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Response of Soil Properties to Land Use Change from Wheat to Pig Production

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Abstract

A significant change in land use has been a continued increase in large, intensive outdoor pig production which is largely fueled by increased economic and market forces. While this change has solved the need for animal welfare, customer satisfaction of natural and organic pork and the need for reduced capital input to sustain business for farmers, the environment, however, stand at no gain to the present moment. Increased accumulation of N surplus in soil has continued to increase leaching propensity, threatening surface water pollution. In this study, an investigation was conducted at Field Research Unit, University of Leeds Farm Ltd to determine the possible changes on soil from transformation from wheat to pig production. Soil core samples were collected from two paddocks Gilt and Gilt Train each stocked with 30 gestating sows ha^{-1} for 3 and 2 weeks respectively, and from adjacent analogous field without animals (control) at 0 – 5 cm depth before and after the introduction of pigs. Soil pH, soil texture, soil moisture, soil dry matter, water holding capacity, soil organic matter and N mineralization were measured. Laboratory analysis on soil pH and soil texture indicated that there was no change in the two soil properties from before and after the introduction of pigs. One-way analysis of variance (ANOVA) conducted on samples before the pig introduction (n=18) to determine difference in space, indicated that moisture content ($P<0.05$), dry matter content ($P<0.05$) and N mineralization ($P<0.0005$) were significantly different in soils under Gilt, Gilt Train and control. No significant difference was observed in case of water holding capacity ($P=0.252$) and soil organic matter ($P=0.077$). The one-way ANOVA result for samples after the introduction (n=18) revealed no significant difference ($P>0.05$) in any of the soil properties mentioned under the three soils treatments. One-way repeated measures ANOVA were also employed to determine change in time. Similar soil properties were compared and the results showed that, moisture content ($P<0.0005$), dry matter content ($P<0.0005$) and N mineralization ($P<0.05$) were statistically significantly different under soils in time. However, transformation did not elicit statistically significant change under soils in water holding capacity ($P=0.905$) and soil organic matter ($P=0.477$). Overall, this short term finding demonstrated that land use change from arable crop to outdoor pigs production had no effect on soil physical properties. Low organic matter deposition from the pigs had affected the rate of N mineralization and consequently the soil moisture and the dry matter content of the soils. Moisture content and dry matter could also be affected by the frequency and intensity of pigs treading, which causes compaction. Subsequent studies could measure compaction effect from outdoor pig system.

Keywords: Moisture content; soil quality; biodiversity; Pollution; Mineralization

Introduction

Changes in agricultural land use have been a focus of research for many years because of its role in affecting soil fertility and related properties (e.g. soil organic carbon, soil nitrogen and phosphorus, soil bulk density) and ultimately the value of ecosystem services [1-4]. A major change has been a continued interest among pig farmers for a large scale, intensive outdoor production which is driven by increased economic and market forces [5]. These forces fueled by demands for animal welfare, minimal capital input needed to sustain the industries, and consumers preference for a more natural and organic pork have compounded these increase as compared to indoor production [6,7]. In the United Kingdom, for example, the proportion of sows in pigs breeding herds increased from 69% in 2012 to 71% in 2015, and that of dry sows increased from 14% to 16% [8]. The current estimate was 42% outdoor breeding herds [9]. While this farming system have continued to attract farmers (e.g. for its animal welfare and low capital investment) [10], concerns about environmental impacts (e.g. as nitrate losses via leaching, runoff and gaseous emissions) threatening ecosystems is also growing [11]. The intensity in outdoor pig production, coupled with insufficient management practice transpired into these environmental problems [7]. The present day practice in terms of dietary provision and stocking density can cause high levels of nutrients to build on free draining soil, especially when vegetation is removed from paddocks by sows foraging activity [7]. Foraging behaviour of pigs, especially when in large density can also lead to widespread soil and vegetation damage. Consequently, this would translate into reduced composition in vegetation as a result of treading and selective grazing [7].

Soil quality assessment is a major tool of sustainable agricultural land management that helps to evaluate both spatial and temporal patterns of variation in soil physical properties [12]. Soil quality indicators are measurable soil attributes that influence the capability of the soil to sustain crop production and biodiversity [13,14], livestock production [15,16] or environmental function [4,17]. These measurable attributes of the soil could be physical, chemical and/or biological parameters [4,18]. Measured changes in the soil properties, for example trend of change (increase or decrease, positive or negative), extent of change (percentage over a baseline values or rates of change), and/or duration of change could be used as indicators for assessing agricultural land management [12,14].

