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Improving Soil Health of Commercial Vegetable Home Gardens through Conservation Agriculture in Cambodia

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ABSTRACT: Tillage systems are components of broad agricultural practices that affect soil properties and soil health. These changes include soil respiration, density, moisture, and pH. Conservation agriculture practices have the potential to improve soil health by reducing tillage. In agricultural production, there can be numerous approaches to achieving consistently high yields annually; however, this study specifically looked at conventional tillage and conservation agriculture systems. This study aimed to determine soil fauna biodiversity and soil health under conservation agriculture (CA) and conventional tillage (CT) management practices of vegetable production in Cambodia. Five CA and five CT plots were selected and included in this study. Fifty soil samples were collected from CA and CT plots for soil fauna measurement, and in-situ tests were made using Biofunctool© for soil health assessment. The results showed that the abundance of soil fauna and aggregation stability were greater in CA than in CT. Soil fauna biodiversity enhancement may provide better soil health for soil improvement by adapting farming management practices.

Keywords: conventional tillage, soil fauna, soil health, vegetable home garden.

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INTRODUCTION

Agricultural practices, specifically tillage systems, can affect soil properties and health changes (Reynolds & Borlaug, 2006). Conventional tillage (CT) practices can increase erosion of soil resources. The principal adverse effect of erosion is lowering fertility through removing organic matter and nutrients in eroded sediment (Young, 1987). One specific approach to control soil fertility loss is conservation agriculture.

Conservation agriculture (CA) practices have the potential to improve soil health by reducing tillage and can be applied to all crops, including annual crops, horticultural crops, and tree crops. CA is a farming system that uses minimum soil tillage to zero soil disturbance, continuous mulching and ground cover, and diverse species in a crop rotation (Hobbs et al., 2008). This system has benefits such as improved soil moisture retention, reduced soil erosion, reduced farm labour, and improved crop yield (Kassam et al., 2009).

This study examined conventional and conservation agriculture systems, and tested the difference in several soil health parameters between vegetable farmers who follow conventional practices and those following conservation agriculture principles. The evaluation of soil health is based on measuring physical, chemical and biological parameters identified as indicators (Doran and Parkin, 1996). Karlen et al. (2003) have proposed a conceptual framework based on an integrative view of the soil system which is opposed to the "reductionist approach that intends to assess soil health through the measurement of a set of individual soil attributes". This study analysed the soil health of CA and CT management practices by comparing soil health parameters using the 'Biofunctool package'. The Biofunctool package is a set of measurements to evaluate the effect of different management practices on soil function. The parameters used together help to assess soil health (Thoumazeau et al., 2019).

This study aimed to determine soil fauna biodiversity and soil health under conservation agriculture and conventional tillage management practices of vegetable home gardens in Northwest Cambodia.

MATERIALS AND METHODS

Study Area

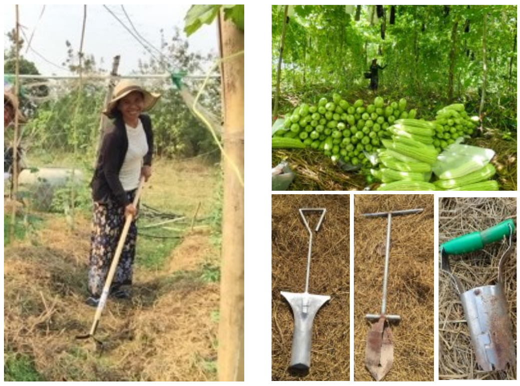
This study was conducted in Anlong Tamey village, Chheou Teal Commune, Bannan District, Battambang Province in the north-west of Cambodia. In this rural commune, there are many small vegetable plots, each family managing a variety of vegetable plots and rice paddies. Eight farmers with CA and CT-managed plots were selected for this study. For CA plots, conservation agriculture practices were applied for one year (January – December, 2018), and before this time, they were farmed conventionally in the same way as the farmers remaining plots. In other words, eight farmers agreed to change management practices and follow strict CA management for one year when selecting their vegetable plots. CT plots were selected next to CA plots to reduce variability.

