

Long-Term Impacts of Cover Crops, Chicken Litter, and Crop Rotations on Soil Health in No-Till Systems

Xinhua Yin^{1*}, Virginia R. Sykes²

¹Department of Plant Sciences, University of Tennessee, Jackson, TN, USA

²Department of Plant Sciences, University of Tennessee, Knoxville, TN, USA

Email: *xyin2@utk.edu

How to cite this paper: Yin, X.H. and Sykes, V.R. (2024) Long-Term Impacts of Cover Crops, Chicken Litter, and Crop Rotations on Soil Health in No-Till Systems. *Open Journal of Soil Science*, 14, 675-688.
<https://doi.org/10.4236/ojss.2024.1411033>

Received: September 17, 2024

Accepted: November 3, 2024

Published: November 6, 2024

Copyright © 2024 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Identification of management practices that can improve soil health is critical to improving the sustainability of soybean [*Glycine max* (L.) Merr.] production. The objective of this study was to examine the long-term effects of continuous soybean, corn-soybean, and soybean-cotton rotations with chicken litter and cover crops (hairy vetch, wheat, fallow) on soil health parameters, including nutrient accumulation and soil organic matter dynamics under a split plot design. The depth intervals of soil sampling were 0 - 15, 15 - 30, 30 - 60, and 60 - 90 cm. Chicken litter resulted in 62.1% and 32.8% higher water extractable organic soil N content than fallow and wheat, respectively, in the surface 0 - 15 cm of soil only. However, there was no significant difference in 1-day Solvita respiration, water extractable organic C, C/N ratio, health score, moisture, earthworm, organic matter, pH, or CEC of soil among fallow, hairy vetch, chicken litter, and wheat regardless of soil depth. Unexpectedly, annual application of chicken litter at 4.4 Mg ha⁻¹ as an N source or growing a winter-season cover crop such as hairy vetch or wheat for continuous 16 years did not significantly increase soil organic matter or water extractable organic soil C. Annual application of chicken litter at 4.4 metric tons (Mg) ha⁻¹ for 16 years increased soil nitrate-nitrogen (NO₃⁻-N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), and zinc (Zn) contents by 92%, 400%, 134%, 20%, 43%, 206%, and 430% in 0 - 15 cm depth compared with their initial soil values, respectively, extracted with Haney H3A-2 (2 g L⁻¹ lithium citrate + 0.6 g L⁻¹ citric acid + 0.4 g L⁻¹ malic acid + 0.4 g L⁻¹ oxalic acid) solution. The increases enhanced soil supply of these nutrients to following crops, but also increased the risks of losing them to the environment. Hairy vetch caused higher H3A extracted soil manganese (Mn) content than fallow and chicken litter in 0 - 60 cm. There was no significant difference in 1-day

Solita respiration, water extractable organic C and N, health score, moisture, organic matter, pH, CEC, or population of earthworm of soil among continuous soybean, corn-soybean, and soybean-cotton in any soil depth. Another major finding of this study was that continuous soybean exerted no adverse effect on soil health relative to the commonly used corn (*Zea mays* L.)-soybean and soybean-cotton (*Gossypium hirsutum* L.) rotations under no-tillage after 16 years. To mitigate the risks of nutrient runoff and leaching from long-term chicken litter application, we recommend reducing litter application rates and integrating cover crops into crop rotations to enhance nutrient cycling and reduce environmental impacts.

Keywords

Cover Crops, Crop Rotations, Soil Health, Soil Profile, Fallow, Hairy Vetch, Wheat, Chicken Litter, Corn, Soybean, Cotton

1. Introduction

Concern regarding sustainable crop production and environmental quality calls for the adoption of conservation management strategies to safeguard soil, water, and air resources. Cover crops and crop rotations are among the most promising conservation practices [1]. In general, cover crops provide marked advantages over no cover crop in improving soil structure and fertility, reducing soil erosion, decreasing weed, pest, and disease incidences, lessening groundwater contamination, and lowering production costs. For instance, legume cover crops could partially replace fertilizer nitrogen (N) [2]. In loamy soils, cover crops increased the percentage of water-stable aggregates and decreased bulk density and penetration resistance [3]. Crop rotation offers significant benefits in improving soil health and productivity, distributing economic risks and workload, enhancing internal resource utilization, and reducing impacts of pests and pathogens compared with monoculture. For example, long-term experiments in various areas reported 10 to 17% yield increases when corn was grown in rotation than in monoculture [4] [5].

Chicken litter is generated in large quantities in Tennessee and many other southeastern states, and has long been used as a soil amendment that adds essential plant nutrients and organic matter to the soil [6] [7]. Farmer interest in using chicken litter in crop production has increased over the past decade, and many regularly utilize chicken litter in their management practices to address rising fertilizer costs and soil health deterioration. Although chicken litter possesses functions such as providing plant nutrients and organic matter to the soil as cover crops do, the comparisons of cover crops with chicken litter in improving soil health is rarely available.