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Land use or land cover management with increased agricultural inputs and livestock operations has been linked to be an important source of N, P and sediments transport from catchments and has often been pointed as a major cause of surface water pollution [1,3]. Nitrogen and phosphorus are valuable nutrient inputs needed to sustain the productivity of agro-ecosystems, the mobilization of both nutrients, however, can have harmful effects on water systems. Eutrophication in surface waters (e.g. dams, lakes, estuaries and rivers) in addition to other physico-chemical factors (e.g. increased water inflow due to high rainfall and stratification) can cause algal blooms. This situation depletes the water of dissolved oxygen, reduces its aesthetic value, increases toxicity and consequently loss of, and changes in, species diversity [15,19]. Nutrient transport is highly dependent on runoff rate, which in turn is affected by numerous other factors such as rainfall, temperature, and antecedent soil moisture content [1]. Chichester [20] observed that nitrogen losses in runoff were highest in the summer when rainfall intensity increased within a short time of fertilizer application. Also amount of N transported in surface water decreased as the amount of effective soil cover increased. However, leaching of N often occurs as a result of high N concentrations from grazing animal urine patches, rather than from direct fertilizer influx [19]. Soil nitrogen is readily available in soil organic matter (SOM) and is not utilized by plants or leached out to waters unless mineralized to nitrate or ammonium by soil organisms. Therefore, as soil organisms decompose organic matter, nutrients are transformed into dissolved inorganic substances that plants can use. This process, referred to as mineralization, supplies the plants with much of the nitrogen essential for growth and development. Soil organisms are therefore important agents for improving soil fertility in that they help supplement the plants with nutrients by freeing them from bonded organic molecules. For example, proteins undergoes conversion process to ammonium (NH_4^+) and then to nitrate (NO_3^-) [2,4]. The mineralization of organic matter is also an important pathways where nutrients such as phosphorus and sulphur, and pool of other micronutrients (e.g. iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl) and nickel (Ni)) are supplied to plants [1,4,19]. Soil organic matter, therefore, is a major source of nutrients to plants and can influence soil physical properties, such as infiltration rate, structure and water holding capacity [12]. Furthermore, if soil organisms are absent or inactive, more fertiliser will be required as supplements for plants which will further engender risk of nutrients and sediment transport to surface and subsurface waters [4]. Indeed, soil pH maintains nutrient supply to plants, root development and fertilizer utilization efficiency, which consequently affects the use of water by plants [15]. Moreover, N application to grasslands can present risks of N loss into the ecosystem in the form of N_2O emission with significant consequence on climate change [21].

Integration of crops with livestock can promote organic matter in the soil, however, the possibility for livestock to cause soil damage or compaction is also of growing concern among many mixed crop-livestock farmers [22]. The situation translates into reduced macro-porosity and infiltration rate, which subsequently increases the rate of surface runoff [16,19,22,23]. Damage of soil from grazing livestock can affect dry matter contents which act as soil cover, through burying, crushing and bruising of leaves thereby increasing the susceptibility of nutrients loss to ecosystems [24]. Soil compaction is the compression of an unsaturated soil body causing a breakdown in the soil inter-aggregate and consequently leading to reduced soil porosity [19]. Compaction of soil from grazing livestock varies in intensity and is defined by soil type, moisture content of the soil, and the rate and type of stocking animals, with effects most obvious between 5 and 10 cm depth in the soil profile [16,24,25]. Greenwood [26] observed the effects of sheep stocking rates on soil physical properties (hydraulic conductivity, soil strength and bulk density) in a long term grazing trial and found that compaction by sheep was confined to the upper 5 cm of the soil profile which resulted into a decreased porosity, largely due to loss of pores that are greater than 1.2 mm equivalent diameter. However, in a follow up study after 30 years and with stocking rate of 10, 15 and 20 sheep/ha, grazed pastures were observed to have similar soil physical properties, and therefore, soil physical properties appear to be relatively irresponsive to long term stocking rate. Poaching or puddling in contrast to compaction, describes the slurry state of soil under wet condition when compressed by grazing animals [19]. Pugging in very wet soil by grazing livestock produces deep hoof marks and is often linked with decreased pasture re-growth [16,19]. Soil physical degradation at 5 cm depth can naturally be improved quickly through the burrowing actions of high concentration of soil macro-invertebrates connected with dung decomposition [19]. For example, Herrick and Lal [27] observed an increased air-filled porosity and infiltration rate and a decreased bulk density at 3 cm topsoil under cattle dung patches. Several studies conducted around the world revealed the effects of outdoor production of livestock on soil properties and environmental quality: pigs [14,28], dairy and sheep [24,29], deer [23,30] or even heavy farm machinery [30-32], only few or none of these studies considers short term effects of outdoor pig production on soil physical properties (e.g. soil organic matter or mineralizable N). Here, we tested the null hypothesis that, there would be no change in soil physical properties (mineralized nitrogen, soil organic matter, soil moisture content, water holding capacity, soil texture by particle size and soil pH) when measured before and after replacing an arable crop with outdoor pig production, compared with a control in a short-term study (3 weeks).

Materials and Methods

Field sites and sampling

The study site was established at Field Research Unit, University of Leeds Farm Ltd (latitude: 53°51'27.73"N, longitude: 1°20'41.80"W). The study field was transformed from wheat to pig production. Wheat cultivation had been carried out on the field for some years and until the time of this study, the field was in stubble from the harvest of the preceding year. Prior to pig introduction, the field was divided into 8 distinct paddocks by electric wire fencing (Figure 1). A total of 210 gestating sows were delivered to the field in 4 batches with a stocking rate of 30 sows ha^{-1} as follows: 13/06/2016 (2×30 sows) – 1st batch, 04/07/2016 (2×30 sows) – 2nd batch, 25/07/2016 (2×30 sows) – 3rd batch and 15/08/2016 (1×30 sows) – 4th batch. The first group of animals was split into two paddocks marked Gilt and Gilt Train (Figure 1), this was while they get used to the electric fencing. Soil samples were collected from the two paddocks and the adjacent analogous field (control) before the introduction of sows on the 09/06/2016, and after the introduction on the 30/06/2016 using a bulk density corer (corer rings, 53 mm diameter), at a sampling depth of 0 – 5 cm. The pigs in the Gilt Train paddock stayed for duration of 2 weeks, while those in the Gilt paddock were there for 3 weeks duration of this study. A total of 36 soil cores (6 replicates x 3 treatments x 2 samplings) were collected from random locations within a 12m×5m area, and all organic field floor materials were removed using a spade before soil cores were taken. The locations of the sampling points are indicated on Figure 1. Soil cores (3–4 per sample location) were removed using a palette knife from the corer rings and placed in a labeled sample bags which were

