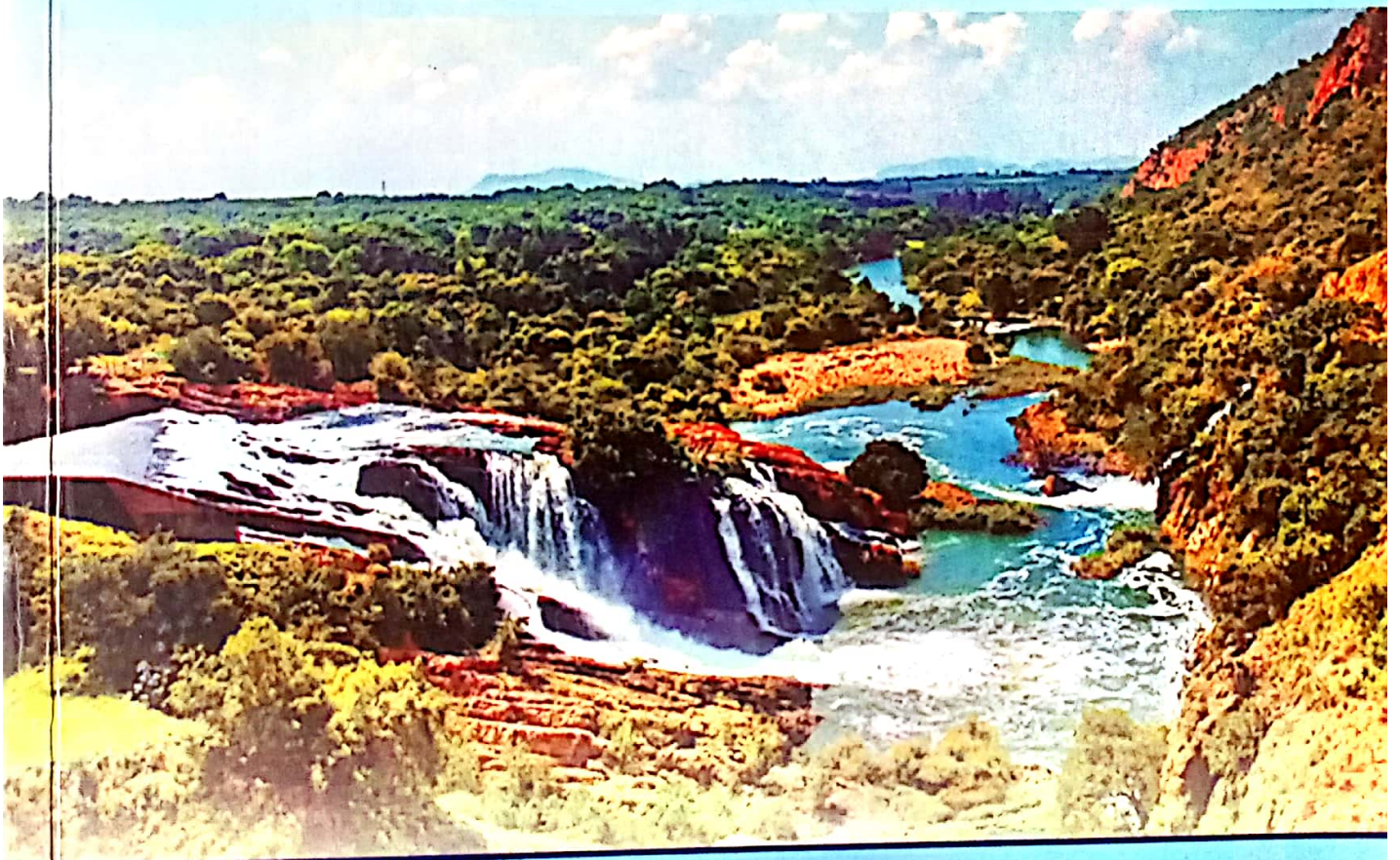


ENVIRONMENT AND THE **CHALLENGE OF SUSTAINABLE** DEVELOPMENT



ADEBISI ADEDAYO



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Adebisi Adedayo

Edited by
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CHAPTER 21

Simulating the Impact of Tillage Methods on Biophysical Parameters in River Oyun Catchment Area, Kwara State, Nigeria

T. M. Agaja and L. T. Ajibade

Introduction

Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation involving activities such as ploughing, digging, overturning, shovelling, hoeing and raking (Aina, 2011). The term tillage used broadly, embraces all operations of seedbed preparations that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. Tillage includes mechanical methods based on conventional technologies of ploughing and harrowing, weed control using herbicides and fallowing with cover crops controlled by direct seeding through its residue mulch according to Ohu (2011).

