The Effects of Agricultural Engineering Operations on Soil/Water in a Typical Medium-Scale Farm Environment in South-Western Nigeria

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ABSTRACT: A study to investigate how operations in afarmaffect the adjoining soil and water environment was conducted during the 2013 major crop growing season in a farm located in South-Western Nigeria. The soil texture in the farm is loamy and it was a rain-fed agriculture. Six soils samples were randomly taken from the farm(after second ploughing) and from undisturbed soil from adjoining forest, at depths of between 0 and 15cm. Two water samples were collected, one from the site (earth pond) and the other from off farm (stream) using 1litre container. Moisture content, bulk density, porosity, pH, soil organic matter, total organic carbon, available P, exchangeable bases (K, Ca, Na, Mg), extractable micronutrient (Fe, Mn, and Zn) for soil samples and pH, available P and K for water samples were determined. From the resultsobtained there were marked effects of the farm operation on the parameters measured, when compared with those from the control site. These were higher at the control site than the farm site. And this show that, farming operation in the site considerably degrade the soil and water environment, the worst being soil organic matter, total organic carbon, K, Ca, Mg, exchange acidity, Fe, moisture content and porosity for soil and pH, available P and K for water samples. These are in spite of the moderate level of tractorization and fertilizer applications in the farm environment from where the samples were taken. It is concluded that, environmental control measures should be put in place even in the farms operating under low level mechanization and chemical application.

Keywords: Agricultural Engineering operations, tillage, fertilizer application, soil, water, soil physical and chemical properties.

INTRODUCTION

Farm land tillage, fertilizer application, crop protection, harvesting and processing, erosion control and irrigation are some of the aspects of Agricultural Engineering operations that adversely affect the environment (Botkin and Keller 1997; Serpil, 2012; Aikins and Afuakwa, 2012).Tillage affects the physical, chemical and biological properties of soils. Research results shown that tillage of soils in several parts of Africa affect soil aggregate, temperature, water infiltration and retention (Ofori 2009). Thefavourable effects of microorganisms and earthworms are well established. These microorganisms, earthworms and others are disturbed and several are killed during tillage especially tillage using heavy equipment. According to Unger *et al*, (1991) the two practices with major impact on soil conservation are crop residue management and tillage. Traditional ploughing-in of crop residues is now giving way to surface soil residue management, which is more related to soil and water conservation, particularly in the semi-arid tropics.

Fertilizers are used to fortify the soil and to increase the rate of productivity. These cause several undesirable effects on water quality creating health hazards. It has been observed that soils suffer pollution dueto excessive use of fertilizers andgrowth regulation agents (Serpil*et al.* 2012). Thus farm soils are becoming increasingly polluted with toxic chemicals and heavy metals, which reach the food chain, and ultimately are ingested by human beings and animals.In cultivated lands, ions of nitrogen, phosphorus, and potassium are commonly in the sub optimal amounts, because of their being the chief constituents of commercial fertilizers. These chemicals such as N, P, K are the main constituents of commercial fertilizer, but excess of these adversely affect the soil.

According to the National Institute of Environmental Health Science (NIEHS(2010), pesticides can prevent crop failure, control invasive plants, and promote a uniformly green lawn. Some pesticides reduce blemishes on fruits and vegetables, ensuring that a greater proportion of the crops are marketable. Pesticides when used above the prescribed doses adversely affect soil fertility and photo toxicity. It also causes groundwater pollution through seepage. The unwise use of pesticides and insecticides on crop land contribute to soil pollution. When pesticides are spread over a cultivated land, part of their residues goes into the soil contaminating crops. Aldrin remains for one to six years and it is harmful to soil. Similarly DDT lasts for four to ten years, which chemical reaction becomes more toxic to human beings through soil and plants (Suresh 2006). The rate of degradation of residual pesticides is a function of its chemical properties and formulation. Increase in chloride content is caused by excessive use of pesticides. Persistent rate of pesticides application affect soil types, soil moisture content, temperature, uptake by plants, leaching by plants and wind erosion. Therefore, it is difficult to generalize about soil persistence of pesticides, which is higher in percentage in soil having more organic matter content, while it is lower in sandy soil. Pesticides can get into water via drift during pesticide spraying, by runoff from treated area, leaching through the soil. In some cases pesticides can be applied directly onto water surface e.g. for control of mosquitoes.

Although tractorisation and the use of chemicals in farms in South-Western Nigeria are minimal, there is the need to determine whether even this limited application have noticeable effects on soil/water in the area.The objective of this study wasto document the types of operations and equipment being used in a typical intermediate capacity farm, to determine the effects of tillage operations on soil properties, and to determine in particular the effects of the application of fertilizer and other chemicals on farmlands, on soil and water environment.

