourable water, air and thermal regime. These soils are not inclined to primary soil compaction. Compaction of medium heavy soils is mainly secondary (man-made compaction by intensive agriculture exploitation).

Table 2 Physical properties changes in individual parts of erosive transect

	Depth m	Bulk density (g.cm^{-3})		Porosity %	
		2000	2001	2000	2001
Voderady (top)	0 – 0.1	1.19	1.33	55.13	49.80
	0.3 – 0.35	1.24	1.38	53.71	49.95
Voderady (slope)	0 – 0.1	1.14	1.22	57.32	54.30
	0.3 – 0.35	1.37	1.28	49.09	53.77
Voderady (base)	0 – 0.1	1.38	1.35	48.57	49.17
	0.3 – 0.35	1.48	1.45	44.62	44.72

Kečovo

Erosive transect (with slope inclination 8 – 12°) is localized near Domica cave on the permanent grassland. Heavy (clayey loamy soil) Stagni-Cambisols is in the top of erosive transect but in the slope (erosive part of transect) and in the base (accumulation part of slope) is medium heavy soil (loamy soil) the same soil type.

We can say (on the base of radioisotope ^{137}Cs analyses) that transect (especially in the past when was used like an arable soil) was intensively influenced by erosive processes. The concentrations of caesium in the individual depths of profile (accumulation part of slope) are higher (thrice) than in the profile of erosive part of slope as well as the top of slope (Tab. 3).

Table 3 Radioisotope ^{137}Cs content in individual parts of erosive transect

	^{137}Cs (Bq.kg^{-1})				
Transect	0 – 0.20 m	0.20 – 0.25 m	0.25 – 0.30 m	0.30 – 0.35 m	0.35 – 0.40 m
Kečovo – top		4.3	0.6	0.6	0.5
Kečovo – slope		3.8	1.2		1.1
Kečovo – base		7.4	6.9	3.8	0.7

Presence of water erosion processes (not so intense as the past) is confirmed by the humus content differentiation on the erosive transect, but in the individual soil profiles too. The uppermost humus contents were measured on the accumulation part of slope (in the depth of 0.40 m is humus content relatively high). On the contrary lowermost humus contents were measured on the erosive part of slope (Fig. 5). The influence of time on humus content dynamic is not significant (short time period of observation).

Uppermost available phosphorus content was measured (in the year 2001) in the accumulation part of slope (base), lower concentrations of this macronutrient were determined in the top and the erosive part of slope (Fig. 6). This spatial differentiation can be caused by processes of water erosion. Time differentiation (years 2000 – 2001) of phosphorus on this erosive transect is very interesting because in the year 2001 was determined significant increasing this element in the accumulation part of slope (more than 100 %) in the depth (0 – 0.10 m). We can say this parameter (available phosphorus) is very variable and it is influenced by many factors (especially intensity using of fertilizers and consumption by crops). From this point of view the determination of available phosphorus content in the soil is not very good parameter for observing of water erosion influence on the soil (Styk, 2001).

Figure 5

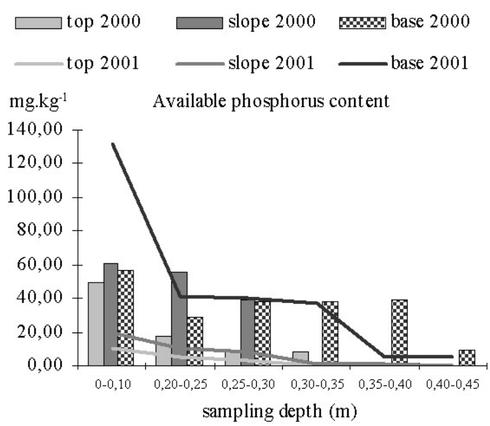
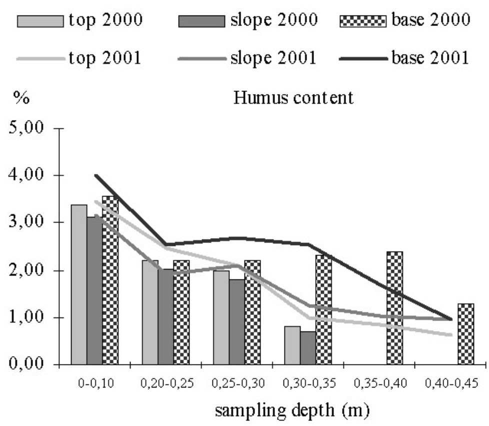


Figure 6



Neogene sediments were the parent material for development of the soils this part of region. This parent material probably had the influence on pH value of these soils. In the topsoil is slightly acid (Fig. 7) on all erosive transects (in the depth of 0 – 0.10 m) and with deeper depth pH values are lower (in the top and erosive part of transect). On the contrary, in accumulation part of transect the pH values do not decrease with deeper depth (are similar in all sampled soil profile). It can be caused with accumulation of soil material from upper parts of erosive transect (probably influence of water erosion in the past).

Content of fraction < 0.01 mm in the soil can be influenced by natural heterogeneity of surrounding. From the top of transect content of fraction <0.01mm decrease towards to accumulation part (Fig. 8).

Figure 7

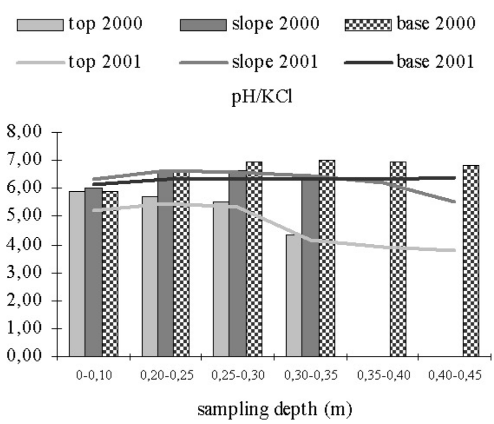
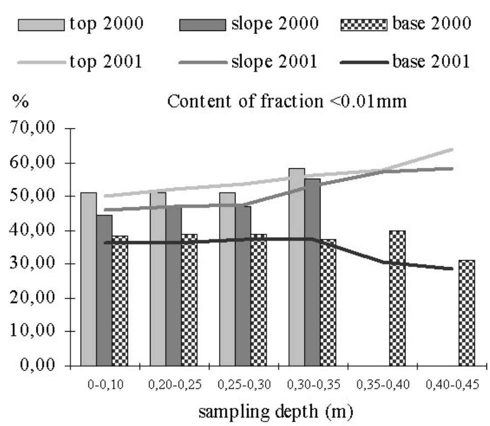


Figure 8



Influence of erosive-accumulation processes on physical properties changes on the soil of erosive transect is not significant. The topsoil has a similar bulk density even porosity in all observing parts of transect (Tab. 4). Time dynamic (years 2000 – 2001) of these physical properties is not important.

Table 4 Physical properties changes in individual parts of erosive transect

	Depth m	Bulk density (g.cm^{-3})		Porosity %	
		2000	**2001**	**2000**	**2001**
Kečovo (top)	0 – 0.1	1.36	1.35	48.74	49.40
	0.3 – 0.35	1.48	1.48	45.77	44.95
Kečovo (slope)	0 – 0.1	1.44	1.42	45.82	46.12
	0.3 – 0.35	1.47	1.45	46.25	47.34
Kečovo (base)	0 – 0.1	1.23	1.14	52.60	54.30
	0.3 – 0.35	1.30	1.34	50.90	51.20

CONCLUSIONS

We are observing the influence of water erosion processes on soil parameter changes (textural composition, physical properties, pH/KCl, humus and available phosphorus content) in the time (time dynamic) and in the space (spatial and profile differentiation) on two erosive transects (Voderady – arable soil, Kečovo – permanent grassland). On the basis of obtained results (from analyses of radioisotope ^{137}Cs activity) we detected that water erosion is running more or less on both erosive transects but the intensity is various, only. Intensity of influence erosive-accumulation processes on soil is dependent on relief, growing plant, intensity of rainfall, manner cultivation of soil, agricultural exploitation etc. We were determined significant influence of water erosion processes on quantitative soil parameters changes in space (spatial and profile differentiation) on erosive transect in Voderady. In accumulated part of this transect (base) the humus content nearly 3% in the depth of 0.40 – 0.45 m was measured. It was caused by accumulation of soil matter which was translocated from upper parts of this transect.

