

## Case study on biological and chemical soil properties during the transition from intensive agriculture to an organic food forest

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### Abstract

*A food forest was planted in several sections over a period of five years. This is used to conduct a case study monitoring soil properties as a function of time since conversion. Classical soil microscopy was used to assess bacterial and fungal abundance, and the resulting videos were analysed using image analysis*

**Keywords:** soil-microscopy, machine vision, soil microorganisms, agriculture

### Introduction

Food forests are a low-maintenance, sustainable, food production system based on woodland ecosystems, incorporating fruit and nut trees, shrubs, herbs, vines and perennial vegetables with yields directly useful to humans. The transition from high intensity cropland targeting maximum yields of a single crop through excessive use of agrochemicals [Wyckhuys et al. (2025)] to an organic food forest represents an agroecological conversion from a highly productive but ecologically brittle [Tiftonell (2020)] farming system to a more biodiverse and resilient system. Conventionally intensive managed farmland typically shows a low diversity of soil microorganisms, often fungi and protists are hardly present. Especially for the resilience of orchard type regions in a food forest [Moereels et al. (2024)] a functional soil food web is crucial and found to be present in traditional orchard meadows [Sattler et al. (2024)]. This study investigates how bacterial and fungal biomass respond to the conversion from intensive agriculture to an organic food forest over a five-year period.

### Material and Methods

Before the transition into a food forest was started, the plot in the “Gäuboden” region in the southeast Bavaria was managed for 30 years at a regime of intensive conventional practices with deep tillage, having a crop rotation of potato – grain - sugar beet. During this time neither organic fertilizer nor intercropping was applied.

In a section of the food forest investigated a typical espalier type orchard planting was applied with 35 old variety apple trees on M25 rootstock. In the second year an underplanting with flowers, herbs and vegetables was supplemented. A broadfork was used to break up soil compaction. To create a suitable seedbed for flowers and vegetables only minimal tillage was applied prior to sowing.

Two composts made out of on-farm materials were applied at the area. Fresh field compost was made of straw-based cow manure, wood chips and alfalfa. It was used to increase the soil organic matter and therefore applied yearly in layers of five to ten cm at the root area of trees and vegetable beds. Mature vermicompost made from food scraps, bokashi and field compost was used to inoculate seeds and seedlings for an enhancement of biodiversity at the rhizosphere in a amount comparable to seed or root volume.

For the chemical analysis of the soil an Albrecht type analysis was conducted. Following a recommendation of this analysis a yearly sulfur treatment of 100kg/ha was applied.

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To evaluate the microbial activity a soil-suspension was prepared by mixing soil with water in a 1:50 dilution and microscopically analysed at a magnification of 400x [Shainidze et al. (2019)]. From this sample, five videos at different fields of view are taken while adjusting the focal plane across the width of the sample. These videos allow to count moving bacteria (cocci and lactobacilli) with image recognition. Therefore the algorithm finds five areas in each field of view on the sample, that are not covered by large objects like organic or mineral matter. The moving bacteria are counted and this procedure is repeated at five different fields of view on the sample plate. This allows the calculation of the mean and mean variation of moving bacteria as relative bacteria activity proxy for the resulting 25 repetitions.

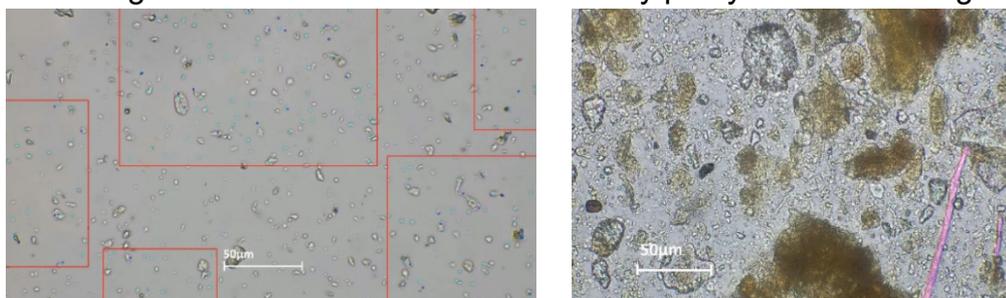


Figure 1: left: Bacterial detection in 5 areas of interest  
right: Fungal detection in pink after focus stacking

A sharp picture of greater objects like fungal hyphae can be achieved by using focus stacking. As in some soils only in one or two fields of view fungi are present, the calculation of a mean deviation is not productive. For simplicity the number of pixels, that are assigned to a hyphae, are counted in the five fields of view. This estimate allows to compare the fungal dissemination in different samples but gives no actual value comparable to other biodiversity assessments.

