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EARTHWORMS AS BIOINDICATOR OF LAND USE IN AGROECOSYSTEMS

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Abstract

Earthworms are important soil organisms influencing many soil properties. We observed earthworm abundance and fresh body biomass in relation to abiotic parameters at 6 study sites, each of them with two different land use categories (arable land and permanent grasslands) located in various natural conditions of Slovakia. Unexpectedly, the maximum number of earthworm individuals (majority of them were immatures) was recorded in arable land (139.9 per 1 m^2). We explain this extreme as a consequence of erosion process. The situation in the other 5 study sites was in line with literature sources, and the earthworm body biomass and density were lower in the arable lands than in the permanent grasslands. At permanent grasslands with higher earthworm abundance we measured better oxic conditions in the soils. This work was supported by the Slovak Research and Development Agency (APVV-0098-12).

Key words: *earthworm, land use, body biomass, oxidation reduction potential, penetration resistance, soil moisture*

1. INTRODUCTION

Earthworms are important soil organisms. The role of earthworms in soil fertility is known since 1881, when Darwin published his last scientific book entitled “The formation of vegetable mould through the action of worms with observations on their habits”.

Earthworms influence soil structure by creating burrows, by bringing litter into the soil, fragmenting it and mixing it with humus and mineral soil, by homogenizing the soil, and by the ejection of casts (Brown et al. 2000). The cycling of nutrients is a critical ecosystem function that is essential to life on earth. Soil macro-invertebrates play a key role in soil organic matter transformations and nutrient dynamics at different spatial and temporal scales through perturbation and the production of biogenic structures for the improvement of soil fertility and land productivity (Lavelle & Spain 2001). Through their activity in the soil, earthworms can influence plant growth. The influence of earthworms on their environment can be large-scale, changing landscapes and vegetation (Jouquet et al. 2006).

Earthworms are classified as “ecosystem engineers”, which means that they affect their environment, either biotic or abiotic, that go beyond their own body size and life span (Jones et al. 1994).

Earthworm may be used as bioindicator because they are very sensitive to both chemical and physical soil parameters. Tillage, crop type, pesticide inputs have been demonstrated to affect earthworms in agroecosystes. Earthworm biomass or abundance can offer a valuable tool to assess different environmental impacts such as tillage operations, soil pollution, different agricultural input, trampling, industrial plant pollution, etc. (Paoletti 1999). Christensen and Mather (1990) showed that earthworm number and biomass reflect both natural soil parameters, e.g. sand content, and agricultural practices. Cluzeau et al. (1987) proved earthworms to be good bioidnicators of microclimate, and nutritional and toxic conditions of vineyard soils. Earthworm species inhabiting metal-contaminated soils have species-specific behavioural characteristics such as burrowing and feeding activities which evidently affect their responses to metal contamination (Reinecke et al. 1999).

In addition, earthworms often constitute a major proportion of the macrofauna biomass (Edwards 2006, Edwards & Bohlen 1996). They can influence soil chemical, biological, and physical processes (Suthar 2009).

In our research we investigated the response of earthworms to land use and existing physical soil parameters at 6 study sites, each of them with two different land use (arable land and permanent grasslands) located in various natural conditions of Slovakia.

2. MATERIAL AND METHODS

We analysed 6 different study sites with two different land use (arable land - AL and permanent grasslands - PG) located in different natural and climate conditions of Slovakia (Tab. 1).

Table. 1 Site characteristics

Study site	Geographical location	Altitude (m a s.l.)	Long-term average temperature (˚C)	Long-term average rainfall (mm)	Slope (˚)	Soil type	Soil texture
ST	Eastern Slovak Hills	121	8.9	559	0	Fluvisol	clayey
ME	Krupina Plain	151	8.7	606	0	Fluvisol	sandy loam
ZA	Borská Lowland	170	9.2	525	2	Regosol	sandy
CO	Slovak Karst	354	8.6	620	7	Cambisol	loamy
TA	Kremnica Mountain	647	8.1	795	2	Cambisol	loamy
VI	Low Tatras	945	6.2	950	5	Rendzina	loamy

Abbreviations: ST – Stráňany, ME – Medovarce, ZA – Závod, CO – Čoltovo, ZE – Zeleneč, TA – Tajov, VI – Vikartovce

We measured biotic (earthworm number - EN and earthworm fresh body biomass - EBB) and abiotic parameters (soil moisture - θ, penetration resistance - PR, and oxidation-reduction potential – Eh).