Although various evaluations have been done during the past several decades on the effects of cover crops, chicken litter, and crop rotations on soil properties and crop productivity, most of them are based on short-term experiments [8]-

[10]. Because long-term impacts are much steadier than short-term effects [11] [12], they are substantially superior to short-term effects in being used to assess the effects of conservation practices and systems on soil health. Meanwhile, long-term studies can delineate stability and risks of management practices due to year-to-year variability in weather, pest pressure, and crop prices [12] [13]. Without such long-term information, farmers and policymakers are unlikely to make decisions and craft regulations that reflect the real impacts of conservation practices and systems on the environmental sustainability and crop productivity and profitability. Therefore, more evaluations on the long-term impacts of cover crops, chicken litter, and crop rotations, particularly their interactions, on the soil health are warranted and will be useful for making relevant decisions and policies, and predicting future soil health changes over the long run.

We hypothesized that long-term application of chicken litter would significantly increase soil nutrient availability (e.g., phosphorus) and improve soil health compared to cover crops, with crop rotations influencing nutrient cycling and organic matter retention. Thus, the objective of this study was to examine the long-term effects of cover crops, chicken litter, crop rotations, and their interactions on the soil health parameters under no-till production. This study addressed the critical gap in long-term research on soil health by comparing the effects of chicken litter and cover crops on nutrient accumulation and organic matter dynamics over 16 years under no-tillage.

2. Materials and Methods

2.1. Field Trial

An already existing long-term field experiment at the University of Tennessee Research and Education Center at Milan was used for this study in 2018. This experiment was initiated on a Loring soil (fine-silty, mixed, thermic Oxyaquic Fragiu-dalf) in 2002, and had so far been continually conducted on the same plots for 16 years. A split-block (strip plot) design with three replications was used in this study. The three soybean-related crop rotations of continuous soybean [*Glycine max* (L.) Merr.], corn (*Zea mays* L.)-soybean, and soybean-cotton (*Gossypium hirsutum* L.) were the main treatments. The four winter-season soil management practices of no bio-cover (fallow), hairy vetch (*Vicia villosa* L.), chicken litter, and wheat (*Triticum aestivum* L.) were the sub-treatments.

Wheat and fallow plots received 67 kg N ha⁻¹ yr⁻¹, while vetch plots received only 50 kg N ha⁻¹ yr⁻¹ because of calculated N contribution from hairy vetch, in the form of urea prior to the planting. Similarly, chicken litter plots received the equivalent of 67 kg N ha⁻¹ yr⁻¹ as seasonal available N from chicken litter, which meant approximately 4.4 Mg ha⁻¹ yr⁻¹ of chicken litter were applied annually, varying slightly from year to year based on actual N content. There were approximately 30.5 g N kg⁻¹, 31 g P₂O₅ kg⁻¹, and 28 g K₂O kg⁻¹ in chicken litter on average. Corn received 129 kg N ha⁻¹ yr⁻¹ as side-dress application in May - June each year. Muriate of potash (KCl) was applied to all plots in April of each year at a rate of

112 kg ha⁻¹ yr⁻¹ (K₂O rate). Nitrogen was applied via a 10 T and 1010 T Series Drop Spreader (Gandy, Owatonna, MN). Poultry litter was applied with a New Idea 3726 Series (New Idea, Coldwater, OH). Wheat and hairy vetch cover crops were planted with a John Deere 1560 drill. Row spacing was 19 cm in 13.8 by 104.6 m strips planted perpendicular to crop rows. Hairy vetch and wheat cover crops were seeded at a rate of 34 and 100 kg ha⁻¹, respectively. Cover crops were planted approximately mid-October through mid-November following the preceding summer cash crop, and then terminated with herbicides prior to planting the subsequent summer cash crop in the following year. For 2018, corn was the crop grown in corn-soybean rotation, and soybean was the crop grown in soybean-cotton rotation. Corn and soybean were planted in the selected plots on May 9, 2018. More details about treatments and management practices of this experiment are available in [6] [14] [15].

2.2. Sampling and Measurements

Composite soil samples were collected at the depth intervals of 0 - 15, 15 - 30, 30 - 60, and 60 - 90 cm with 10 cores per sample from each subplot for the analyses of soil health before corn and soybean planting during April 9-11, 2018. Soil samples were collected randomly across the subplot. The timing of sampling occurred in early April, prior to planting, after cover crops were terminated and before chicken litter was applied. The following soil health analyses were conducted on the above soil samples: 1-day soil respiration (Solvita); water extractable organic carbon (WEOC); water extractable organic nitrogen (WEON); and organic acid H3A-2 (2 g L⁻¹ lithium citrate + 0.6 g L⁻¹ citric acid + 0.4 g L⁻¹ malic acid + 0.4 g L⁻¹ oxalic acid) extractable phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), boron (B), iron (Fe), sodium (Na), aluminum (Al), phosphate (PO₄-P), and available nitrogen (N) (NO₃⁻-N, NH₄⁺-N). A soil health score was calculated for each subplot with the following equation: 1-day CO₂-C/10 + WEOC/100 + WEON/10 [16]. The soil samples collected for the above soil health tests were also used for the analyses of some basic chemical properties, which included soil pH, organic matter, and cation exchange capacity (CEC) with Mehlich 3 as the extractant.

