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Fields Preparation Techniques for Rice Production: 2: Impacts on Carbon Sequestration, Soil pH and Grain Yield of Lowlands Rice in Southeastern Nigeria

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Abstract:
An inland valley of Federal College of Agriculture, Ishiagu, Ebonyi State, research farm was used in 2018 and 2019 cropping seasons to determine the impacts of fields' preparation techniques on carbon sequestration, soil pH and grain yield of rice in Ishiagu. A randomized complete block design was employed for the study. Field preparation techniques employed include; Cleared, tilled, seedlings-transplanted and hand weeding (C/T/ST//HW); Non-selective herbicide applied, cleared, tilled, seedlings-transplanted and herbicide for weeding (N-H/C/T/ST); Applied non-selective herbicide, cleared, broadcasted seeds and herbicide for weeding (N-H/C/B); Applied Non-selective herbicide, broadcasted and herbicide for weeding (N-H/B); Cleared, tilled, seedlings-transplanted and herbicides for weeding (C/T/ST/S); Applied Non-selective herbicide, cleared, tilled, seedlings-transplanted and hand weeding (NHw/ C/T/ST/Hw). Results showed that C/T/T/HW sequestrated soil carbon higher (37.02 g/m2) than other field techniques in the 1st year, as N-H/C/B and N-H/C/T/T gave the highest improvement in the 2nd year. Soil organic carbon (SOC) improvement (1.3443%) in the 1st year was obtained from C/T/T/HW plots, whereas in the 2nd year, N-H/C/B plots gave the highest (1.5070%) significant ($p < 0.05$) increase. Results revealed that C/T/T/HW plots increased pH higher (5.13) in the 1st year, while in the 2nd year, N-H/C/T/T gave the highest (5.40) improvement. Findings from this study showed that soil carbon sequestration can be greatly enhanced by the type of rice field management practice(s) adopted during planting and at the time of weed control. It is therefore concluded that, since herbicides application is the most common practice and cheaper approach in the study area, farmers are recommended to use non- selective herbicides to clear the vegetation but use manual weeding operation subsequently in the control of weeds with proper water management which will help in weed control in their rice fields.

Keywords: Herbicides, rice grain yield, carbon sequestration, broadcasting, transplanting

INTRODUCTION

The production of lowland rice in most rice producing areas in Ebonyi State is rain-fed dependent (Nwite *et al.*, 2013 and 2017); and application of non- selective herbicides to clear the vegetation and subsequent broadcasting of rice seeds (In-situ) is the predominant land preparation techniques in the study area. In most cases, farmers do not adhere to manufacturers' manuals or instructions during the application of these herbicides leading to misuse and inappropriate applications. This agricultural or farming practice has led to variations in the crop yield, soil organic carbon build and ecological changes. Farmers in the study area do not have environmental risk awareness of using wrong farming practices; they adopt non-sustainable farming practices such as the extensive use of herbicides instead of mechanical or cultural method of weed control in their rice fields, thus affecting soil organic carbon characteristics and fertility status (Malamataris *et al.,* 2023). Traditional field technique for water management systems in the lowlands rice production in Ebonyi State that is regarded as a major rice producing State in Nigeria are characterized by the fact that farmers focus on storage of water in the rice field, without any possibility to divert water from one place to another. Poor soil fertility and inefficient weed and water control are the major constraints to proper utilization of these inland valleys for sustainable rice-based cropping (Nwite *et al.*, 2013).

The soils of the studied area are known in decades past to have a high potential for carbon sequestration because soil organic carbon content can be conserved, restored and increased through appropriate land uses and agricultural management practices that can be applied at the landscape level (Corsi *et al*., 2012), but the current land uses and agricultural management practices in the area is gradually facing out, hence, affecting the soil health and potentials.

Soil organic carbon (SOC) sequestration is mainly influenced by such key factors as the amounts of carbon input (Bahman and Ginting, 2003), plant residue management (Thelen *et al*., 2010), soil depth (Blanco-Conqui and Lal, 2007) and soil texture (Gami *et al*., 2009). Storage of SOC in agricultural systems is a balance between carbon additions from non-harvested portions of crops (Wu *et al*., 2008), organic sources (Thalen *et al*., 2010), and carbon losses, primarily through organic matter decomposition and release of respired CO_2 to the atmosphere.

