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Effect of water erosion on surface-dwelling invertebrates

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Abstract. The main factor causing the degradation of soils throughout Europe is water erosion; however, there is a lack of information on the effect of water erosion on surface-dwelling invertebrates. Our research on this effect was done in 4 fields situated on a slope in the Břeclav district, South Moravia, in the Czech Republic; three fields were planted with maize and one with sunflowers. Five pitfall traps were set at the top, five in middle and five at the bottom of the slope in each field. The data obtained were analyzed using CANOCO to evaluate effects of environmental factors on two groups of soil fauna: ground beetles and spiders. For all the maize fields the highest species diversity and abundances of both groups of soil invertebrates were recorded at the bottom of the slopes and the lowest diversities in the middle of the slopes. The soil that had accumulated at the bottom of slope due to erosion was rich in terms of nitrogen and humus and quality of the humus.

Key words. Spiders, ground beetles, pitfall traps, water erosion.

INTRODUCTION

Soil degradation leads to a reduction in soil productivity and decreases in non-production functions of soil that contribute to land degradation. The main factor causing soil degradation in the Czech Republic and the whole of Europe is water erosion. Currently, the issue of erosion is partly addressed by Good Standards of Agricultural and Environmental Conditions (GAEC) (Anonymous 2010), namely Standard No 1 (measures to protect soil on land with a slope of more than 7°) and Standard No 2 (growing certain crops on land highly vulnerable to erosion). However, these measures are insufficient to protect land threatened by erosion. Therefore, there have been various negative changes in landscapes and whole the terrestrial environment. In terms of soil science the scientific literature contains lots of information on the changes in physical and chemical properties of soil during erosion and its negative effect on plant production. There is also a lot of information on soil erosion of land under different crops (e.g. Wei et al. 2014). However, there is a lack of information on the effect of erosion on surface-dwelling invertebrates, which are an integral part of agroecosystems affecting decomposition, nutrient cycles and pest management.

MATERIALS AND METHODS

We recorded the effect of erosion on soil surface-dwelling invertebrates in 4 fields in the Břeclav district, South Bohemia, the Czech Republic: Krumvíř "K1" – field planted with sunflowers with a 9.6° slope; Krumvíř "K2" – field of maize with a 8.3° slope, Horní Bojanovice "HB" – field of maize with a 6.9° slope and Hustopeče "HU" – field of maize with a 4.2° slope. Five traps in line (10 m spacing) were set at the top (E), five in middle (S) and five at the bottom (A) of the slopes in each of the fields. Traps consisted of a plastic cup (0.3 l) inserted in a glass jar. The cup was filled with a 4% formaldehyde solution with added detergent and the traps covered by tightened paper roofs kept in place by nails, which served to prevent the traps from drying out. Traps were set in all the above fields at end of June 2012 and inspected every

Table 1. Number of individuals (ind. / 5 traps / 10 weeks) of ground beetles and spiders caught at the different localities by traps at different positions in the fields studied. K1, K2, HU and HB – abbreviations for localities, see the text; position of traps on slope: E – top of slope, S – middle of slope, A – bottom of slope