Population of earthworms is another important measurement of soil health. Population of earthworms was determined on a subplot basis during the growing season. Sampling was done using 30 × 30 × 15 cm soil monoliths from which earthworms were sorted by hand. Two monoliths were taken from each subplot on June 14, 2018. Soil water availability is another key indicator of soil health [17]. Soil samples were collected in the top 15 cm with three samples from each subplot for the determination of soil moisture content during the late growing season on August 13, 2018.

2.3. Statistical Analysis

Analysis of variance was performed with a split block randomized complete block

design using the mixed model macro (%MMAOV) in SAS version 9.3 (SAS Institute, Cary, NC). The three crop rotations and four soil amendment treatments (cover crops and chicken litter) were whole plots and subplots, respectively, and both were treated as fixed experimental factors. The three replicates were treated as a random factor. The treatment means were separated with the Fisher's protected least significant difference (LSD). Probability values less than 0.05 for all analyses were considered significant.

3. Results and Discussion

Since no significant interactive effect was observed between cover crops, chicken litter, and crop rotations on any of the aforementioned measurements regardless of soil depth (data not shown), only the primary effects of cover crops, chicken litter, and crop rotations would be presented and discussed below.

3.1. Long-Term Effects of Cover Crops and Chicken Litter on Soil Health Parameters

Soil health results showed that there were significant differences in water extractable organic N in 0-15 cm of soil (**Table 1**), with chicken litter resulting in 62.1% and 32.8% higher water extractable organic soil N content than fallow and wheat, respectively. However, no significant difference in water extractable organic soil N was observed among the four soil management treatments in any deeper layer (data not shown).

Table 1. Long-term effects of cover crops and chicken litter on respiration, water extractable C and N, health score, moisture, organic matter, pH, and earthworm of soil in 0 - 15 cm.

Soil management	Respiration	WEOC	WEON	WEOC/WEON	Health score	Moisture	Organic matter	pH	Earthworm
	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹			g kg ⁻¹	g kg ⁻¹		counts m ⁻³
Fallow	80.2a [†]	157.7a	9.5b	17.6a	10.4a	297a	21.2a	6.1a	181a
Hairy vetch	82.0a	166.6a	11.9ab	15.1a	10.8a	287a	20.6a	6.1a	74a
Chicken litter	102.0a	182.9a	15.4a	13.9a	13.3a	300a	22.8a	6.4a	126a
Wheat	94.0a	169.5a	11.6b	15.9a	12.0a	280a	21.8a	6.1a	63a
Significance	ns	ns	*	ns	ns	ns	ns	ns	ns

WEOC, water extractable organic C; WEON, water extractable organic N.[†] Means in a column followed by different letters are significantly different with Fisher's protected least significant difference (LSD) at 0.05 probability level. Significance indicates statistical significance for the F test at 0.05 probability level. *, significant at 0.05 probability level; ns, not significant at 0.05 probability level.

Chicken litter plots received the equivalent of 67 kg N ha⁻¹ yr⁻¹ as seasonal available N from chicken litter, which meant 4.4 Mg ha⁻¹ yr⁻¹ of chicken litter were applied annually as 50% bioavailability of N was assumed for the present season. Although there were as much as 67 kg N ha⁻¹ yr⁻¹ of unavailable N applied per growing season, these N would gradually become available for plant uptake during

the following seasons. That is why chicken litter treatment had significantly higher water extractable organic soil N content in 0 - 15 cm than fallow and wheat after 16 years of treatment imposition.

There was no significant difference in 1-day respiration (Solvita), water extractable organic C, C/N ratio, health score, moisture, or earthworm of soil among fallow, hairy vetch, chicken litter, and wheat regardless of soil depth (only data in the 0 - 15 cm layer are presented in **Table 1**). Meanwhile, soil organic matter and pH (**Table 1**) or CEC (data not shown) did not differ among the cover crops, chicken litter, and no cover in any depth.

Unexpectedly, annual application of chicken litter at 4.4 Mg ha⁻¹ as an N source or growing a winter-season cover crop such as hairy vetch or wheat since 2002 did not significantly increase soil organic matter or water extractable organic soil C in 2018. The possible explanation for the above phenomenon might lie in that both chicken litter and above-ground biomass of cover crops were returned to the soil surface without any incorporation into the soil profile under no-tillage, which would cause quick decomposition of chicken litter and cover crops into inorganic substances under humid and warm weather conditions in Tennessee. In addition, the soil samples in this study were collected in April 2018 before chicken litter was applied and the cover crops were just terminated, which might have partially caused the insignificant differences in soil organic matter and water extractable organic soil C among the cover crops, chicken litter, and no cover.

Similarly, Adeli *et al.* (2019) found that chicken litter application increased soil nitrate content relative to fallow at the 0 - 15 cm soil depth in spring before cotton planting in Mississippi [18]. Chalise *et al.* (2018) reported in a northern state of South Dakota that a mixture of winter rye (*Secale cereale L.*) and hairy vetch as cover crop did not increase soil organic C in 0 - 15 cm relative to no cover crop [19]. Blanco-Canqui and Jasa (2019) observed in Nebraska that legume cover crops had no effects on soil properties but grass-cover crops increased soil organic matter after 12 years [20]. Abdollahi and Munkholm (2014) reported in Denmark that a fodder radish cover crop did not increase soil organic C or total N relative to no cover in 0 - 10 or 10 - 20 cm [21]. Studies in different areas showed that soil moisture content during the growing season of the following crop was similar under a winter-season cover crop cover relative to no cover [19] [20] [22].