MATERIALS AND METHODS

Study Site: The study area is located inIlorain Afijio Local Government Area, Oyo State, Nigeria, its geographical coordinates are 7^{o}48′ 0′′ North, 3^o 54′ 0′′ East. The average daily temperature in the study area ranges between 25^{o}C and 35^{o}C. The rainfall over the State varies from an average of 1200mm at the onset of heavy rains to 1800mm at its peak inthe southern part of the State to an average of between 800mm and 1500mm at the northern part of the state.The experiment was conducted during the 2013 major crop growing seasons. The experimental plots were located on awell-drained sandy loam soil in between the South and North. The sandy loam soil at the study site is an Alfisol classified as clayey skeletal Oxic – Paleustalf (USA, 1999).

Experimental Design: The experiments were arranged in a randomized complete block design with two tillage treatments consisting of after second disc ploughing and no tillage from adjoining forest. Six soil sampleswere randomly collected; three from the site and three from the adjoining forest. Two water samples were collected from an earth pond within the farm and from the stream from the boundary just 8mdownstream.

Operations and Equipment in Use at the Farm

These were;

i. Tillage operation using disc plough and disc harrow (100-120 hectares)

ii. Planting operation using maize planter and soya bean planter

iii. Fertilizer application using fertilizer broadcaster/spreader (NPK; 15:15:15, urea 4600 i.e., pure nitrogen)

iv. Pesticides application using knapsack sprayer (phytozine)

v. Harvesting operation using corn picker

viii. Soil erosion control using contouring and terracing

Samples and sampling Technique

Six soil samples were randomlytaken, three from the farm and three from undisturbed soils in adjoining forest. Each of the soil samples was taken at a depth of between 0 to15cm using a cutlass and a soil auger. The sharp end of the soil auger was carefully screwed in a vertical position and it was ensured that there was uniform entry to the desired depth. The samples were transferred to a tray for homogenizing before storing in sample bags. Precaution was taken to ensure that the samples were not taken near the roots of large trees, roads, foundations of buildings or constructions. Samples were also not taken near piles of manure, compost, lime or harvested crops. The precaution was taken so as to avoid contamination of the samples and compaction within sample points.

Two water samples were taken at different locations, one from the farm (earth pond) and the other from the off farm (stream at the boundary). The water samples were taken from the site in a 1 litre capacity container and at the surface forthe control. The empty containers were rinsed several times with the water collected at the downstream. The samples were filled slowly into the containers to prevent turbulence and exclude bubbles and seal. Each sample was labelled immediately after collection and taken to Agronomy laboratory of the University of Ibadan for chemical analysis.

Determination of Soil Properties

Each moist soil sample was oven-dried at $103 \pm 2°C$ untilconstant weight was attained in accordance with (ASABE Standard, (2008). The moisture content was calculated as the weight of moisture in the soil sample divided by the weight of the oven dry soil. Bulk density values were evaluated using the ratio ofweight of each oven-dried soil sampleper unit volume of the soil corers (Blake and Hartage(1986). Total porosity was calculated from the values of the dry bulk density and an assumed particle densityof 2.65 Mg m^{-3} (Chancellor, (1994).

Some of soil samples collected fromsampling points werebulked andwere analyzed in the laboratory for chemical constituents and properties. These include pH, soil organic matter, total organic carbon, available P, exchange bases (K, Ca, Na and Mg), exchangeable acidity and micronutrients (Fe, Zn, Mn). Soil pH was determined in soil-water medium at ratio 1:1 using the Coleman's pH meter. Particle size analysis was carried out using hydrometer method (Bouyoucos, (1951). Soil organic carbon (SOC) was determined by the Wakley and Blackprocedure (Nelson and Sommers, (1982). Soil organic matter wasestimated as organic carbon multiply by 2.724 (Odu*et al*.(1986). Available(P) was extracted by Bray's P1 method (Bray and Kurtz, 1945) and read on the atomic absorption spectrophotometer. Exchangeable cations (K, Ca, Na and Mg) were first extracted using 1.0N NH_40AC (Jackson, (1958). Thereafter, K, Na and Ca were determined by the flame photometer while Mg was read from the atomic absorption spectrophotometer (AAS). Micronutrients(Fe, Zn and Mn) were extracted with sodium bicarbonate and their concentrations determined on the AAS. Exchangeable acidity was determined by the titration method described by Yuan (1959).

Water Samples and Analyses

In the Agronomy laboratory, each water sample was filtered using a Walt man's No1 filter paper to remove solid impurities. The filtered water sample was kept in a stoppered bottle of 50ml capacity and kept in a refrigerator till it was required for analysis; 5 ml of each of the water samples was taken for the determination of pH, available P and K contents. The pH of water was determined using the digital electronic pH meter, while available P and Kwere read from the atomic absorption spectrophotometer (AAS).