Soil and farming practices

The soil was a brown cracking clay belonging to the Toul Samroung soil group (White et al., 1997) and classified as a Vertisol or Alfisol according to the USDA soil classification (Soil Quality Institute Staff, 1998). The soil characteristics and farming practices are described in Table 1.

Table 1. Soil characteristics and farming practices of conservation tillage (CT) and conservation agriculture (CA) plots in this study.

CT plot	*CA plot*
Soil conditions:	*Soil conditions:*
• Texture group: clay loam	• Texture group: clay loam
• Clay: 27.15%	• Clay: 29.61%,
• Silt: 42.64%	• Silt: 41.78%,
• Sand: 35.57%	• Sand: 22.99%
• pH: 7.54 ± 0.71	• pH: 7.11 ± 0.92
• Soil organic carbon: 1.78 ± 0.3 %	• Soil organic carbon: 2.23 ± 0.24
Farming practices	*Farming practices*
• Date of beginning: 2000 – 2022	• Date of beginning: January, 2017
• Land size: 300 m²	• Land size: 300 m²
• Raised-bed size: 1 m x 10 m x 0.2 m	• Raised-bed size: 1 m x 10 m x 0.2 m
• Land preparation: plough twice, rake once for weed cleaning per crop cycle and raise beds before planting every crop cycle.	• Land preparation: plough twice and rake once for weed cleaning, then make permanent raise-beds before planting; no more ploughing and raking for the next crop cycles, using a hole digger for

CT plot	CA plot
• Organic mulch: none • Weeding: using hoe. • Fertilizer application per crop cycle: Urea: 5 kg, DAP: 5 kg, 15-15-15: 5 kg, and cow manure: 300 kg. • Watering: using hand water sprinklers. • Crops (Lo et al., 2021): chilli pepper (*Capsicum annuum*), cucumber (*Cucumis sativus*) and eggplant (*Solanum melongena*).   	planting seedlings. • Organic mulch: rice straw (15t/ha) • Weeding: using hand tools or manual weeding to minimize soil disturbance. • Fertilizer application per crop cycle: Urea: 1 kg, DAP: 1 kg, 15-15-15: 1 kg, and bat guano: 10 kg. • Watering: drip irrigation connects to individual plant with micro pipes. • Crops (Lo et al., 2021): bitter gourd (*Momordica charantia*), cauliflower (*Brassica oleracea* var. botrytis), chilli pepper (*Capsicum annuum*), Chinese kale (*Brassica oleracea* var. *Alboglabra*), cucumber (*Cucumis sativus*), eggplant (*Solanum melongena*), okra (*Abelmoschus esculentus*), sponge gourd (*Luffa aegyptiaca*), wax gourd (*Benincasa hispida*), and yard-long bean (*Vigna unguiculata* subsp. *Sesquipedalis*).  

Soil Fauna Measurements

Soil samples were collected in February 2019 to measure soil fauna and soil health studies. A total of 50 soil samples were collected from 5 CA and 5 CT plots, with five sub-samplings made in each plot for the measurements of soil fauna. Soil was taken from the plots in an area of 25 cm^2, and a hole was dug from 0 to 30 cm. The Berlese method (Edwards and Fletcher, 1970) was used in the laboratory to extract soil fauna from 1 kg of soil from each sample. After one week, fauna samples from beakers were placed in petri dishes. Samples were assessed once a week for four weeks. Fauna samples were examined using a stereo microscope. The soil fauna was counted and classified according to the taxonomic groups' phylum, class, and order.

Soil Health Measurements

Three key function indicators were used according to the Biofunctool® package (Thoumazeau et al., 2019): carbon transformation, nutrient cycling, and soil structure maintenance (ten indicators) to provide an overall assessment of soil quality. In-field tests with bio-functional tools, two out of the ten indicators, including the water infiltration test (Lassabatère et al., 2006), aggregate stability (AggSoil) at 0 – 5 cm and 5 – 10 cm depth for the soil structure (Herrick et al., 2001) were selected. All the measurements were tested in the fields, with 8 CA and 8 CT plots.