3.2. Long-Term Effects of Cover Crops and Chicken Litter on H3A Extracted Macronutrients in Soil

There were significant differences in soil NO₃⁻-N content in 0 - 15 cm, P and K in 0 - 15 and 15 - 30 cm depths, Ca in 0 - 15 cm, Mg in 0 - 15, 15 - 30, and 30 - 60 cm, and S in 15 - 30 and 60 - 90 cm with H3A as the extractant among the four soil management treatments (**Table 2**). Specifically, hairy vetch, chicken litter, and wheat resulted in higher NO₃⁻-N content than fallow in 0 - 15 cm. Significantly

higher P and K levels were observed under chicken litter than fallow, hairy vetch, and wheat in the 0 - 15 and 15 - 30 cm depths. Chicken litter caused significant higher Ca content than fallow, hairy vetch, and wheat in 0 - 15 cm. Magnesium content was significant higher with chicken litter than fallow, hairy vetch, and wheat in 0 - 15 cm, and hairy vetch and wheat in 15 - 30 cm. Sulfur content was significantly higher under chicken litter than hairy vetch and wheat in 15 - 30 cm and the other three soil management treatments in 60 - 90 cm.

Table 2. Long-term effects of cover crops and chicken litter on H3A extracted macronutrients in soil.

Soil depth (cm)	Soil management	H3A extracted macronutrients						
		NO ₃ ⁻ -N	NH ₄ ⁺ -N	P	K	Ca	Mg	S
		mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
0 - 15	Fallow	0.63b [†]	1.04a	23.7b	45.8b	133.9b	38.7b	13.0a
	Hairy vetch	1.10a	1.23a	25.2b	35.2b	125.1b	32.4b	10.3a
	Chicken litter	1.21a	1.06a	118.6a	107.2a	160.8a	55.4a	14.9a
	Wheat	1.15a	1.29a	35.0b	55.3b	141.6b	36.1b	11.3a
	Significance	*	ns	***	**	***	***	ns
15 - 30	Fallow	1.12a	1.20a	13.2b	26.6b	136.2a	36.6ab	19.3ab
	Hairy vetch	1.34a	1.24a	16.4b	28.9b	135.2a	28.4c	14.9b
	Chicken litter	1.00a	1.28a	38.4a	57.8a	122.7a	39.2a	27.0a
	Wheat	0.99a	1.37a	16.8b	30.4b	131.8a	33.2bc	15.8b
	Significance	ns	ns	**	**	ns	**	*
30 - 60	Fallow	1.47a	1.07a	10.7a	20.1a	119.8a	43.4a	36.9a
	Hairy vetch	1.94a	2.76a	10.9a	28.8a	115.4a	32.1b	26.1a
	Chicken litter	1.08a	1.04a	14.2a	30.0a	114.8a	40.0ab	43.7a
	Wheat	1.82a	1.24a	9.4a	19.1a	114.1a	30.7b	23.9a
	Significance	ns	ns	ns	ns	ns	*	ns
60 - 90	Fallow	1.23a	1.16a	10.8a	22.8a	95.8a	47.1a	27.0b
	Hairy vetch	2.13a	1.86a	12.0a	44.7a	90.6a	45.1a	24.6b
	Chicken litter	1.29a	1.10a	11.9a	23.3a	109.4a	44.7a	45.8a
	Wheat	1.51a	1.10a	9.6a	25.4a	86.9a	37.8a	23.8b
	Significance	ns	ns	ns	ns	ns	ns	*

[†] Means within a soil depth in a column followed by different letters are significantly different with Fisher's protected LSD at 0.05 probability level. Significance indicates statistical significance for the F test at 0.05 probability level. *, significant at 0.05 probability level; **, significant at 0.01 probability level; ***, significant at 0.001 probability level; ns, not significant at 0.05 probability level

Because chicken litter contains N, P, K, Ca, Mg, and S, the contents of these nutrients were higher in some soil depths under chicken litter than the other soil management treatments. It was obvious that the annual application of chicken litter at 4.4 Mg ha⁻¹ as an N source since 2002 resulted in tremendous accumulation of P in 0 - 15 cm (Figure 1), which would increase the risk of losing P to the environment. In addition, annual application of chicken litter at 4.4 Mg ha⁻¹ as an N source since 2002 also resulted in a tremendous accumulation of K in 0 - 15 cm (Figure 2).

