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Short communication

Impact of land-use change towards perennial energy crops on earthworm population

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ABSTRACT

The aim of the study was to investigate the impact of the cultivation of newly introduced perennial bioenergy crops on earthworm species composition, number and biomass at an experimental site in Western Germany. The included crops were Szarvazi (*Agropyron elongatum*), Switchgras (*Panicum virgatum*), Sida (*Sida hermaphrodita*), Silphie (*Silphium perfolatum*), Igniscum (*Fallopia sachalinensis*), and a wild flower mix (WFM) relative to silage (*Zea maize*). In sum, earthworm population at that site consisted of 8 species, *Lumbricus rubellus* and *Allolobophora cupulifera* being dominant species. Species number varied in a range of WPM (8) > Szarvazi (7) > Sida (6) > Silphie, Igniscum (5) > Switchgras, Maize (4). Earthworm number and biomass significantly increased in all newly introduced energy crops. On comparison within the perennial crops, it was found that earthworm number was significantly highest in Sida and lowest in Switchgras plots. The differences within the remaining crops were small and not significant. From an agro-ecological point of view and deduction from earthworm population data, it might be concluded that Szarvasi, Sida and wild flower mix can be seen as important energy crops in future bioenergy production in Western Germany.

1. Introduction

Biofuel crops are increasingly cultivated in order to produce biomass for bio-methanisation, heating, or ethanol production. This development is in the context of the EU initiative to produce 20% of primary energy supply by renewable resources by the year 2020. In many European countries, silage (*Zea maize*) is the leading energy crop for bio-methanation and thus, is increasingly cultivated throughout Europe. In Germany, the proportion of silage maize used for bio-methanation based on the whole arable area is approximately 10% (FNR, 2013). In some regions this proportion is much higher up to 20%, and at the local farm scale it may exceptionally reach 80%. As a consequence there is a trend towards mono-cultivation of silage maize, especially in catchment areas of biogas plants (Kruska and Emmerling, 2008). Much effort therefore has been done to establish new energy crops for biomass production in addition to maize. Those crops are in most cases perennial crops in order to improve soil health and the overall agricultural crop diversity at a landscape scale. Our first results on bio-methanation potentials of these crops emphasize that crop yields, biogas yields and methane contents may vary highly spatial-temporally relative to silage. However, under favourable growing conditions and in specific years the expected bio-methanation potentials are comparable to silage or higher (unpublished data).

The aim of the present study was to investigate the feedback of the cultivation of newly introduced energy crops on earthworm numbers, biomass, and species composition in a field experiment. These perennial energy crops were Szarvazi (common name Tall Wheatgrass; *Agropyron elongatum*),Switchgras (common name Wand Panic Grass; *Panicum virgatum*),Sida (common name Virginia Mallow; *Sida hermaphrodita*), Silphie (common name Cup Plant; *Silphium perfolatum*),Igniscum (common name Giant Knotweed; *Fallopia sachalinensis*), and a wild flower mix. This mixture consisted of 24 annual (e.g. *Helianthus annus*, *Malva mauritanica*, *Malva verticillata*), biennial (e.g. *Dipsacus sylvestris*, *Daucus* carota) and perennial flowering species of high growing rate (e.g. *Inula helenium*, *Malva alcea*, *Medicago sativa*). From the second year on, plant composition adapts to local conditions and perennial species replace annual and biennial ones. Maize (*Zea maize*) in rotation with green rye (*Cecale cereale*) was used for comparison. The overall intention of this study was to gain insights in future trends of biodiversity in soil in a changing land-use towards bioenergy production.

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Table 1
Mean (±S.E.; $n = 4$) soil pH ($CaCl_2$), amounts of SOC ($g\,kg^{-1}$), N ($g\,kg^{-1}$), MBC ($mg\,kg^{-1}$), percentage of coverage and C-to-N ratio of harvest litter. Differences within the treatments were not significant (Kruskal–Wallis *H*-test and post-hoc Nemenyi-test; $n = 4$).

	pH	SOC	N	MBC	ASC[a]	C-to-N[b]
Maize	5.5 (±.02)	13.5 (±.05)	.147 (±.010)	199 (±28)	10–25	35.1
Szarvazi	5.5 (±.04)	13.3 (±.03)	.168 (±.010)	217 (±23)	75–100	30.0
WFM	5.6 (±.03)	13.4 (±.04)	.166 (±.011)	259 (±19)	75–100	36.2
Switchgras	5.9 (±.04)	13.7 (±.02)	.166 (±.014)	295 (±15)	50–75	24.8
Sida	5.6 (±.03)	13.1 (±.02)	.140 (±.008)	268 (±7)	75–100	26.9
Silphie	5.6 (±.01)	13.2 (±.05)	.166 (±.024)	261 (±10)	75–100	36.3
Igniscum	5.6 (±.12)	13.2 (±.06)	.172 (±.018)	251 (±25)	75–100	35.6

[a] Average of soil covering: percentage of soil surface covered by plants during thecultivation period.
[b] Average C-to-N ratio of post-harvest residues.