		K1			K2			HB			HU		
	code	E	S	A	E	S	A	E	S	A	E	S	A
Anchomenus dorsalis (Pontoppidan, 1763)	AncDor	14	8	2	8	6	40	4	4	2	245	104	48
Brachinus crepitans (Linnaeus, 1758)	BraCre	2	0	5	2	1	12	1	0	1	85	27	16
Calosoma auropunctatum (Herbst, 1784)	CalAur	0	0	2	0	0	0	0	0	0	8	2	13
Carabus coriaceus Linnaeus, 1758	CarCor	1	0	0	5	0	0	0	0	0	0	1	0
Carabus scheidleri Panzer, 1799	CarSch	0	0	0	1	4	2	0	0	0	0	0	0
Carabus ullrichii Germar, 1824	CarUll	0	0	0	1	0	0	0	0	0	0	0	0
Cylindera germanica (Linnaeus, 1758)	CylGer	4	3	1	6	4	4	6	2	4	0	0	5
Dolichus halensis (Schaller, 1783)	DolHal	31	86	128	123	167	321	19	76	162	1844	1853	808
Harpalus distinguendus (Duftschmid, 1812)	HarDis	0	0	0	2	6	3	0	0	0	4	0	0
Harpalus spp.	Harspp	0	0	0	0	0	2	0	0	0	0	0	0
Poecilus cupreus (Linnaeus, 1758)	PoeCup	30	13	19	47	25	173	6	14	50	99	47	42
Poecilus sericeus Fischer von Waldheim, 1824	PoeSer	0	0	0	0	0	0	0	2	1	1	0	1
Pseudoophonus rufipes (De Geer, 1774)	PseRuf	287	578	573	1620	1420	2025	621	794	1102	6198	2692	2402
Pterostichus melanarius (Illiger, 1798)	PteMel	231	128	222	124	129	659	66	41	1362	208	44	129
Bathyphantes gracilis (Blackwall, 1841)	BatGra	0	0	0	0	0	1	0	0	0	0	0	0
Diplostyla concolor (Wider, 1834)	DipCon	0	0	1	0	0	0	0	0	0	0	0	0
Diplocephalus cristatus (Blackwall, 1833)	DipCri	0	2	0	0	0	1	0	0	0	0	0	0
Erigone atra Blackwall, 1833	EriAtr	0	0	0	1	0	2	0	0	1	0	0	1
Erigone dentipalpis (Wider, 1834)	EriDen	0	1	1	2	0	2	0	0	0	0	0	0
Gnaphosa bicolor (Hahn, 1833)	GnaBic	0	1	0	0	0	0	1	0	0	0	0	1
Meioneta rurestris (Koch, 1836)	MeiRur	2	0	0	1	0	1	0	0	0	0	1	0
Microlinyphia pusilla (Sundevall, 1830)	MicPus	0	1	1	0	0	0	0	0	0	1	0	0
Oedothorax apicatus (Blackwall, 1850)	OedApi	373	376	323	50	45	141	39	52	90	50	121	154
Oedothorax retusus (Westring, 1851)	OedRet	0	4	2	1	0	0	0	0	1	1	1	0
Pachygnatha degeeri Sundevall, 1830	PacDeg	1	0	0	0	0	0	0	0	0	0	0	0
Pachygnatha listeri Sundevall, 1830	PacLis	0	0	0	0	0	2	0	0	0	0	0	0
Pardosa agrestis (Westring, 1861)	ParAgr	34	22	81	99	108	151	38	37	42	43	86	91
Pardosa palustris (Linnaeus, 1758)	ParPal	0	2	1	0	0	3	0	0	0	0	0	0
Pardosa spp.	Parspp	1	2	0	5	6	8	3	5	13	2	0	5
Pirata hygrophilus Thorell, 1872	PirHyg	0	1	0	1	0	0	0	0	0	0	0	0
Porrhomma microphthalmum (Cambridge, 1871)	PorMic	1	0	1	1	0	2	0	0	0	0	0	3
Robertus arundineti (Cambridge, 1871)	RobAru	1	1	1	11	2	0	5	28	2	0	0	0
Steatoda albomaculata (De Geer, 1778)	SteAlb	0	0	0	0	0	0	0	0	0	1	0	0
Tenuiphantes cristatus (Menge, 1866)	TenCri	0	0	1	0	0	0	0	0	1	0	1	0
Tenuiphantes flavipes (Blackwall, 1854)	TenFla	0	0	0	0	0	0	0	0	0	0	0	1
Trochosa ruricola (De Geer, 1778)	TroRur	6	3	1	0	0	13	0	0	6	1	0	1
Trochosa spp.	Trospp	11	0	1	0	5	2	0	0	7	0	0	0
Trochosa terricola Thorell, 1856	TroTer	17	6	7	2	6	6	0	1	21	1	1	10
Xysticus cristatus (Clerck, 1757)	XysCri	0	0	0	1	0	0	1	0	1	0	0	0
Xysticus spp.	Xysspp	0	2	2	1	0	1	2	2	1	2	0	0
Zelotes sp.	Zelspp	0	0	0	0	0	0	1	0	0	0	0	0

two weeks up to the end of September 2012. Content of each trap was separately transported to the laboratory in small ZIP-locked plastic bags where the contents were immediately categorized in terms of the two groups of invertebrates.

In addition to estimating the surface activity of soil invertebrates, selected soil characteristics were determined using standard methods (Zbíral et al. 2011): Soil acidity was measured by the displacement reaction using KCl. Amount of humus was measured using the "wet method" by titration of Mohr's Salt, quality of humus was measured in terms of the ratio of humic to fulvic acids. Kjendal's method was used to quantify total nitrogen; Cation-exchange capacity (KVK) was evaluated using Ammonium acetate.

The data obtained were analyzed using the CANOCO programme in Windows 4.5© (Ter Braak & Šmilauer 1998) to evaluate effects of environment on the two groups of soil fauna, ground beetles (Carabidae) and spiders (Araneae). The environmental variables were the field, position of traps on slope, soil pH, amount of nitrogen, amount and quality of humus and cation-exchange capacity.