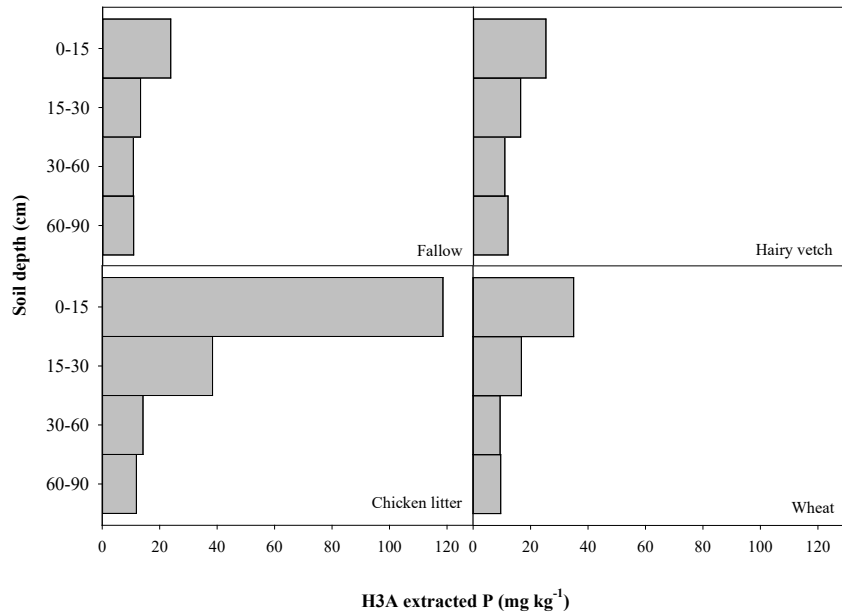


Figure 1. Long-term effects of cover crops and chicken litter on H3A extracted P.

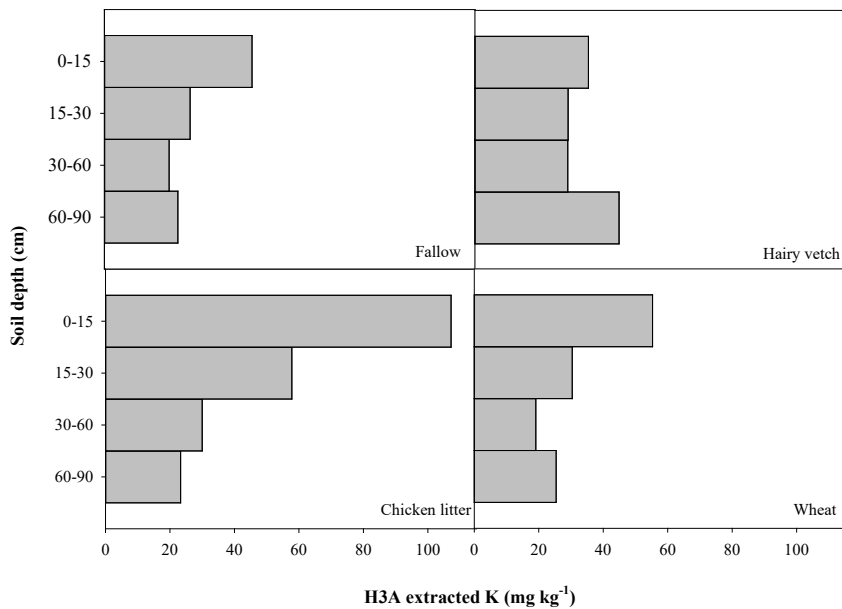


Figure 2. Long-term effects of cover crops and chicken litter on H3A extracted K.

Schomberg *et al.* (2009) in Georgia found that after ten-year application of chicken litter at 4.4 Mg ha⁻¹ yr⁻¹ (1995-2000) and 11.2 Mg ha⁻¹ yr⁻¹ (2001-2005), soil nutrient contents in the surface 15 cm reflected 25, 4, 45, and 26% of the input from chicken litter for P, K, Ca, and Mg, respectively [23]. Moore and Edwards (2007) observed that the long-term use of alum with chicken litter reduced P runoff and leaching [7]. Dozier *et al.* (2017) found that soil properties, including soil organic matter, pH, inorganic N, and available P and K were generally unaffected by the use of cover crops [24]. Abdollahi and Munkholm (2014) reported that a fodder radish cover crop did not increase available soil P and K relative to no cover in 0 - 10 or 10 - 20 cm [21].

3.3. Long-Term Effects of Cover Crops and Chicken Litter on H3A Extracted Micronutrients in Soil

Significant effects of cover crops and chicken litter were observed on Mn content in 0 - 15, 15 - 30, and 30 - 60 cm, Cu and Zn in 0 - 15 and 15 - 30 cm, and Fe in 60 - 90 cm with H3A as the extractant (Table 3). It was interesting to note that hairy vetch resulted in significantly higher Mn content than fallow and chicken litter in 0 - 15, 15 - 30, and 30 - 60 cm (Table 3). Chicken litter caused higher Cu and Zn levels than fallow, hairy vetch, and wheat in 0 - 15 and 15 - 30 cm depths. Soil Fe content was higher with hairy vetch than fallow, chicken litter, and wheat in 60 - 90 cm.

Table 3. Long-term effects of cover crops and chicken litter on H3A extracted micronutrients in soil.