There are two main types of tillage systems which are the conventional tillage and conservation tillage. Conventional tillage is a tillage system using cultivation as the major means of seedbed preparation and weed control. It is defined as any tillage and planting system that leaves less than 15 percent residue cover after planting or less than 560 kilograms per hectare of small grain residue equivalent throughout the critical wind erosion period as proposed by CTIC (2004). It includes systems such as *Mechanized tillage* involving mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowing and Traditional tillage

which is practiced mostly by manual labour. It uses native tools which are generally few and simple, the most important are the cutlass and hoe which come in many designs depending on function (Aina *et al.*, 1993).

Conservation tillage (CT) is defined as any tillage and planting system that covers 30 percent or more of the soil surface with crop residue after planting, to reduce soil erosion by water (CTIC, 2004). There are many variations of conservation tillage systems covering a broad spectrum of farming methods primarily aimed at reducing soil disturbance, conserving and managing crop residue to reduce erosion. Ohu (2011) divided conservation tillage practices to include No-tillage, Ridge tillage, Strip tillage and Mulch tillage.

Land and land resources presently are faced with issues such as erosion, improper land management problems such as degradation, pollution, overgrazing among others as reported by Ahaneku (2010). Agricultural sustainability is needed as it increases the trend in per capita productivity to meet the present needs without jeopardizing the future potential. With continued population growth and increasing demand on water resources, conservation tillage will have an increasing role to play in farming during this millennium. The world population has been projected to be expected to be 8.5 and 9.0 billion by 2025 and 2050 respectively (Berry *et al.*, 2003). Therefore, the greatest threat to sustaining agricultural productivity in the Nigerian farming communities and the world at large is the declining productivity of soil caused by the loss of soil fertility through the erosion of the top-soil. This is due to the use of inappropriate land use practices and the loss of soil water content, soil structure and porosity. Thus, transformation of natural resources not only brings the affected land under nature's degradation regime but also accelerates the process (Aromolaran, 1998).

Abundance of land in Nigeria has prevented the adoption of

conservative agriculture which according to Gilleret *al.*, (2009), the potential of Conservative Agriculture (CA) in Africa is based on widespread adoption in the America. CA is said to increase yields, reduce labor requirements, improve soil fertility reduce erosion and sustain the land resources. Yet, empirical evidence is not clear nor consistent on many of these points neither is it clear which of the principles of CA contribute to the desired effects (Gilleret *al.*, 2009)

In Nigeria like many parts of the third world countries, solute transfer or pollution is an acute problem. Several studies on water pollution and soil degradation have focused on water channel pollution, erosion, nutrient loss among others (EPA, 1999; Clark *et al.*, 1993; Abuludeet *al.*, 2007; Ifabiyi, 2008) but few provided information on sources of pollutant. Consequently, the effort at reducing pollution has not been too successful since a little understanding exists on sources and processes of pollution as well as land preparation activities especially in watershed areas. Thus, from the foregoing, this study seeks to determine the effect of tillage methods on some biophysical factors within the study area by simulating into a model through the use of Soil Water Assessment Tool (SWAT).

Study Area

The study was carried out at the University of Ilorin Teaching and Research Farm, Ilorin (UTRF) and National Centre for Agricultural Mechanization (NCAM), Idofian which are located in Ilorin South Local Government Area and Ifelodun Local Government Area, Kwara State respectively. UTRF is located between latitudes $8^{\circ}28''\text{N}$ and $8^{\circ}29'30''\text{N}$, and between longitudes $4^{\circ}38'30''\text{E}$ and $4^{\circ}40'30''\text{E}$ NCAM is located between latitudes $8^{\circ}22''\text{N}$ and $8^{\circ}23''\text{N}$, and between longitudes $4^{\circ}40''\text{E}$ and $4^{\circ}41''\text{E}$ (Figures 1) The Ilorin-Lokoja trunk A road marks the northern limit from the Oyun river bridge (Ahaneku, 1990). The climate of the study area falls within the tropical hinterland climatic zone. It is tropical and seasonal having dry season

occurring between November to April, and rainy season between May and October (Mustapha, 2008). The temperature ranges from 20°C-30°C. **The vegetation is Guinea savannah grassland** which is characterized by the presence of fire tolerant woody shrubs and trees which are biologically suited to withstand dry conditions such as locust bean trees, shear butter trees etc. The soil is ferruginous tropical soil and classified as Topic Haplustalf of Eruwa, and Odo-owa series. The parent material consists of Micaceous schists and genesis of basement complex origin which are rich in ferro-magnesian minerals.