Data Analysis

To test the significance of the difference in means of soil fauna biodiversity (abundance and richness) and soil health (aggregate stability and water infiltration). nonparametric Wilcoxon rank sum test (Wilcoxon test; Cuzick, 1985) was used to compare differences between CA and CT samples using the 'ggplot2' R package (Wickham, 2011). All statistical analyses were performed with the R statistical software version 3.6.3 (R Core Team, 2020).

RESULTS AND DISCUSSION

Soil Fauna Biodiversity

A total of twenty-one taxonomic orders of soil fauna were found in both the CA and CT plots (Fig. 1). Most soil fauna found in CA were Oribatida (54%), Mesostigmata (17%), and Polydesmida (18%), and this was higher than what was observed in CT soil samples.

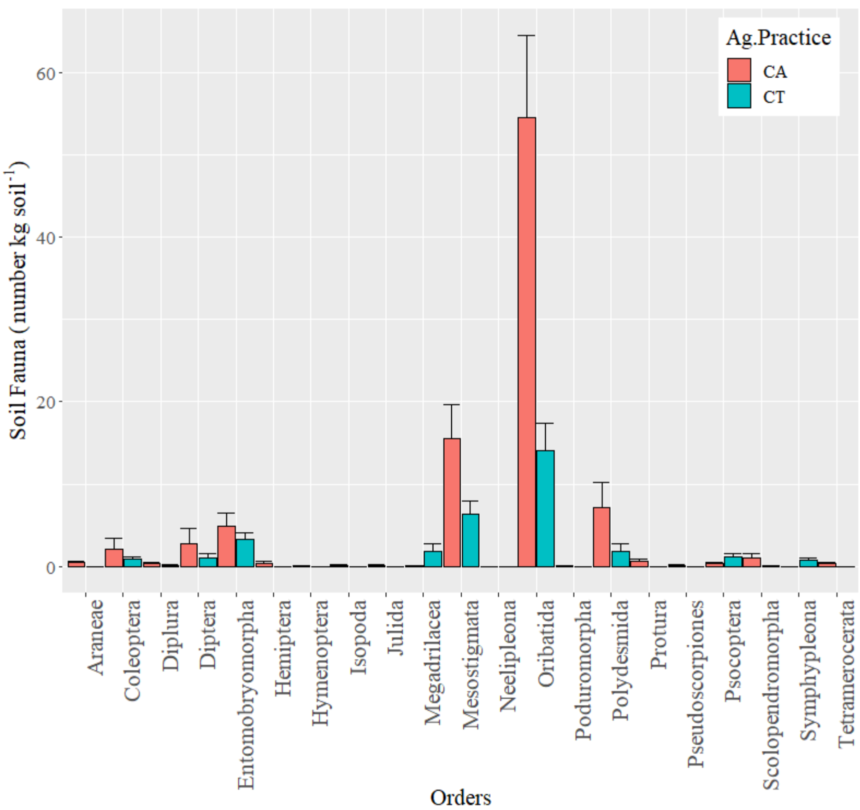


Fig. 1. Mean of soil fauna abundance in CA (Conservation Agriculture) and CT (Conventional Tillage); note: Ag.Practice – agriculture practice management.

The abundance of soil fauna was significantly greater for CA than CT (Fig. 2, left), indicating that farm management affected soil fauna abundance. In contrast, the richness of soil fauna was not significantly different between CA and CT (Fig. 2, right).