Transect in Kečovo (permanent grassland) was in the past (when was used as an arable soil) more influenced by processes of water erosion. Decreasing influence of erosive processes on the soil was achieved by grass over this transect. Changes of physical properties on both monitored transects were not significant.

We can say on the basis of monitored properties in the time (time dynamic) that noticeable trend of their changes was not observed in the period of time (2000 – 2001 years). It is probably caused by short-term period of monitoring of these properties.

Finally, we have found out that humus content is from all monitored soil properties the best indicator of erosive processes presence. Available phosphorus spatial differentiation had in some examples the least logical course. Available phosphorus is relatively variable indicator in soils. Its presence in soil is influenced by its input to the soil in form of various kinds of fertilizers and consumption of this element by plants (every species of plants have an individual requirement for their nourishment by phosphorus and its available supply in soil, as well).

REFERENCES

FULAJTÁR, E., JANSKÝ, L., 2001: Vodná erózia pôdy a protierózna ochrana, VÚPOP, Bratislava, 310 s.

LINKEŠ, V., LEHOTSKÝ, M., STANKOVIANSKY, M. 1992: A contribution to the knowledge of the soils water erosion on the hilly lands of Danubia lowland with use of ^{137}Cs. Vedecké práce VÚPU. Bratislava: VÚPOP, 1992, č. 17, p. 111 – 121.

STYK, J., 2001: Monitoring vodnej erózie na poľnohospodárskych pôdach. In: Monitoring pôd SR. Priebežná správa, VÚPOP Bratislava, december, s. 124 – 137.

THE ACCUMULATE FUNCTION OF SOIL AND ITS CATEGORISATION CONCERNING NUTRIENTS

AKUMULAČNÁ FUNKCIA PÔD A JEJ KATEGORIZÁCIA VZHĽADOM K ŽIVINÁM

STANISLAV TORMA
Soil Science and Conservation Research Institute Bratislava, regional work place, Reimannova 1, SK – 080 01 Prešov, Slovak Republic,
e-mail: torma@vupop.sk

ABSTRACT

Based on nitrogen mineralization intensity in soil, (by Bielek, 1998) chosen soil parameters (depth, stoniness, sloping and clay particles) five soil categories were formed by soil capability to cumulate nutrients, the categories were mapped with aspect to accumulation of nitrogen, phosphorus and potassium in soil. Very strong capability to accumulate nitrogen has farmland 44%, very strong capability to accumulate phosphorus has farmland 56%, and similarly very strong capability to accumulate potassium has farmland 16% in Slovakia. On the other hand, very weak capability of nutrient accumulation showed farmland only 16% in the case of nitrogen, 14% at phosphorus and 20% in the case of potassium.

KEYWORDS: accumulate function of soil, nutrient accumulation, chosen soil parameters

ABSTRAKT

Na základe intenzity mineralizácie dusíka v pôde, (podľa Bieleka, 1998) vybraných pôdnych parametrov (hĺbka pôdy, obsah skeletu v pôde, svahovitosť pôdy a obsah ílových častíc v pôde) bolo vytvorených 5 kategórií pôd podľa schopnosti akumulovať živiny a boli vytvorené mapy schopnosti pôdy akumulovať dusík, fosfor a draslík. Veľmi silnú schopnosť akumulovať dusík má 44% poľnohospodárskych pôd, veľmi silnú schopnosť akumulovať fosfor má 56% poľnohospodárskych pôd a veľmi silnú schopnosť akumulovať draslík má 16% poľnohospodárskych pôd Slovenska. Naopak, veľmi slabú schopnosť akumulovať živiny má len 6% pôd v prípade dusíka, 14% pôd v prípade fosforu a 20% pôd v prípade draslíka.

KĽÚČOVÉ SLOVÁ: akumulačná funkcia pôdy, akumulácia živín, vybrané pôdne parametre

INTRODUCTION

In the first place it is necessary to give attention to the productive function of the soil at the evaluation of meaning of soil functions from the soil nutrient point of view. This basic function (soil ability to offer biomass production) is exploited by man thousands of years. When regarding the non-productive functions of soils, e.g. functions that do not directly participate on the biomass production, it is given much attention to the accumulate and transport function. These ones directly influence the nutrient movement and accumulation in the soil and make possible for the plants to take in the nutrients for yield creating.

The accumulation itself plays very important role from the point of view of accumulation water, warmth, nutrients but also the harmful matter for the soil and plants. The soil is able to accumulate a huge amount of nutrients and nutrients accumulation is a significant part of its fertility.

The accumulation function indicates the ability of soil to keep and step by step to accumulate the plant nutrients in the soil in various forms. It is to mention that in the first place the very low mobile and fixed forms are sharing on nutrients accumulation. The ability of soil to accumulate of nutrients need not to mean the positive aspect from this point of view because first of all it is necessary to accumulate these forms of nutrients that are available for plants. However, the specific share of accumulated nutrients makes so called potential available nutrients forms, i. e. such form of nutrients that is momentary not available but it can on the base of dynamical balances in the soil gradually to fill up the pool, which contains nutrients forms available for plants.

MATERIALS AND METHODS

The evaluation of accumulate function concerning the nutrients went out from the soil ability to accumulate and keep the individual nutrients in the soil profile. In the case of nitrogen we oriented ourselves on its mineral form and it was getting about the soil ability to accumulate the mineral nitrogen from the organic matter (Bielek, 1998). The most important factor in phosphorus and potassium accumulation in the soil is the “volume” of soil. The methods of categorisation went out from the soil depth and content of gravel. The slope of area makes also the important role because soils on the steep slopes have naturally lower ability to accumulate the nutrients. All these parameters contained in the code of bonited pedo-ecological units (BPEU). The coefficient was attached to each parameter and on the base of their mutual combination were determined five categories of soil ability to accumulate the nutrients - very low, low, good, high and very high.

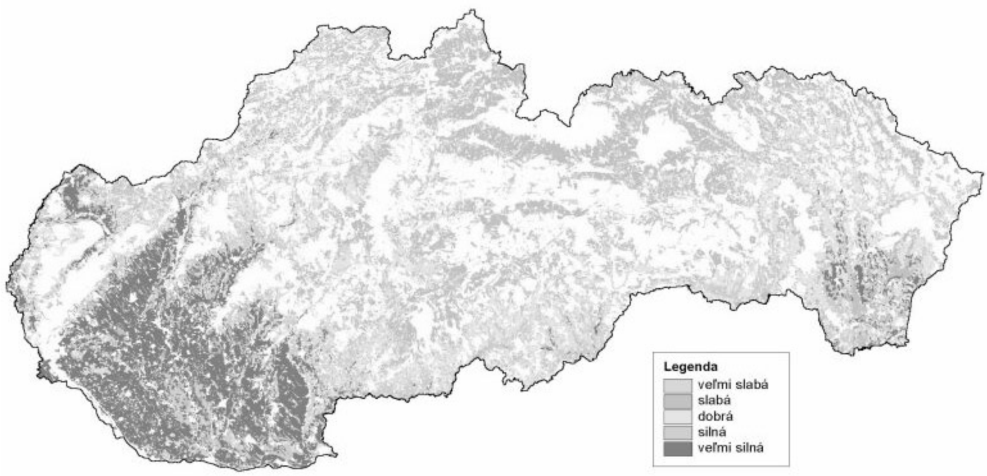
RESULTS AND DISCUSSION

The ability to accumulate nitrogen is very important characteristics of the soil. Although nitrogen is containing in the soil in many forms, we were oriented ourselves on its mineral forms. According to Bielek (1998) the mineralisation of nitrogen is dependent on the soil quality, or on point values of BPEU. The amount of mineralised nitrogen for each soil bonited unit he calculated on the base of exponential equation $y=2.01.e^{0.0045x}$, where y = the amount of mineralised nitrogen and x = point value of soil. Bielek (1998) determined three categories of intensity of nitrogen mineralisation, we used his model and divided these soil ability to five categories for the synchronisation to other mentioned nutrients:

Table 1 Soil ability to accumulate nitrogen (Bielek, 1998)

Category of soil ability to accumulate nitrogen	**The amount of mineralised nitrogen (mg $N_{an}.kg^{-1}$ of soil in 14 days)**	**Point values**
Very low	less than 2.100	0 – 20
Low	2.101 – 2.350	25 – 40
Good	2.351 – 2.600	45 – 60
High	2.601 – 2.850	65 – 80
Very high	more than 2.850	85 – 100

Figure 1 Soil categorisation according to nitrogen accumulation (Legend: veľmi slabá – very low, slabá – low, dobrá – good, silná – high, veľmi silná – very high)



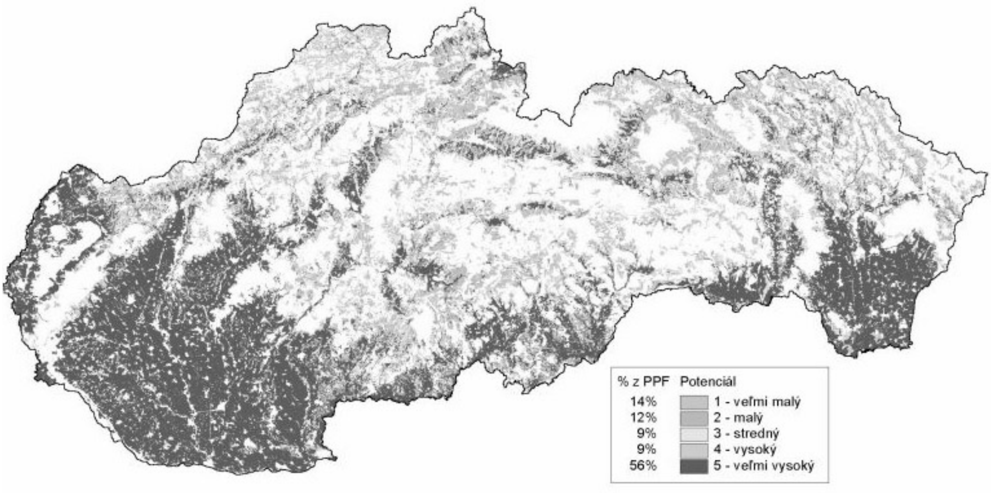
Accumulation of phosphorus depends in first place on the "volume" of soil. It means it goes out from the gravel content and depends on slope of individual sites. The categorisation of soil ability to accumulate of phosphorus was made on the base of combination of mentioned soils and sites parameters. All these parameters can be characterised by 5th and 6th place in framework of 7 places code of BPEU. When regarding three categories of soil depth (shallow, medium and deep), four categories of gravel content (non or sporadic gravely, slightly gravely, gravely, very gravely) and five categories of slope (plain or slope less than 3°, moderate slope 3 – 7°, medium slope 7 – 12°, expressive slope 12 – 17° a steep slope more than 17°), it were obtained 60 combinations of these parameters. The coefficients were assigned to each parameters - for soil depth 0.20, 0.45 and 0.80, for gravel content in the soil 0.60, 0.70, 0.85 and 1.00 and for slope 0.2, 0.4, 0.6, 0.8 and 1.0 The mutual relationship of these coefficients determined five categories of soil ability to accumulate phosphorus:

Table 2 Soil ability to accumulate phosphorus

Category of soil ability to accumulate phosphorus	**Coefficient**	**Point values**
Very low	less than 0.048	0 – 20
Low	0.048 – 0.126	25 – 40
Good	0.127 – 0.238	45 – 60
High	0.239 – 0.384	65 – 80
Very high	more than 0.384	85 – 100

The phosphorus accumulation in the soil directly depends on the soil depth and indirectly on the gravel content in the soil and slope of site. The deep soils, without gravel that are on the plains or slope less than 3° are able to accumulate the phosphorus in the great amounts. For the shallow soils with high content of gravel and soils on the slopes more than 12° is this ability too low.

Figure 2 Soil categorisation according to phosphorus accumulation (in % from farmland area of Slovakia) (Legend: veľmi malý – very low, malý – low, stredný – good, vysoký – high, veľmi vysoký – very high)



Potassium accumulation, like phosphorus one, depends in the first place on the soil "volume" but the content of clay particles makes an extraordinary important role. Unfortunately we did not know the quantitative composition of clay minerals in the soils but the fact is that potassium can be very simply fixed not only on their surface but directly in their structure. Therefore this parameter has the most important significance in the case of potassium accumulation. The categorisation of soil ability to accumulate potassium went out from the same characteristics like at phosphorus but the next one was assigned – the clay content in the soil. This parameter is characterised by 7th place in framework of 7 places code of BPEU. Regarding above mentioned categories of soil depth, gravel content in the soil, sites slope and following five categories of soil texture (sandy and loamy sand, sandy loam, loam, clayey loam and clayey and clay) were obtained 300 combination of these four parameters. By the same way, like at phosphorus, the coefficients were assigned to each parameter (in the case of texture 0.125, 0.250, 0.375, 0.525 and 0.675) and their mutual relationship determined five categories of soil ability to accumulate potassium

Table 3 Soil ability to accumulate potassium

Category of soil ability to accumulate potassium	**Coefficient**	**Point values**
Very low	less than 0.0230	0 – 20
Low	0.0230 – 0.0462	25 – 40
Good	0.0463 – 0.1428	45 – 60
High	0.1428 – 0.2940	65 – 80
Very high	more than 0.2940	85 – 100

The potassium accumulation in the soil directly depends on the soil depth and clay content in the soil and on the other side indirectly on the gravel content in the soil and slope of site. The deep soils with high content of clay (clayey loam soils, clayey soils and clay) without gravel that are on the plains or slope less than 3°, are able to accumulate the potassium in the great amounts in comparison with shallow, sandy soils, soils with high content of gravel and soils on the slopes more than 12°.

Figure 3 Soil categorisation according to potassium accumulation (in % from farmland area of Slovakia) (Legend: veľmi malý – very low, malý – low, stredný – good, vysoký – high, veľmi vysoký – very high)

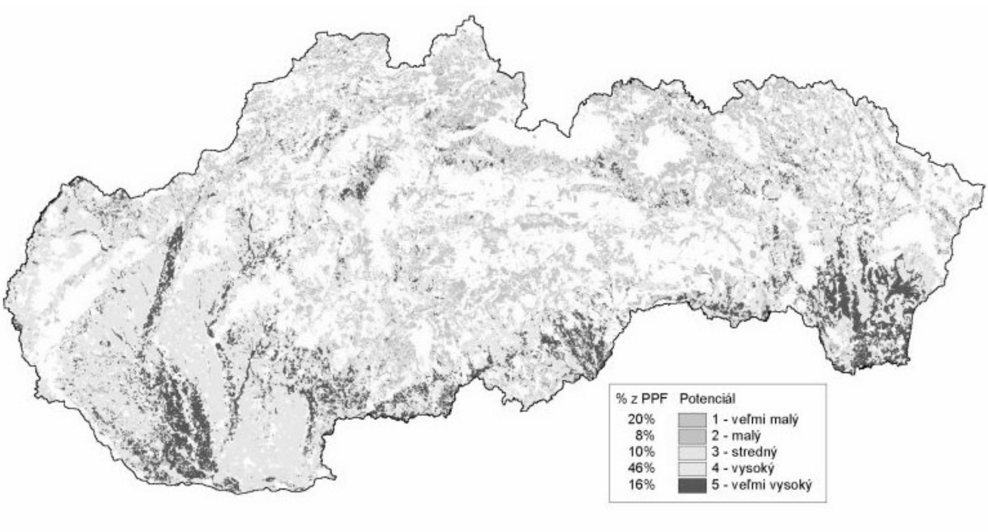


Table 4 The share of individual soil categories concerning nitrogen, phosphorus and potassium accumulation (% of agricultural soil areas in Slovakia)