We collected earthworms by hand sorting (35x35x20 cm of soil), seven samples for each plot (one as an arable land and one as a permanent grasslands) in April – May 2014. The earthworms were collected, counted, washed in water, weighted and preserved in ethanol.

Penetration resistance (PR) was measured with an electronic penetrometer (Eijkelkamp Penetrologger) with a cone diameter of 1 cm^2 and a 60˚ top angle cone. Cone resistance was recorded in MPa per cm of soil depth and expressed as an average value of 10 penetrations per plot in the soil layer of 0 – 20 cm.

Soil moisture level (θ) was measured by soil moisture sensor (ThetaProbe) in the soil moisture volume percentage by measuring the changes in the dielectric constant.

Oxidation-reduction potential (Eh) was measured by oxygen diffusion meter (Eijkelkamp) as Redox potential between the soil and the Pt-electrode expressed in mV.

3. RESULTS AND DISCUSSION

3.1. Earthworm abundance in soils with different land use

Earthworms belong to the biggest soil macrofauna species. Organism size plays an important role in soil biological interactions, because the soil habitat is composed of differently sized pores (Brussaard et al. 2007). Earthworms are a major component of soil fauna communities in most ecosystem and comprise a large proportion of macrofauna biomass (Edwards 2004, Bhadauria & Saxena 2010).

At 6 study sites, the average body biomass of the earthworms per 1 m^2 ranged from 0 to 44.1 gm^{-2} in arable land, and from 29.2 to 81.3 gm^{-2} in grasslands (Tab. 2). The density of earthworms per 1 m^2 ranged from 0 to 139.9 individuals.m^{-2} in arable land, and from 87.5 to 121.3 individuals.m^{-2} in grasslands (Tab. 3).

Table. 2 Basic statistical characteristics of earthworm fresh body biomass at 6 study sites under different land use ($g.m^{-2}$)

Study site	AL				PG			
	Min	Max	**Mean**	Median	Min	Max	**Mean**	Median
ST	0.0	11.4	2.9	0.0	2.4	173.1	**81.3**	73.5
ME	0.0	71.8	23.0	15.5	3.3	40.8	**29.2**	31.0
ZA	0.0	0.0	**0.0**	0.0	9.8	67.8	45.5	54.7
CO	13.1	75.1	**44.1**	45.7	12.2	71.0	36.3	38.4
TA	0.0	31.0	19.9	27.8	9.0	47.3	30.3	34.3
VI	1.6	50.6	16.2	42.4	49.0	57.1	40.3	42.4

Abbreviations: ST – Stráňany. ME – Medovarce. ZA – Závod. CO – Čoltovo. ZE – Zeleneč. TA – Tajov. VI – Vikartovce

Table. 3 Basic statistical characteristics of earthworm density at 6 study sites under different land use (individuals.m^{-2})

Study site	AL				PG			
	Min	Max	**Mean**	Median	Min	Max	**Mean**	Median
ST	0.0	24.5	7.0	0.0	16.3	155.1	**121.3**	130.6
ME	0.0	57.1	18.7	16.3	16.3	155.1	93.3	98.0
ZA	0.0	0.0	**0.0**	0.0	32.7	171.4	109.6	122.4
CO	40.8	212.2	**139.9**	179.6	49.0	187.8	88.6	57.1
TA	0.0	65.3	31.5	24.5	32.7	138.8	95.6	89.8
VI	8.2	73.5	33.8	114.3	40.8	122.4	**87.5**	114.3

Abbreviations: ST – Stráňany. ME – Medovarce. ZA – Závod. CO – Čoltovo. ZE – Zeleneč. TA – Tajov. VI – Vikartovce

The earthworm body biomass and density of individuals per m^2 were at all 6 study sites lower in arable land than in the permanent grasslands with one exception (Fig. 1, 2).

