Néhány talajtulajdonság tájvédelmi szempontú értékelése

Doktori (PhD) értekezés tézisei

Evaluation of Some Soil Properties from the Aspect of Landscape Protection

PhD thesis

Szabó Szilárd

Debreceni Egyetem
Debrecen, 2004.

PRECEDENTS AND AIMS

An ever-increasing load is exerted upon the environment by the development of the society and by the related increase of the space and resources needs. The environmental load affects all of the elements of the system despite the fact that which of these is affected directly as some elements may be affected indirectly. Environmental systems are open systems the elements of which are in mutual interconnection therefore we should bear in mind in the course of environmental investigations that single elements cannot be protected alone just with the recognition of the entire system. On the one hand, different landscape systems respond differently to the same environmental load and on the other hand, the very same landscape may react variably to different environmental loads thus there is no point in studying general landscape sensitivity you need to name the exact effect to which landscape sensitivity is related. The less disturbance a system has to suffer the greater the potential is for self-purification or regeneration of the system.

Several scientists contributed to the professional literature of landscape sensitivity (e.g. *Brunsden, D.* 2001; *Fazekas I.* 2003; *Heathwaite, A. L.* 1993; *Lóczy D.* 2002; *Mezősi G. – Mucsi L,* 1993; *Kerényi A. – Csima P.* 1999; *Kerényi A. – Szabó Gy.* 2001; *Perkins, J. S. – Thomas, D. S. G.* 1993).

We picked soils from the landscape elements for the evaluation indicated in the title because soils give a decent basis for landscape protection investigations. Soil forming factors are the same as the landscape factors so that the harming effects of the society will be observable and detectable on them sooner or later. These effects strike through the system as a chain-reaction and leave their imprints on the landscape elements. These imprints remain in soils for a longer period of time and become detectable by laboratory investigations.

Several scientists have carried out studies on the role of soils in the landscape systems, on their sensitivity related to environmental effects, on their self-purification potential and on the acidification as well which is the main aspect of our work (*Blaskó L.* 2002; *Filep Gy. – Csillag J.* 1993; *Filep Gy. – Filep T.* 1999; *Filep Gy. – Rédy L.* 1987-1988; *Füleki Gy.* 1995; *Hüttl, R. F. – Freilinghaus, M.* 1994; *Karuczka A. – Löki A.* 1998; *Molski, B. A. – Dmuchowski, W.* 1986; *Reuss, J. O. – Walthall, P. M.* 1990; *Stefanovits P.* 1995; *Vallejo, V. R. et al.* 2000; *Várallyay Gy.* 2003).

The subject of the paper is to study the effects of agricultural soil treatment. The solving of the following problems was pointed as the goals of our work:

- To study the similarities and the differences between the properties of the Cambisols of vineyards and arable lands and also between the soils of the different categories.
- To review the modern horizontal heterogeneity of the soil properties.
- To enlighten the change in the soil acidification forms based on the study of different soil profiles.
- To investigate the connection between the soil properties the relief and the elements of the water budget equation. Furthermore to find out whether there is a detectable correlation among the hydrometeorological conditions the runoff and the evaporation or not.
- To identify the factors that influence the soil pH and the buffer capacity.
- To find out whether there is any soil acidification in the area or not and if yes, in what measure.
- To study the multi variance weighting landscape evaluation method on the example of soil acidification and to see whether it is applicable to the estimation of the landscape sensitivity or not.

- To show the role of the different acid loads on the mobilization of heavy metals. We compare the amounts mobilized according to the different exposition times the acid concentrations and the land-use. We analyse the correlation between the soil properties and the solved concentrations on each metal.
- To study the amount of metals taken up by rye-grass from soils, of different places and land-use under the effects of zinc and cadmium loading. Furthermore we investigate which soil properties determine the concentration of metals taken up by the plants.

MATERIALS AND METHODS

The majority of our investigations were carried out in a study area in the Bükkalja (enclosed by the settlements Bogács Bükkzsérc and Cserépfalu). We collected samples from 4 further areas for the laboratory experiments.

We used soil samples from 3 sampling periods (1979-1988; 1995-1997 and 1999-2003) that enabled us to study the time factor of the acidification processes acting in the area besides analysing the present state.

