

The examination of the effects of erosion and bentonite soil conditioning on the communities of springtails and the soil's biological activity

Ph.D. Theses

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ANTECEDENT OF WORK AND GOALS

Preventing soil degradation, measuring the seriousness of degradation; and soil conditioning is important from the viewpoint of protecting the environment and the national economy. The (EC-COM 2002) has defined soil threats, soil degradation processes. Among these processes ,,declining biodiversity of soil" can be discovered beside declining in organic matter, contamination, soil sealing, compaction, salinization, flood and landslide.

The United Nations has proclaimed 2010 to be the International year of Biodiversity. In addition, there is an increasing need for data of soil degradation. Concerning that, several international initiations have been started, for instance the ENVASSO (ENVironmental ASessment of Soil for Monitoring) Project. One aim of that was to choose such biological indicators that could follow up the biological degradation of soils.

The aim of this Ph.D. thesis is to examine the soil's biological degradation. While examining potential biological answers occuring due to soil degradation, it is important to choose the exact group of animals and the accurate indicator of that. In the course of this work analyzing springtails (*Collembola*) is emphasized. As it has been demonstrated severally, biological degradation also follows physical and chemical soil degradation due to the inappropriate land use. Besides decreasing microbiological activity of soils, species richness of soil fauna is descending, too. In relation to arable lands and grazed grasslands Gardi et al. (2002) have shown, that the soil biological degradation has lower effect on epi-edaphic (living on soil surface) Collembola compared with eu-edaphic (living in soil) species. Therefore, this phenomenon was recommended to characterize the deterioration of habitat. The rate of epi-edaphic and euedafic species are used as the indicator of soil degradation.

In point of mesofauna and abiotic environmental indicators affecting springtails, Larsen et al. (2004) appointed that especially in case of the abundance of springtails there are two dominant factors: the soil structure and the decline of pore space (the declining number /120/ of rough pores). According to the examinations of Didden (1987), Hopkin (1997) and Joosse (1981) the number of springtails in soil is influenced by the next physical parameters: the size and number of pores of soil, the connection of pore channel systems, the percentage of moisture and temperature. On the basis of Eaton et al. (2004), springtails affect organic matter degradation; consequently the productivity of the specific area. The removal of organic matter or duff and plantage has significantly decreased the populations of springtails.

On the grounds of the results mentioned before, it is expectable that the erosion of soil implicates the degradation of the mezofauna of soil; since beside the decline of the topsoil

rich in organic matter - which is the habitat of mesofauna – the soil's moisture retention capacity and ventilatedness also decay. The last two are the main abiotic factor of mezofauna. In this work it is investigated on how Collembola fauna changes indifferent positions of erosion on a catena-type area.

By analogy with the previous examination, since water conservation of soils is an all-essential abiotic factor, it is examined by making experiments in field conditions whether physical and chemical soil parameters accompanying land reclamation influence springtails or not.

Factually, the soil biological consequences of bentonite land reclamation are followed up. Bentonite has an advantaged effect on the soil's physical and chemical attributes (Szegi et al. 2005), because it contains a high amount of montmorillonite. As a consequence of that, soil has a high cation exchange- and water-retention capacity. Marie et al. (1999) investigateded communities of springtails among soil-living animals on soils having low mesoporosity. Some biochemical parameters were examined like ATP content, phosphatase and urease enzyme activity. Biochemical background-variables analyzed on different sample areas were in close connection with the soil's phisycal and chemical characteristics and background variables.

Concentrating on the decline of biodiversity among the soil threats, the main line was to examine what mesurable biological consequences soil degradation had, and what biodegradational effect it had.

In cognition of that, my aims are as follows:

- Searching the effect of erosion on one member(Collembola) of the soils mesofauna in one catena;
- Detecting interrelation between some background factors of soil degradation, and some parameters of community of springtails and other soil living animal collections;
- Application of eco-morphological indices related to springtails (EMI ecomorphological index and BSQ indicator of biological soil quality) in differently degraded soils;
- The examination of activities of different soil ezymes in differently degraded areas;
- The examination of the effect of bentonite as soil improving material on the community of springtails.