Usui and Kasubuchi (2011), submitted that after herbicide application, the diurnal variation in CO_2 concentration was reduced, and the minimum concentration of CO_2 increased. They went further to state that the high CO_2 concentration during the daytime and the reduction in variation after herbicide application were caused by a decrease in CO_2 consumption owing to the inhibition of photosynthesis. The herbicide application could lead to changes in CO_2 concentration by the reduction of cyanobacteria and microalgae (Usui and Kasubuchi, 2011).

Usui *et al.* (2003) reported that CO_2 concentration is related to pH in ponded water and that comparing pH with RpH (the pH at which the CO2 concentration of the water is in equilibrium with that of the air) confirmed whether the water had absorbed or emitted CO_2.

The study aims at evaluating different field techniques in inland valley rice field as they affect carbon sequestration, pH of the soil and grain yield of rice.

MATERIALS AND METHODS

The study was carried out at the inland valley rice field at Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria, during the 2018 and 2019 cropping seasons. The field was under rice cultivation by the Institution before the study. The area is located within latitude 05^o 56′ N and longitude 07^o 41′E. The mean annual rainfall and mean monthly temperature have been reported as 1350 mm and 30^o C respectively. The area lies within the derived savanna vegetative zone of South Eastern Nigeria. There are two reported distinct seasons, the dry season which spans November to March, at times extend to April, and the rainy season which spans April to October (Nwite *et al.*, 2008).

Geologically, the area is underlain by sedimentary rock derived from successive deposit of the cretaceous and tertiary period and lies within Asu River Group (Lekwa *et al.,* 1995). The location lies within the Asu River Group and consists of Olive brown sandy shale, fine grained micaeous sandstones and mudstones deposited in an alternating sequence. Generally, Ebonyi State lays mostly in the Ebonyi (Aboine) river Basin and Cross River plains. The area contains two main geological formations. The soil is hydromorphic and belongs to the order Ultisol. It has been classified as typic Haplustut (FDALR, 1985).

Agronomic Practices

Land Preparation:

The land used was prepared according to the specifications outlined in each treatment. The plot size measured 2.6 m x 3.4 m.

Rice fields preparation techniques employed for the study and their descriptions include the following;

- Clear, till and transplant + use of hand weeding (C/T/T/HW). The plots involved were cleared, tilled manually with native hoe, and followed by transplanting. Hand weeding was adopted during weeding operation.
- Non-selective herbicide was applied, cleared, tilled and transplanted + use of herbicide for weeding (N-H/C/T/T). A branded name non-selective herbicide (Uproot) was applied to kill the grasses in the affected plots; after two weeks of application, the plots were cleared of the dead grasses, later tilled with native hoe and rice seedlings transplanted. During the weeding operation, a branded name – orizo plus selective herbicide was applied in the designated plots.
- Non-selective herbicide (Uproot) was applied, cleared, broadcast + use of herbicide for weeding (N-H/C/B). A branded name non-selective herbicide (Uproot) was applied at the rate of 150 mls a.i./20 litres of water to kill the grasses in the affected plots; after two weeks of application, the plots were cleared of the dried grasses, re-touched with the same herbicide at the rate of 100 mls a.i/20 litres of water. This was followed by broadcasting of rice seeds at the rate of 40 kg/ha. Weeding of the plots was carried out using orizo-plus selective herbicide at the rate of 150 mls a.i./20 litres of water.
- Non-selective herbicide was applied and rice seeds broadcast + use of herbicide for weeding (N-H/B).
- Clear, till and transplant + use of orizo-plus selective herbicide for weeding (C/T/T/S). The plots involved were cleared, tilled manually with native hoe, and followed by transplanting. During weeding operation, orizo-plus selective herbicide was used for weeding.
- Non-selective herbicide was applied, clear, till and transplant + use hand weeding (N-Hw/C/T/T/ Hw). A branded name non-selective herbicide (Uproot) was applied to kill the grasses in the affected plots; after two weeks of application, the plots were cleared of the dried grasses, later were tilled with native hoe and rice seedlings transplanted. Hand weeding was used during weeding operation in the affected plots.