The first experimental site is located at UTRF and is drained mainly by Oyun River which takes her source cross-section from Ita-Oregun in Osun State and flow through Otan-Aiyegbaju (also in Osun State) to Offa and finally to Ilorin where it is dammed at the University of Ilorin main campus while the second experimental site National Center for Mechanized Agriculture (NCAM) Idofian experimental site which is located in the center of NCAM which forms parts of the lower catchment area of River Oyun that bounds it to the West. The catchment of Oyun River is located between latitudes 9°50' and 8°24' North and Longitudes 4°38 and 4°03 East. Its total area is 800.0 km² with a length of 71.4 km and it lies within Kwara State (Figure 1). The drainage pattern of the University of Ilorin Teaching and Research Farm is dendritic pattern with the tributaries joining Oyun and Asa River obliquely. The Oyun and Asa Rivers' path mark the topographical lows, while the highest portions are to the east and south-east. Cross section from the east to the west will give a shallow V-shaped topography. The second experimental site which is located in the center of NCAM, Idofian forms parts of the lower catchment area of River Oyun that bounds it to the West. The main River that drains the study area joins the Asa River which finally empties its water into the Niger River at Jebba in Niger state (Unilorin Master Plan, 1977).

Majority of the people in the study area practice subsistence

The map displays the study area in the Niger Delta region. It includes a legend with the following symbols:

- Settlements (represented by small squares)
- Locations (represented by black dots)
- Streams (represented by dashed lines)
- Uniform Dam (represented by a hatched rectangle)

The map shows several settlements: Fufu, Ama, Ennere, Apala, Fafoku, Amayo, Dongari, Imba, On Gata, and Idofian. The location of the study is marked with a black dot and labeled 'PS'. The map is bounded by coordinates 4°30'0"E to 4°42'0"E and 4°34'0"N to 4°38'0"N. A scale bar indicates distances up to 5 km, and a north arrow is present in the bottom right corner.

Source: National Space Research and Development Agency (2014)

Four treatments with three replicates were carried out using Randomized Complete Block Design (RCBD). They were treatment A (zero or no-tillage), treatment B (plough and harrow), treatment C (plough, harrow and ridge), and treatment D (heap traditional farming). These are conservative and conventional tillage types used in the study area. Simulation was made from the experimental plot for the entire Oyun drainage basin. Maize (*ZeaMays.L. SWAM 1* variety) was planted for two farming seasons (i.e 2015 and 2016 farming year) on plot size of 5m x 5m at spacing of 75cm between rows and 50cm within row. NPK (15:15:15) fertilizer was applied at 4 weeks and 8 weeks of planting, pre-emergence and

post emergence herbicide for weed control were administered on the sets of the experimental plot as a normal agronomic practice.

These covered for both conventional and conservative tillage methods used in the study area..Soil Water Assessment Tool (SWAT) was used to model the pattern and process of pollution from the tillage types through a ARCSWAT 2012.10.19 for ARCGIS software 10.2, 10.3 and 10.4. Some of the components/features modeled and used to generate data for the Hydrologic Response Unit (HRU) in the SWAT environment are stated in the Table 1.

Table 1: Features modeled in SWAT

HRU	Hydrologic Response Unit
SUB	Sub basin
PREC mm	Precipitation
SURQGEN mm	Surface runoff generated in HRU during time step (mm H2O)
SED th	Sediment yield (metric tons/ha)
SURQ mm	Surface runoff contribution to stream flow in the main channel
USLE_LS	Soil loss during the time step calculated with the USLE equation
GWQ mm	Groundwater contribution to stream flow (mm H2O)
ET mm	Actual evapotranspiration
NO3 kgh	NO3 in surface runoff (kg N/ha)
ORGN kgh	Organic N yield (kg N/ha)
BIOM th	Biomass
YLD th	Crop yield (metric tons/ha)

Source: Author's fieldwork (2017)

Maps and satellite images showing the landuse types, soil, climate, relief and drainage were sourced from National Space Research and Development Agency, Nigerian Geological Agency, Kaduna State and Kwara State Bureau of Lands and Survey. Data were complemented with information from relevant books, journals, internet sources, and literature.