Our results showed that land use connected with specialised management practices directly influence the spatial distribution as well as functioning ecology of earthworms in lands. Significant loss of soil faunal biodiversity or species richness in arable lands is connected with intensive cultivation, high fertilizer inputs and crop monoculture. In addition, the population density and mass of earthworms are strongly reduced by tractor traffic in arable land (Hansen & Engelstad 1999). A corresponding reduction in earthworm populations as a result of soil compaction has been found in several investigations (Pizl 1992, Söchtig & Larink 1992).

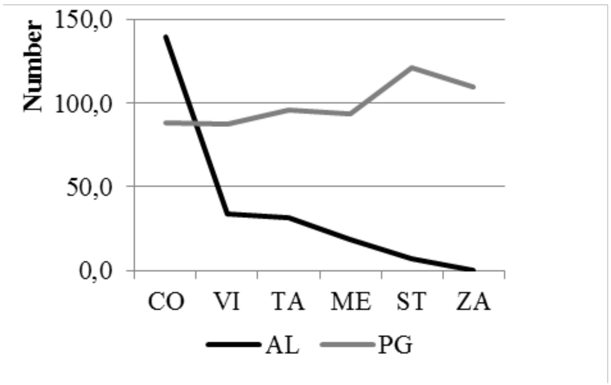

Fig. 1 Earthworm number of individuals per m^2 at 6 study sites under different land use (AL - arable land, PG – permanent grasslands)

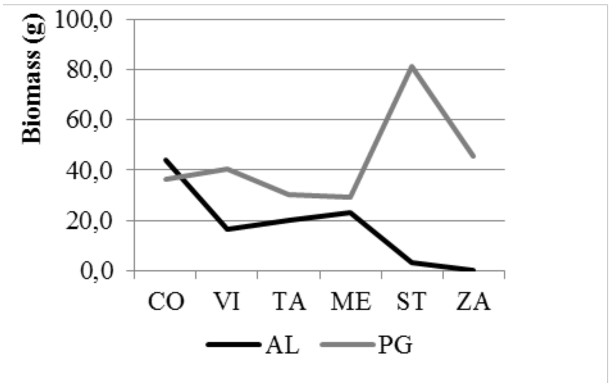

Fig. 2 Earthworm body biomass per m^2 at 6 study sites under different land use (AL - arable land, PG – permanent grasslands)

Many authors (Marhan & Scheu 2005, Lamandé et al. 2003, Fromm et al. 1993) found earthworms to be more abundant and populations to have greater biomass under long-term pasture than under long-term cropping. Overall, this statement is valid in our research with one exception.

In CO study site, the number of individuals and body biomass per 1 m^2 are higher at AL than at PG plot. In addition, the maximum number of earthworm individuals per 1 m^{-2} (139.9) from all 6 study sites (Al and PG) was surprisingly recorded at CO study site at AL. In the file of the 6 arable lands this number represents the most remote value. We explain this extreme case as a consequence of erosion processes that are in addition more significant at AL than at PG with permanent cover plant. Earthworm research was done in the accumulation part of the slope rich in organic matter, nutrients and with this connected further appropriate soil parameters.

3.2. Effects of earthworm on abiotic soil parameters

Many authors (Eekeren 2010, Cole et al. 2006) argue that earthworms have a positive effect on many soil parameters. They affect soil structure, promote humification, create pores and increase infiltration capacity, improve permeability and aeration of the upper soil layers, decrease soil penetration resistance.

Our results do not confirm significant correlations between observed soil parameters (soil moisture - θ, penetration resistance - PR, and oxidation-reduction potential – Eh) and earthworm numbers and body biomass (Fig.3-8).