Soil depth (cm)	Soil management	H3A extracted micronutrients				
		Mn	Cu	Zn	B	Fe
		mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
0 - 15	Fallow	17.8c [†]	0.54b	0.66b	0.38a	135.8a
	Hairy vetch	43.3a	0.60b	0.75b	0.43a	159.2a
	Chicken litter	25.9bc	1.65a	3.50a	0.51a	148.3a
	Wheat	33.7ab	0.66b	0.91b	0.55a	200.1a
	Significance	***	***	***	ns	ns
15 - 30	Fallow	12.1c	0.45c	0.43b	0.31a	107.9a
	Hairy vetch	44.8a	0.59b	0.56b	0.37a	151.7a
	Chicken litter	19.6bc	0.86a	1.13a	0.39a	105.7a
	Wheat	35.0ab	0.65b	0.66b	0.35a	147.6a
	Significance	**	***	*	ns	ns
30 - 60	Fallow	6.0b	0.55a	0.41a	0.34a	107.2a
	Hairy vetch	14.9a	0.62a	0.60a	0.38a	150.6a
	Chicken litter	7.7b	0.58a	0.44a	0.31a	98.9a
	Wheat	10.2ab	0.61a	0.41a	0.28a	110.6a
	Significance	*	ns	ns	ns	ns

Continued

	Fallow	8.2a	0.65a	0.42a	0.33a	121.9b
	Hairy vetch	8.7a	0.73a	0.92a	0.58a	264.0a
60 - 90	Chicken litter	7.6a	0.68a	0.55a	0.37a	107.1b
	Wheat	6.2a	0.67a	0.55a	0.38a	160.8b
	Significance	ns	ns	ns	ns	*

† Means within a soil depth in a column followed by different letters are significantly different with Fisher's protected LSD at 0.05 probability level. Significance indicates statistical significance for the F test at 0.05 probability level. *, significant at 0.05 probability level; **, significant at 0.01 probability level; ***, significant at 0.001 probability level; ns, not significant at 0.05 probability level.

Higher Mn content in the form of Mn^{2+} in 0 - 15, 15 - 30, and 30 - 60 cm of soil with hairy vetch than fallow and chicken litter might be related to the fact that soil moisture content was higher under cover of hairy vetch residues on the soil surface than fallow and chicken litter, which resulted in less oxygen content in the soil, and thus increased the reduction of Mn^{4+} to Mn^{2+} , the latter was the form of Mn measured in this study. Higher soil Mn content in 0-60 cm with hairy vetch than fallow and chicken litter would be beneficial for improving Mn nutrition of the following crops on Mn-deficient soils. Schomberg *et al.* (2009) reported in Georgia that after a ten-year application of chicken litter at $4.4 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ (1995–2000) and $11.2 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ (2001-2005), soil nutrient contents in the surface 15 cm reflected 17 and 97% of the input from chicken litter for Mn and Zn, respectively [23].

Overall, the large increases of available P and Zn in soil because of chicken litter application may be of concern due to the agronomic and environmental implications of excessive accumulation of these two nutrients. However, movements of P, K, Ca, Mg, Cu, and Zn were generally limited to the top 30 cm of soil, which indicates a limited potential for movements of these nutrients to greater depths following long-term chicken litter application in this fine silty soil. Therefore, reducing runoff losses of soil nutrients appears to be the more effective approach to target for protecting the environment.

3.4. Long-Term Effects of Crop Rotations on Soil Health Parameters

There was no significant difference in 1-day respiration (Solvita), water extractable organic C and N, health score, moisture, organic matter, pH, CEC, or population of earthworm of soil among continuous soybean, corn-soybean, and soybean-cotton in any soil depth (data not shown). Meanwhile, H3A extracted macronutrients or micronutrients generally did not differ among the three crop rotation treatments regardless of soil depth (data not shown).

Zuber *et al.* (2015) found that corn-soybean rotation resulted in similar soil organic C and total N as continuous soybean [25]. Although soybean in rotation with corn or cotton did not improve soil health compared with continuous

soybean in this study, rotational soybean might still offer significant benefits in distributing economic risks and workload, improving internal resource utilization, and reducing impacts of pests and pathogens relative to continuous soybean.

Although corn produced much more biomass and returned much more crop residues to the field than soybean, it was unexpectedly noted that corn-soybean rotation did not significantly increase soil organic matter or water-extractable organic soil C in any depth relative to continuous soybean after 16 years of no-till production. The possible interpretation for this phenomenon might lie in that the aboveground residues of corn and soybean were returned to the soil surface without any incorporation into the soil profile under no-tillage, which would cause quick decomposition of crop residues into inorganic substances under humid and warm weather conditions in Tennessee. Because the return of crop residues on soil surface without incorporation into soil had a greater impact on shallower soil depth, corn-soybean rotation might have higher soil organic matter or water extractable organic soil C content than continuous soybean if a shallower soil sampling depth, such as 0 - 2.5 or 0 - 5 cm was used in this study. Different soil amendments have varying effects on crop growth, yield, and soil properties [9] [26]. To mitigate the risks of nutrient runoff and leaching from long-term chicken litter application, we recommend reducing litter application rates and integrating cover crops into crop rotations to enhance nutrient cycling and reduce environmental impacts. Our results suggest that over-application of chicken litter might result in greater accumulation of nutrients such as NO_3^- -N, P, K, Ca, Mg, Cu, and Zn. Our study is among the few that assess the long-term effects of organic amendments and cover crops on soil health in a no-tillage system, providing valuable insights for other agroecological zones, including regions with different climatic conditions.