	Soil ability to accumulate nutrients				
	Very low	**Low**	**Good**	**High**	**Very high**
Nitrogen	6	13	16	21	44
Phosphorus	14	12	9	9	56
Potassium	20	8	10	46	16

It can be stated that the soil ability in Slovakia to accumulate all three basic plant nutrients is very good. Till 65 % of agricultural soil area has high and very high ability to accumulate nitrogen and phosphorus, in the case of potassium it is 62 %. It means that the nutrient losses are relative low and they occur mainly on the slopes (caused by water erosion) and on the texturally light soils (leaching of potassium).

REFERENCES

BIELEK, P., (1998): Dusík v poľnohospodárskych pôdach Slovenska. VÚPÚ Bratislava, 256 s., ISBN 80-85361-44-2.

DEMO, M. a kol., (1998): Usporiadanie a využívanie pôdy v poľnohospodárskej krajine. SPU Nitra – VÚPÚ Bratislava, 302 s. ISBN 80-7137-525-X.

TORMA, S., (2002): Prístup k hodnoteniu pôd akumulovať živiny. Prvé pôdoznalecké dni v SR (vedecká konferencia s medzinárodnou účasťou), Račkova dolina, 17.-19.6.2002, VÚPOP, SPS Bratislava, s. 461 – 467, ISBN 80-89128-00-9.

MODEL OF PRODUCTION – ECOLOGICAL FARMLAND USE AND ARRANGEMENT

Model produkčno-ekologického usporiadania a využívania poľnohospodárskych pôd

Jozef VILČEK
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

The topic of models and modeling at farmland use optimization has been in the centre of activities of the Soil Science and Conservation Research Institute expert team since 1995. During the model named PEDOPT 2000 formation it was been improved and extended in new blocks. Today it consists following modules: land use and arrangement, soil characteristics, plant nutrition and fertilization, soil contamination, soil appraisal (subsidies), form production and distribution. The purposeful model is working in environment WinBase 602, version 4.0. The model objective is to contribute to more effective and rational farmland use in Slovakia.

Keywords: model, modeling, soil arrangement and use

ABSTRAKT

Problematikou modelov a modelovania pri optimalizácii využívania poľnohospodárskych pôd sa riešiteľský kolektív VÚPOP zaoberá už od roku 1995. V priebehu tvorby modelu, ktorý dostal pomenovanie PEDOPT 2000, bol a je tento neustále zdokonaľovaný a rozširovaný o nové bloky. V súčasnosti pozostáva z nasledujúcich modulov: usporiadanie a využívanie pôd, charakteristika pôd, výživa a hnojenie plodín, kontaminácia pôd, cena pôdy (dotácie), výroba a rozdelenie produkcie. Účelový model pracuje v prostredí WinBase 602 verzii 4.0. Cieľom modelu je prispieť k efektívnejšiemu a racionálnejšiemu využívaniu poľnohospodárskych pôd Slovenska.

Kľúčové slová: model, modelovanie, usporiadanie a využívanie pôd

INTRODUCTION

In present scientific knowledge may-be does not exist any scientific discipline that could make detour, or even ignore problem of modelling and models. The same situation is in agriculture. The models became important mean of the research and knowledge primarily in sophisticated and hyper complicated dynamic systems like soil.

Particularly together with modern computing techniques exploitation, at parallel limitation material, technical and economical options in agrosector, modeling obtains still greater significance. Besides the models teach us how to solve problems systematically in their complexity, they allow us paralelly to implement such experiments, which cannot be solved via field experiments. Furthermore they enable us to predict agrosystem behavior for different ecological conditions, this enables us decision-making process in different levels of management decisive activities from central to local positions.

The model is thought in the form of really existing system that on some level of likeness reflects or is reproducing the research object and is presenting it in the process of knowledge in a such way that new research brings new information about the object (Dubnička, 1994). From this is resulting a model never can be complex reflection of the modeled object essence.

In the Soil Science and Conservation Research Institute Bratislava within the solution of the scientific-technical N. 27.07 „Conservation and Natural Resource Soil Use“ was proposed and constructed computing model of farmland use optimization in Slovakia. Its objective was to help by obtaining, if possible, as much as was acceptable of professional and practical data of soil and in this way make easier decision activities on farmland effective utilization.

MATERIALS AND METHODS

At the model formation our starting point was recent information about the soils of Slovakia, the information was composed into the model in the form purposeful databases.

Among basic starting point program databases are incorporated:

– bonity databank on the soils of Slovakia (Soil Science and Conservation Research Institute (VUPOP), Research Institute for Economics of Agriculture and Food),
– Bonited Pedo-Economical Units (BPEJ) categorization within typological-production categories (Džatko, et al., 2002),
– limits for soil incorporation within pollution zones, data about the Hygienical Preservation Zones share, with expression of concrete yield production reduction in the territories,
– Methodology of Particular Farming System on Farmland and determination of detriment (Research Institute of Soil Fertility, 1995),
– BPEJ categorization into erosion risk degrees (Jambor et al., 1998),
– soil point values (Džatko et al., 2002) and BPEJ price (Notification Finance Ministry SR 465/91 Code),
– cropping system structure parameters and ha-yields by typological-production categories and BPEJ (Džatko, Vilček, 1993),
– irrigation parameters - effect on yields (Irrigation Research Institute, 1994),
– BPEJ possible economical parameters (VÚPOP, 1998) and others.

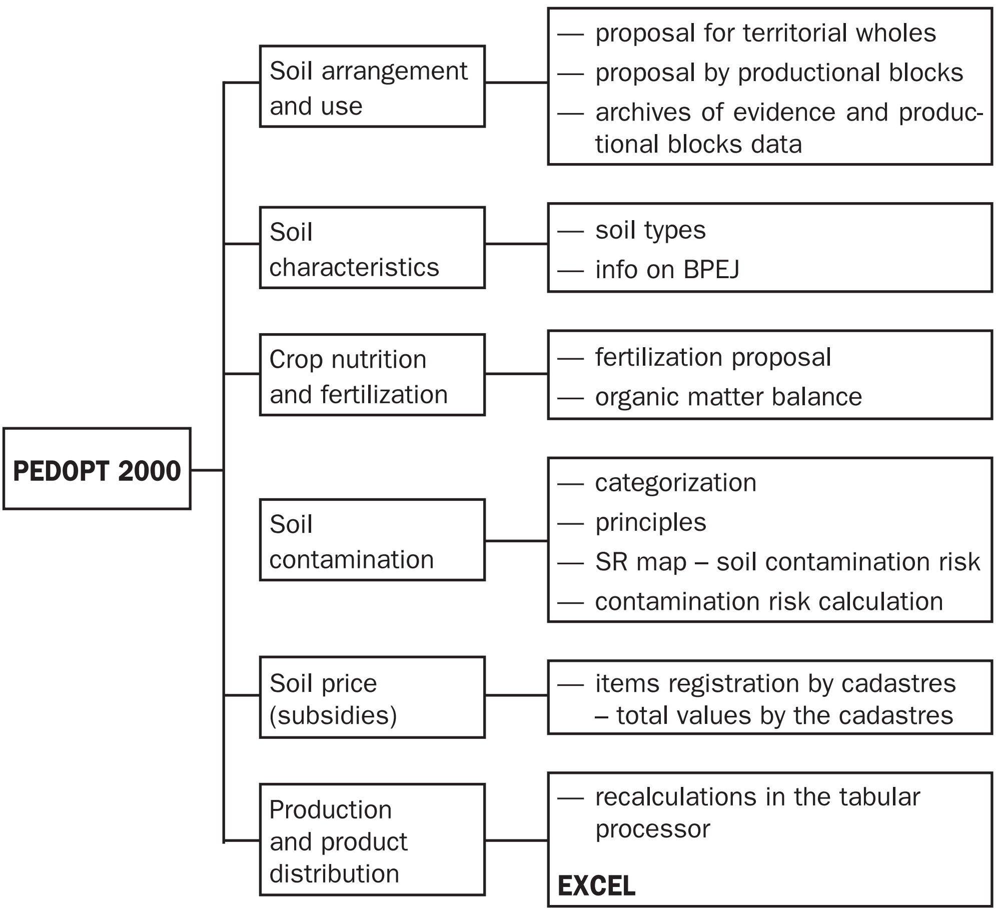
At optimization nutrition and fertilization were into the program included VÚPOP methodological book-lets concerning principles of fertilizer rates calculation (Bujnovský, Ložek, 1996), as well as soil organic matter balance (Jurčová, Bielek, 1997). Purposeful model is working in environment of the WinBase 602 in version 4.0.