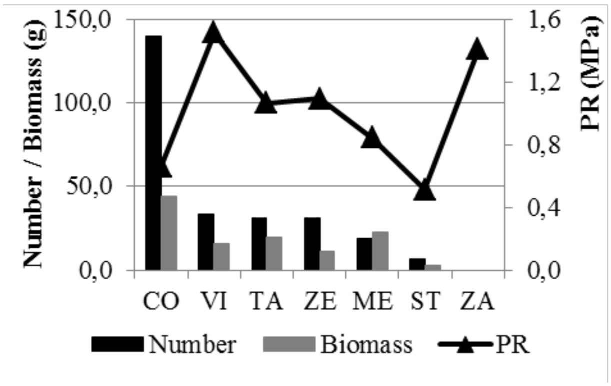

Fig. 3 Earthworm number, biomass and penetration resistance at arable land

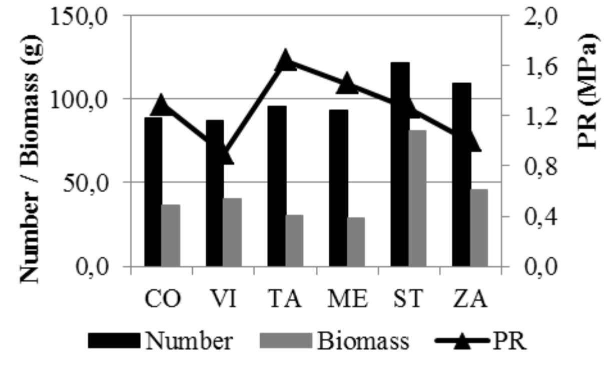

Fig. 4 Earthworm number, biomass and penetration resistance at permanent grasslands

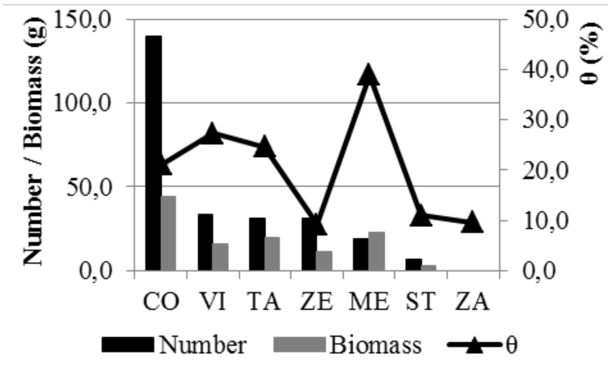

Fig. 5 Earthworm number, biomass and soil moisture at arable land

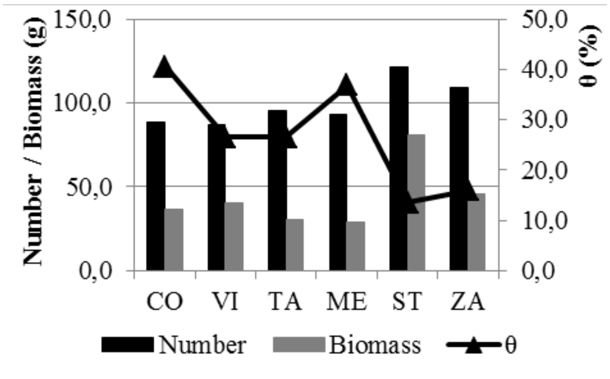

Fig. 6 Earthworm number, biomass and soil moisture at permanent grasslands

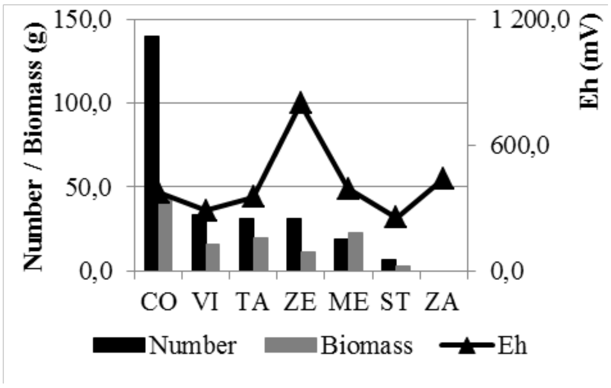

Fig. 7 Earthworm number, biomass and oxidation-reduction potential at arable land