4. Conclusions

Chicken litter resulted in 62.1% and 32.8% higher water extractable organic soil N content than fallow and wheat, respectively, in the surface 0 - 15 cm of soil only. However, there was no significant difference in 1-day Solvita respiration, water extractable organic C, C/N ratio, health score, moisture, earthworm, organic matter, pH, or CEC of soil among fallow, hairy vetch, chicken litter, and wheat regardless of soil depth. Unexpectedly, annual application of chicken litter at 4.4 Mg ha^{-1} as an N source or growing a winter-season cover crop such as hairy vetch or wheat for continuous 16 years did not significantly increase soil organic matter or water extractable organic soil C.

Annual application of chicken litter at 4.4 Mg ha^{-1} as an N source for 16 years significantly increased H3A extracted NO_3^- -N, P, K, Ca, Mg, Cu, and Zn contents in the 0 - 15 cm of soil by 92.1%, 400.4%, 134.1%, 20.1%, 43.2%, 205.6%, and 430.3%, respectively, relative to fallow. These increases would be beneficial for improving soil supply of these nutrients to the following crops. In addition, hairy vetch resulted in higher H3A extracted soil Mn content in 0 - 60 cm than fallow

and chicken litter, which would be beneficial for improving Mn nutrition of the following crops on Mn deficient soils. To mitigate the risks of nutrient runoff and leaching from long-term chicken litter application, we recommend reducing litter application rates and integrating cover crops into crop rotations to enhance nutrient cycling and reduce environmental impacts. There was no significant difference in 1-day Solvita respiration, water extractable organic C and N, health score, moisture, organic matter, pH, CEC, or population of earthworm of soil among continuous soybean, corn-soybean, and soybean-cotton in any soil depth. Meanwhile, H3A extracted macronutrients or micronutrients generally did not differ among the three crop rotations regardless of soil depth. Thus, another major finding of this study was that soybean in rotation with corn or cotton resulted in similar soil health status as continuous soybean after 16 years, which suggests growing soybean continuously year by year exerts no adverse effect on soil health relative to the commonly used corn-soybean and soybean-cotton rotations under no-tillage.

Acknowledgments

We acknowledge the support of this study by the United Soybean Board. We are grateful to Mr. Robert Sharp and the staff of the University of Tennessee Research and Education Center at Milan for their technical assistance.

Conflicts of Interest

The authors declare none.

References

- [1] Drury, C.F., Tan, C., Welacky, T.W., Oloya, T.O., Hamill, A.S. and Weaver, S.E. (1999) Red Clover and Tillage Influence on Soil Temperature, Water Content, and Corn Emergence. *Agronomy Journal*, **91**, 101-108. <https://doi.org/10.2134/agronj1999.00021962009100010016x>
- [2] Blevins, R.L., Herbek, J.H. and Frye, W.W. (1990) Legume Cover Crops as a Nitrogen Source for No-Till Corn and Grain Sorghum. *Agronomy Journal*, **82**, 769-772. <https://doi.org/10.2134/agronj1990.00021962008200040023x>
- [3] Villamil, M.B., Bollero, G.A., Darmody, R.G., Simmons, F.W. and Bullock, D.G. (2006) No-Till Corn/Soybean Systems Including Winter Cover Crops. *Soil Science Society of America Journal*, **70**, 1936-1944. <https://doi.org/10.2136/sssaj2005.0350>
- [4] Higgs, R.L., Peterson, A.E. and Paulson, W.H. (1990) Crop Rotation: Sustainable and Profitable. *Journal of Soil and Water Conservation*, **45**, 68-70.
- [5] Mannering, J.V. and Griffith, D.R. (1981) Value of Crop Rotation under Various Tillage Systems. Agronomy Guide AY-230. Cooperative Extension Service, Purdue University.
- [6] Ashworth, A.J., Allen, F.L., Saxton, A.M. and Tyler, D.D. (2016) Long-Term Corn Yield Impacted by Cropping Rotations and Bio-Covers under No-Tillage. *Agronomy Journal*, **108**, 1495-1502. <https://doi.org/10.2134/agronj2015.0453>
- [7] Moore, P.A. and Edwards, D.R. (2007) Long-Term Effects of Poultry Litter, Alum-treated Litter, and Ammonium Nitrate on Phosphorus Availability in Soils. *Journal*

