

# Assessing Earthworm Populations in Some Hungarian Horticultural Farms: Comparison of Conventional, Organic and Permaculture Farming <sup>†</sup>

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**Abstract:** Soil is one of the most important, non-renewable natural resources of humans. People use soils for food production, thus maintaining soil health is crucial. Farming systems have a tremendous impact on soil biota. Effects can be negative and positive. Less intensive farming (e.g., organic and permaculture) is known to be more favorable for soil life while intensive farms known for their negative effects. Our aim was to compare different farming systems based on the density of earthworms. Fifteen small-scale (0.3–2 ha) farms in Hungary with similar agroecological features were selected for comparison. All of them are horticultural farms with diverse crops in the crop rotation, the only difference is the farming systems, i.e., one intensive (conventional), and two extensive types (organic and permaculture). Earthworms were sampled in May and September 2020, six replicates on each site, by hand sorting of 25 × 25 × 25 cm soil blocks. In May, abundance of earthworms were significantly higher in case of permaculture farms compared to organic and also conventional farms. However, we did not find significant differences in earthworm abundance in September. Earthworm species number was significantly higher in permaculture farms in May however there was no significant difference in September. We did not find significant differences regarding Shannon diversity indices. Based on our soil-wise experiences it is of great importance to know as much soil information as possible (i.e., soil thickness, soil organic matter content, texture, soil management, fertilizers used, soil moisture content at the time of the counting, soil cover etc.) for considering earthworms data as good indicator for soil quality assessment.

**Keywords:** biodiversity; soil biota; land use; agroecology; ecosystem services

## 1. Introduction

The concept of ecosystem service evaluation of the natural environment is used worldwide [1–5], just as well as in Hungary [6]. Soil provides vital ecosystem services for humans, e.g., climate regulation [7], carbon storage [8,9], nutrient and water cycling [10], etc. Modification of potential production capabilities has always been an important topic [11,12]. Despite its crucial role, the soil is still less appreciated and it is not managed responsibly [13,14], even though there have been researches and monitoring dealing with the evaluation of systems and the possible positive soil quality change, e.g., after the abandonment of arable fields [15–23].

The assessment of the multiple contributions of soils to ecosystem services delivery has been investigated by some authors [24–28].

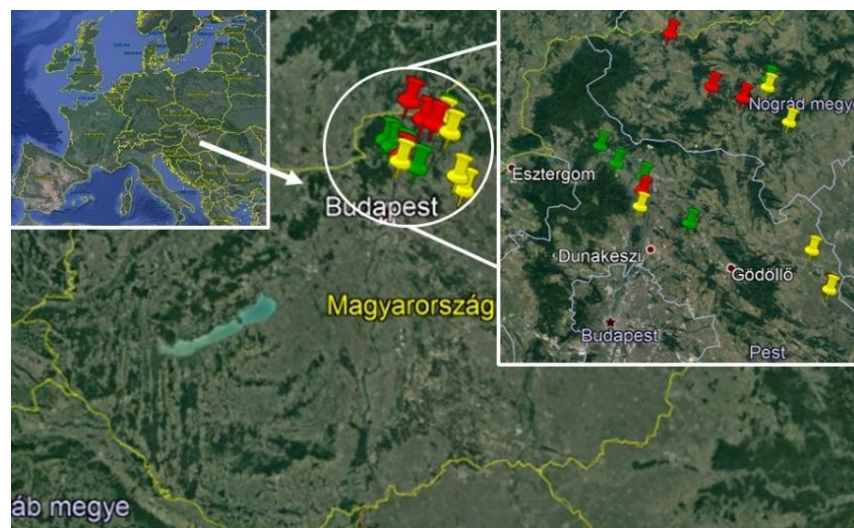
Using earthworms as indicators, it is worth mentioning that soil moisture plays a crucial role in their suitability as indicators. Earthworms are an important part of the soil biota [29,30] they are also called soil ecosystem engineers as they contribute to soil formation. But they are also key elements in soil food web, in nutrient cycling and decomposition processes [31]. This is why we often use them as indicators for soil health [32,33].

