Some statistical aspects of monitoring of soil change in Slovakia

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Abstract
Stratified soil monitoring network in Slovakia has been constructed on ecological principles where all soils, substrates, climatic regions, polluted and non-polluted areas are included. There are 318 monitoring sites on agricultural soils in Slovakia. Soil parameters are monitored and evaluated in harmony with EC for soil monitoring according to threats to soil (soil contamination, salinisation and sodification, decline in soil organic matter, compaction and erosion). The obtained results are evaluated separately according to soil type, subtype, geology, land use with regard to their area. If small spatial variability of measured parameters is significantly decreases. Basic statistical procedures are used with regard to some statistical aspects (to evaluate comparable couple files, frequency of measured data; the object of statistical evaluation must be correctly defined – area of site, soil type, respective subtype, evaluated parameter, depth of soil profile, etc.). Finally, so-called environmental statistical evaluation could be one of important statistical aspects of monitoring soil change.

Key Words
Soil monitoring, statistical aspects, environmental statistical evaluation, soil variability

Introduction
Soil monitoring in Slovakia is a vital component, alongside soil database and maps. Its importance consists of providing information about changing with space and time and answering questions about whether the quality of a soil is improving, deteriorating or staying about the same under a particular use and management practice.

Behaviour of soils and their variability
Individual soil units are open dynamic systems which are the results of the mostly long to very long sometimes medium to relatively short evolution-genesis of soil. Old soils have achieved the state of dynamic equilibrum with the other component of environment (climate, vegetation, groundwater, etc.). These soils are often characteristic with narrow range of parameters in space opposite the young soils, where the values of soil properties are rather dynamic and heterogenous. Variability of soils is often changed and decreased in the following sequence: initial soils – forming soils – strongly weathered soils. In the soil monitoring network of Slovakia are included all mentioned soils and therefore the area of monitoring site must accept this reality.

Design
The monitoring site is of circular shape with a radius of 10 m and an area of 314 m^2 where the variability of soil properties in space is low. The soil monitoring network was constructed on the basis of ecological principles. It means all soil types and subtypes, geology, various climatic and emission regions, lowland and highland are included. The result of this principle is 318 monitoring site in stratified network on agricultural land in Slovakia. Every monitoring site is located by GPS in WGS 84 coordinates system.

Basic principles of evaluation of monitored data
Basic soil parameters are monitored and evaluated in harmony with the European Commission for soil monitoring according to threats to soil (soil contamination, salinisation and sodification, decline in soil organic matter, soil compaction and erosion). During the evaluation process some statistical aspects are accepted, as follows (Kobza, 2008):

- basic characteristics of variability (range of variability, mean and standard deviation, dispersion, coefficient of variability)
- testing of statistical hypothesis (comparison of two comparable files, where parametric and non-parametric tests could be used)
- evaluation of dependence between parameters (e.g. regression)
- reciprocal correlation of several parameters using correlation matrix with values of correlated coefficients

- factor analysis
- prediction (estimation of development of observed parameters in time).

During the evaluation process it is necessary to take into account not only method of statistical evaluation, but also the concrete area of evaluated object (in this case-soil) which consists of units (e.g. Chernozems, Cambisols, etc.) with other additional specifications (e.g. Cambisols under grassland, on arable land, cultivated, non-cultivated, protected, non-protected, etc.). In addition, it may be said that, so-called **environmental statistical evaluation** (accepted previous principles) could be one of important statistical aspects of national-scale soil monitoring in effort to increase the objectivity of obtained results. In the following table 1 the basic statistical data are given on the example of three various soil bodies (all soils included in soil monitoring network, one soil unit-Stagnosol and finally the basic monitoring site with area 314 m^2).

Table 1. Basic statistical characteristics of three various soil levels.