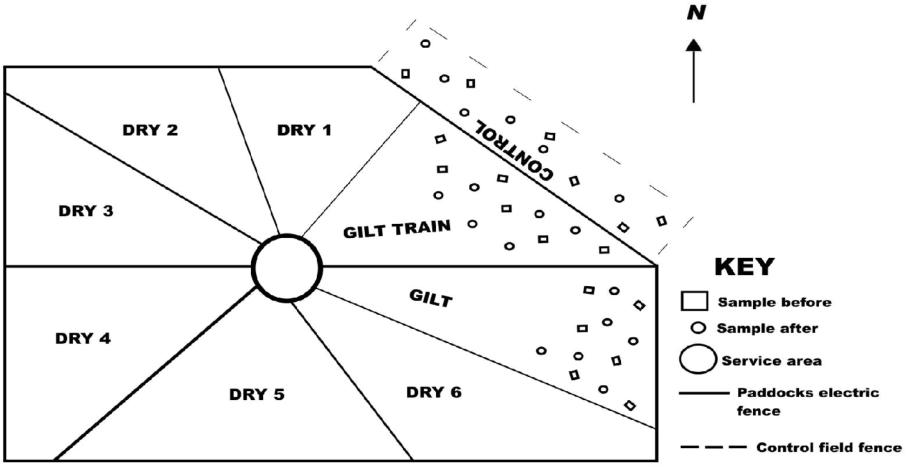

Figure 1: The study field showing the 8 paddocks in which pigs were progressively introduced. The Gilt, Gilt Train paddocks and the control field adjoining the Gilt Train paddock were sampled. The dotted square and the circle represent sampling points before and after introduction of pigs respectively.

kept loosely-tied with much of the air expelled. The corer rings were cleansed between collection of each replicates of sample using distilled water and a disposable cloth. Each sample was measured on a weighing scale up to 500 g and preserved in polystyrene storage boxes with ice, for onward transportation to the University of Leeds. Samples were taken to Faculty of Biological Sciences Teaching Laboratory and stored in a cold room at 4°C until preparation the following day.

Soil sample preparation

Sterile techniques were used for sample preparation. Two plastic trays and a 2 mm sieve were sterilized with 70% ethanol and cleansed using a laboratory tissue paper and allowed to dry for 2 minutes. Before making any contact with the soil, hands (with gloves on) were also sterilized. This was to deactivate all living, viable microorganisms and spores that would be present on the surfaces (trays, sieves and hands). The rough field sample was poured onto the ethanol-cleansed tray and all vegetation, large soil fauna and stones observed were removed. Compacted soils cores were gently finger crumbled, mixed and then turned over frequently to avoid excessive surface drying by making a cone and quarter of the soil three times before sieving. Soils were sieved with the 2 mm sieve (¼ at a time) to give a fine earth fraction. The first fraction of the sieved soil was placed in a sample bag (air expelled and neck tied) and was used to determine moisture content and water holding capacity. The other three fractions were placed in another sample bag (air expelled and neck tied) and were used for biological and physico-chemical analysis. Samples were rolled up into the polystyrene storage boxes with ice and stored back in the cold room at 4°C until use.

Moisture content (MC) and Water holding capacity (WHC)

Moisture content (MC) was determined on field fresh soils (sieved at 2 mm). Mass (g) of crucibles was measured using a wind shield balance set at 3 decimal places. 10 g of fresh soil was added into the crucibles and weighed. Each sample was replicated 3 times and crucibles containing soils were oven dried at 104°C for 24 hours. After the drying period had elapsed, samples were taken out from the oven and placed in desiccators with desiccant to cool for 15 minutes. Samples were weighed back on the balance after cooling to determine mass (g) of crucibles and dry soil. Gravimetric water holding capacity (WHC) was measured by the tube method [33] on sieved fresh soil. Funnels with tubing on the base and a tubing clip were fixed on stands. A glass wool (2 cm^3) was inserted into the base of the funnels to form a permeable seal that would stop soil dropping into the funnel spout but allowing the passage of water. The glass wool was wetted with 30 ml DI H_2O to check that water flows freely. After water had drained, 100 ml beakers were placed under the tubing. 50 g of fresh soil was weighed on a balance (2 decimal places) and poured into the funnels and allowed to settle over the glass wool plug and the tubing clip was tightly closed. De-ionized water (DI H_2O) was collected in a 100 ml measuring cylinder and poured carefully over the soil and allowed to be taken up by the soil for 30 minutes. After the taken up period had elapsed, the tubing clip was released and the water that drains out of the funnels was collected in the 100 ml beakers placed underneath for 16 hours. A Para film was used to seal the top of the funnels, and the gaps between the tubing and the 100 ml beakers during the draining period to prevent evaporation due to movement of air current in an uncontrolled temperature environment. After elapsed of the draining period, the 100 ml measuring cylinder was used to measure the amount of water that was released from the soil. The soil that remained was at field capacity or 100% water holding capacity (WHC) with all large pores drained under gravity but smaller pores filled with water. The moisture content of the soil at field capacity was measured following the same procedure outlined for measuring moisture content (MC) above.