The vast majority of the analyses were made on our own samples (from 1999-2003). This means 99 surface samples and samples from 30 drillings and soil profiles (94 samples). The soil analyses were carried out in the soil and sediment analysing laboratory of the Institute of Geography. We carried out the missing but informative soil analyses of the samples taken in 1979-1988 in the same laboratory.

Besides the routine analyses that were carried out in every case we examined the buffer capacity of 214 samples for which the pH of soil suspensions were measured at 8 points (8x214=1712 measurements).

In the course of the construction of the soil acidification maps (for which we used the data of the 1979-1988 samples) we standardised the data with different dimensions involved in the study then we prepared maps from these data with interpolation and finally they were weighted and the layers were summarised. The control of the maps took place by cross-tabulation and by analysing the recently collected samples.

For studying the metal mobilization 10 samples were treated by 0,005 and 0,1 M HCl for 1 day, 1 week and 1 month repeated three times. Besides 20 samples were treated by 0,01; 0,1; 1 and 10 M HNO_3 for 1 hour, 1 day and 1 week again repeated 3 times. After the treatment concentrations of Cu, Ni, Co, Zn, Mn and Fe were measured by F-AAS technique (this resulted in 10x2x3x3x6=1080 and 20x4x3x3x6=4320 measurements for the HCl and the HNO_3 treatment respectively).

The metal uptake of plants was studied in co-operation with the Fleishmann Rudolf Agricultural Research Institute using rye-grass as test plant. In the course of the investigation we measured the metal accumulation of plants grown on the soils of 3 land-use types of 4 different production places (arable land forest grassland). Two series of growing pots were set in the laboratory and 5 ppm zinc and 5 ppm cadmium was added to one of them and the other one was the control series to study the effects of load on the plants. This experiment was repeated four times (4x3x2x4=96 growing pots). The determination of the metal concentrations of the plants and soils was made in the Central Laboratory of the Institute of Environmental Management measuring the concentrations of ten metals (Al, Mn, Fe, Zn, Cd, Pb, Ni, Cu, Cr, Co) and that of phosphorous.

We prepared the digital 3 D model and the land-use map of the study area based on topographic maps on the scale of 1:10000.

We analysed the 40-60 years data sets of 10 meteorologic stations and also the 20-40 years temperature data sets of 3 stations in monthly rate. Based on this we calculated the average precipitation and the 5 % and 10 % probability values of the 1-6 days great precipitations and Thornthwaite's potential evapotranspiration.

We used statistical and GIS methods as SPSS 8.0 for Windows IDRISI 32R2 Surfer 8.0 for Windows and AutoCad R13 for analysing the results.

RESULTS

1. Results gained by the spatial heterogeneity studies of soils

According to the coefficient of variation of the soil properties we came to the conclusion that *horizontal heterogeneity is greatest in the hydrolytic acidity and the organic content*. These two soil properties are greatly influenced by human impact that is the result of fertilising and liming. This is important because later activity is based on these factors so improper sampling might results in the overestimation or underestimation of the real needs. *We should highlight the heterogenity of copper and zinc among metal concentrations* as these metals strongly bonded to colloids: significant amount of clay and organic matter is eroded from arable lands that are uncovered for much of the year therefore the concentration of metals that are bonded to the clays is very variable. *Greater concentrations are associated with greater clay content that suggests accumulation in our case*.

On the example of soil liming we proved that ignoring the horizontal differences of soils may lead to improper decisions from landscape protection and environmental protection and also from economic point of view.

We examined pH, organic content and metal content for detecting differences in the land-use types. *We found significant differences in pH and organic content and also in copper and zinc contents of arable lands and vineyards.* On the other hand *arable lands show differences in the categories while vineyards do not*. The reason for this lies in the fact that the arable lands are treated by the same fertilising and liming methods over extensive areas while rows of vines in vineyards are owned by different owners with different financial and thus different fertilising and liming possibilities. Differences in the metal concentrations might be the results of different land treatment (e.g. Cu sulphate spraying) and of that there was rigol cultivation before creating vineyards and therefore the *material of the B horizon of the soil containing higher amount of clay got to the surface and copper and zinc was bonded to it.*

Representing pH and organic content on maps the minimum curvature and kriging methods were considered to give the best results among interpolation methods based on the RMSE values. Visually analysing the maps, however, the minimum curvature turned out to be accurate only in the most limited sampling area with significantly increasing uncertainty towards the margins. *The map drawn by the kriging method is very similar at the sampling points and gives acceptable results at the data lacking sites as well.* Comparing them we emphasize that significant errors may occur even in the most accurate methods and therefore correct representation can only be imagined by sufficient amount of data.