Soil analysis for biological and chemical parameters have been carried out in autumn 2025 at a depth of 0-20cm on three sample spots at the field and two compost materials:

- **Vermicompost** - was used for bio-inoculation of seedling roots and seeds
- **Field compost** - was used for yearly fertilisation to target carbon rise
- **Conventional** – is a region of the plot that is still in intensive crop production
- **2 years** – is a region of the plot that was converted in an organic orchard 2023
- **5 years** – is a region with few trees and biointensive market-gardening converted 2020

## Results

An overview of the chemical and biological parameters is given in Table 1.

Table 1: Chemical and biological soil parameters for used composts and soil plots

|                       | Vermi compost | Field compost | 5 years    | 2 years    | Conventional |
|-----------------------|---------------|---------------|------------|------------|--------------|
| pH (H <sub>2</sub> O) |               |               | 7,8        | 7,3        | 7,1          |
| Organic Matter %      | 18,6          | 15,4          | 3,1        | 2,0        | 1,8          |
| Calcium               | 39,4 g/kg     | 13,5 g/kg     | 5220 kg/ha | 3770 kg/ha | 4124 kg/ha   |
| Magnesium             | 10,4 g/kg     | 7,7 g/kg      | 651 kg/ha  | 390 kg/ha  | 378 kg/ha    |
| Potassium             | 14,8 g/kg     | 14,2 g/kg     | 1244 kg/ha | 475 kg/ha  | 581 kg/ha    |
| Sodium                | 1 g/kg        | 0,4 g/kg      | 133 kg/ha  | 52 kg/ha   | 26 kg/ha     |
| Sulfur ppm            | 4             | 2,3           | 32         | 4          | 8            |
| Phosphorus            | 12,7 g/kg     | 4,6 g/kg      | 482 kg/ha  | 85 kg/ha   | 61 kg/ha     |
| Bacteria µg/g         | 697±155       | 1038±349      | 2404±1038  | 674±270    | 617±198      |
| Fungi                 | 7263          | 3453          | 845        | 316        | 10           |

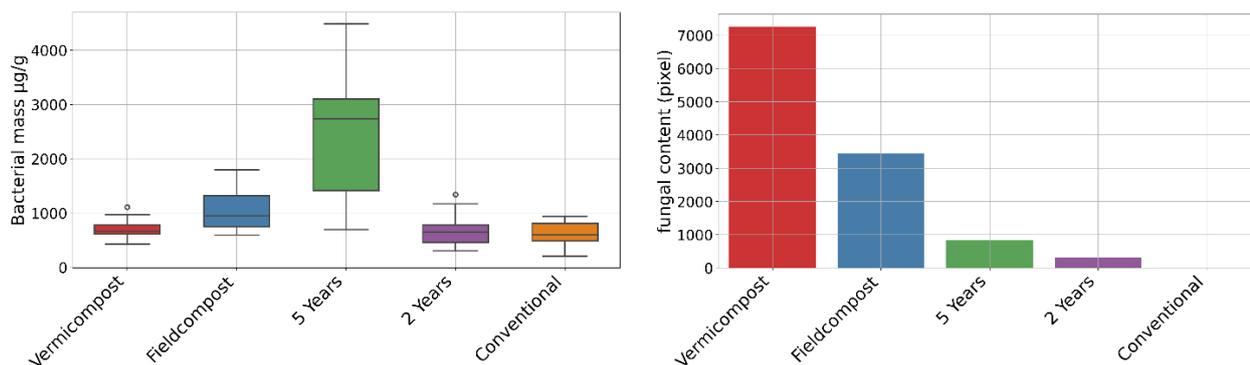


Figure 2: left: Bacterial mass in  $\mu\text{g/g}$  for composts and successions of conversion, right: fungal content for composts and successions in arbitrary units (pixel)

The results of the chemical soil analyses displayed in Table 1 show a low sulphur level for the conventional and two-year sample. For the five-year sample the potassium and phosphorus level are above the desired range of the Albrecht type analysis, magnesium and sodium are elevated. The vermicompost has high levels of fungal content, whereas the field compost shows a high level of bacterial mass. The bacterial mass and fungal content in the soil increased after the change in management system.

## Discussion

The transition from conventionally high-intensity cropland to an organic food forest involved using a fungal-dominated vermicompost for seed inoculation and fresh field compost for nutrition, along with an increase in carbon levels. In this case study, these practices led to a rise in soil organic matter and an expansion of the soil food web, as indicated by higher fungal and moving bacterial levels within five years.

The intensive use of compost results here to an emerging overfertilization in potassium and phosphorus. Chemical and biological effects of compost application are strongly interconnected and need to be evaluated carefully.

The method of soil microscopy combined with image recognition algorithms gives a semi-quantitative presence indicator. Compared to standard methods like Phospholipid Fatty Acid or DNA based methods it is simpler, quicker and cheaper. In this study, it was a useful tool to monitor transition processes in soils and helped to choose and create suitable compost.

## References

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