Soil organic matter (SOM)

Soil organic matter (SOM) was determined by Loss on Ignition (LOI) [34]. Mass (g) of pre–heated crucibles (that have been dried in a muffle furnace and allowed to cool in desiccators with desiccant) was determined on a balance (set at 4 decimal places). The crucibles were pre-heated to remove any moisture. 2 g of soil (sieved to 2 mm and dried for 24 hours at 104°C) were added to the crucibles and the mass (g) of the crucibles and dried soil were weighed. Crucibles were heated in the muffle furnace overnight for 16 hours at 550°C. After the 16 hours drying period had elapsed, the muffle furnace was turned off to allow cooling to 105°C at which temperature the door of the furnace was opened and the crucibles were removed using tongs and placed into the desiccators to cool for 30 minutes. After the cooling period had elapsed, the mass (g) of the crucibles and ignited soil were weighed back on the balance (set at 4 decimal places).

Soil texture by particle size and soil pH

Before analysis, soils were sieved at 2 mm and air dried for 72 hours at 40˚C. Soil texture by particle size was determined following the procedure described in ISO 11277:1998: method by sieving and sedimentation [35]. Soil pH was measured according to procedure outlined in ISO 10390:2005 using de-ionized-water-extract solution (2.5:1 volume – volume ratio). Representative soils (9 out of 18) were randomly selected from the samples taken before and after the introduction of pigs. 10 ml of soil was measured (3 replicates per sample plus a standard sample) into a 50 ml centrifuge tubes (overtime fine soil particles settle to the bottom of a container, we made sure all particles types are represented by not only sampling the lighter ones on the top) and added 25 ml of de-ionized water using automatic dispenser. 25 ml of de-ionized water was measured into another 50 ml centrifuge tube (blank sample without soil). The blank and the standard samples were used to determine accuracy of test samples results read by the pH meter and were read after reading every 9 test samples. Therefore, test samples results that differ significantly from the chain of others could be easily detected and variation in test results attributed to malfunction of the pH meter. We used orbital shaker to shake the suspension at 200 rpm for 60 minutes and allowed to settle for 1 hour. An electrode was calibrated with pH 4 and pH 7 buffer solutions and rinsed. Starting with the blank and then the standard, samples were swirled to re-suspend the soil particles and the electrode was carefully inserted into the sample suspension and results were read by the pH meter.

Nitrogen (N) Mineralization by short term incubation

Nitrogen (N) mineralization by short term incubation was determined by procedures outlined by Waring and Bremner [36] in which short term static anaerobic incubation was proposed. The rate of the N mineralization process is determined by measuring the quantity of NH_4^+ -N produced during 7 days of waterlogged incubation at a temperature of 40˚C. Before incubation, moisture content of samples (below 40% WHC) were adjusted (up to 40 – 60% WHC) to put all soils at equal chance for microbial processes. 100 g of sieved soil (2 mm) was measured into a labeled sample bag. A wick was made using a laboratory tissue paper which was wetted with de-ionized water, and any dripping water was strip out. The wick was then inserted into the opening of the sample bag but was protected from touching the soil, and tightened at the base using a rubber band. Samples were then incubated at a constant temperature of 20˚C for 7 days to resuscitate microbial activity. The purpose of the wick was to allow for aeration of nitrifying microorganisms in the soil by keeping the environment moist most of the time, and was replaced after every 3 days. After the elapsed of the incubation period at 20˚C, soils were weighed (10 g to 2 decimal places) into a labeled 50 ml centrifuge tubes (with 6 replicates per analytical samples; 3 set as control, and the other 3 as test). The control samples were taken to cold room and stored at 4˚C for 7 days. The test samples were added 20 ml distilled water and shaken manually until the soil was suspended within the liquid and then incubated at a constant temperature of 40˚C for 7 days with samples being re-suspended regularly every day. After the elapsed of 7 days incubation period at 40˚C, a third set of 50 ml centrifuge tubes were labeled 'blank' and 20 ml distilled water was added to the control and the blank tubes (The reagent blank was to determine background nitrate levels in the centrifuge tubes). 20 ml 2 M KCl solution was added to the sample tubes (test, control and blank) and orbital shaker (New Brunswick Scientific, EDISON, NJ – U.S.A) was used to shake the samples at 150 rpm for 60 minutes. Samples were centrifuged at 3500 rpm for 5 minutes and supernatants filtered and collected in a clean and labeled 50 ml centrifuge tubes for N mineralization analysis which was conducted using C:N auto-analyzer at the School of Geography, University of Leeds.

Statistical and data analysis

One-way analysis of variance (ANOVA) in SPSS statistics version 23 were used to determine the effects of land use changes on soil physical properties (soil moisture content, water holding capacity, dry matter content, organic matter content and mineralized nitrogen) under three treatments (Gilt, Gilt Train and Control). Treatments from before and after the introduction of pigs were analyzed separately using the ANOVA to determine whether there was significant difference in space. One-way repeated measures ANOVA was also used to determine significant variation in time by analyzing samples data from before and after the introduction of pigs together. Similar soil properties were compared from before and after (i.e. soil moisture content before × soil moisture content after, soil organic matter before × soil organic matter after etc.). Mean values for differences between treatments or groups were compared using least significant difference (LSD) at $P<0.05$.