RESULTS AND DISCUSSION

In the field of models and modeling at farmland use optimization team of the researchers at the Soil Science and Conservation Research Institute (VÚPOP) has been working since 1995. During formation of the model named PEDOPT 2000, the model has been permanently improved and extended for new blocks. Today it is composed of following moduls:

– soil arrangement and use
– soil characteristics
– crop nutrition and fertilization
– soil contamination
– soil prices (and subsidizing)
– production and its distribution

PEDOPT 2000 – program scheme



Module – Soil Arrangement and Use includes the submodels:

Proposal for territorial wholes – principle is, based on the BPEJ known, to recommend optimum land use system (land structure, cropping system, ha-yields prediction, etc.) with enumeration of possible economical parameters and detriment in the case of farming in the zones of hygienical water conservation, or in areas of pollution.

Proposal by the Blocks of Production and Evidence and Data of Production Blocks – these submodels formation resulted from the requirements of the European Union concerning receiving direct payments and subsequent formation so called LPIS (Land Parcel Identification System). Based on the BPEJ input data and chosen crop in the production block the program offers information on possible production, point value and price, homogeneity, fertilization and plant preservation. After the consent this data can be archived in their itemization by years, cadastres, or crops. Issues can be offered also in printed form.

Module Soil Characteristics was formed with aspect to improved soil informativeness need in Slovakia. In simplified form it offers basic information on main soil representatives and BPEJ.

In the Submodel *Soil Types* an user can choose any soil type interesting for him and the program will provide him a view on typical soil profile, its basic characteristics, extention, suitability for agricultural use, as well as possible subtypes, varieties and forms. Included is also schematic soil map of Slovakia.

After the submodul *Info on the BPEJ* launching the program offers information on given BPEJ basic characteristics and parameters. A potential user will get information on the proper BPEJ code, corresponding climatic region, main soil unit, sloping, exposition, depth, stoniness, as well as soil texture. Important is also an information on the chosen BPEJ price both, in 5- and 7-position codes, on the degree of soil resource taking off with concrete height for stable or temporal occupation, BPEJ point value, on the rate water erosion risk, as well as classification into typological-production category.

By this procedure wanted the team of authors help to current users – laymen at orientation in relatively complicated pedological topics, as well as relatively quickly to obtain necessary data about the soil.

Module – Crop Nutrition and Fertilization is itemized to the submodul Fertilization Proposal and Organic Matter Balance.

The Fertilization Proposal after input required parameters based on valid and common methodologies (field name, dominating BPEJ, acreage, pH measured, P and K levels) in their itemization by fields and selected crops to determine need of nitrogen, phosphorus and potash fertilizers, as well as $CaCO_3$ need and farmyard manure These data are expressed in kg per ha – total for the field and farm, respectively. The user has a chance to make fertilizer choice from the predefined selection that evidently can be supplemented permanently in the program adjustation. The submodul enables also economical calculations, when based on valid fertilizer prices are also calculated proper costs for the fertilizer management, totally by fields and farm.

Organic Matter Balance introduces the transformed and for the program purposes adjusted „Methodology of Soil Organic Matter Balance and Organic Manuring Need Determination“ (Jurčová, Bielek, 1997). The target is to simplify organic manures need into soil recalculation. Based on carbon balance by the fields, selected kind of organic matter need is determined and subsequently is made total balance fore the farm. Required sets printing are obvious.

Module – Soil Contamination is informing on farmland classification by the categories of soil vulnerability to heavy metal contamination. For the categories is referentially proposed possible system of use, based on input data on soil type, pH, clay content and heavy metal levels is the soil classified into proper category showing on the risk element. The module also includes Map of Potential Crop Production Contamination Risk by heavy metals in Slovakia. The module is working based on the principles of the methodology recalculation presented in the report VTP 514-79 „Pedo-ecological Parameters of Rural Country Arrangement and Use“ – (VUPOP Bratislava, Barančíková, In: Vilček et al., 1999).

Module – Soil Price (Subsidies) was elaborated for determination potential subsidies on the soil, their recalculation, with its content the module is expanding the PEDOPT 2000 recent options.

User orders input data – BPEJ code, BPEJ acreages in itemization by the kind of land (arable land, permanent grassland) by cadastral territories relevant for him. The program based on internal databases on the BPEJ prices and proper valid soil price groups and subsidy tariffs for promotion farming in mountainous and in other ways handicapped regions, includes the subject and its cadastral territories into proper soil price group and also recalculates possible subsidy in Sk.

It is obvious, the user can print necessary issues for internal use. Output is the review on soil prices by BPEJ, kind of land, cadastre territories and subject total.

Module – Production and Product Distribution provides for the user an information on possible economical parameters of crop products implementation. Based on the production distribution chosen structure, costs of production and real prices the program provides an information about concrete crop, group of crops, as well as the farm possible economical result. Input data (crop acreage, ha-yield) are automatically read from the module Soil Arrangement and Use. These data can be modified by the user, i.e. modeled in the sense of suitable land use.

The module can introduce desirable tool for the cropping system and grown production distribution. In well defined form it gives information about crop growing efficacy in given conditions, i.e. it is showing to possible risks in the crop selection, as well as production distribution.

CONCLUSIONS

The model PEDOPT 2000 developed was during its generation continually tested by practical purposeful outputs. It has been addressing all agricultural practice, decision sphere, students for their diploma works. The PEDOPT 2000 was presented at various professional events including international exposition Agrokomplex 2001, where it was awarded by Honored Award by the Minister of Agriculture.

In further development the team of authors is considering the program possible further extension in such new submodels that will be interesting for next users. The team s effort has been to make the program available for present status of computing technique by the model practice. Therefore both, technical and program requirements are available almost for everybody.

REFERENCES

Dubnička, J.: Modely a modelovanie vo vedeckom poznaní, In: Modely a modelovanie rastlinnej produkcie. Nitra, VŠP, SAVP 1994, s. 8 – 16.

Bujnovský, R., Ložek, O.: Zásady výpočtu dávok hnojív a ich aplikácie, VÚPÚ, Bratislava, 1996, 56 s.

Džatko, M.: Hodnotenie produkčného potenciálu poľnohospodárskych pôd a pôdnoekologických regiónov Slovenska, VÚPOP Bratislava, 2002, 88 s.

Jambor, P., Ilavská, B.: Metodika protierózneho obrábania pôd, VÚPÚ Bratislava, 1998, 70 s.