We showed that the vertical heterogeneity of the soil pH and the hydrolytic acidity exhibit the traces of human impact. We found that the treatment of both arable lands and vineyards result in soil acidification. Thus the layers of the soil profiles indicate the treatments applied in the area: following the changes in pH and lime content shows whether there was any liming in the area. *We identified characteristic profile types on the basis of their pH.*

2. Correlations between soils, relief and precipitation conditions

Our conclusions were drawn on the basis of our digital 3 D model of the area and on the temperature data and also on the results of the soil measurements.

We showed significant negative correlation between the elevation above sea level and the thickness of the humus containing layer. This is the result of greater erosion related to the increase of slope steepness with the increase of elevation.

Relief is dominated in the spatial distribution of the precipitation. We found close correlation between the elevation above sea level and the precipitation values. There is a double maximum in the great precipitation values: in June and in August.

Greatest runoff rates are associated with the compact and for most of the year uncovered areas that are not having the steepest slopes. These areas are mostly arable lands. In this case close correlations with soil properties were not found, which can be explained by that this method produces only a general picture of the runoff. The intensity of the runoff and the resultant erosion may be greatest at the time of snow melting in spring when it follows a wet winter. These kinds of problems together with factors influenced by the soil properties cannot be taken into consideration in our model. *Closest correlation was measured with the annual average precipitation.*

The map of the evapotranspiration constructed on the basis of 3 stations does not give detailed image but it is useful in determining trend like changes. *Evaporation gradually decreases from the South to the North, however, it is not significant.*

Infiltration cannot be determined accurately without evapotranspiration data so in this case only an estimation is given. However, *we were able to identify areas with high infiltration values where leaching is a dominant factor in the soil genesis processes*.

We found negative correlation between the elevation above sea level and infiltration and also between the buffer capacity and infiltration. There is a positive correlation between the elevation above sea level and runoff and also between evaporation and pH. This latter correlation is close the correlation coefficient is 0,74 ($p<0,01$) which is very high even though numerous other factors also influence pH.

We can conclude that although lack of data presented methodological limits the results are acceptable. This method is capable for the identification of leached and eroded areas thus it might be an effective tool in the course of landscape protection and environmental protection measurements.

3. Results of the investigations on the factors determining the buffer capacity of soils

Buffer capacity in general is the property of the soil that is able to reduce the effect of loading. In this work we studied this reduction capacity in relation to a particular environmental load namely the resistance of soils against acid contamination.

We concluded that *buffer capacity is in close significant correlation to pH, hydrolytic acidity, $CaCO_3$ content, soil instauration, humus quality and clay fraction.*

Buffer capacity is primarily determined by hydrolytic acidity of the soil: the greater the hydrolytic acidity is the less buffer capacity the soil has. Multiple regression analysis indicates that *the hydrolytic acidity is directly followed by the clay content and $CaCO_3$ content and then the quality of humus.*

We emphasized the role of clay (mineral) content in soil acidification. When *clay fraction content increases pH also increases while hidden acidity decreases the reason for this is the absorption of H_3O^+ ions in the clay minerals.* It is not the smallest grain size fraction that *determines* buffer capacity but the *0,002-0,001 mm fraction*.

Due to the low quality of humus in the case of our samples organic material increases acidity.

Titration curves showed significant change at 0,0005 M 0,002 M and 0,01 M HCL amounts. There were significant differences detected in the soils of arable lands and vineyards: *pH of soils from arable lands is already significantly lower at 0,002 M HCL load.*

4. Trends in acidification in the study area

We showed that *there was a significant acidification in the area in the past 24 years*. pH decreased by 0,12-08 while hydrolytic acidity increased by 3,7-7,9. In a 1 km^2 area the rate of areas having lower pH than 5 increased from 0,3 % to 5 % while those having higher pH than 6 decreased to 1/10.