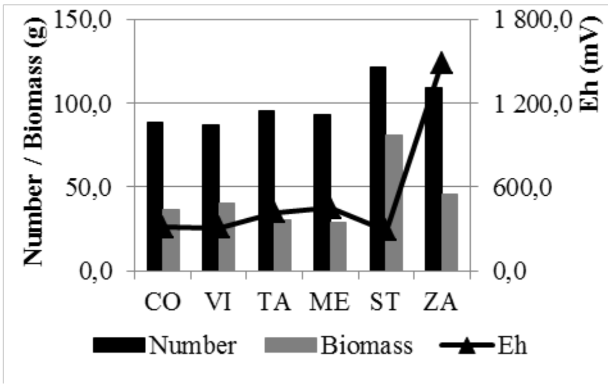

Fig. 8 Earthworm number, biomass and oxidation-reduction potential at permanent grasslands

The values of PR ranged from 0.52 to 1.52 MPa at AL, and from 0.90 to 1.64 MPa at PG. We measured higher values of PR at PG than at AL in 4 from 6 cases (Fig. 9). The values of θ ranged from 9.5 to 39.0 % at AL, and from 13.5 to 40.6 % at PG. We measured higher values of θ at PG than at AL in 4 from 6 cases (Fig. 10).

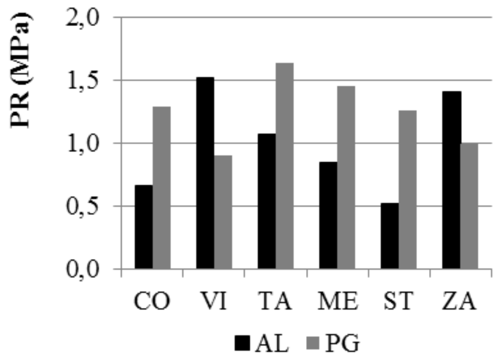

Fig. 9 Penetration resistance (PR) at 6 study sites under different land use (AL - arable land, PG – permanent grasslands)

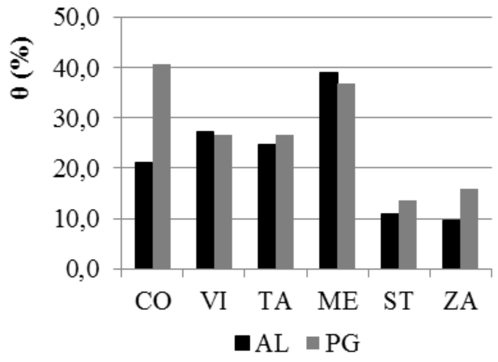

Fig. 10 Soil moisture (θ) at 6 study sites under different land use (AL - arable land, PG – permanent grasslands)

More significant relations were observed in the case of Eh. At PG with higher earthworm abundance we measured better oxic conditions in the soils. The values of Eh ranged from 253 to 440 mV at AL, and from 287 to 1 486 mV at PG. Oxidation-reduction potential was at all 6 study sites higher at PG than at AL with the exception of CO study site (eroded plot) (Fig. 11). These results are in line with theories about positive role of earthworm in aeration (Eisenhauer et al. 2010, Sheu 2003).

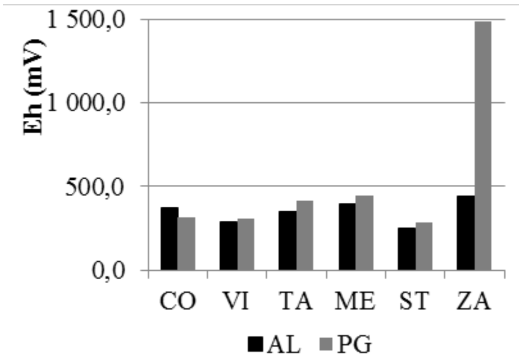

Fig. 11 Oxidation-reduction potential (Eh) at 6 study sites under different land use (AL - arable land, PG – permanent grasslands)

CONCLUSIONS

Our results demonstrated the usefulness of earthworms as bioindicators of land management. We confirmed that earthworms are richer in agroecosystems with more extensive land management. But we found out that some natural soil process (in our case soil erosion) may markedly influence abundance and earthworm activities irrespective of land management. Values of measured abiotic soil parameters confirmed positive role of earthworms on aeration in different agroecosystems.

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