Jurčová, O., Bielek, P.: Metodika bilancie pôdnej organickej hmoty a stanovenia potreby organického hnojenia, VÚPÚ, Bratislava, 1997, 154 s.

Vilček, J. a kol.: Pôdnoekologické parameter usporiadania a využívania poľnohospodárskej krajiny. (záverečná správa), VÚPOP Bratislava, 1999, 113 s.

Vilček, J. a kol.: Pedologické aspekty hodnotenia a efektívneho využívania produkčného a mimoprodukčnho potenciálu pôd (záverečná správa VTP 27-07/01), VÚPOP Bratislava, 2002, 52 s.

CONTAMINED AREAS IDENTIFICATION FOR SELECTED RISK ELEMENTS

Identifikácia kontaminovaných plôch podľa vybraných rizikových prvkov

Ján VOJTÁŠ, Libuša MATÚŠKOVÁ
Soil Science and Conservation Research Institute, Bratislava

ABSTRACT

Soil resources hygienical status was assessed based on farmland agronomic characteristics, pollution and criteria for judgement by valid legislation of Slovak Republic. From the view of contamination character can be in Slovakia territory itemized oligo-element and poly-element areas of pollution. The polluted territory was growing for the elements in following order from cobalt (0.1%) through mercury (2%) to arsenic (8%).

Keywords: polluted area, identification of pollution, risk element, Co, As, Pb, Ba, Hg, Cd, Cr, Zn, Cu, Ni

ABSTRAKT

Hygienický stav poľnohospodárskeho pôdneho fondu bol vyhodnotený na podklade agronomických charakteristík poľnohospodárskych pôd, znečistenia a kritérií na posudzovanie kontaminácie podľa platnej legislatívy SR. Z hľadiska charakteru kontaminácie môžeme na území Slovenska vyčleniť bodové, malo-plošné a veľko-plošné oblasti kontaminácie, kde podľa počtu rizikových prvkov môžeme vyčleniť oligo-prvkové a poly-prvkové oblasti znečistenia. Kontaminované územie vzrastá pre jednotlivé prvky v tejto postupnosti od kobaltu (4%) cez ortuť (21%) až po nikel (56%) => (Co < As < Pb < Ba < Hg < Cd < Cr < Zn < Cu < Ni).

Kľúčové slová: kontaminované miesto, identifikácia kontaminácie, rizikový prvok, Co, As, Pb, Ba, Hg, Cd, Cr, Zn, Cu, Ni

INTRODUCTION

Almost all the human society development was linked with the technology of obtaining and processing metals. By winning and metals processing man gives them not only new form, but he brings about also intensive their wide spreading in environment. Soil is typical with high sorption capacity and is very well sorbing positively loaded ions of metals. Therefore permanent supplying, though in low concentrations during long period, is leading to metal accumulation in soil. "Metallic pressure" on biosphere conditioned by man activities can provoke technogenic and geochemic anomalies, their values will be permanently increased paralelly with growth of economic people activity intensity. Therefore is necessary to know potential risk of the metals, regularities and their behaviour in the system soil-plant, as well as character and intensity of their input into food chain.

MATERIAL AND METHODS

Hygienical status of the soil resources (PPF) was assessed based on agronomic characteristics of farmland and criteria for the farmland contamination judgement by valid legislation. In Slovakia soil quality arbitration has been since 1994 valid Resolution of Agricultural Ministry SR (MP SR) n. 531/1994-540, where mentioned values are valid for standard soil containing 10 % humus and 25 % clay (for other ratio humus/clay are used recalculation formulas).

Today within EU-countries has been running the process the methods unification for soil pollution determination and establishment new methods for risk metals bio-availability from the view of agricultural production for their penetration risk into food chain determination.

Soil of Slovak Republic hygienical status was elaborated based on soil characteristics and valid legislation (Resolution of Agricultural Ministry SR n. 531/1994-540). Data on 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 Bratislava (VÚPOP).

RESULTS AND DISCUSSION

For mapping polluted areas were used following criteria:

- textural fraction under 0.001 mm in gentle earth
- humus supply in gentle earth
- risk element contents in A-horizon.

Based on these criteria soils of Slovakia were classified into 6-hygienical zones:

D0 – presence of risk element is lower than half A-reference value in the standard MP SR n. 531/1994-540.

D1 – risk element presence is lower than 9/10 of A-reference value and equal or higher, than half

A – reference value in the standard MP SR n. B1/1994-540

D2 – risk element presence is lower than A-reference value and equal or higher than 9/10 of A-reference value in the standard MP SR n. 531/1994-540.

A – risk element presence is lower than B-indication value and equal or higher than A-reference value in the standard MP SR n. 531/1994-540.

B – risk element presence is lower than C-indication value or equal or higher than B-indication value in the standard MP SR n. 531/1994-540.

C – risk element presence is higher than C-indication value in the standard MP SR n. 531/1994-540 (Tab. 4).

Table 1 Hygienical zones of risk substances in soil

Hygienical zone	Risk substance content interval	Pollution status	Measures
D0	D0 < 0.5*A-limit	No to very weak	Monitoring
D1	0.5*A-limit >= D1 < 0.9*A-limit	Weak to starting	Monitoring
D2	0.9*A-limit >= D2 < A-limit	Advanced	Monitoring
A	A-limit >= A < B-limit	Evident	Monitoring
B	B-limit >= B < C-limit	Strong	Monitoring
C	C-limit >= C	Very strong	Rescue

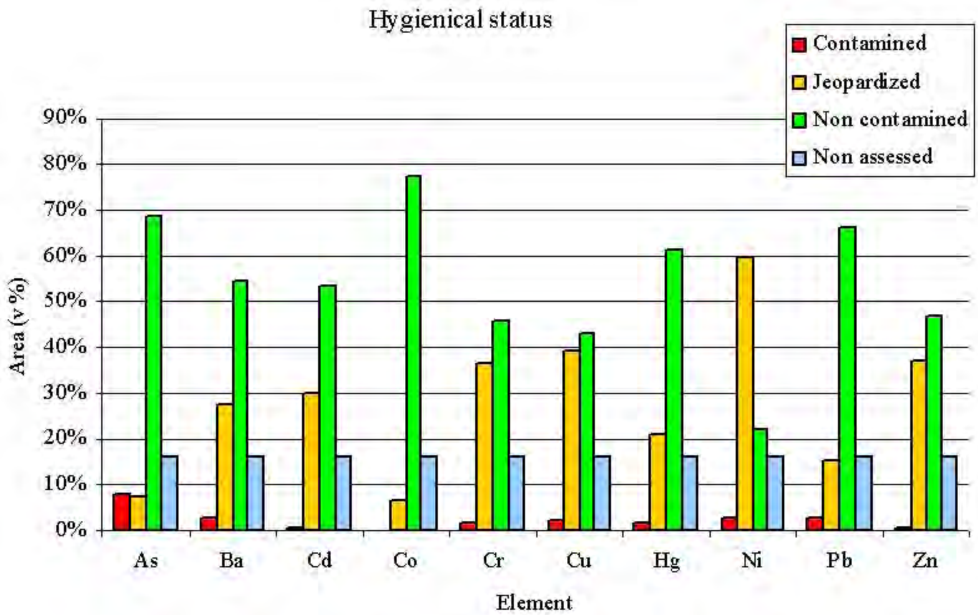
From the view of pollution character can be in the territory of Slovakia itemized: point, small-area and large-area contamination areas, where by risk element number can be delimited oligo-element and poly-element pollution areas.

Area distribution of the hygienical zones itemized for selected risk elements is presented in Table 2 and Figure 2. Polluted territory is growing for the elements in following order from Cobalt (0.1 %) through mercury (2 %) to arsenic (8 %) = (Co < Cd < Zn < Cr < Hg < Cu < Ni < Ba < Pb < As).