Related to those my hypotheses and predictions are as follows:

- Soil degradation and erosion have measurable soil-biological consequences: the number of species and the number of springtails decrease.
- The number of springtails closely relate to the background factors of soil degradation: the organic matter content of soil and the soil moisture retention capacity.
- In the case of erosion on sedimentation area the content of organic materials could also be higher, probably, higher number and species number of sptringtails could be found. That could happen as a consequence of a supposedly better economy of humidity and a better availability of nutrient, thus, the number of springtails, the species number and diversity are higher in the case of sample areas possessing depth level of topsoil/mould.
- Index measuring the biological statement of soil (BSQ: indicator of biological soil quality) give a higher value on less eroded soil than on eroded.
- Allocating a certain amount of bentonite as soil conditioner on acid sandy soil has a favourable effect on the communities of springtails: their number increases.

MATERIAL AND METHOD

Areas to examine

The aim was to find a sample area, where along a transect areas are exposed in a different measure to erosion.

The other viewpoint was to be chernozem soils in the area, because in agricultural aspect it is the most valuable; and in our country a great deal of cultivation takes place on soils that could be rated to that type of soil.

In the course of this research, work was going on two different sample areas. On the first area the effect of erosion, on the second one the effect of soil conditioning were examined.

- Szent István University Experimental Farm in Józsefmajor (agricultural area)
- Nyíregyháza (small-parceled soil improving experimental area)
 University of Debrecen Center of Agicultural- and Management Sciences, Research Institutes and Experimental Farm, Research Center of Nyíregyháza
 (Debreceni Egyetem Agrár- és Gazdálkodástudományok Centruma Kutatóintézetek és Tangazdaság Nyíregyházi Kutató Intézet (DE AGTC KIT))

Józsefmajor

The sample area was the experimental farm of the Szent István University in Józsefmajor. Processess of soil degradation and their soil biological consequences were examined here on an erodated catena along a transect. This area also met the next requirements: differently degraded chernozem soils are found here.

Nyíregyháza

The second area to examine is handled by Debreceni University. It is located in the area of University of Debrecen – Center of Agicultural- and Management Sciences, Experimental Farm, Research Center of Nyíregyháza (DE AGTC KIT). From the point of soil research it is covered with sandy soils of sour chemical reaction. In this area the kind of effect of betonite was investigated on Collembola in soil.

The method of sampling and experimental arrangement

Józsefmajor: experiment number one

At the time of planning search in Józsefmajor, pre-examinations were done in the autumn of 2005 in the Farmland of Szent István University to appoint where and in what sample number main examination need to be fulfilled. Four soil profile were examined located along an erodated gradient, transect. The first profile is Vermi–Endocalcic Chernozem, the second is Endocalcic Chernozem, the third is Haplic Calcisol, and the fourth is the slope sediment of Chernozem. In the first diagram are showed erosion-free, less-erodated, highly erodated area and the segment which represents aggregation area. Sampling repeated in four times was done alone a transect made up by eleven points. Samples were taken from the soil's ten centimeter up-coat level to determine the species number and the total number of springtails. Sampling happened into a 500 cm³ cylinder, which was 10 centimeters high and its diameter was 8 centimeters. Test holes were seated 20 meters far away from each other. The first four test holes were in non-erodated area (Figure 1).



Figure 1: topographical localization of levels of soil degradation illustrated by soil segments

Józsefmajor: experiment number two

Experiment number two was done in spring, in summer and in autumn of 2006. Collecting samples befell in 3 x 10 points (A,B and C transect). Five degraded levels were separated on the basis of phisycal, chemical background factors and topographical localozation: (1) reference, (2) non-eroded 1, (3) non-eroded 2, (4) highly erodated, (5) accumulated area. Here, the number and species number of springtails were assigned from samples taken of those five points, in six repetitions. Apart from that, drills took place in order to ascertain the level of topsoil and samples were collected so that the content of organic matter could be examined.