Results

Soil physical properties before the introduction of pigs

There was no variation in soil texture and soil pH as observed during the laboratory analysis (Table 1), and therefore were not subjected to statistical analysis. Prior to statistical analysis, data was subjected to test of normality, and two outliers were observed. After adjustment, however, a normally distributed data was found, as assessed by inspection of box plots, Shapiro-Wilk test $P>0.05$. Data is presented as average per cent score over the control value. Soil moisture content was statistically significantly different between treatments (ANOVA: $F(2,15)=5.754$, $P<0.05$). A follow up bonferroni post hoc test revealed a significant difference in moisture content between soils under Gilt and Gilt Train ($P=0.012$). However, no significant difference was found between soils under Gilt and the control ($P=0.405$), and under Gilt Train and the control ($P=0.271$). On average, moisture content was 2.1% higher in soils under Gilt Train, as compared with 2% reduction in soils under Gilt (Table 1). This showed that soils under Gilt Train has a higher propensity for keeping soil moisture due in part to higher amount of organic matter content that was in these soils as compared to the soils under Gilt. Water holding capacity was not statistically significantly different between treatments (ANOVA: $F(2,14)=1.525$, $P>0.05$). On average, water holding capacity (WHC) showed a 4% increase in soils under Gilt Train, as compared with 0.1% increase in soils under Gilt (Table 1). This also revealed that the amount of organic matter that was in these soils had played a role in their respective ability retain water. There was a statistically significant difference in dry matter content between treatments (ANOVA: $F(2,15)=5.754$, $P<0.05$). Bonferroni post hoc test revealed a significant difference in soils under Gilt and Gilt Train ($P=0.012$), however no significant difference was observed in dry matter content between Gilt and the control ($P=0.405$) and between the Gilt Train and the control ($P=0.271$). Average dry matter content was 2.5% lower in soils under Gilt Train as compared with 2% increase in soils under Gilt (Table 1), suggesting that though soils under Gilt had significant amount of dry matter, the reduction in the soil moisture and water retention capacity would have a significant negative impact on these soils. For example, low moisture would affect organic matter as the two were correlated to some extend and both play a role on the ability of soil to retain water. Soil organic matter showed no significant difference between treatments (ANOVA: F(2,15)=3.052, P>0.05). On average, there was 0.69% increase in soil organic matter in soils under Gilt Train as compared with 0.38% reduction in soils under Gilt. N mineralization was highly statistically significantly different between treatments (ANOVA: F(2,14)=15.021, P<0.0001). A follow up Bonferroni post hoc test showed a highly statistically significantly different result between soils under Gilt and Gilt Train (P=0.0005), and between soils under Gilt and the control (P=0.008). On average, mineralizable N was 10% higher in soils under Gilt Train as compared with 12% reduction in soils under Gilt (Table 1), suggesting that the share amount of organic matter and moisture in the soils under Gilt Train had significant impact on the ability of the soils to perform N mineralization, which also depended on the activity of nitrifying soil organisms. Soils under Gilt Train were therefore, susceptible to leaching tendency as compared to soils under Gilt which has a reduced level of mineralized nitrogen.

Soil physical properties after the introduction of pigs

There was no variation in soil texture and soil pH as observed during the laboratory analysis (Table 2), and therefore were not subjected to statistical test. Normality test conducted revealed a normally distributed data without an outlier, as assessed by box plots inspection, Shapiro-Wilk test P>0.05. Data is presented as average per cent score over the control value. One way ANOVA showed no significant difference in the soil moisture content between treatments (ANOVA: F (2,15)=2.475, P>0.05). On average, moisture content was 0.63% higher in soils under Gilt Train as compared with a reduction by 0.6% under Gilt (Table 2), suggesting that the introduction of the pigs had no influence on the soil moisture content between treatments, Gilt and Gilt Train even after the 3 and 2 weeks introduction of the pigs respectively. There was also no significant difference in water holding capacity between treatments (ANOVA: F (2,15)=0.920, P>0.05). On average, water holding capacity was 0.65% higher in soils under Gilt Train as compared with 0.12% increase observed in soils under Gilt (Table 2). This revealed that water holding capacity did not show significant response to the introduction of the pigs between both treatments. ANOVA did not reveal significant difference in dry matter content between treatments (ANOVA: F(2,15)=2.475, P>0.05). Dry matter content was 0.63% lower in soils under Gilt Train as compared with soils under Gilt which showed a 0.6% increase (Table 2), suggesting that there was no significant effect of pigs introduction on the dry matter 3 weeks after in the Gilt paddock and 2 weeks after in the Gilt Train paddock. Soil organic matter was not statistically significantly different between treatments (ANOVA: F (2,15)=0.489, P>0.05). On average, soil organic matter was 0.32% higher in soils under Gilt Train as compared with 0.09% reduction in soils under Gilt (Table 2). This showed that in both the Gilt and Gilt Train paddocks where the pigs duration of stay was 3 and 2 weeks respectively, the soil organic matter showed no significant improvement. There was no statistically significant difference in mineralizable N under soils as determined by ANOVA, F (2,7)=2.145, P>0.05. This suggests that the introduction of the pigs did not result in significant changes in N mineralization between both treatments. On average, N mineralization was 16.15% higher in soils under Gilt Train as compared with 4% reduction in N mineralization observed in soils under Gilt (Table 2).