RESULTS AND DISCUSSION

Soil Properties

The mean of soil chemical and physical properties for samples taken from the two sites (site A and control site B) are presented in Table1. Soil samples from both sites were acidic with low soil organic matter at the site. The total organic carbonwas higher at the control than at the site. The percentage of available P was higher at the site and lower at the control. The percentages of exchangeable bases were all also generally lower at the site except sodium which recorded the higherpercentage while the control recorded the higherpercentage that is Potassium, Calcium, and Magnesium respectively. The percentage of extractable micronutrientsMn and Zn were higher at the site except Fe which recorded the lower percentage. The percentage of exchangeable acidity was higher at the control site than site A. The soils at the sites were sandy-loam soil.

Table 1 Mean Values of Chemical and Physical Properties Constituent of Soils (0 to 15cm) at the Two Experimental Sites (Site A and Control B).

Soil Properties	Unit	At Site A	At Control Site B	% diff = $\frac{A-B}{A} \times 100$
pH		5.45	5.30	+2.75
Soil Organic Matter	g/Kg	29.76	40.01	−34.44
Total Organic Carbon	g/Kg	17.26	23.21	−34.47
Available P	mg/Kg	51.30	21.72	+57.66
Exchangeable K	cmol/Kg	0.38	0.40	−5.26

Exchangeable Ca	cmol/Kg	1.24	2.48	−100
Exchangeable Na	cmol/Kg	1.27	1.22	+3.94
Exchangeable Mg	cmol/Kg	0.95	1.38	−45.26
Exchangeable acidity		0.28	0.43	−53.57
Fe	mg/Kg	55.45	64.75	−16.77
Zn	mg/Kg	5.67	3.49	+38.45
Mn	mg/Kg	202	86.60	+57.13
Moisture Content	%	13.99	22.65	−61.90
Bulk Density	mg/cm³	0.42	0.38	+0.10
Porosity	%	22.04	23.47	−6.9
Sand	g/Kg	778	798	−2.57
Silt	g/Kg	94	104	−10.64
Clay	g/Kg	128	98	−23.44
Textural Class		Sandy-loam	Sandy-loam	

Soil physical properties

Soil bulk density is probably the most frequently measured soil quality parameter in tillage experiments (Rasmussen, (1999). The percentage of dry bulk density produced by tractorizedplot (after second ploughing) was higher than that of the No tillage (control site). This is as expected as the level of compaction itself and indication of the pressure on microorganisms in the soil causing death of this.Soil compaction causes three problems because of pressure. These are, killing of microorganisms, moisture removal and difficult root penetration. These are factors that affect plant growth and yield.Ojeniyi and Agboola (1995) had reported that repetitive tillage degraded soil qualities and caused rapid collapse of soil structure. In the sub-humid and humid regions of the tropics, the high intensity rainstorms tend to increase the loosening effects of tillage. Intensive soil cultivation which may increase soil bulk density is intimately connected with reduced porosity and the alteration of pore size distribution (Ojeniyi 1990). Even in the site examined, with relatively moderate level mechanization there was loose low porosity.

Soil moisture is source of water for plant use in particular in rain fed agriculture. Soil moisture is highly critical in ensuring good and uniform seed germination and seedling emergence (Arsyid*et al*.(2009), crop growth and yield. The No tillage plot recorded the higherpercentage of soil moisture contentthan that of after second ploughing plot. Studies conducted on an Afisol, in South-Western Nigeria byNdaeyo*et al*. 1995 also indicated that zero tillage had higher soil moisture content in the profile than ploughed plots and it was attributed to the soil moisture reserve through rainstorm amelioration.

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. It is known that soil pores are of different sizes, shapes and continuity and these characteristics influence the infiltration, storage and drainage of water, the movement and distribution of gases and the ease of penetration of soil by growing roots (Kay and VandenBygaart, (2002). In the present work the No tillage recorded the higher percentage of total porosity being 1.43% higherthan that of after second ploughing plot, which produced the lowerpercentage of total porosity.Ahn and Hintze (1990) observed that tillage practices lowered porosity due to decline in organic matter and weakening of soil structure.