Inorganic fertilizer (NPK 20:10:10) combined with rice husk dust was applied basally at 200 kg/ha and 5 t/ha, respectively, in all the plots. The rice husk dust was applied to those plots where seeds broadcasting was carried out at the time of the broadcasting, while the rice husk dust was applied and incorporated to the tilled and transplanted plots at the period of tillage operation. The NPK 20:10:10 was applied two weeks after germination or two weeks after transplanting as the case may be.

Planting:

- **Broadcasting method:** The test crop was rice (*Oryza sativa* –FARO 57 variety). The plots where rice seeds broadcasting was adopted as a method had no determined plant spacing but were thinned 2 weeks after germination where they were found to be crowded. The broadcasted rice seeds started germinating after 4 days. The plots were ponded with water after one month of germination.
- **Transplanting:** Nursery bed was established for these plots where rice transplanting method was practiced. In this regard, a raised bed was made, followed by broadcasting of rice seeds on the raised bed. The seed rate in transplanting is 30kg/ha as against 40kg/ha in broadcasting method. Prepared nursery was ready for transplanting into field at the age of 3 weeks, as transplanting of seedlings at later age reduces tillering rates. Transplanting was done by uprooting the seedlings and washing-off the attached soil particles on the roots and transplanted with the aid of fork-sticks. Planting space of 20 cm x 20 cm was used in the transplanted plots to give a plant population of 221 stands/plots and a total of 250,000 stands/ha.

Weeding:
Weeding operation was carried out manually by hand or with herbicides according to the treatments' specifications at the right time.

Soil Sampling and Laboratory Analyses
Bulk soil samples were collected from 0 to 20 cm depth using soil auger and core samples were also collected before the field preparation specifications for pre-planting soil analysis. Similarly, after each cropping season (after harvest), another set of auger and core soil samples were taken from individual plots. The auger samples were air-dried and sieved through 2.0-mm mesh and taken to laboratory for particle size distribution, soil pH and organic carbon analyses. The soil pH was determined in distilled water and 0.1 N KCl solution using a soil solution of 1:2.5 (Mclean 1982). SOC was determined by wet oxidation method (Walkley and Black 1934) as modified by Nelson and Sommers (1996). Particle size distribution of the samples was determined by the hydrometer method (Gee & Bauder 1986). The core samples were allowed to drain freely for 24 h before being oven dried for determination of bulk density by the Blake and Hartge's (1986) method.

Statistical Analysis
Data collected were analyzed using GENSTAT 3 7.2 Edition. Significant treatment means were separated and compared using Fisher's least significant difference (F-LSD) at 5% probability level according to Obi (2002).

RESULTS AND DISCUSSION

Initial Soil Characteristics of the Studied Soil (0 – 20 cm depth)
Table 3.1 indicated that the textural class of the studied soil is sandy clay soil with percentage level of clay as 200 g/kg, 230 g/kg silt and 530 g/kg fine sand content, while the coarse sand value stands as 40 g/kg. The results also showed organic carbon percent as 1.14% as total nitrogen and pH of the soil recorded 0.84 % and 4.8, respectively. The soil carbon sequestration and initial soil bulk density of the area is 18.84 g/m^2 and 1.64 Mg/m^3.

Table 3.1 Initial soil characteristics of the studied soil (0 – 20 cm depth)

Soil Properties	Values
Clay (g/kg)	200
Silt	230
Fine sand	530
Coarse sand	40
Textural class	Sandy clay
Organic carbon (%)	1.14
Total nitrogen (g/kg)	0.84
pH (H_2O)	4.8
Bulk density (Mg/m^3)	1.68
Carbon sequestration (g/m^2)	18.84

Effects of Rice Fields Preparation Techniques on Carbon Sequestration and Soil Organic Carbon

Results in Table 3.2 revealed that there were significant ($p < 0.05$) variations on soil carbon sequestration due to the different field techniques studied. It was recorded that C/T/T/HW (clear, till and transplant + hand weeding) with a value 37.02 g/m^2 sequestrated soil carbon higher than other field study within the 1st year of study. It was obtained that in the 2nd year, it was N-H/C/B (Apply non-selective herbicides, clear and broadcast + selective herbicide) and N-H/C/T/T (Apply non-selective herbicides, clear, till and transplant + selective herbicide) that gave the best significant improvement on the carbon sequestration of the studied soil.