Farm management, mostly soil cultivation [34] can greatly influence soil biota and functioning [35–38]. Inadequate soil management can cause compaction [39] and lower water holding capacity. Thus, in a managed agro-ecosystem, like horticulture farms, good soil quality depends on the farmer to a great extent [40]. The objective of our study was to compare different horticultural farms regarding earthworms abundance and diversity to see how the different farming systems (conventional, organic and permaculture) affect the results and which provides more ideal conditions for earthworms. The main consideration was that scientific knowledge on permaculture systems in regards to biodiversity indicators is missing. Our preliminary hypothesis was that permaculture farms provide the most ideal conditions and have the highest abundance and diversity of earthworms, while conventional have the least.

## 2. Experiments

### 2.1. The Study Sites

Fifteen sites, 5 conventional (K), 5 organic (B) and 5 permaculture farms (P) in Hungary were selected with similar size (0.3–2 hectares) and agro-ecological features, horticultural production with diverse crop rotation (Figure 1). All farms are small scale, with direct marketing to customers.



**Figure 1.** Location of the studied sites (green points: permaculture, yellow: organic, red: conventional farms) (Google Earth Pro 2020, own editing).

*Permaculture farming* is a complex design system that goes beyond the principles of organic farming and creates a sustainable human environment [41]. Permaculture is not only a set of practices or a cropping technique, it is a holistic approach to how practitioners look at farming and their role in the ecosystem [42,43]. By *organic*—also known as biological, ecological—*farming* we mean a complex farming alternative, which enables the production of healthy food under environmentally friendly, strict conditions and controlled conditions. Organic farming also builds on using natural processes, instead of substituting them with external inputs while conventional farming aims to exclude or at least minimize

the natural factors which affect their farming conditions by using external inputs, infrastructures, etc. [44,45]. *Conventional farming* is a profit-oriented, intensive form of agriculture, which relies primarily on the use of synthetic pesticides and fertilizers, and often uses monoculture on large fields. Soil quality is an important focus of both extensive farming systems. In organic farming they try to improve and sustain soil quality by crop rotation, adding organic manure instead of fertilizers [46], while in permaculture, farmers try to minimize soil disturbance, cover the surface with mulch, use complex polycultures and companion planting [47]. No-tillage is getting more acknowledged but it is still not a prevalent technique [48].

### 2.2. Used Methods

Earthworm population was assessed on the 21–23. of May and the 11–13. of September, 2020. Soil blocks (25 × 25 × 25 cm) were excavated in situ in six replicates at each site on a plastic sheet and were thoroughly searched for the earthworms according to the ISO 23611-1:2006 [49]. The numbers were recorded, the biomass was measured and the earthworms were preserved in 70% ethanol, then placed in 4% formaldehyde solution for fixation, then stored in 70% ethanol for species identification. The earthworm species were determined by the external and internal characteristics of earthworms, based on Csuzdi and Zicsi [50] and Csuzdi [51]. Soil horizons and types were assessed by Pürckhauer type core sampler (1 m depth) between 11–13 of September, 2020. All collected species presence-absence and abundance data were registered in matrices. We calculated species number and Shannon diversity by all collected presence-absence and abundance data of species on field. Residuals of every relationships between different categorical (type of farms) and numeric factor (earthworm species numbers and abundances) variables were checked for normality with Shapiro-Wilk normality test. TukeyHSD test was used for normally distributed residuals and in cases of non-normally distributed residuals, Kruskal-Dunn’s posthoc test was applied to determine significant differences ( $p < 0.05$ ) between different type of farms. Every calculation were made in R 3.5.1. programming environment [52] by the ‘PMCMR’, ‘PMCMRplus’ and the ‘vegan’ packages.