RESULTS AND DISCUSSION

During this research 30,576 ground beetles (Carabidae; belonging to 13 species) and 2,960 spiders (Araneae; 23 species and 6 families) were caught and identified. The field with sunflowers, K1, was the most diverse. The low abundance of ground beetles is similar to that recorded by Honěk (1988), who reports higher densities of Carabidae in sparse than dense crop stands. At K1 spiders were the most abundant (Fig. 1). The dominant species at all localities and especially in this field (K1) was the rare false-widow spider, *Steatoda albomaculata*, a typical spider of very dry sandy habitats (Buchar & Růžička 2002). The most diverse community of ground beetles was recorded at locality HU, which was planted with maize and with the slightest slope. A slope of 4.2° does not result in erosion according GAEC, nevertheless erosion is also affected by the length of the slope. Although this slope was the slightest it was very long; so erosion was also important at HU.

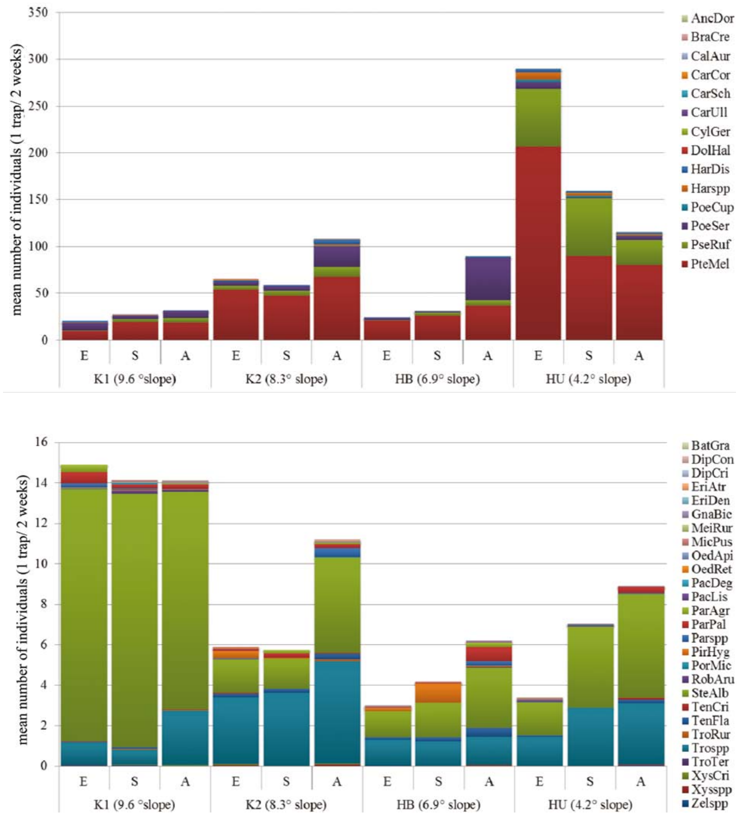

Fig. 1. Activity (number of individuals trapped) of (top) ground beetles and (below) spiders recorded at different positions on slopes in fields: E – top of slope, S – middle of slope, A – bottom of slope. For the abbreviations of species names see Table 1 and the abbreviations for localities see text.

Table 2. Characteristics of the soils on the slopes studied – mean values with respect to position on slope: E – top of slope, S – middle of slope, A – bottom of slope

position on slope	pH/KCl	KVK (mekv/kg)	N_{tot} (%)	humus (%)	humus quality
E	7.23	258.8	0.17	0.4	0.73
S	7.28	244.8	0.15	0.6	0.67
A	7.19	231.0	0.19	1.4	0.97

The dominant ground beetles at HU were *Pterostichus melanarius* and *Pseudoophonus rufipes*. Both species are open habitat specialists, very common in Central Europe (Hůrka 1996).

At the two sites studied the abundance of both ground beetles and spiders was greater at the bottoms of the slopes. In addition, the highest diversity of both groups of invertebrates was recorded at the bottoms of slopes in all three maize fields (Fig. 2).

Canonical correspondence analysis resulted in a model that accounts for 38.4% of the variability in species data (Fig. 3). The first axis accounts 23% of variability and corresponds mainly with the position of the traps on the slopes and the second axis accounts for another 10%, and corresponds mainly with the type of crop. It is clear, that water erosion has a marked effect on the quality of the soil and distribution of the species. Soils at the bottoms of slopes are more fertile (Table 2) with a higher amount of nitrogen and humus. The quality of the humus at the bottom of the slopes was also the highest (conditional effect in model, F=6.20, p=0.002). Humus loss from slopes in maize fields can be as much as several hundred kilograms per hectare (Bucur et al. 2007), with some of this humus accumulating at the bottom of slopes. On the other hand, soils at the top of slopes are less acidic and have a higher cation-exchange capacity and the activity of ground beetles and spiders was associated with their position on the slope (conditional effect in model, F=2.55, p=0.002).