Soil physical properties before and after the introduction of pigs

Normality test conducted prior to analysis showed that there were no outliers and the data was normally distributed, as assessed by the inspection of box plots and Shapiro-Wilk test (P>0.05) respectively.

Soil moisture content

Soil moisture was statistically significantly different at the different time points before and after the introduction of pigs, Wilks' Lambda=0.19, F(1,17)=69.937, P<0.0005, η^2=0.804. Thus, there is significant evidence to reject the null hypothesis that there would be no change in soil moisture content when measured before and after the introduction of pigs. Follow up comparisons with Bonferroni indicated that each pairwise difference was significant, P<0.0005. There was a significant variation in moisture content over time (Figure 2). Soil moisture content declined in soils under Gilt following the introduction of the pigs which lasted for 3 weeks but this was also the case of soils under the control field. Consequently, soil moisture content also decreased in soils under Gilt Train following the introduction of pigs which lasted for 2 weeks which followed the same pattern with the soils under the control field. This revealed that the decline in the moisture content in both the Gilt and the Gilt Train paddocks was not a result of the introduction of the pigs.

Moisture content at 100 per cent water holding capacity (WHC)

Land use change did not lead to any statistically significant changes in water holding capacity over time, Wilks' Lambda=0.99,

Field	Soil depth (cm)	Soil pH	Soil Texture	MC (%)	MC at 100 % WHC	DMC (%)	SOM (%)	N (µg NH_4^+ -N/ml)
Control	0-5	7.62	Loam	14.40	35.26	85.60	7.51	40.93
Gilt	0-5	7.53	Loam	12.64	35.37	87.36	7.13	29.06
Gilt Train	0-5	7.6	Loam	16.41	38.99	83.56	8.2	50.57
ANOVA				*	ns[a]	*	ns[a]	*

[a]Not significant at P>0.05

*Significant at P<0.05

Table 1: Average physical properties of soils in wheat stubble before introduction of pigs. MC: Moisture Content; WHC: Water Holding Capacity; DMC: Dry Matter Content and SOM: Soil Organic Matter.

Field	Soil depth (cm)	Soil pH	Soil Texture	MC (%)	MC at 100 % WHC	DMC (%)	SOM (%)	N (µg NH_4^+ -N/ml)
Control	0-5	7.78	Loam	18.47	36.46	81.53	7.34	23.70
Gilt	0-5	7.69	Loam	17.87	36.58	82.13	7.25	27.62
Gilt Train	0-5	7.7	Loam	19.10	37.11	80.90	7.66	39.85
ANOVA				ns[a]	ns[a]	ns[a]	ns[a]	ns[a]

[a]Not significant at P>0.05

*Significant at P<0.05

Table 2: Average physical properties of soils after the introduction of pigs. MC: Moisture Content; WHC: Water Holding Capacity; DMC: Dry Matter Content and SOM: Soil Organic Matter.

F(1,17)=0.015, P>0.05, η^2=0.001. Thus, there is no evidence to reject the null hypothesis that there would be no change in the water holding capacity when measured before and after the introduction of pigs, and cannot accept the alternative hypothesis. There was no significant change in the water holding capacity over time (Figure 3), suggesting that the introduction of the pigs had no effect on the water retention capacity of soils under Gilt even after 3 weeks of introduction as compared with the soils under the control field, and on the water retention capacity of soils under Gilt Train, 2 weeks after introduction as compared with the control soils.

Soil dry matter content (DMC)

Land use change elicited statistically significant changes in the dry matter content over time, Wilks' Lambda=0.19, F(1,17)=69.937, P <0.0005, η^2=0.804. Post hoc analysis with a Bonferroni adjustment revealed that there was a statistically significant decrease in dry matter content over time (Figure 4). Thus, there is strong evidence to reject the null hypothesis that there would be no change in the dry matter content when measured before and after the introduction of pigs. The dry matter content in the soils under both the Gilt and the Gilt Train paddocks followed the same pattern with the soils under the control field before and after the introduction of the pigs, suggesting that the decrease in the dry matter content in both paddocks was not as a result of the introduction of pig.

Soil organic matter (SOM)

The result did not indicate a statistically significant effect of time on soil organic matter, Wilks' Lambda=0.97, F (1,17)=0.528, P>0.05, η^2=0.030. Thus, there is no evidence to reject the null hypothesis that there would be no change in the soil organic matter when measured before and after the introduction of pigs, and cannot accept the alternative hypothesis. There was no significant change in the soil organic matter over time (Figure 5). This revealed that the introduction of the pigs which lasted for 3 weeks under Gilt had no significant impact on the soil organic matter as compared with the organic matter under the control field. There was also no significant change in the soil organic matter after the introduction of the pigs which lasted for 2 weeks under Gilt Train as compared with the soil organic matter under the control field.