The lowest improvement on the soil carbon sequestration in the 1st year was recorded in plots with N-H/B, N-H/C/B, N-H/C/T/T and N-H/C/T/T/Hw as their values are statistically same and lower from other field techniques studied. Generally, there were significant increasing variations on the carbon sequestration among the different field techniques studied except in plots with C/T/T/HW system where the carbon sequestration decreased from 37.02 g/m^2 in the first year to 29.82 g/m^2 in the second year of study.

Soil organic carbon (SOC) was shown to have been significantly ($p < 0.05$) varied in both first and second year of study (Table 3.2). The results showed that best significant ($p < 0.05$) soil organic carbon improvement (1.3443%) in the 1st year was obtained from plots with C/T/T/HW, while N-H/C/T/T/ Hw (non-selective herbicides, clear, till and transplant + hand weeding) with value of 1.1067% recorded the least improvement. In the 2nd year, N-H/C/B plots gave the highest (1.5070%) significant ($p < 0.05$) increase on the soil organic carbon as plots with N-H/C/T/T/Hw recorded the lowest (1.2227%) improvement on the SOC within the period. Generally, it was noted that there was a strong positive relationship or link between soil organic carbon and carbon sequestration especially in the 2nd year of study, as the same field preparation technique (N-H/C/B) gave the best significant ($p < 0.05$) increased soil carbon sequestration and organic carbon pools. Studies have shown that soil organic carbon (SOC) sequestration is mainly influenced by such key factors as the amounts of carbon input (Bahman and Ginting, 2003) and plant residue management (Thelen *et al*., 2010).

Table 3.2: Effects of rice fields preparation techniques on carbon sequestration and soil organic carbon

Treatments applied	Carbon sequestration (g/m^{-2})		Soil organic carbon (%)	
	Year 1	Year 2	Year 1	Year 2
C/T/T/S	31.45	32.42	1.1820	1.3037
C/T/T/HW	37.02	29.82	1.3443	1.1323
N-H/B	27.04	32.18	1.1393	1.3443
N-H/C/B	26.51	37.58	1.1423	1.5070
N-H/C/T/T	28.98	36.83	1.1157	1.3440
N-H/C/T/T/ Hw	26.59	30.65	1.1067	1.2227
Grand mean	**29.60**	**33.25**	**1.1717**	**1.3090**
F-LSD 0.05	**3.540 p = < .001**	**5.105 p = 0.031**	**0.03867 p = < .001**	**0.04197 p = < .001**

N-H/C/T/T = Apply non-selective herbicides, clear, till and transplant + selective herbicide; C/T/T/HW= clear, till and transplant + hand weeding; N-H/C/B = Apply non-selective herbicides, clear and broadcast + selective herbicide; N-H/B = Apply non-selective herbicides, broadcast+ selective herbicide; C/T/T/S = Clear, till and transplant + selective herbicide; N-H/C/T/T/Hw = non-selective herbicides, clear, till and transplant + hand weeding; F-LSD=Fisher's least significant difference

Effects of Rice Fields Preparation Techniques on Soil Bulk Density and pH (H_2O)

The results showed that bulk density of the studied soil did vary in the 1st year of study but did not change among the different field techniques in the 2nd year of study (Table 3.3). It was obtained that the highest significant increased bulk density of 1.377 Mg/m^2 was recorded in plots with C/T/T/HW in the 1st year, while the least reduction of BD was obtained in N-H/B plots with 1.187 Mg/m^2. Soil BD in the 2nd year was best reduced in the same N-H/B managed plots.

Soil pH was significantly ($p < 0.05$) influenced by the different field techniques in both 1st and 2nd year of study. It was obtained that in the 1st year, the most improved pH in water (5.13) was recorded in the C/T/T/HW plots, followed by C/T/T/S managed plots (5.03) while the least pH of 4.83 was obtained from N-H/B plot. In the 2nd year, N-H/C/T/T plots gave the highest (5.40) significant ($p < 0.05$) improvement on the soil pH, while the lowest pH (5.03) was obtained in plots with N-H/B field management.