Nyíregyháza: bentonit experiment

In this experiment, in an agricultural area, the effect of bentonit on the number of springtails was investigated. Bentonite was apported to land for soil cultivation in different quantities. While sampling, cabbage rape was being grown, as a test plant in the sampled land. Twenty parcels were marked out in the land. Parcels received five different treatments (2002): 0, 5, 10, and 15 t/ha bentonit, and 250 kg/ha organic fertilizer imparted (2005).

Test plants were as follows in the order of years: buckwheat (*Fagopyrum esculentum* Moench), mustard (*Sinapis alba* L.), rye (*Secale cereale* L.), rye vetch (*Secale cereale* L. and *Vicia villosa* L.), rape (*Brassica napus oleifera*) (Makádi, 2010). The experiment was set in four repetition, in accidental blokk disposition. The land to search is located on a typical shroud of sand area.

Methods

Phisical soil measuring methods

In the course of these searchings, the next soil phisical parameters were measured:

- the simplificated moisture retential capacity of soil,
- mofdified microaggregate stability of soil (Kacsinszkij-féle diszperzitás faktor és módosított Vageler-féle struktúra factor);
- bulk density of samples of ploughland (Buzás, 1993);
- and the depth of topsoil.

Chemical soil measuring methods used

In pursuance of research the next chemical soil parameters were surveyed on soil samples:

- content of organic matter by the method of Walkley-Black (Walkley 1947);
- chemical reaction by electrometric method (Buzás, 1988);
- cation exchange capacity modificated procedure by Mehlich (Buzás, 1988);
- determining CaCO₃ content with the method of Scheibler (Buzás, 1988);
- the content of Water-Soluble Carbon (WSC) and of Carbohydrates (WSChy), (Garcia, 1997).

Soil biological methods and searces used

The next soil biological parameters were examined in this examination:

- determinging the symmetry of microbes possessing "strategies"; number of microbes' Colony Forming Units (CFU);
- searching the unities of springtails with the help of ISO 23611 (2006 E) method;
 - o number, species number and composition of springtails
 - o rate of epi- and eu-edafic springtails
 - o Shannon-Wiener-diversity index
- eco-morfological index and BSQ (indicator of biological soil quality) index (Parisi, 2005); the number of mites;
- the number of earthworms
- analyzing enzym activity (dehydrogenase, urease, β-glucosidase, phosphatase) (Garcia, 1997).

Data processing

Statistic processes

The induction was made by variance-analysis and regression-analysis; together with using non-parameter comparisons by Kruskal-Wallis test, with the help of SPSS 14.0 and Statistica 7.0 programs.

Searching diversity

Searchig diversity was done with the help of Shannon-Wiener formula.

BSQ index

While working out BSQ index, the aim was to receive a picture of the composition of soildweller animals with a relatively simple method, expressing the quality and biological statement of soil (Parisi et al, 2005).

The principle of the method (BSQ) is that the different species of springtails prefer different soil clime. This could also be identified in morfological stigmata, even without definition at species level which makes it uncomplicated to appoint the index. On the grounds of those, so-called morphotypes could be determined that are labelled "eco-morphological-index" (EMI). So first, morphotypes found in the sample are determined (receiving a rate-number: the EMI points); and the summation of those gives BSQ index.

RESULTS

Examining background factors that characterize soil degradation; applying to the topsoil of erosion catena in Józsefmajor, the next results were found: The depth of topsoil as expected was the highest ,90 cm, in the case of non-erodated profile (NE); 40 and 10 cms in the case of less-erodated (LE) and highly-erodated (HE) areas. In accumulated profile (AP) 80 cm was the depth of topsoil. The soil organic matter and the cation exchange capacity (T-rate) showed a decreasing tendency while erosion was intensifying. In the case of both parameters the less rates were measured at highly-eroded (HE) areas (SZA: 0,5%; T-rate: 24 cmol/kg), the largest rates were measured at accumulated profile (AP). Water-soluble carbon (WSC) showed a similar picture. CaCO₃ content was significatly the highest at highly-erodated areas (HE), because the CaCO₃ rich parent material got near the top due to the erosion.

