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Earthworm diversity and ecosystem services in agriculture – Choosing appropriate taxon indicators and measurements

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Agriculture and biodiversity are strongly linked. Whilst agriculture is a main driver impacting biodiversity, farmers could benefit from ecosystem services linked to biodiversity. Hence, indicators of functional biodiversity are needed. However, finding correct indicator values is not trivial. Earthworms were sampled on nine German farms with a combined method. In total 3205 earthworms from 10 species were collected. Six measurements applicable as taxon indicators were calculated for the data.

Keywords: soil diversity, interpolation, extrapolation, biodiversity indices, biodiversity estimators

1 Introduction

According to the Convention on Biological Diversity (CBD 1992), biodiversity is the variety of all living organisms and the ecosystems to which they belong. Ecosystem services are the benefits that the ecosystems provide to humans (Wall et al. 2012). As a consequence, agriculture and biodiversity are closely related. Farmers actively manage biodiversity, both in a positive and in a negative way. Whereas ecosystem services in natural undisturbed ecosystems are high, crop production from these systems is very low. On the contrary, intensively managed agricultural ecosystems provide high yields, but other ecosystem services are low. Sustainably managed systems support both, high yields and various ecosystem services (Foley, 2005). As a result, farmers can benefit from ecosystem services linked to biodiversity like pollination or natural pest control (Zhang et al. 2007; Power 2010).

Awareness of the link between biodiversity and ecosystem services forces food business to think about integrating this topic into their environmental management and marketing to mitigate biodiversity impacts. For this purpose, indicators of functional biodiversity have to be developed, that can be integrated into the biodiversity management along the value chains of organic food stuff. Although several aspects could be addressed in this field, this study focuses on ecosystem services provided by the diversity of organism in the soil and the development of corresponding indicators, causal models and communication tools. Before causal relations of biodiversity and ecosystem services can be analysed, reliable and valid indicators for both concepts are required. Different indicators and measures can be used to assess biodiversity (Figure 1). The analysis of these measures is challenging, because of incomplete sampling and dependence of results on sampling effort (Figure 2). The aim of this paper is to address the measurement of biodiversity and especially the aspect of taxon indicators. An appropriate analysis will be exemplified with earthworm data.

2 Material and Methods

Data was collected in 2014 on nine farms located in southern Bavaria (Germany) in the surroundings of Munich. Five organically (org) and four non-organically respectively conventionally (con) managed farms were selected. In total 64 plots, representing the different crops in rotation and the grassland habitats found on these farms, were sampled.

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Earthworms were assessed with three replications per plot with a combination of an expellant solution (AITC mustard oil) and a time-restricted hand sorting procedure according to Dennis et al. (2012). All individuals were counted and weighted. The adult specimens were identified to species level. Only the data on abundance of adult specimens was used for the statistical analysis. Juveniles were excluded because these specimens cannot always be determined to species level. For the statistical analysis in R 3.1.3 (R Development Core Team 2015) the packages "BiodiversityR 2.5-1" (Kindt and Coe, 2005) and „iNEXT 2.0.1" (Hsieh et al., 2014) were used.

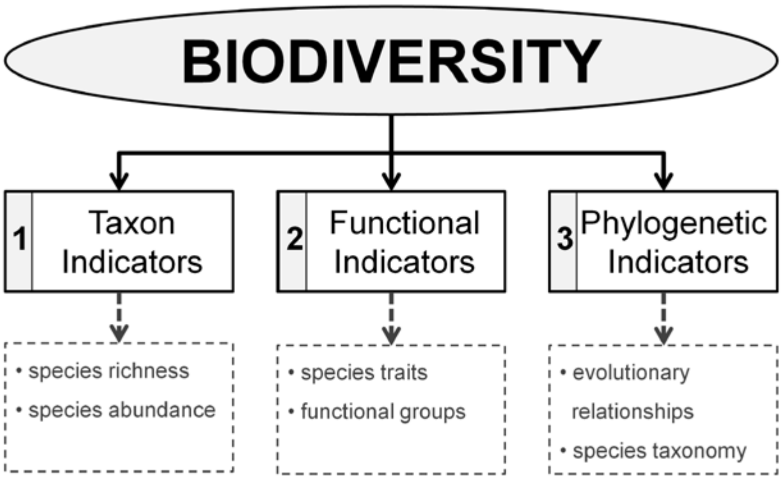

Figure 1 Classification of biodiversity indicators (Cardoso, 2015)