Table 3.3: Effects of rice fields preparation techniques on soil bulk density and pH (H_2O)

Treatments applied	Bulk density(g/m^{-2})		Soil pH (H_2O)	
	Year 1	Year 2	Year 1	Year 2
C/T/T/S	1.330	1.243	5.03	5.33
C/T/T/HW	1.377	1.317	5.13	5.30
N-H/B	1.187	1.197	4.83	5.03
N-H/C/B	1.160	1.247	4.87	5.27
N-H/C/T/T	1.300	1.370	5.00	5.40
N-H/C/T/T/ Hw	1.200	1.253	4.87	5.20
Grand mean	**1.259**	**1.271**	**4.96**	**5.26**
F-LSD 0.05	**0.1494 p = 0.044**	**NS**	**0.0978 p = < .001**	**0.1435 p = 0.003**

N-H/C/T/T = Apply non-selective herbicides, clear, till and transplant + selective herbicide; C/T/T/HW= clear, till and transplant + hand weeding; N-H/C/B = Apply non-selective herbicides, clear and broadcast + selective herbicide; N-H/B = Apply non-selective herbicides, broadcast+ selective herbicide; C/T/T/S = Clear, till and transplant + selective herbicide; N-H/C/T/T/Hw = non-selective herbicides, clear, till and transplant + hand weeding; F-LSD=Fisher's least significant difference

Effects of Rice Field Preparation Techniques on Grain Yield of Rice

The rice grain yield in the first year was not significantly ($p < 0.05$) improved among the studied field preparation techniques. The results (Table 3.4) indicated that C/T/T/HW adopted plots gave the highest (5.89 t/ha) mean rice grain yield, whereas N-H/B plots recorded the lowest (3.93 t/ha) rice grain yield. The results (Table 3.4) revealed that plots with N-H/C/T/T/Hw yielded significantly ($p < 0.05$) higher (8.40 t/ha) of grains than other field techniques used, while N-H/B plots recorded the least (3.45 t/ha) grain yield within the 2nd year of study. It was generally observed that the second-year rice grain yield performed appreciably higher than the first year of the study, except in N-H/B fields where its yield reduced by 0.48 t/ha. It was recorded that in N-H/C/T/T/ Hw field method, the difference in yield between year 1 and year 2 of the study was 20.2% yield difference. Herbicides have remarkably reduced farming labor and contributed to an increase in labor productivity; therefore, a good understanding of the manufacturers' advice or instruction for each product must be strictly adhered to, to avoid overuse or misuse.

Table 3.4: Effects of rice field preparation techniques on grain yield of rice (t ha^{-1})

Treatments applied	Rice Grain yield (tons/hectare)	
	Year 1	**Year 2**
C/T/T/S	4.18	4.88
C/T/T/HW	5.89	7.66
N-H/B	3.93	3.45
N-H/C/B	5.54	5.60
N-H/C/T/T	5.07	5.87
N-H/C/T/T/ Hw	5.58	8.40
Grand mean	**5.03**	**5.98**
F-LSD 0.05	**NS**	**2.141**

N-H/C/T = Apply non-selective herbicides, clear, till and transplant + selective herbicide; C/T/T/HW= clear, till and transplant + HAND WEEDING; N-H/C/B = Apply non-selective herbicides, clear and broadcast + selective herbicide; N-H/B = Apply non-selective herbicides, broadcast+ selective herbicide; C/T/T/S = Clear, till and transplant + selective herbicide; N-H/C/T/T/Hw = non-selective herbicides, clear, till and transplant + hand weeding; F-LSD=Fisher's least significant difference