Parameters	**Basic monitoring network in Slovakia - all soil types**							
	Arable soil (n = 223)				Grassland (n = 95)			
	Xmin	Xmax	X	V	Xmin	Xmax	X	V
Cox (%)	0.45	4.21	1.29	0.27	0.75	14.48	2.73	6.12
pH/KCl	3.89	7.92	6.46	0.75	3.56	7.16	5.24	1.29
Parameters	**Basic monitoring network in Slovakia- Stagnosols**							
	Arable soils (n = 37)				Grassland (n = 12)			
	Xmin	Xmax	X	V	Xmin	Xmax	X	V
Cox (%)	0.50	2.34	1.03	0.10	0.85	3.66	1.94	0.75
pH/KCl	4.47	7.42	5.96	0.62	4.59	7.04	5.83	0.68
Parameters	**Basic monitoring network in Slovakia – one monitoring site**							
	Arable soils (n = 5)				Grassland (n = 5)			
	Xmin.	Xmax.	X	V	Xmin.	Xmax.	X	V
Cox (%)	1.48	2.36	1.94	0.12	1.91	2.18	2.04	0.04
pH/KCl	4.92	5.13	5.05	0.02	5.42	5.68	5.46	0.02

V – coefficient of variability, x – arithmetic mean

In Slovakia, we have completely realised three monitoring cycles for the time being. In the following Figure 1 is presented the histogram of available potassium development on Cambisols which are the most extended soils in Slovakia.

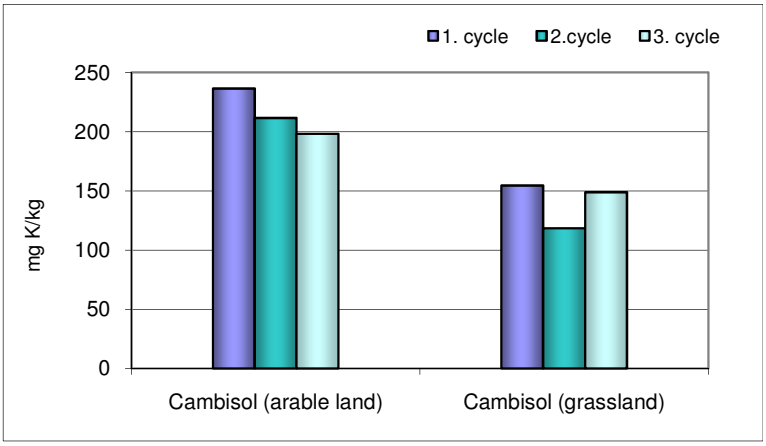

Figure 1. Development of available potassium in the arable layer of agricultural soils in Slovakia.

There are differences between arable soils and soils covered by grass. The higher content of potassium on arable soils is caused by fertilisation level, which is slightly decreased in time. Change in time is not statistically significant and it is very similar to variability in space of monitoring site area, which is a very important factor of evaluation (under conditions of Slovakia was max. 300-350 m^2 determined in effort not to change variability in space for variability in time). The statistical evaluation is often used for **prognosis of monitored parameters for the future**. This evaluation is provided so that outside conditions affecting the

development of measured parameters in time are not changed (so-called “ceteris paribus” principle). Minimum evaluated data set of 8 in this case is recommended. An example on the path of fluorine in the air and soil in the surroundings of an aluminium factory in the Žiarska kotlina (depression) in Central part of Slovakia is given in Figure 2.

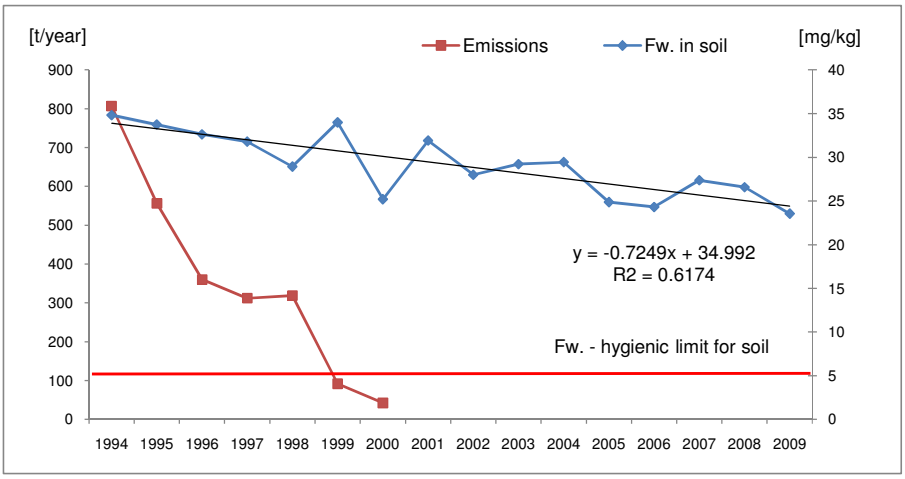

Figure 2. Amounts of fluorine in air and soil in the surroundings of an aluminium factory.