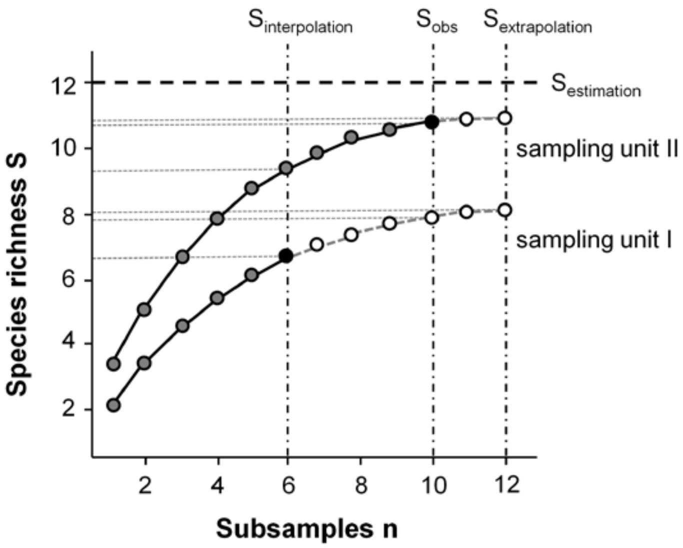

Figure 2 Relation between subsamples and species richness for sampling units and a range of sampling effort (gray: interpolated; black: observed; white: extrapolated). The dashed line indicates an estimated species richness (Chao et al., 2014).

3 Results and Discussion

In total 3205 (903 g) earthworms from 10 species were collected. 70 % of individuals and 36 % of biomass were juvenile specimens. 8% of the individuals were anecic, 80 % endogeic and 11 % epigeic group members. For biomass this was 42 %, 49 % and 9 % respectively. Results for six taxonomic indicator measurements are presented in Table 1. There were no significant differences between organically and conventionally managed farms. In total 3205 (903 g) earthworms from 10 species were collected. 70 % of individuals and 36 % of biomass were juvenile specimens. 8 % of the individuals were anecic, 80% endogeic and 11% epigeic group members. For biomass this was 42 %, 49 % and 9 % respectively. Results for six taxonomic indicator measurements are presented in Table 1. There were no significant differences between organically and conventionally managed farms.

Table 1 Farm level results for taxonomic biodiversity indicators: Observed, inter- and extrapolated species richness, biodiversity indices and estimator (based on data)

Farm	Management system	Sub-samples	Indivi-duals	S_{obs}	$S_{rar;6}$	$S_{ext;12}$	exp. $Shannon_{rar;6}$	inv. $Simpson_{rar;6}$	Chao 2
1	organic	8	193	8	7,9	8,0	6,6	5,8	8,0
2	organic	6	80	5	5,0	5,7	4,1	3,7	5,8
3	organic	6	21	7	7,0	9,9	5,6	4,7	13,7
4	organic	7	80	9	8,9	9,1	7,7	6,9	9,1
5	conventional	8	155	6	6,0	6,0	5,3	4,9	6,0
6	conventional	7	96	6	5,7	6,7	4,8	4,3	6,9
7	conventional	7	118	7	6,6	8,6	5,2	4,4	10,9
8	organic	8	109	7	6,7	7,2	5,7	5,1	7,2
9	conventional	7	96	7	7,0	7,0	6,0	5,3	7,0

4 Conclusions

Results were easily available from species data and provide valid measurements for taxon indicators. Similar statistical methods can be used to calculate proper measurements for functional and phylogenetic diversity indicators. These indicators can then be used to develop and test causal models and to clarify the relationship between farming practices, biodiversity and ecosystems services. Finally, this findings will foster sustainable agricultural.

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