Table 2 Slovakia territory pollution status assessment

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
As	3.2 %	7.8 %	7.4 %	68.9 %	15.9 %
Ba	0.9 %	2.5 %	27.5 %	54.2 %	15.9 %
Cd	0.0 %	0.5 %	30.2 %	53.4 %	15.9 %
Co	0.0 %	0.1 %	6.7 %	77.3 %	15.9 %
Cr	0.2 %	1.6 %	36.7 %	45.8 %	15.9 %
Cu	0.2 %	2.0 %	39.0 %	43.1 %	15.9 %
Hg	0.4 %	1.9 %	21.0 %	61.2 %	15.9 %
Ni	0.1 %	2.4 %	59.5 %	22.2 %	15.9 %
Pb	0.4 %	2.6 %	15.4 %	66.1 %	15.9 %
Zn	0.0 %	0.6 %	36.7 %	46.8 %	15.9 %

Figure 1 Slovakia territory pollution status assessment



Arsenic (As)

In Earth Crust is approximately 1.8 mg.kg^{-1} As. Mean As-content in soil is 8.7 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) is in farmland of Slovakia in layer 10 cm mean As-content 15.7 mg.kg^{-1}.

Metallic As and As-sulphids are toxicologically non significant. Strong toxic are substances of As^{3+}. Central nerve-system is badly damaged and there are proved cancerogenous effects on organisms. From the view of environment hygiene it is dangerous for high accumulation coefficient enabling high accumulation in alluvial sediments, soils and higher organisms. Pollution sources are mainly flying ash of heating plants and burning plants. Into soils it is getting besides other in the form of arsenic pesticides (Beneš and Pabianová, 1987).

Arsenic contamination (zone B+C) is from the view of Slovakia farmland in the level 7.8 % (Tab. 3). It is concentrated to central parts of Slovakia – Spišsko-Gemerské Rudohorie and Nízke Tatry Mountains.

Table 3 Slovakia farmland hygienical status with aspect to arsenic in topsoil

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
As	3.2 %	7.8 %	7.4 %	68.9 %	15.9 %

As-contamination is demonstrated as large-area pollution, this is linked with rich mining – metallurgical tradition in this territory. In remaining territory pollution forms point-like and small-area territories in surroundings of industrial wholes.

Barium (Ba)

Mean Ba-content in Earth Crust is 425 mg.kg^{-1}. It is most accumulated in acid magmatic rocks (on average 830 mg.kg^{-1}) and in clayic shales and clays (on average

580 mg.kg^{-1}) (Beneš, Pabianová, 1986). Mean Ba-contents in soils is 522 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Čurlík et al., (1999) is in Slovakia farmland A-horizons mean Ba-content 396 mg.kg^{-1}. Soil pollution sources are particularly chemical, metallurgical, smelting and metallurgical industry, respectively.

Barium pollution (zone B+C) is with aspect to Slovakia farmland in the level 2 % (Tab. 4) where dominating phenomenon is B-referential level exceeding. It is concentrated into Slovakia central parts – Spišsko-Gemerské Rudohorie and Nízke Tatry Mountains.

Table 4 Slovakia farmland hygienical status with aspect to barium in topsoil

Element	Contamined zone C	Contamined zone B + C	Jeopardized zone D2 + A	Non contamined zone D0 + D1	Non assessed
Ba	0.9 %	2.5 %	27.5 %	54.2 %	15.9 %

It is demonstrated in the form of large-areas pollution, this is probably connected with Ba-presence as isomorphic by mixture in K-feldspars and plagioclases of magmatic rocks in soil cover substratum.

In remaining territory it forms point and small areas territorial contaminations in surroundings of industrial wholes.

Cadmium (Cd)

Mean Cd-content in Earth Crust is 0.2 mg.kg^{-1}. Most it is accumulated in clayic shales and clays – up to 0.8 mg.kg^{-1} (Beneš, 1994). Average Cd-content in soils is 0.48 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) in Slovakia farmland is in uppermost layer (10 cm) mean Cd-content 0.285 mg.kg^{-1}.

Environment pollution source in our conditions are cadmium pollutants emitted by industry, particularly however direct application of phosphorus and multicomponent fertilisers with Cd-content, and municipal sludges applied on farmland. Cadmium movement in soil profile is influenced particularly by pH of soil, redox potential, clay minerals and some other minerals, humus, and Fe, Mn and Al oxides.

Cadmium contamination (zone B+C) is from the view of Slovakia farmland in the level 0.5 %, whereby dominating phenomenon is B-indicate value exceeding.

Table 5 Slovakia farmland hygienical status for cadmium in topsoil

Element	Contamined zone C	Contamined zone B + C	Jeopardized zone D2 + A	Non contamined zone D0 + D1	Non assessed
Cd	0.0 %	0.5 %	30.2 %	53.4 %	15.9 %

It is focused to central and northern parts of Slovakia – Vysoké Tatry, Spišsko--Gemerské Rudohorie and Nízke Tatry mountains. It is demonstrated as large-areas pollution, this is linked particularly with pollution load through distant transition from neighbouring countries and developed industrial activities in inner basins of Western Carpathians. On remaining territory Cd-pollution forms point and small-areas contaminations in surroundings of industrial wholes.

Cobalt (Co)

In Earth Crust is approximately 40 mg Co.kg^{-1}. Average Co-level in soil is 8.5 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) is in Slovakia farmland, in layer uppermost 10 cm mean Co-content 12.32 mg.kg^{-1}. Co-deficiency in soils is visible at values under 5.0 mg.kg^{-1} (Beneš, Pabianová, 1987).

Co-contamination (zone B+C) is from the view of Slovakia farmland in the level 0.1 %. It forms point and small-areas contaminations in surroundings of industrial wholes.

Table 6 Slovakia farmland hygienical status for cobalt in topsoil

Element	Contamined zone C	Contamined zone B + C	Jeopardized zone D2 + A	Non contamined zone D0 + D1	Non assessed
Co	0.0 %	0.1 %	6.7 %	77.3 %	15.9 %

Chromium (Cr)

In the Earth Crust is approximately 100 mg Cr.kg^{-1}. Mean Cr-level in soils is 65 mg.kg^{1} (Kabata-Pendians and Kabata, 1992). By Linkeš et al., (1997) is in Slovakia farmland in uppermost layer 10 cm mean Cr-level 72.6 mg.kg^{-1}.

Chromium toxicity is dependent from stage of oxidation. Change Cr^{3+} to Cr^{6+} (oxidation) reaction, and Cr^{6+} to Cr^{3+} (reduction) has primarily microbial character in presence of easily decomposable organic mass. Plant sensibility to chromium is various. In spite of low chromium release level from soil, Cr is phytotoxic (particularly Cr^{6+}) and its transfer into food chain can be very marked (Beneš, 1994).

Contamination by chromium (zone B+C) is from the view of Slovakia farmland in the level 1.6 %, where dominating phenomenon is exceeding B-indicate value. Cr-contamination is concentrated in central, northern and eastern part of Slovakia – Vysoké Tatry, Nízke Tatry, Spišsko-Gemerské Rudohorie and East Slovakian Lowland.

Table 7 Slovakia farmland hygienical status for chromium in topsoil

Element	Contamined zone C	Contamined zone B + C	Jeopardized zone D2 + A	Non contamined zone D0 + D1	Non assessed
Cr	0.2 %	1.6 %	36.7 %	45.8 %	15.9 %

It is demonstrated as large-area pollution, this is connected particularly with pollution load through distant transfer from neighbouring countries with industrial activities. In remaining territory Cr-pollution forms point and small-areas contaminated territories in surroundings of industrial wholes.