## 3. Results

### 3.1. Soil Characteristics

The soil type on most farms according to WRB [53] belongs to Luvisols (9 of 15) with mostly shallow humus layer (Table 1), except for P3, B5 and K5 which are all located on the Szentendre Island and close to Danube river (see Figure 1). B2 and P1 are Arenosols with sandy texture and shallow humus layer. B1 and K1 farms are 100 m away from each other at the same village, they are Chernozems with deep humus layer (50–58 cm). P5 and K4 farms have Fluvisol type soil, P5 farm is very close to the Danube, while K4 is close to Ipoly river with very deep humus layer (105 and 70 cm, respectively).

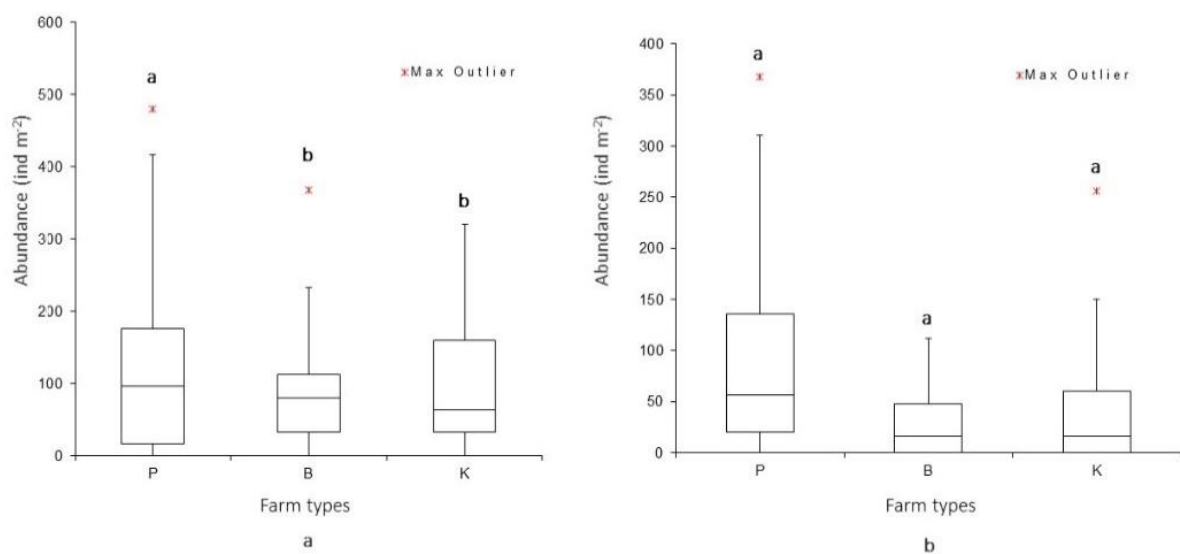
**Table 1.** Soil types and total thickness of all humus layers (based on their colors) in the studied farms (P = permaculture; B = organic; K = conventional).

Farms	Soil Type (WRB, 2015)	Total Thickness of All Humus Layers (cm)
P1	Arenosol	0–30
P2	Luvisol	0–30
P3	Luvisol	0–67
P4	Luvisol	0–23
P5	Fluvisol	0–105
B1	Chernozem	0–58
B2	Arenosol	0–20
B3	Luvisol	0–41
B4	Luvisol	0–20

B5	Luvisol	0–84
K1	Chernozem	0–50
K2	Luvisol	0
K3	Luvisol	0
K4	Fluvisol	0–70
K5	Luvisol	0–100