- of Environmental Quality*, **36**, 163-174. <https://doi.org/10.2134/jeq2006.0009>
- [8] Almeida, T.F., Robinson, E., Matthiesen-Anderson, R., Robertson, A.E. and Basche, A. (2024) Effect of Cover Crop Species and Termination Timing on Corn Growth and Seedling Disease. *Agronomy Journal*, **116**, 1792-1803. <https://doi.org/10.1002/agj2.21601>
- [9] Ddamulira, G., Malaala, A., Otim, A., Florence, N. and Maphosa, M. (2022) Soil Amendments Improved Tomato Growth, Yield and Soil Properties. *American Journal of Plant Sciences*, **13**, 960-971. <https://doi.org/10.4236/ajps.2022.137063>
- [10] Bashyal, M., Mulvaney, M.J., Devkota, P., Wilson, C., Iboyi, J.E., Leon, R.G., *et al.* (2023) Summer Crop Rotational Effects on Carinata Nitrogen Management in the Southeastern USA. *Agronomy Journal*, **115**, 2030-2043. <https://doi.org/10.1002/agj2.21373>
- [11] Mitchell, C.C., Westerman, R.L., Brown, J.R. and Peck, T.R. (1991) Overview of Long-Term Agronomic Research. *Agronomy Journal*, **83**, 24-29. <https://doi.org/10.2134/agronj1991.00021962008300010010x>
- [12] Stanger, T.F. and Lauer, J.G. (2008) Corn Grain Yield Response to Crop Rotation and Nitrogen over 35 Years. *Agronomy Journal*, **100**, 643-650. <https://doi.org/10.2134/agronj2007.0280>
- [13] Grover, K.K., Karsten, H.D. and Roth, G.W. (2009) Corn Grain Yields and Yield Stability in Four Long-Term Cropping Systems. *Agronomy Journal*, **101**, 940-946. <https://doi.org/10.2134/agronj2008.0221x>
- [14] Ashworth, A.J., Allen, F.L., Wight, J.P., Saxton, A.M., Tyler, D.D. and Sams, C.E. (2014) Soil Organic Carbon Sequestration Rates under Crop Sequence Diversity, Bio-covers, and No-Tillage. *Soil Science Society of America Journal*, **78**, 1726-1733. <https://doi.org/10.2136/sssaj2013.09.0422>
- [15] Ashworth, A.J., Allen, F.L., Saxton, A.M. and Tyler, D.D. (2017) Impact of Crop Rotations and Soil Amendments on Long-Term No-Tilled Soybean Yield. *Agronomy Journal*, **109**, 938-946. <https://doi.org/10.2134/agronj2016.04.0224>
- [16] Haney, R.L. and Haney, E.B. (2015) Estimating Potential Nitrogen Mineralisation Using the Solvita Soil Respiration System. *Open Journal of Soil Science*, **5**, 319-323. <https://doi.org/10.4236/ojss.2015.512030>
- [17] Singh, S., Jagadamma, S., Yoder, D., Yin, X. and Walker, F. (2021) Cropping System Management Responses to Cornell and Alabama Soil Health Assessment Methods in the Southeastern United States. *Soil Science Society of America Journal*, **86**, 106-117. <https://doi.org/10.1002/saj2.20357>
- [18] Adeli, A., Brooks, J.P., Read, J.J., Shankle, M.W., Feng, G. and Jenkins, J.N. (2019) Poultry Litter and Cover Crop Integration into No-Till Cotton on Upland Soil. *Agronomy Journal*, **111**, 2097-2107. <https://doi.org/10.2134/agronj2018.05.0328>
- [19] Chalise, K.S., Singh, S., Wegner, B.R., Kumar, S., Pérez-Gutiérrez, J.D., Osborne, S.L., *et al.* (2019) Cover Crops and Returning Residue Impact on Soil Organic Carbon, Bulk Density, Penetration Resistance, Water Retention, Infiltration, and Soybean Yield. *Agronomy Journal*, **111**, 99-108. <https://doi.org/10.2134/agronj2018.03.0213>
- [20] Blanco - Canqui, H. and Jasa, P.J. (2019) Do Grass and Legume Cover Crops Improve Soil Properties in the Long Term? *Soil Science Society of America Journal*, **83**, 1181-1187. <https://doi.org/10.2136/sssaj2019.02.0055>
- [21] Abdollahi, L. and Munkholm, L.J. (2014) Tillage System and Cover Crop Effects on Soil Quality: I. Chemical, Mechanical, and Biological Properties. *Soil Science Society of America Journal*, **78**, 262-270. <https://doi.org/10.2136/sssaj2013.07.0301>
- [22] Krueger, E.S., Ochsner, T.E., Porter, P.M. and Baker, J.M. (2011) Winter Rye Cover

- Crop Management Influences on Soil Water, Soil Nitrate, and Corn Development. *Agronomy Journal*, **103**, 316-323. <https://doi.org/10.2134/agronj2010.0327>
- [23] Schomberg, H.H., Endale, D.M., Jenkins, M.B., Sharpe, R.R., Fisher, D.S., Cabrera, M.L., *et al.* (2009) Soil Test Nutrient Changes Induced by Poultry Litter under Conventional Tillage and No-Tillage. *Soil Science Society of America Journal*, **73**, 154-163. <https://doi.org/10.2136/sssaj2007.0431>
- [24] Dozier, I.A., Behnke, G.D., Davis, A.S., Nafziger, E.D. and Villamil, M.B. (2017) Tillage and Cover Cropping Effects on Soil Properties and Crop Production in Illinois. *Agronomy Journal*, **109**, 1261-1270. <https://doi.org/10.2134/agronj2016.10.0613>
- [25] Zuber, S.M., Behnke, G.D., Nafziger, E.D. and Villamil, M.B. (2015) Crop Rotation and Tillage Effects on Soil Physical and Chemical Properties in Illinois. *Agronomy Journal*, **107**, 971-978. <https://doi.org/10.2134/agronj14.0465>
- [26] Ighovie Efe, S. and Edwin Okpali, A. (2012) Management of Petroleum Impacted Soil with Phytoremediation and Soil Amendments in Ekpan Delta State, Nigeria. *Journal of Environmental Protection*, **3**, 386-393. <https://doi.org/10.4236/jep.2012.35048>