Nitrogen mineralization

There was a statistically significant changes in N mineralization over time, Wilks' Lambda=0.53, F (1,10)=8.541, P<0.05, η^2=0.461. Follow up comparisons with Bonferroni indicated that each pairwise difference was statistically significantly different, P<0.05. There was a significant variation in N mineralization over time (Figure 6). Thus, there is strong

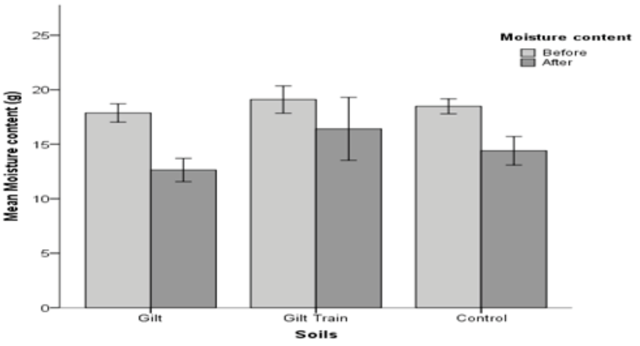

Figure 2: Mean of moisture content in the different soils sampled at 0 – 5 cm soil depth. Each gram is the mean of at least 2 replicates. The error bars represent mean ± 1 standard deviation.

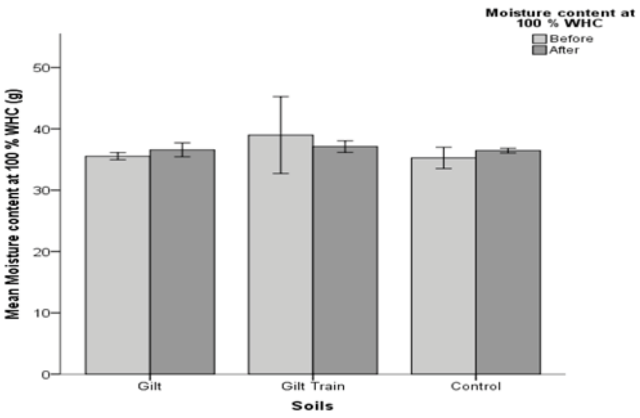

Figure 3: Mean of water holding capacity in the different soils sampled at 0 – 5 cm soil depth. Each gram is the mean of at least 2 replicates. The error bars represent mean ± 1 standard deviation.

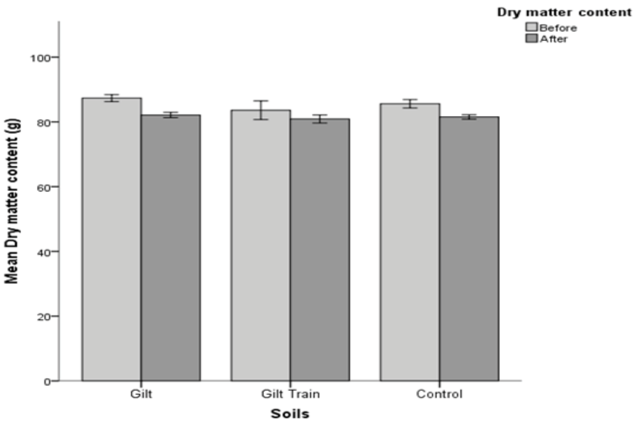

Figure 4: Mean of dry matter in the different soils sampled at 0 – 5 cm soil depth. Each gram is the mean of at least 2 replicates. The error bars represent mean ± 1 standard deviation.

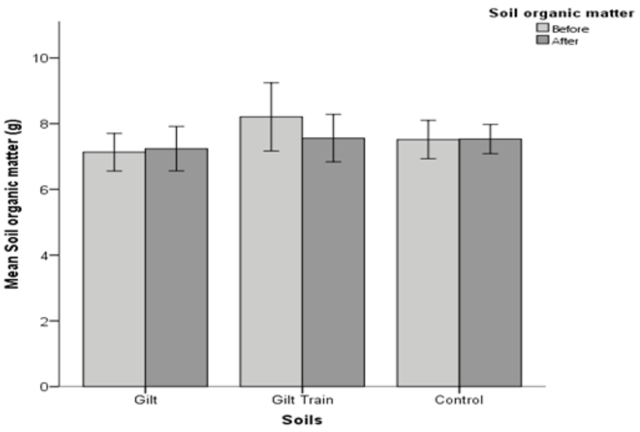

Figure 5: Mean of soil organic matter in the different soils sampled at 0 – 5 cm soil depth. Each gram is the mean of at least 2 replicates. The error bars represent mean ± 1 standard deviation.

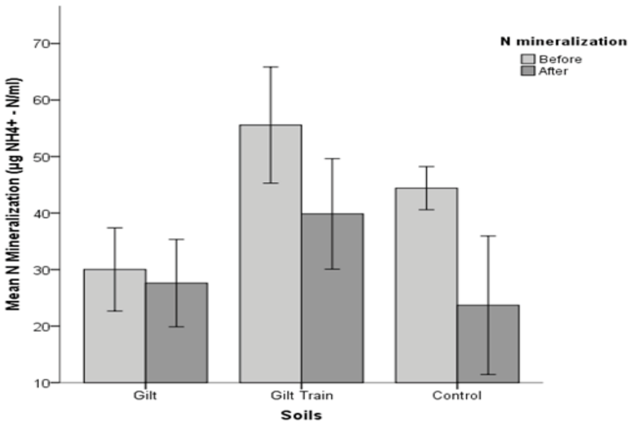

Figure 6: Mean of N mineralization in the different soils sampled at 0 – 5 cm soil depth. Each microgram is the mean of at least 2 replicates. The error bars represent mean ± 1 standard deviation.

evidence to reject the null hypothesis that there would be no change in N mineralization when measured before and after the introduction of the pigs. N mineralization showed a decline in soils under Gilt following the 3 weeks introduction of the pigs. Consequently, this was also the case of the soils under the control field. N mineralization was also lower in soils under Gilt Train following the 2 weeks introduction of the pigs as was the situation of the soils under the control field. This revealed that the introduction of the pigs in both the Gilt and the Gilt Train paddocks did not yield any significant effect on the nitrogen mineralization.