5. Landscape sensitivity analysis with multiple weighting

We came to the conclusion that *weighting landscape sensitivity analysis is not applicable to soil acidification*. The majority of the errors were caused by that in the course of the weighting it was not possible to take into account the fact that there are very acid areas that do not become more acid significantly while others still do. The limiting factor is the hydrolytic acidity as it cannot be fitted properly into the equation.

However, we were able to prepare sufficiently accurate maps based on the buffer capacity and the hydrolytic acidity. Where the buffer capacity is low *acidification potentially can occur* and may cause damage while high hydrolytic acidity indicates *the need for soil melioration*.

6. Effect of acid loading on the mobilization of heavy metals

In the course of HCl loading pH increased with time in every case. Regarding heavy metals new equilibrium developed to the changing pH: we showed measurable amount of rebinding in the case of zinc and nickel. In general the concentration of metals solved increased with time.

Different amounts of acid load caused significant differences in pH however there are some exceptions regarding metal concentrations: significant concentration differences developed only after the one day treatment in the case of iron and also only after the one month treatment in the case of zinc.

Our experience was that in the course of *the HNO_3 experiment not always the strongest acid and not the longest treatment time resulted in the maximum concentrations of solved metals. In several cases almost the entire amount of mobilizable metals was solved by the 1 M acid, or the 1 day treatment period.*

The order of solvability changes with the concentration of the acids used or with the extraction time.

We studied the correlations between metal mobilization and soil properties.

In the case of copper we found significant correlation with pH buffer capacity clay content and humus materials. Buffer capacity pH clay content and humus quality is in positive correlation with the mobilizing copper. Due to the fact that copper is bonded to organic and inorganic colloids greater values of the above mentioned variables result in greater values of metals accumulated in soils and mobilized by acid load. The one week exposition could not dissolve more metals than the one month treatment.

The concentration of the mobilized nickel is in negative correlation with pH buffer capacity clay content and humus quality and shows positive correlation with the coarse sand content. Highest concentrations of dissolved nickel occur when loaded longer than 1 day or by more concentrate acids than 1 M.

According to our results *the majority of the cobalt content of our soil samples is associated with manganese oxides and with the fine grains of the soil.* These soil properties together with the pH and the buffer capacity influenced most the mobilizing amount of cobalt. Our measurements proved that *cobalt mobilizes relatively easily* as 1 M acid load dissolved most of it.

In the case of *zinc* pH, buffer capacity, $CaCO_3$ content and the 0,002-0,001 mm fraction reduce mobilization at 0,01 M acid load but as the concentration of the load increases these cannot buffer the effect of the acid so that the so far bonded ions become dissolved. *Humus materials of lower quality* cannot resist even the low acid load thus the zinc bonded to them mobilizes. In contrast, humus materials of *better quality* cannot buffer the effects of only the acids more concentrated than 1 M.

The *quantity of manganese dissolved by acid load is in significant negative correlation with pH, buffer capacity, humus quality, $CaCO_3$ content and clay content.* Greater values for these soil properties reduce solution.

Solution of the *iron* content of soils *showed close correlation with humus materials of lower quality*. Greater values for these increased the quantity of iron mobilised. Increase in clay content reduces solution of iron.

We showed that in several cases *there were significant differences in the metal mobilization, of vineyards and arable lands*. Copper and zinc mobilized better from the soils of vineyards while more nickel cobalt and manganese were mobilized from the soils of arable lands (there was no difference in the case of iron).