This figure refers to very important role of soil in environment where despite a strong decrease of fluorine in air, the content of this element in soil is still high (5-times the valid hygienic limit for Slovakia).

In addition, also some **basic interpolation methods using GIS** are included in national-scale soil monitoring in Slovakia, as follows (Bliš̌an, 2005):

- triangle methods (linear interpolation)
- inverse distance square (IDS)
- kriging

In the following Figure 3 is shown the kriging semivariogram of pH/KCl values as a function of their distance in the Medzibodrožie region, which has been studied as pilot area of an ENVASSO project (Environmental Assessment of Soil for Monitoring) in the framework of 6. FP (Kobza and Dobos, 2008).

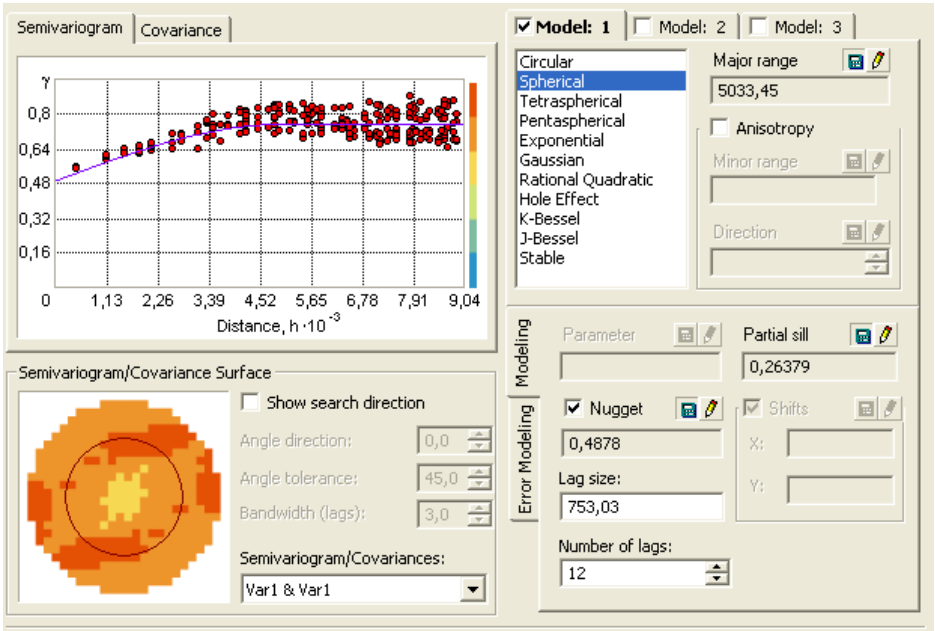

Figure 3. Semivariogram of pH/KCl in Medzibodrožie region.

It may be said that traditionally used technologies of GIS are mostly directed to management and reporting of 2D data for the time being. In such systems (Arc Info, Arc View) it is possible to create a wide range of maps which are used especially for evaluation of sensitive regions of Slovakia.

Conclusions

On the basis of obtained results it was determined that spatial variability decreases as the statistically evaluated object is getting smaller (e.g. in direction: national soil area – district – cadaster – field – soil type – soil subtype, etc.). Spatial variability is increasing for soil parameters which are more influenced by human activity (e.g. pH, soil organic carbon, available nutrients – P and K). Finally, during the evaluation process it is necessary to take into account not only statistical methods, but also area of the evaluated object (in this case – soil) which consists of units (e.g. Cambisols, Stagnosols, etc.) with other additional specifications (arable land, grassland, cultivated, non-cultivated, protected, non-protected, etc.).

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