2. Materials and methods

The study area was located near Trier (West Germany). Soils were silty-loamy Luvisols derived from air-blown silt (loess). Earthworms were collected in a combination of hand-sorting and extraction with AITC (Allyl-isothiocyanate) according to Zaborski (2003) during May/June 2013 in the fourth year of cultivation. Briefly, each crop has been sampled in quadruple each of two repeated measurements of $0.25\,m^2$ each. All results are given per square meter. Species determination followed Sims and Gerard (1999) and Blakemore (2007). For soil chemical analyses soil samples were taken at each replicate plot (0–15 cm depth), subsequently air-dried and sieved ≤2 mm or pulverized by a ball-mill. The pH was determined potentiometrically in 0.01 M $CaCl_2$ with a glass electrode. The content of total soil organic carbon (SOC) and N was measured simultaneously by gas chromatography after combustion at 1100 °C using an EuroEA elemental analyser (HekaTech, Wegberg, Germany). Microbial biomass C (MBC) was analyzed on moist soil samples by the chloroform fumigation extraction method according to Vance et al. (1987). Percentage of soil surface covered by plants during the cultivation period has been evaluated by the method of Braun-Blanquet. Harvest residues of all investigated crops have been sampled previous to harvest and characterised by their C-to-N ratio. Representative samples were dried at 105 °C for 24 h and subsequently pulverized with a ball mill prior to C- and N-analysis. For statistical comparisons of treatments a non-parametric Kruskal–Wallis *H*-test and a post-hoc Nemenyi-test were used.

3. Results and discussion

The pH ($CaCl_2$) of the soil was in a range of 5.5 (Maize, Szarvazi) to 5.9 (Switchgras). Amounts of SOC varied from 13.1 $g\,kg^{-1}$ dr.M. (Sida) to 13.7 $g\,kg^{-1}$ dr.M. (Switchgras). The highest amount of MBC was found in Switchgras (295 $mg\,kg^{-1}$ dr.M.) and the lowest (199 $mg\,kg^{-1}$ dr.M.) in maize fields (Table 1). Compared to maize plots percentage of soil coverage was much higher in all plots cultivated with perennial crops. The C-to-N ratio of harvest

Table 2
Summary table of species abundance and fresh biomass in fields cultivated with different newly introduced energy crops and silage maize.

Species	No m^{-2}; g m^{-2}	Maize	Szarvazi	WFM[a]	Switchgras	Sida	Silphie	Igniscum
Lumbricus terrestris (Linnaeus)	Abundance		1	1		3		1
	Biomass		3.8	6.77		12.29		1.08
Lumbricus rubellus (Hoffmeister)	Abundance	3	10	13	1	12	10	5
	Biomass	3.17	8.38	12.52	1.17	13.13	10.90	5.05
Aporrectodea caliginosa (Savigny)	Abundance	1	6	7	3	6	11	
	Biomass	.74	2.81	6.11	3.22	5.13	7.00	
Allolobophora chlorotica (Savigny)	Abundance		1	4	8	4	4	
	Biomass		.29	1.31	1.49	1.03	1.12	
Aporrectodea rosea (Savigny)	Abundance		1	2		2		1
	Biomass		.30	.31		.54		.25
Aporrectodea antipai (Michaelsen)	Abundance		1	2				
	Biomass		.34	.53				
Allolobophora cupulifera (Tétry)	Abundance	2	1	2	1	2	2	1
	Biomass	.81	.26	.56	.29	.55	.82	.40
Aporrectodea longa (Ude)	Abundance	2		9			2	1
	Biomass	5.76		16.39			2.78	1.59
Epigeic juv.	Abundance	2	9	4	3	17	14	7
	Biomass	.11	7.44	3.10	.38	11.10	5.12	7.32
Endogeic juv.	Abundance	3	10	15	13	15	7	14
	Biomass	.30	3.06	2.76	1.27	2.68	1.23	3.57
Anecic juv.	Abundance	1		1		5	1	2
	Biomass	.20		.80		5.24	1.21	1.88
Species number		4	7	8	4	6	5	5

[a] Wild flower mix.