The higher diversity of carabids and spiders, and abundance of spiders (and carabids at localities K1, K2 and HB) recorded at the bottom of the slopes in maize fields is most likely to be due to runoff. The more favourable soil conditions at the bottoms of slopes can result in higher productivity and more food for the animals studied. Although spiders are predators, the most dominant

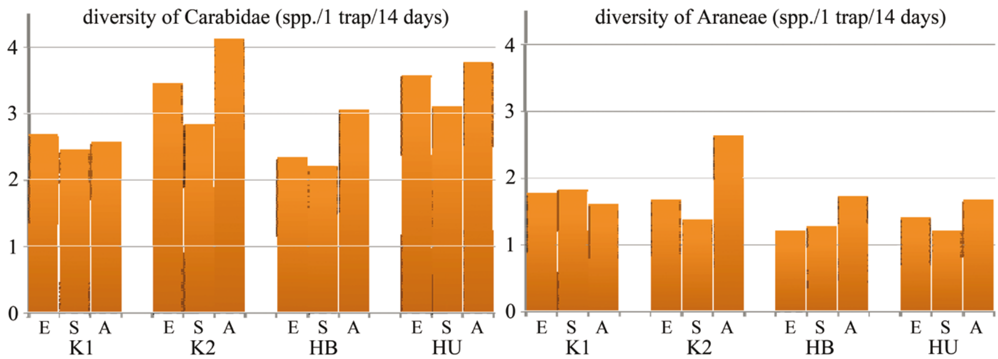

Fig. 2. Diversity of ground beetles and spiders (mean number of species /1 trap /2 weeks) recorded at different positions on slopes in fields: E – top of slope, S – middle of slope, A – bottom of slope. For the abbreviations for the localities see text.

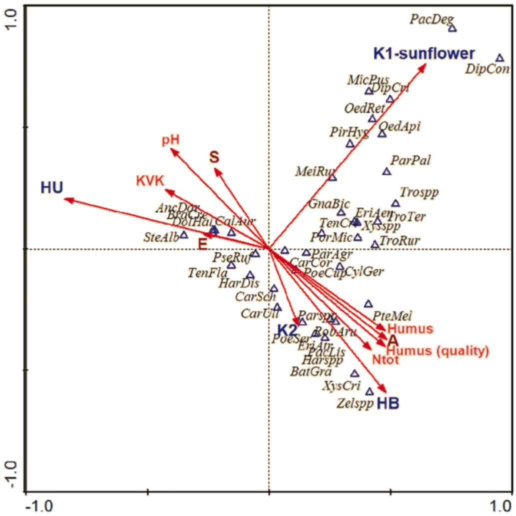

Fig. 3. CCA biplot of the distributions of ground beetles and spiders on the four slopes studied. K1, K2, HU and HB – abbreviations of localities, see text; position of traps on slope: E – top of slope, S – middle of slope, A – bottom of slope; KVK is cation-exchange capacity; Ntot – amount of nitrogen (total). For abbreviations for species see text.

species of ground beetles, *Dolichus halensis*, *Pseudoophonus rufipes* and *Pterostichus melanarius*, are polyphagous, which switch from eating seeds to invertebrate prey during the course of a year (Skuhravý 1959, Lundgren 2009, Šustek 2014).

Comparing the catches of soil invertebrates on slopes at four localities indicates that it is probably mainly ground beetles that are washed down the slopes by water erosion. Spiders that construct nets, like small species of Lyniphiidae (e.g. dominant species *Oedothorax apicatus*), or simple threads (e.g. dominant *Pardosa agrestis*), are less at risk of being washed away by running water. The nets of spiders can help them survive as they can also serve as physical gills (Rovner 1987). Spiders are able to climb and anchor themselves to vegetation. In dense crops planted on slopes (sunflowers are planted at higher densities than maize) spiders are more likely to survive. A similar situation is reported for fields on slopes protected by hedgerows in China (Wu et al. 2009) in which there are much higher abundances and diversities of spiders near (and in) hedgerows than in open fields with steep slopes.

The results presented clearly indicate there are differences in the communities of spiders and ground beetles at sites affected by erosion and those where there is an accumulation of eroded soil. In the future it is important to study erosion in fields with the same crop, as the type of crop affects the structure of invertebrate communities. Nevertheless the data from this preliminary investigation clearly indicates that water erosion can affect ground beetles and spiders.

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