Copper (Cu)

Mean content in Earth Crust is approximately 55 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) in Slovakia farmland in uppermost layer 10 cm is mean Cu-content 22.59 mg.kg^{-1}. In soil it is in the form Cu^{2+} and complexes fixed to organic mass, sesquioxides and in primal and secondary minerals. Small Cu-quantity is in soil solution (0.01 mg.kg^{-1}). Cu-bioavailability for plants is influenced particularly by soil reaction and humus. Cu-deficiency in soils is visible at values under 20 mg.kg^{-1} (organic soils), or under 10 mg.kg^{-1} (heavy and light soils). Copper excessive concentrations in soil solution are toxic for plants and are fixed mainly to rooting system Cu-level treatment is possible via liming and soil organic manuring (Beneš, Pabianová, 1987). Under Cu-polluted soils we understand soils Cu-level above 36 mg.kg^{-1} in sense of MP SR Resolution n. 531/1994-540 (A-value exceeding).

Copper pollution (zone B+C) is from the view of Slovakia farmland in the level 2.0 %, whereby dominating phenomenon is B-indicate value exceeding. It is concentrated to central, northern and south-western party of Slovakia – Vysoké Tatry, Nízke Tatry, Spiško-Gemerské Rudohorie and Danubian Lowland.

Table 8 Slovakia farmland hygienical status for Cu in topsoil

Element	Contamined zone C	Contamined zone B + C	Jeopardized zone D2 + A	Non contamined zone D0 + D1	Non assessed
Cu	0.2 %	2.0 %	39.0 %	43.1 %	15.9 %

Cu-contamination is large-area, this is connected particularly with pollution load through distant transfer from neighbouring countries and by industrial activities. In remaining territory there are point and small-area contamined territories in surroundings of industrial wholes.

Mercury (Hg)

In Earth Crust is approximately 0.2 mg.kg^{-1} Hg. Hg-contents in soils ranges round 0.1 Hg mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) in Slovakia farmland in uppermost layer 10 cm mean content is 0.075 mg.kg^{-1}.

Mercury has one of the highest accumulation coefficients (1.10^{6}), it causes extraordinary high and strong Hg-accumulation in sediments of water recipients and fauna, and flora. Hg has considerable affinity to methyl by help of microorganisms and result is extraordinary toxic and volatile organic compounds that gradually contamine whole populations of organisms even at low temperatures. Therefore Hg-hygienical limits are very strict (Beneš, 1994). Hg-contamination (zone B+C) is with aspect to Slovakia farmland in the level 1.9 %, where dominating phenomenon is exceeding B-indicate limits. Hg-contamination is concentrated to central and northern parts of Slovakia – Malá and Veľká Fatra, Vysoké Tatry, Spišsko-Gemerské Rudohorie and Nízke Tatry.

Table 9 Slovakia farmland hygienical status for mercury in topsoil

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
Hg	0.4 %	1.9 %	21.0 %	61.2 %	15.9 %

It is large-area pollution, this linked particularly with emission load through remote transfer from neighbouring countries and developed mining and metallurgical activities. In remaining territory Hg-pollution forms point and small-area contaminations in surroundings of industrial wholes.

Nickel (Ni)

Mean Ni-content in Earth Crust is estimated to 75 mg.kg^{-1}. Average Ni-level is soil is 22 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) is in Slovakia farmland topsoil 10 cm mean nickel content 12.79 mg.kg^{-1}.

Soil organic mass adsorb Ni in organically fixed forms, where part of it can be easily soluble chelates. Ni-solubility is non-linearly to soil reaction. Most available Ni-forms are in soils with pH 6.5 – 7.0 (Beneš, 1987). Nickel is toxic for higher organisms, it in plant it exceeds 50 mg.kg^{-1} in dry mass (Šindelařová, 1988).

Worst situation in Ni-contamination (zone B+C) in the cases, where 2.4 % Slovakia farmland exceeds B-indicate value. It appears as total Slovakia farmland pollution with exception of south-western part of Central Slovakia, where is soil relatively non-

-polluted and there occur only point and small-area contamination in surroundings of industrial wholes.

Table 10 Slovakia farmland hygienical status for nickel in topsoil

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
Ni	0.1 %	2.4 %	59.5 %	22.2 %	15.9 %

Lead (Pb)

Mean Pb-content in Earth Crust is estimated 125 mg.kg^{-1}. Mean Pb-level in soil is 35 mg.kg^{-1} (Kabata-Pendias and Kabata, 1984). By Linkeš et al., (1997) Slovakia farmland contains in topsoil 10 cm mean Pb-level 24.87 mg.kg^{-1}.

Lead is toxic and dangerous mainly through its easy bioaccumulation in live mass. By help of bacteria is formed tetramethyllead – very dangerous for central nerve system of higher organisms. In soil is Pb less mobile, however Pb-mobility in presence of chelate complexes and fulvo acids surprisingly growths and its bioavailability for plants is increased. Lead uptake is reduced by liming and manuring (mature composts).

Pb-contamination (zone B+C) is from the Slovakia farmland point of view in the level 2.6 %, whereby dominating phenomenon is B-indicate value exceeding.

Table 11 Slovakia farmland hygienical status for lead in topsoil

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
Pb	0.4 %	2.6 %	15.4 %	66.1 %	15.9 %

Pb-pollution is concentrated in northern part of Slovakia – Vysoké Tatry, Spišsko-Gemerské Rudohorie and Nízke Tatry monntains. Spiš appears as large-area pollution, this is particularly connected with emission load through remote transfer from neighbouring countries and developed industrial activities in inner basing of Western Carpathians. In remaining territory are formed point and small-area of contamination and in surroundings of industrial wholes.

Zinc (Zn)

In Earth Crust is approximately 70 mg.kg^{-1} Zn. Mean Zn-content in soil is 61 mg.kg^{-1} (Kabata – Pendias and Kabata, 1984). By Linkeš et al., (1997) is in Slovakia farmland, uppermost layer 10 cm mean Zn-content 64.26 mg.kg^{-1}. Zn-toxicity is visible particularly in acid soils and at Fe surplus. At higher concentrations is Zn phyto-toxical.

Zinc contamination (zone B+C) is from the view of Slovakia farmland in the level 0.6 %, where dominating phenomenon is B-indicate value exceeding. Zn-contamination is concentrated in Slovakia central part and Malé Karpaty Mountains.

Table 12 Slovakia farmland hygienical status for zinc in topsoil

Element	Contamined zone C	Contamined zone B+C	Jeopardized zone D2+A	Non contamined zone D0+D1	Non assessed
Zn	0.0 %	0.6 %	36.7 %	46.8 %	15.9 %

Zn-pollution appears as large-area one, this is linked particularly with emission load through remote transfer from neighbouring countries and developed industrial activities in inner basins of Western Carpathians. In remaining territory is formed point and small-area contaminations in surrounding of industrial wholes.

CONCLUSIONS

Farmland hygienical status was assessed based on information database system of the Soil Science and Conservation Research Institute, Bratislava, whereby were data of agronomical characteristics of farmland. Also principles of Slovak Republic valid legislation concerning farmland contamination judgement were applied.

From the view of contamination character can be in the Slovakia territory itemized point, small-area and large-area contamination wholes, where by risk elements number can be delimited oligo-elemental and polyelemental areas of pollution. Contamined territory for the elements increases in following order from cobalt (0.1 %) through mercury (2 %) to arsenic (8 %) = (Co < Cd < Zn < Cr < Hg < Cu < Ni < Ba < Pb < As).

REFERENCES

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

Bielek, P. a kol., (2003): VTP 27-07 Ochrana a efektívne využívanie prírodného zdroja pôdy VÚPOP, Bratislava.

Čurlík, J. a kol., (1999): Geochemický atlas pôd Slovenska časť V. – Pôdy. Bratislava, VÚPOP, 99 s., príl.

Kabata – Pendias, A., Pendias, H., (1992): Trace elements in Soils and Plants, CRC Press London, 2nd edition, 365 p.

Linkeš, V. et al., (1997): Monitoring pôd Slovenskej republiky, VÚPÚ, Bratislava, 128 s.

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