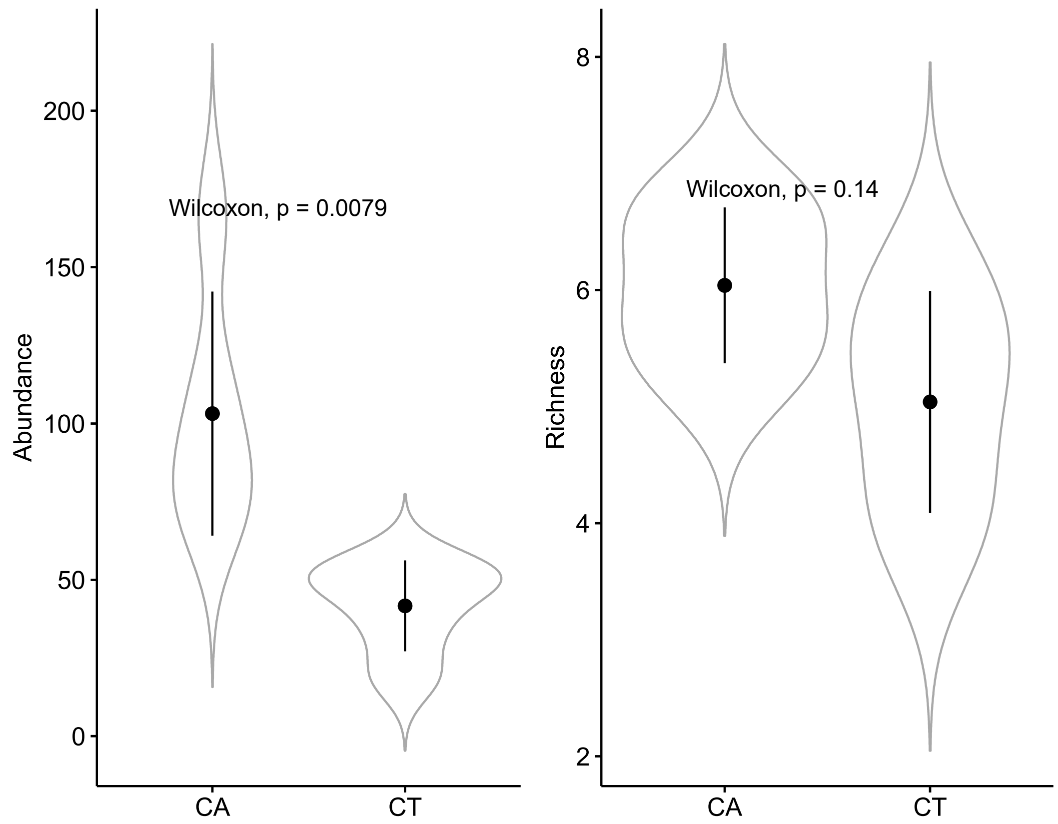


Fig. 2. Violine plots showing mean comparisons between conservation (CA) and conventional tillage (CT) for soil fauna abundance (total numbers of fauna found in one kg of fresh soil; left) and soil fauna richness (numbers of taxonomic order found in one kg of fresh soil; right) at 0 – 30 cm soil depth; (n = 5).

The most prevalent fauna orders in the CA soils were Oribatida (56%), Polydesmida (19%), and Mesostigmata (17%). In a study comparing ground-dwelling arthropod sampling, Thomas et al. (2009) found that Coleoptera (43%), Diptera (84%), Collembola (58%), and Araneae (42%) were most common. The soil in CA is covered with organic mulch, has not been tilled, and undergoes crop rotations that may support the fauna observed in the CA soil. Oribatida is a mite important in increasing microorganisms and sounds in soil organic matter degradation. They are particularly susceptible to soil mechanical disruption (Wissuwa et al., 2013). It is not surprising that we find them as a significant component in CA soils. The amount of Polydesmida millipedes in CA soils is larger than in CT soils because they like living in undisturbed forest soils. Mesostigmata are free-living predatory mites, typically found living in larger numbers in the CA soils than CT soils (Thomas et al., 2009). A total of 19 different orders were represented by soil fauna in CA soils, but only 11 were found in CT soils. This represents a 42% reduction in the diversity of soil fauna in CT soils. There was also roughly a 20% reduction in total fauna numbers in CT soils. Conservation agriculture supports larger, more diverse soil fauna populations than conventional tillage. However, cropping systems and organic matter adding to the conventional tillage affecting soil fauna biodiversity need future studies.