7. Results of the small growing pot heavy-metal uptake analysis

Plant uptake of zinc in the control samples is greatest in the plants from forests soils and lowest in samples from arable land regarding all of the study areas. *In the case of contaminated soils the results are the same (forest>grassland>arable land)* except for the samples from Albert-farm - where plants of the arable land showed the greatest zinc concentration and those of the forest revealed the lowest values. *In the case of cadmium* the results are not so clear. *The order in grasslands and forests is very variable regarding both control and contaminated samples.*

We detected that *although, the difference between the zinc and cadmium load of the soils compared to the metal content of the soil is about 500 times (1/10 in the case of zinc and 50 times in the case of cadmium) the difference in the plant uptake is only 4-7 times.* So regarding a given concentration plants take up relatively more zinc than cadmium. This fact is very important and useful regarding the toxicity of the latter. *There is no significant difference in the land-use in this topic so we came to no general conclusion.*

There is a close correlation between the zinc and cadmium uptake of plants and the cadmium concentration of soils plays an important role in it. Zinc shows positive correlation while cadmium exhibits negative correlation with organic matter. This can be explained by that zinc prefers fulvous acids when forming readily solvable kelats while cadmium bonds to more complexly polymerized humus material with longer carbon chain. Therefore zinc is solved even by root acids in contrast to cadmium that can be solved only by stronger acids. Besides organic colloids *inorganic colloids i.e. clay fraction also showed close correlation*.

A témában megjelent tanulmányok

Szabó Sz. 1999. Talajok savanyodás-érzékenységének térinformatikai ábrázolása, mint a többváltozós, súlyozásos tájanalízis részfeladata, Geográfus Doktoranduszok IV. Országos Konferenciája, 1999. október 22-23., Szeged, http://phd.ini.hu

Szabó Sz. 1999. Landscape Sensitivity Research in the Bükkalja Region, 2nd International Conference of Ph.D. Students, 8-14 August 1999., Natural Sciences, University of Miskolc, pp. 229-236.

Szabó Sz. 2000. Tájérzénység-vizsgálatok hegylábi területen a talajok környezetvédelmi- és pufferkapacitásának segítségével – in: Geográfus Doktoranduszok III. Országos Konferenciája, Debreceni Egyetem TTK, 1998. Szeptember 3-4., Debrecen, pp. 129-134.

Szabó Sz. 2000. Talajok savanyúságát meghatározó tényezők statisztikai vizsgálata - in: Geográfus Doktoranduszok V. Országos Konferenciája, Miskolci Egyetem, 2000. október 7-8., Miskolc, pp. 61-66.

Szabó Sz. – Kerényi A. 2000. New aspects of mapping methods of soil sensitivity as a factor of landscape loadability – in Kertész Á. – Schweitzer F. ed. Phisico-geographical Research in Hungary, Geographical Research Institute, Research Centre for Earth Sciences, Hungarian Academy of Earth Sciences, pp. 75-84.

Kerényi A. **– Szabó Sz.** 2001. Levegőkörnyezeti hatások és környezetérzékenység a Tisza mentén – In: Kovács J. – Lóczy D. szerk.: A vizek és az ember. Tiszteletkötet Lovász György Professzor Úr 70. születésnapjára. PTE TTK Földrajzi Intézet, Pécs, pp. 153-162.

Kerényi A. – **Szabó Sz.** 2001. Loadability of the Landscapes and its Role in Landscape Protection, 4th Moravian Geographical Conference CONGEO' 01, Nature and Society in Regional Context, Tisnov, Czech Republic, pp. 83-88.

Szabó Sz. – Szabó Gy. 2001. A talajok pufferkapacitásának és nehézfémtartalmának vizsgálata, A Magyar Földrajzi Konferencia tudományos közleményei, Szeged 2001. október 25-27., SZTE TTK, Szeged, 9 p.

Szabó Sz. 2001. Sensitivity of Soils as a Main Factor of Landscape Sensitivity, Acta Pericemonologica rerum ambientum, Tom I., Debrecen, pp. 62-72.

Szabó Sz. 2001. Connection between Soil and Landscape Sensitivity, The 12th International Symposium On Problems of Landscape Ecological Research „Protected Areas And Landscape Ecological Research", 7-11. November 2000, Stara Lesna, Bratislava, Ekológia, 20. pp. 285-291.

Szabó Sz. 2002. A környezetvédelem sajátos területe: a talajvédelem, Debreceni Szemle, 4., Debrecen, pp. 663-680.