### 3.2. Earthworm Abundance

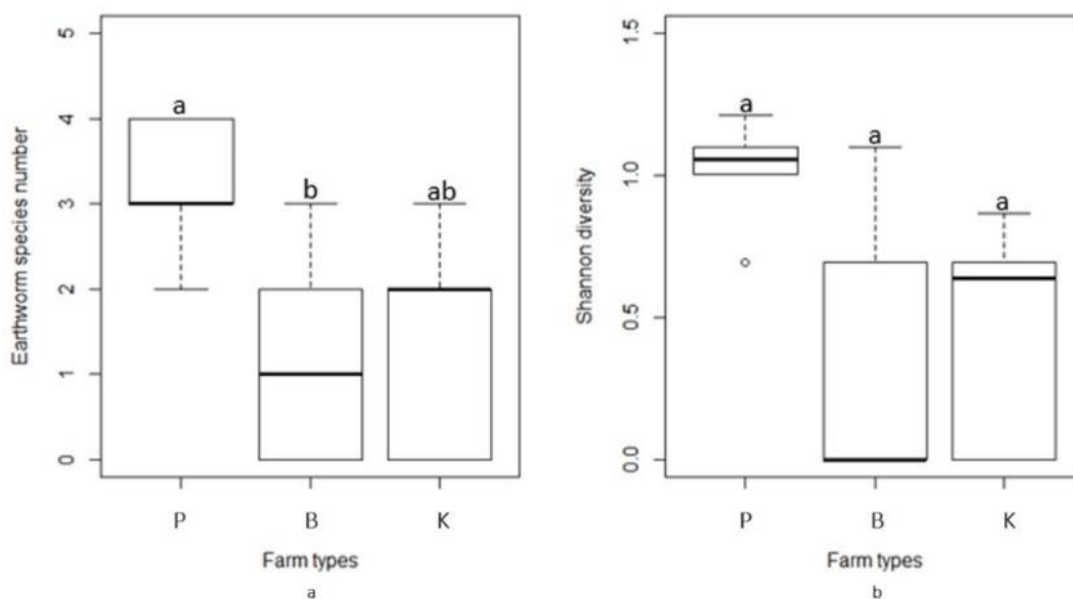
In May 2020, the abundance of earthworms was significantly higher in case of permaculture farms compared to organic and also conventional farms (Figure 2a). However, we did not find significant differences in earthworm abundance in September 2020 (Figure 2b).



**Figure 2.** Earthworm abundance (individual per m<sup>2</sup> in the upper 25 cm, n = 5) in the three farming system in May (a) and September (b), 2020 (P = permaculture; B = organic; K = conventional).