Soil Chemical Properties

Soil pH is extremely important on the decomposition of mineral rock into essential elements that plants can use.The pH of the soils studied was strongly acidic, and the order of increase is control less than the site. The strongly acidic nature of the soils could be attributed to high cropping intensity (which result to the assimilation of most of the basic cations by the crops) and moderate rainfall (which causes leaching).Organic matter plays a major role in soil physical, chemical and biological properties and acts as a source of nutrients, which increase nutrients exchange sites and affect the fate of applied pesticides (Alabandan*et al*.2009). The No tillage (control) had the higher percentage of soil organic matter (SOM).Low organic matter soils are low in boron and often low in zinc, especially sandy soils. Organic matter may form natural chelates aiding in maintaining iron in a soluble form. High organic matter content provides more available boron to plants, but decreases copper availability due to strong bonding of copper to organic matter and may tie up manganese into unavailable organic complexes.The percentage of organic carbon recorded at the site was lower than that of the control. The difference could be attributed to the effect of continuous cultivation that aggravates organic matter oxidation. The results were in agreement with the findings of Negassa (2001) and Malo*et al*. (2005), who reported less organic carbon in the cultivated soils than grassed soils. Exchangeable bases (K, Ca and Mg) where generally lowered at the site except Na which recorded the higher percentage. Thedecline in the nutrient reserve of tilled soils (after second ploughing) could be adduced to highdestruction of soil structure during land preparation which intensified soil erosion (soil wash)that preferentially removed colloidal fraction with high “enrichment ratio” as found by Agbede(2008) andAgbede and Ojeniyi(2009),resulting in a progressive depletion of its nutrient reserves.Negassa(2001) also reported that low exchangeable Ca and Mg observed on tilled plot might be due to leaching, soil erosion and crop harvest. From the result of this work, available phosphorus was found to be greater under after second ploughing.The soil pH might have influenced the level of availability of phosphorus since the availability of phosphorus and its solubility is pH dependent. Ozubor and Anoliefo (1999) observed that soils with low pH value result in the reaction of phosphorus with aluminum and iron to form complex compound such as aluminum phosphate (Al_3PO_4) and iron phosphate ($FePO_4$), which are fixed in the soil and not readily available for plants.

The micronutrients Zn and Mn recorded the higher percentage at tillage site, while Fe recorded the higherpercentage at control site. Zinc is known to synthesize tryptophan, a protein compound needed for the production of growth promoting hormones called auxins. The amount of available Zn in the soil is affected by soil pH, soil texture, soil phosphorus, and weather conditions. Zinc availability to plant decreases as soil pH increases and become deficient in soils with a pH above 6.5. According to Negassa (2001), low Zn concentration in tillage plot might be due to continuous harvesting of crop, organic matter oxidation, removal of the topsoil by sheet and rill erosion that is aggravated by tillage activities. Manganese (Mn) like Mg promotes enzyme transformations. The amount of available Mn in soils is affected by soil pH, organic matter content, soil moisture, and soil aeration.Iron is essential for synthesis of chlorophyll, the green color of plants which functions in photosynthesis but it is not part of chlorophyll molecule. The decrease of Fe on the soil solution is as result of increase of soil pH.Eneji, (1997) reported that the declines observed in some micro-nutrients may be attributed to loss of soil organic matter which has been reported to correlate very well with soil micro-nutrient.

Water Analysis

The mean values of water analysis at the two sites are presented in Table 2. The pH of water samples taken at the control site recorded the higher values, although both water samples were alkaline. The available P and K level at the control were also higher than that of the site. During the data collection, it was observed that the turbidity level of water at the control was higher than that of the site. This may be ascribing to erosion of the colloidal materials such as clay, silt, rock fragments and metal oxides from the soil of the farmsite to the water body downstream or as a result of leaching, drainage and flow from the soil site to the water body downstream. Improperly managed, elements of fertilizer can move into surface water through field runoff or leach into ground water (USEPA 2010).

Table 2: Results of Mean Values of Water Analysis

Properties	Units	At Site	At Control Site	% Difference = $\frac{A-B}{A} \times 100$
pH	mg/l	7.1	7.5	-5.63
Available P	mg/l	0.18	0.25-38.89	
K	mg/l	2.74	6.52-137.96	

CONCLUSIONS

Results from this study revealed that tillage practicesresulted in the decline of soil macro and micro nutrients. The higher declines were observed in after second disc ploughing plot. The reduction in Ca, K and Mg are reflected by the decline in soil organic carbon in mechanically tilled plot due to rapid breakdown and mineralization of the soil organic carbon. The reduction observed in some of the micro-nutrients (Fe, Zn and Mn) may be attributed to loss of soil organic matter. The higher moisture status of control could be adduced to the minimum soil disturbance with little exposure of the soil surface to the atmospheric demand and consequent reduction in soil water. The result of this study showed that No tillage was the most productive soil.

The result from this study also revealed that fertilizer applications even at moderate level adversely affect soil/water environment. The mean pH value of water sample at the site was lower than that of the control though both pH of the water samples from sites were alkaline. The mean values of available P and the potassium at the control were higher than that of the site. This may be as a result of erosion of the colloidal materials such as clay, silt, rock fragments and metal oxides from the soil site to the water body or as a result of leaching, drainage and flow from the soil site to the water body downstream. It is hereby concluded that even low to moderate level mechanization are employed, observable level of soil degradation and water pollution are found. It is therefore necessary that precaution need to be taken even in farms in this category.

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