Enzyme activities showed higher rates in sedimentation areas; but biological degradation could not be demonstrated in non-eroded (NE), less-eroded (LE) and highly-eroded (HE) areas with these parameters. Supposedly, that fact did not concern especially microbial communities and microbial potential available in soil.

 β -glucosidase catalizes β -glucosids' hidrolysis. It plays a role in C-cycle and indicates the potential capacity of soil in the aspect of its capability of organic matter degradation. When sampling in spring and summer the lowest rates were received in highly-erodated areas, the highest ones in accumulated places. But here it was also accumulated places that showed the highest activity. Enzyme activity in accumulated places in 2004 (spring: 4,87 mg INTF/g.h (±0,56); summer: 2,97 (±0,07); autumn: 2,77 (±0,19)) and in 2005 (spring: 4,78 (±0,12); summer: 3,09 (±0,15); autumn: 2,44 (±0,75)) significantly differs from the rates of the other areas in the cases of the three seasons.

Examination of the communities of springtails – Te results of experiment number 1 in Józsefmajor

Reflecting the number of soil-living springtails there are significant differences ($F_{(2,41)}=9,2$; p<0,001) between stages of erosion (Figure 2.). In this examination there was no sampling, because accumulated place (AP) always separated from eroded areas (NE, LE, HE) on the basis of biochemical and microbial surveys. Compared to non-eroded areas there was a 40 per cent of total number decrease in less-eroded areas, and a 75 per cent decrease in highly eroded areas.



Figure 2: the number of springtails in the three differently eroded areas.

The number of springtails closely correlated with some physical and chemical parameters of soil, for example its water retention capacity (r=0,89) and its organic matter (r^2 =0,81).

Species richness of springtails

Apart from the count of springtails the species of them were also determined, when the regular process used in soil-zoological examinations was followed (Gisin, 1960; Mari Mutt, 1980; Loksa, 1967). The determination of species took place with the help of György Traser who identified the species with transmission microscope. Then, on the grounds of his guidance quantity samples were identified under stereo microscope, and the rates of abundance of the certain species were determined. The examinations were done in the Research Institute of Soil and Agrochemistry of the Hungarian Academy of Sciences with the help of Miklós Dombos.

Altogether, thirteen species were found in the area. Abundance rates belonging to different species of springtails showed variant markings. Excepting one or two species, lower abundance was found in the case of highly eroded areas. *Entomobrya multifasciata, Folsomia penicula, Heteromurus nitidus, Lepidocyrtus cyaneus, Orchesella cincta* and *Sminthurus elegans* were the most frequently occurring species in this area. However, except from *Folsomia penicula* amost every species disappeared from the highly eroded area.

Diversity was the greatest in less eroded area and in highly erodated area was observed the least diversity. The highest BSQ index (376) occured in the third sample area in non-eroded

area, and the lowest rate (8) was in the ninth sample area in highly eroded area (see 1st diagram from the chapter of Materials and method, page 8).

Examination of the communities of springtails – Te results of experiment number 2 in Józsefmajor

SoilOrganic Matter content (SOM%) and the depth of topsoil

Table 1.: Soil Organic Matter content (SOM%) and the depth of topsoil in the five sample areas

Sample place	1	2	3	4	5
Characteristic	non eroded area (reference)	non eroded area	non eroded area	eroded area	accumulated area
(SOM%)	3,57 (±0,66)	3,74 (±0,79)	3,64 (±1,20)	2,31 (±0,89)	2,40 (±0,72)
Depth of topsoil	68,3 (±11,3)	57,5 (±4,2)	45,0 (±17,3)	25,8 (±13,6)	38,3 (±18,6)

A 60-percentage-decline was found in the depth of humus layer in the case of the most eroded area compared with the data of reference area (table 1.). In the first sampling area the average depth of humus layer was $68,3 \pm 11,3$ cm, which is the deepest among the examined sample places. Here, the soil organic matter was 3,57% on the average. In the second and the third sample places the depth of humus layer gradually decreased ($57,5\pm4,2$ cm and $45,0\pm17,3$ cm), but they could be considered deep. In these cases the soil organic matter conents were higher as compared to the first sampling area (3,74% és 3,64%). A low humus layer (25,8 cm) was found in the fourth sampling area. In the accumulated area there was a deeper humus layer (38,3cm).