Discussion

The overall short-term response of soils due to land use change from wheat to the introduction of pigs was found to be no significant change in the soil physical properties; soil moisture content, dry matter content and N mineralization. The possible explanation of this is that limited soil organic matter in these soils had a major influence on the other soil properties. The introduction of the pigs did not impact positive change on the organic matter, as the three fields remained fairly the same in terms of soil organic matter (Figure 5). Bot [37] reported that biological decomposition of soil organic matter has the capability of influencing all soil chemical and physical properties and its overall functions – structure and porosity, the rate of water infiltration and the water holding capacity. The water holding capacity of a soil in a particular landscape is influenced by the soil depths, volume of inter-aggregate spores and the proportion of the empty space that hold water against the pull of gravity (FAO, 2004). Furthermore, the decomposition of organic matter is affected by rate of its deposition to the soil, which means that less deposition will result in less decomposition and vice versa, while at the equilibrium state, deposition and decomposition of organic matter remain equal [37]. Studies have reported increase in N surpluses in soils from outdoor production of pigs due in part to soil organic matter accumulation [11], this finding however, was a short term study and no significant changes have been observed in the soil organic matter pool as a result of the land use change. The decrease in N mineralization as observed in this study, could be attributed to limited soil organic matter pool, because as soil organisms break down organic matter to obtain food, excess nutrients are released into the soil for use by plants, some of which escape to wider ecosystem through several interwoven processes, such rainfall, temperature and runoff rate etc. Therefore, decrease in N mineralization is influenced by a decrease in soil organic matter, which in turn is affected by soil organisms. Moreover, increase in N mineralization will be affected by an increase in soil organic matter, which also is influence by microbial activity. The mobilization of nitrogen in runoff also occurs when animals manure is applied to patches with low organic matter in surface layers [38]. Therefore, soil organic matter can also minimize the rate at which nitrogen is leached away from catchment through slowing the rate of runoff. Soil compaction by grazing pigs could affect N mineralization, for example, a study reported by Jensen [39], observed that the rate of N mineralization was less in compacted areas than in the non-compacted areas of arable pastures. Soil compaction increases by decreasing soil organic matter content, resulting in the deformation of soil pores, which will lead to poor soil aeration [40]. Soil aeration is the process by which most soil organisms obtain oxygen, however, lack of oxygen in the soil affects the rate of mineralization as the soil organisms become less active and eventually die [37]. One major factor responsible for low soil moisture in the soil is also soil compaction, which result in the deformation of soil pores as mentioned, but soil texture, soil depth, organic matter content, and soil biological processes all of which can influence soil moisture content on agricultural soils (FAO, 2004). For instance, Hamza and Anderson [32] reported that the depth of livestock-induced compaction is usually apparent at 5 – 20 cm topsoil, and this can have significant impact on the soil moisture. This finding agrees with the finding in this report as the sampled soil cores used in the analysis were taken from 0 – 5 cm, however, the decline in soil moisture as observed in the study could be attributed to different soils capacity to hold water, or stoniness [38]. Soil moisture is also related to organic matter, temperature and soil aeration, thus limited soil moisture affects biomass production and soil microbial processes, conversely sufficient soil moisture improves the production of biomass and hence pool of residues to support soil organisms [37]. Therefore, the decline in the soil moisture as observed in this study could also be attributed to insufficient pool of organic matter. The decline in the dry matter pool as obtained in this study could impede on the soil organic matter. Powlson and Brookes [41] reported that incorporation of straw dry matter into soil can serve beneficial purposes including increasing the quantity of organic matter, which can positively affect the soil texture, water retention capacity and an improved nutrients reserve for plants. In the above study, Powlson and Brookes [41] also observed that N mineralization was much high (40% - 50%) on land where straw dry matter had been incorporated, demonstrating that the long term incorporation of straw dry matter had increased the rate of N mineralization in the soil. This finding further supports our results that the decrease in the N mineralization following the introduction of the pigs was also because of the decreased dry matter that were in the soils [42-44].

Conclusion

This short term study demonstrated that land use changes from arable crop to introduction of pigs had no effect on soil physical properties (mineralized nitrogen, soil dry matter, soil organic matter, soil moisture content and water holding capacity) when measured before and after introduction of the pigs. This was not the case with studies that had reported interesting changes, for example in nitrate leaching losses from outdoor pigs system in contrast to usual arable farming. Therefore, one possible reason that changes were not observed here could be due to the short term duration of the study. However, follow up studies could likely observe significant changes. Nitrate leaching is influenced by soil organic matter, which in many cases affects the generality of soil functions. Better land use management can improve soil physical properties and minimize N leaching losses from outdoor pig production both before and after the introduction. Maintaining vegetation cover during introduction of pigs could improve uptake of N by plants, and this is attainable through; planting of grass types that could withstand the rooting habits of pigs, having the pigs noses ringed to discourage rooting, and incorporating rotational grazing to allow for grass sods to improve. Outdoor pigs production could also be incorporated into arable farming system in such a way that N surpluses built up during introduction of pigs are utilized as much as possible by the subsequent cropping, before winter runoff.

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