Nyizsalovszki R. – **Szabó Sz.** 2003. A talajvízszint mozgásának időbeli és térbeli mozgásai egy hegylábi mintaterületen, Földrajzi Értesítő, (közlésre elfogadva) in print

Szabó Sz. – Bíró T. 2003. Hidrológiai modell alkalmazása a tájértékelésben, Acta Geographica Debrecina, Tom. XXXVI., Debrecen, (közlésre elfogadva) in print

Nyizsalovszki R. – **Szabó Sz.** 2003. A csapadék és a talajvízszint mozgásának kapcsolata és a talajvízszint horizontális mozgása egy Tokaj-hegyaljai mintaterületen, PhD hallgatók VI. Országos Konferenciája, Pécs, (közlésre elfogadva) in print

Szabó Sz. 2003. Soil sampling and mapping soil properties in agricultural and polluted areas, Landscapes Under The European Transformation, Materials of an Intensive Seminar Project, University of Debrecen, Dept. of Landscape Protection and Enviromental Geography, pp. 117-133.

Szabó Sz. 2003. Néhány talajtulajdonság térbeli heterogenitásának vizsgálata Ramann-féle barna erdőtalajon, Környezetvédelmi mozaikok – Tiszteletkötet Kerényi Attila 60. születésnapjára, Tájvédelmi és Környezetföldrajzi Tanszék, Debrecen, pp. 373-382.

Szabó Sz. 2003. Hydrological model as a tool of landscape analysis, Acta Pericemonologica rerum ambientum, Tom II., Debrecen, in print

A témához kapcsolódó előadások

Kerényi A. - **Szabó Sz.** 1998. Loadability of a Part of a Landscape in the Bükk Foothill Region, Lippay János – Vas Károly International Scientific Symposium, Section of Landscape Protection and Reclamation, KEÉ, 1998. IX. 16-18., Budapest

Szabó Sz. 1998. Tájérzénység-vizsgálatok hegylábi területen a talajok környezetvédelmi- és pufferkapacitásának segítségével, Geográfus Doktoranduszok III. Országos Konferenciája, Debreceni Egyetem TTK, 1998. Szeptember 3-4., Debrecen

Szabó Sz. 1999. Talajok savanyodás-érzékenységének térinformatikai ábrázolása, mint a többváltozós, súlyozásos tájanalízis részfeladata, Geográfus Doktoranduszok IV. Országos Konferenciája, 1999. október 22-23., Szeged

Szabó Sz. 1999. Sensitivity of Soils as a Main Factor of Landscape Sensitivity, International Workshop on Enviromental Policy In Eastern And Western Europe, 28-30 August 1999, Debrecen

Szabó Sz. 1999. Landscape Sensitivity Research in the Bükkalja Region, 2nd International Conference of Ph.D. Students, 8-14 August 1999, Natural Sciences, University of Miskolc

Szabó Sz. 2000. Connection between Soil and Landscape Sensitivity, The 12thInternational Symposium On Problems of Landscape Ecological Research „Protected Areas And Landscape Ecological Research", November 7-11, 2000, Stara Lesna, Bratislava

Szabó Sz. 2000. Talajok savanyúságát meghatározó tényezők statisztikai vizsgálata - in: Geográfus Doktoranduszok V. Országos Konferenciája, Miskolci Egyetem, 2000. október 7-8., Miskolc

Szabó Sz. 2000. The Role of Soil Acidification in the Landscape Analysis, Conference on Multifunctional Landscapes, International Approaches to Landscape Research and Management, Centre for Landscape Research, University of Roskilde, October 18-21, 2000, Denmark

Szabó Sz. – Szabó Gy. 2001. A talajok pufferkapacitásának és nehézfémtartalmának vizsgálata, A Magyar Földrajzi Konferencia tudományos közleményei, Szeged 2001. október 25-27., SZTE TTK, Szeged

Kerényi A. – **Szabó Sz.** 2001. Loadability of the Landscapes and its Role in Landscape Protection, 4th Moravian Geographical Conference CONGEO' 01, Nature and Society in Regional Context, Tisnov, Czech Republic

Szabó Sz. 2002. Investigation of soil pollution in agricultural areas, Intensiv Seminar On Landscapes Under The European Transformation, 2002. October 4., Hungary, Debrecen