Abundance of Collembola

The highest number of abundance and species number of Collembola were measured in the areas less exposed to phisical and chemical degradation. 75 % less springtail individuals were found in the samples taken from highly eroded area compared with the reference area (Figure 3.). In the non-eroded place significantly less Collembola were detected than in the three non-eroded area.



Figure 3.: The abundance of Collembola in the erosion catena (2006).

BSQc index in erosion catena

Similarly to the results before the highest BSQc indices were experienced in the case of the non-eroded area. Reference: 67,5 (\pm 32,26); non-eroded-1: 83,6 (\pm 30,16); non-eroded-2: 100,6 (\pm 66,3). The lowest value was detected in the highly eroded place33,6(\pm 11,11).

Bentonite experiment in Nyíregyháza

Examination of the effect of bentonite on Collembola community

Differences were found in abundance of Collembola due to the different treatments of bentonite. The highest abundances were experienced in the cases of 10 and 15 t/h. When the treatments were 0, 5 and 20 t/ha, the abundances were much lower. Collembola species reacted to the treatments in different ways. The abundance of *Ceratophysella armata* was significantly higher in the case of parcels treated 15 t/ha bentonite than the treated 20 t/ha ones. The average of the parcels treated 10 t/ha bentonite showed high abundace of *Ceratophysella armata*, but it was not significantly higher compared with the results from the 0 and 5 t/ha treatments.

NEW SCIENTIFIC RESULTS

New scientific results on the basis of the examinations:

Erosion vs. soil biological degradation:

The examination of more soil enzyms correctly showed the generan biological activity of the soil int he case of differently eroded chernozem soils, in erosion catena:
 Dehidrogenase enzyme is a proper index for expressing the biological activity of the soil which mainly exists in an intracellural form in the soil. In highly eroded area it showed the least activity, and it was the highest in the accumulated area in all the three seasons. But there was no significant difference among non-eroded (NE), less-eroded (LE) and highly (HE) eroded places.

- In the course of examiuning the activity of β -glucosidase enzyme, there were no such seasonal variances like in the case of the activity of dehydrogenase enzyme. The lowest values were detected in higly eroded places in summer and in spring, and the highest values were in the accumulated place. The activity of the accumulated place differentiated in all the four seasons and showed higher values. Among non-eroded, less-eroded and highly eroded areas it did not show a notable difference.

- 2. On the basis of the searchings it cleared out that the different species of Collembola reacted variously to the change of the quality of the soil, to the differently degraded circumstances. But except form one or two species the numbers always decreased as erosion intensified. Excluding *Folsomia penicula* almost all of the species disappeared from the highly eroded area.
- 3. *Shannon-diversity* decreased as erosion grew. The highest diversity was seen in less eroded area, and the lowest was in highly eroded place.
- 4. These examinations showed that the results of the used biochemical and biological simplified methods including the indices concerning Collembola and earthworms showed some conformity with each other and the results of traditional measuring methods. And they are also appropriate for following up the occuring changings.
- 5. On the grounds of the examinations BSQ an eco-morphological indices are suitable for signing the procedures of soil degradation. The lowest BSQ indices were taken from the highly eroded place.

6. Some phisical and chemical soil parameters (soil moisture retention capacity, organic matter content and distribution) could be connected with the abundance and species number of Collembola.

The effect of bentonite soil conditioning on soil biological activity:

7. Springtails reacted to the bentonite treatment. The highest number of them was found in the case of 10 and 15t/ha bentonite allocation. More or less allocation of bentonite eventuated lower number of Collembola. At 20 t/ha there was a decline. Presumably there is an optimal treatment between 5 and 20 t/ha at which soil biological activity reaches the maximum point. However, further examinations are needed to confirm that.