Relationship Between Soil pH and Carbon Sequestration

Figures 1 and 2 revealed that soil pH even though has positive influence on the soil organic carbon, but does not have stronger influence on the soil organic carbon ($R^2 = 0.495$ and $R^2 = 0.0017$) in the 1st and 2nd year, respectively. The results also showed that there was no strong relationship between the soil pH and carbon sequestration (Figures 3 and 4) for the two years of study. The soil pH showed no strong influence as it recorded $R^2 = 0.3153$ in the 1st year and $R^2 = 0.0672$) in the 2nd year of study. The implication of these results for rice fields' management of the inland valley soils for rice production and improved soil organic carbon, including the soil carbon sequestration is that while adopting a particular field preparation practice, priority attention should be on managing the soil pH. These results were in disagreement with the findings of Usui *et al.* (2003), who reported that CO_2 concentration is related to pH in ponded water and that comparing pH with RpH (the pH at which the CO2 concentration of the water is in equilibrium with that of the air) confirmed whether the water had absorbed or emitted CO_2. It could be noted that the difference between their findings and these results could be that their own work was on field ponded water as against the field soil undertaken in this study.

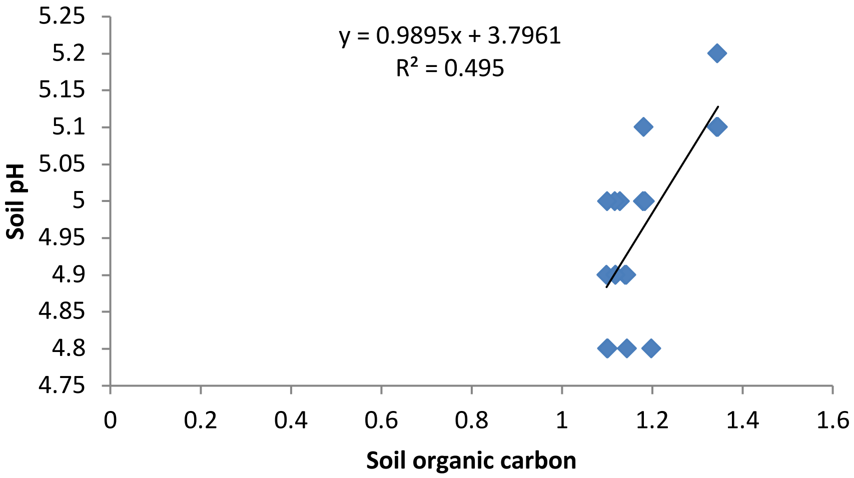

Figure 1: Soil organic carbon and pH relationship in yr 1

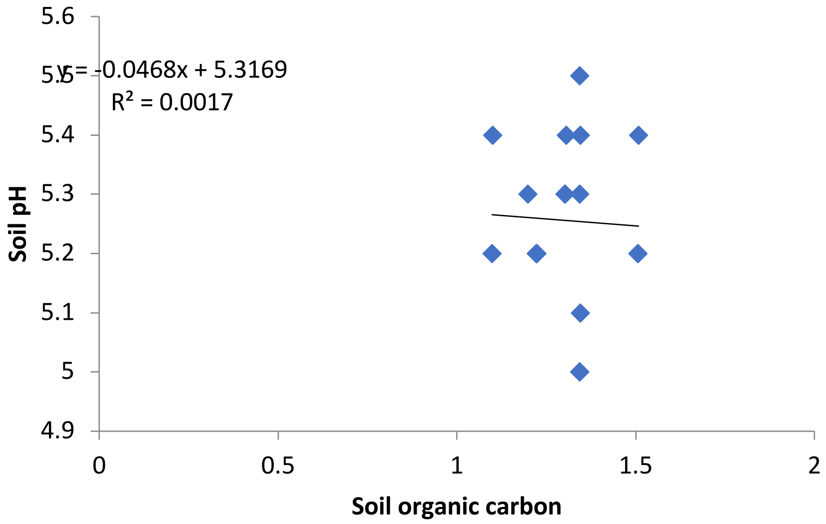

Figure 2: Soil organic carbon and ph relationship in yr 2

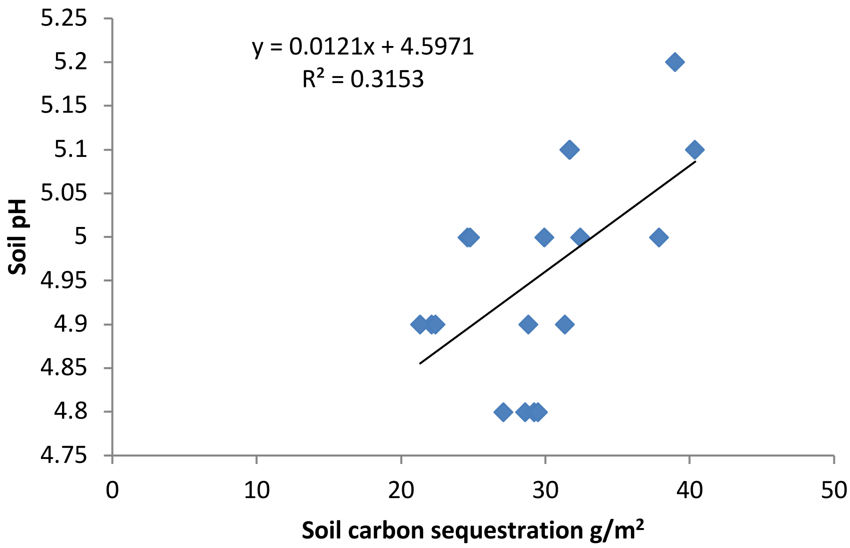

Figure 3: pH/carbon sequestration relationship yr 1

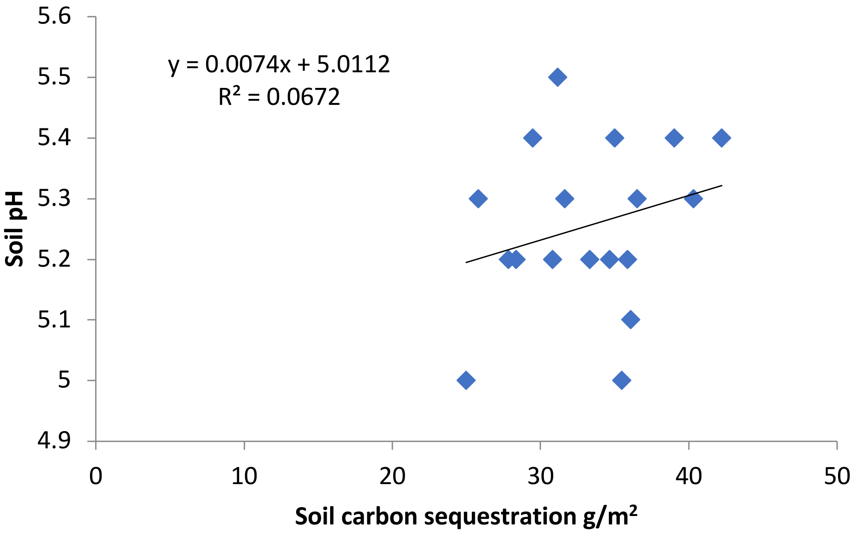