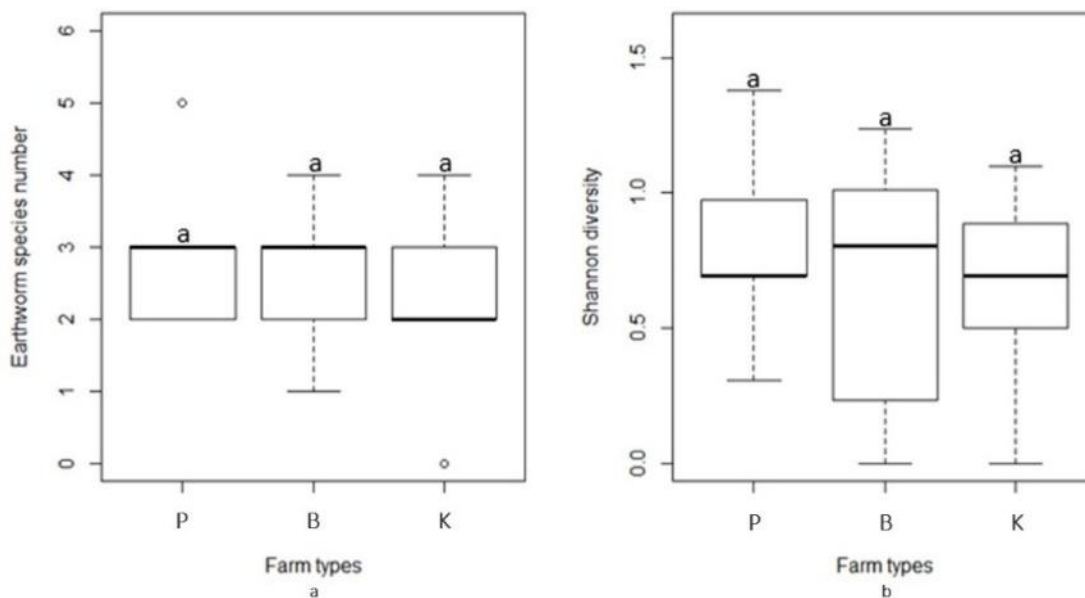
### 3.3. Earthworm Diversity

Earthworm species number was significantly higher in permaculture farms during May sampling compared to organic and conventional farms (Figure 3a). Although, Shannon diversity was greatest in the permaculture farms, there were no significant differences between the farming systems, while lowest Shannon value was found in organic farms (Figure 3b).



**Figure 3.** Earthworm species number (a) and Shannon diversity (b) in the three studied farming system ( $n = 5$ ) in May, 2020 (P = permaculture; B = organic; K = conventional).

During September average of earthworm species number and Shannon diversity were highest in permaculture farms (Table 2), however there were no significant differences between the farming systems neither in species number (Figure 4a), nor in Shannon diversity (Figure 4b).



**Figure 4.** Earthworm species number (a) and Shannon diversity (b) in the three studied farming system ( $n = 5$ ) in September, 2020 (P = permaculture; B = organic; K = conventional).

**Table 2.** Average ( $n = 5$ ) Shannon diversity and species number of the three studied farming systems with standard deviations in May and September, 2020 (P = permaculture; B = organic; K = conventional).

Sampling date	May	May	May	September	September	September
Farming system	P	B	K	P	B	K

<b>Species number (MEAN ± SD)</b>	3.20 ± 0.84	1.20 ± 1.30	1.40 ± 1.34	3.00 ± 1.22	2.60 ± 1.14	2.20 ± 1.48
<b>Shannon diversity (MEAN ± SD)</b>	1.01 ± 0.19	0.36 ± 0.51	0.44 ± 0.41	0.81 ± 0.40	0.66 ± 0.52	0.64 ± 0.42

#### 4. Discussion

Permaculture farm had the highest abundance of earthworms which was significant in May. In previous studies, they also found higher earthworm abundance in no-tillage compared to other tillage types [54,55]. Based on our soil-wise experiences it is of great importance to know as much soil information as possible (i.e., soil thickness, soil organic matter content, texture, soil management, fertilizers used, soil moisture content at the time of the counting, soil cover etc.) for considering earthworms data as good indicator for soil quality assessment. The importance of considering multiple soil factors are also emphasized in the literature [56,57]. In our pilot study, we have found similar patterns in 2019, based on three farms [58] which is in line with what we explored in soil quality during sustainability assessment of permaculture farms compared to organic and conventional farms [59]. The relatively low sample size (15 farms, 5–5 farm from each farm type) is an issue for the statistical analysis and our analyses showed that with a greater sample size and a more robust database we could have probably found more significant statistical results.

#### 5. Conclusions

Ecosystem service is a good concept to promote what is the contribution of biodiversity and ecosystems to human well-being, however, environmental factors must be analyzed carefully, as impact indicators are not always enough to explain differences stand-alone. Our future goal is to analyse farm management and soil characteristics in detail when we have all other relevant information and also to further explore connections of soil biota characteristics to ecosystem service delivery.

**Author Contributions:** A.S., C.C. and P.N. conceived and designed the experiments; A.S. and E.P. performed the experiments; B.S., A.S. and C.C. analyzed the data; Barbara Simon, A.S., E.P. and C.C. wrote the paper. All authors have read and agreed to the published version of the manuscript.

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#### Abbreviations

The following abbreviations are used in this manuscript: P: permaculture farm; B: organic farm; K: conventional farm; SD: standard deviation.

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