CONCLUSIONS, PROPOSALS

In Hungary, researches relating to soil degradation extended mainly to the changes occuring in the phisycal and chemical attributes of the soil till now. Only some articles and studies reported about the changes of the biological characteristics of the soil. That is especially true for the searcings of soil animals. It was appointed along this work that - in cultivated and natural areas - changes in the quality of the soil are always followed by biological answers. Soil degradation together with decay in construction effect Collembola negatively in point of the number and species number; which result corresponds with the rerults of Gardi et.al. (2002). As the organic matter content of the soil and the soil moisture retention capacity declines, the number and species number of springtails declines, too. Soil biological degradation could be demonstrated with the help of the BSQ index.

Life conditions of springtails highly influenced by the soil organic matter available in soil and the surface of the soil. Based on the investigations in Józsefmajor, the abundance, species number and the diversity of Collembola show strong correlation with soil organis matter content. This result was similar to the result of Eaton et al. (2004), where the removal of soil organic matter, litter and vegetation have decreased the populations of Collembola.

Proposals for future research

Proposals for further research in the topic:

- The extension of the examinations carried out;
 - for further sites (eroded sites)
 - For further soil types
- The examination of the applicability of the tested indicators in soil biological monitoring systems;
- Application of bentonite (10-15 t/ha) in other examination.

During this work Collembola was in focus among soil living organisms and several other soil biological parameter were not tested. However, it would be worthwhile to examine the effect of soil physical degradation processes on other soil living organisms. Besides, several issue are coming up in relation to Collembola. For example the BSQc index is not really used in practise and in other researches, because it is a new method, but it is a simply, good indicator

which can help identifying the effect of soil physical degradation processes, and it can be applicable in the characterization of soil biological quality. As method it would be important to test and apply it as widely as possible on other soil types, too.

The "TIM" rendszer talajbiológiai fejlesztésének alternatívái" proposal incudes Collembola as possible indicators in Hungarian soil monitoring system.

I suggest the renewal of these efforts and the application of Collembola as indicators of soil condition characterization in further national and international research.

Publications linked to the thesis

International paper readered, full text with impact factor:

<u>Szeder B.</u>, Simon B., Dombos M., Junko A., Szegi T., 2006: Biological and biochemical investigation on an erosion catena, Cereal Research Communications. V. Alps-Adria Scientific Workshop Opatija, Croatia, 6-11 March, 2006 . 307-310. p. Impakt faktor: 1,037

International paper readered, full text without impact factor:

<u>Szeder B</u>., Makádi M., Szegi T., Tomócsik A., Simon B., 2008: Biological and agronomic indicators of the impact of fieldscale bentonite application, Cereal Research Communications. VII. Alps-Adria Scientific Workshop Stara Lesna, Slovakia, 28 April – 2 May, 2008: 911-914. p.

<u>Szeder B</u>., Eberlin R. 2008: FAO's work in rural development and land tenure – Land consolidation in Central and Eastern Europe. Науковий Вісник Національного Аграрного Університету - Scientific Communication of the National Agricultural University of Ukraine. Actual problems of sustainable development of rural territories of Ukraine - Conference -22-23 May 2008 NAUU Kyiv, Ukraine. N. 124, 2008. 251-259. p.

Hungarian Paper readered, full text:

<u>Szeder B</u>., Simon B., Dombos M., Szegi T. 2006: Biológiai és biokémiai vizsgálatok egy eróziós katénán. Talajvédelem, Sopron, 2006 augusztus 23-25, 75-82. p.

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Simon B., Gál A., Marosfalvi ZS., Hegymegi P., Szeder B. és Michéli E. 2010. Az ENVASSO Projekt által kidolgozott módszertan tesztelése az erózió okozta talaj biodiverzitás csökkenés mérésére. Agrokémia és Talajtan. 60(2011)1. p. Megjelenés alatt

Full text conference proceeding, readered, international language:

<u>Szeder B.</u>, Simon B., Dombos M., Szegi T. Biological investigation on an Erosion Catena. Joint International Conference on Long-term Experiments, Agricultural Research and Natural Resources, Debrecen – Nyírlugos. 357-363. o.