Figure 4: pH/carbon sequestration relationship yr 2

CONCLUSION

The findings from this study within the two years of study showed that soil carbon sequestration can be greatly enhanced by the type of rice field management practice(s) adopted during planting and at the time of weed control in the rice fields. It can be deduced that use of herbicides application as preparatory measure for planting and weeding increasingly influenced soil carbon sequestration in the study area. Applying non-selective herbicides, clear and broadcast plus the use selective herbicide (N-H/C/B) for weeding operation increased carbon sequestration in the 2nd year but increases soil bulk density unimaginably higher within the two years of study, though falls lower than the root limiting level.

The results revealed that soil organic carbon as well increased by the same field management practice in the 2nd year of study. However, soil pH was better appreciated in N-H/C/T/T adopted plots within the periods. Rice grain yield was best improved by N-H/C/T/T/Hw (non-selective herbicides, clear, till and transplant + hand weeding). The findings therefore revealed that constant use of herbicides in rice fields can drastically reduce rice grain yield and increase soil bulk density in the farmers' fields. Since herbicides application is the most common practice and cheaper approach in the study area, farmers are recommended to use non- selective herbicides to clear the vegetation but use manual weeding operation subsequently in the control of weeds with proper bunding for water management which will as well help in weed control in their rice fields.

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