Soil Health

Soil structure data are presented in Table 2. Different agricultural practice management systems had significant effects (P < 0.001) on soil aggregate stability at depths 0 – 5 cm and 5 – 10 cm, respectively. At both soil depths, CA stability score was significantly higher than CT score. However, water infiltration was not significantly influenced by management systems.

Table 2. Effect of different agricultural practices on soil structure maintenance (soil aggregate stability and water infiltration).

Different practice	Aggregate stability (Units) at the soil surface (0 – 5 cm)	Aggregate stability (Units) below the soil surface (5 – 10 cm)	Water Infiltration (mL/min)
CA	5.52	5.29	334.58
CT	2.23	2.31	379.17
P value	<0.001	<0.001	0.75

(CA: conservation agriculture, CT: conventional tillage)
Note: Score from 0 to 6 for aggregate stability and mL/min for water infiltration.

Our results suggest that CA practice significantly (P < 0.01) improves soil aggregation stability at both 0 – 5 cm and 5 – 10 cm depths in comparison with CT (Table 1). Soil structural disturbance through tillage results in a breakdown of soil aggregates and accumulated turnover of aggregate encapsulated soil organic carbon (SOC) (Tivet et al., 2013). In another study, the permanent increase of biomass-C inputs with no soil disturbance in CA was a way to improve soil aggregating agents (Six et al., 2000). Therefore, CA techniques seem to increase soil organic matter in the upper layer, thus increasing the micro-aggregation, aggregate stability (Lal, 2014), and increased SOC due to aggregate encapsulation. This increase improves soil aggregate formation and protects SOC (Tivet et al., 2013). The study of Blanco-Canqui and Ruis (2018) indicated that, compared with CT, CA had the largest difference of soil aggregate stability at a depth of 0 – 5 cm and 5 – 10 cm. CA only increased soil aggregate stability in the upper 10 cm of the soil compared with CT. Soil aggregate stability initially tends to increase its structural quality near soil surface.

On the other hand, our study found a significant increase in CA even at the depth of 0 – 5 cm and 5 – 10 cm after only one year of CA management. This might be because soils in tropical regions decompose organic inputs faster due to warmer soil temperatures and more significant precipitation. Another study by Balesdent et al. (2000) also suggested that increasing soil aggregate stability might have a close relationship with microbial activity and labile C. Therefore, CA practices should increase soil aggregate stability over time, whereas CT disrupts the aggregate process with every tillage operation.

CA practices should increase the water infiltration rate by increasing the number of macro-pores and soil aggregate stability via biological activity (i.e., earthworm burrows) and decaying root channels. Table 1 indicates that CA soil water infiltration rates were not significantly different than those of CT soils. However, our confidence in the water infiltration test is low due to consistent and repeatable performance difficulties. The review of Blanco-Canqui and Ruis (2018) found that CA might not always increase the water infiltration rate and sometimes it could decrease or have no influence from practices. Many studies that did not increase infiltration rate in CA soils were in sandy or sandy loam soils, where infiltration rates are generally high and higher organic matter might slow infiltration rates. We do not have soil texture data for our soils. It seems unlikely that soil water infiltration tests helped assess functional soil attributes in CA and CT treatments. However, the CA systems used organic mulch covers, and this management practice likely improves water infiltration versus the soil often found in CT systems (Hendrix et al., 1988; Alvarez, 1995).

CONCLUSIONS

The results of this study suggest that conservation agricultural practices (CA) have a high potential to improve specific soil health parameters compared to conventional tillage (CT), and that many improvements were demonstrated after only one year of CA practices. Conservation agriculture practices have the potential to improve soil biodiversity and soil health. The soil improvement improves resilience in uncertain weather conditions and seasonal changes (too much water or drought).

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