Results and Discussion

The SWAT analysis generated three (3) hydrological response units (HRU) each for the two study areas. The HRU is the smallest spatial unit of the model because it lumps all similar land use, soil, elevation profile, and slope within a sub basin based on user defined threshold. Shown in Tables 2 is the distribution of the HRU in UTRF and NCAM sub catchments. Figure 2 shows a schematic representation of the hydrologic cycle modelled in SWAT for the study areas

Table 2: Distribution of the HRU in UTRF and NCAM sub catchments

Name	Sub basin	Hydrologic Response Unit	Land Area Covered (m ²)	Tillage method
UTRF	18	44	0.463	PH
UTRF	18	45	0.201	NT, T
UTRF	18	46	0.209	PHR
NCAM	42	103	0.872	NT, T
NCAM	42	104	2.19	PH
NCAM	42	105	2.56	PHR

*NOTE: T-Traditional heap, PH-Plough/Harrow, PHR-Plough/Harrow/Ridge, NT-No Till

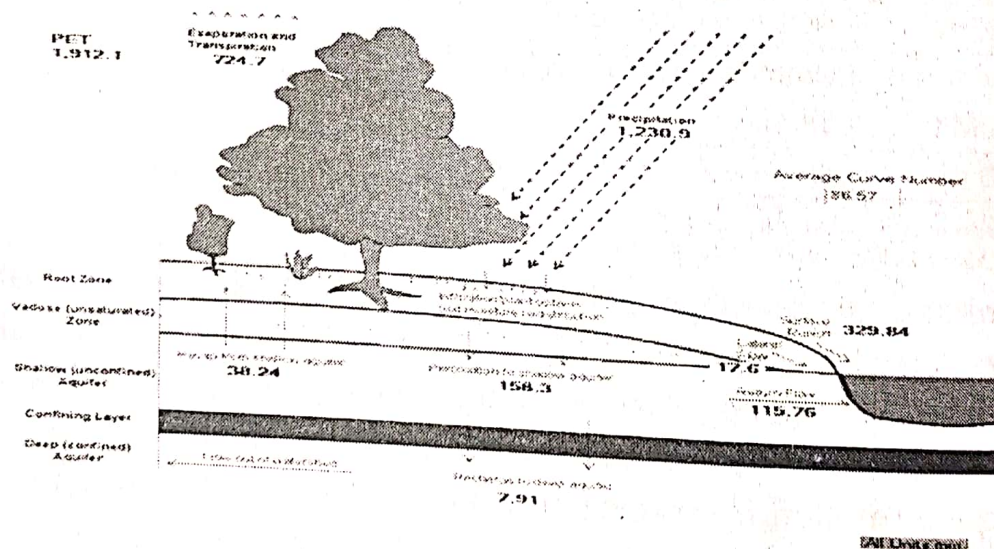


Figure 2: Schematic Representation of the Hydrologic Cycle of the study area.

Source: Author's fieldwork (2017)

From the SWAT, the soil types in both areas are same: Ferric Luvisols albeit with variants. UTRF sub-basin has a variant of the ferric luvisols Lf-26a while NCAM sub-basin has an Lf-12 soil variant. The values for UTRF and NCAM sub-basins are 1.661 and 6 metric tons/ha respectively as shown in Table 3. This shows that NCAM had a greater soil loss compared to UTRF although NCAM has a gentler slope (2.74) as compared to UTRF (6.39) (see Figure 3). In addition, Plough/Harrow treatment had the highest soil loss with 1.05 metric tons/ha while No till, Traditional heap and Plough/Harrow/Ridge treatment plots had 0.201, 0.201 and 0.209 metric ton/ha respectively on UTRF sub-basin. Notill and Traditional heap had the highest soil loss with 2.31 metric tons /ha each, followed by Plough/Harrow/Ridge with 1 while Plough/Harrow had the least values of 0.38 metric tons /ha on NCAM sub-basin (see Table 3). This implies that the topography of area is a major determinant in the amount of soil lost. This is in line with Kauret *al.*, (2003) submission that water and soil losses from a catchment area are a function of its topography(slope), physiographic (land use, soil type, soil depth) climatic and management conditions.

SWAT also modified sediments to account for in-stream deposition and erosion of stream banks and channels. Streams may be either a net source of sediment, or a sink. In-stream sediment modification is impacted by physical channel characteristic's (slope, width, depth, channel cover, and substrate characteristics) and the quantity of sediment and flow from upstream. The value for sediment yield from UTRF and NCAM sub-basins are 28.2 and 27.28 metric tons/ha as shown in Table 3. This is as a result of the mean slope of UTRF sub-basin being higher (6.39) than that of NCAM (2.74) as shown in Figure 3.

Table 3: Soil loss and Sediment yield from the experimental plots

Tillage types	UTRF (USLE_LS)	NCAM (USLE_LS)	UTRF (SED th)	NCAM (SED th)
PH	1.05	0.38	5.31	1.57
NT	0.201	2.31	10.54	10.46
T	0.201	2.31	10.54	10.46
PHR	0.209	1	1.81	4.79
Grand total(metric tons/ha)	1.661	6	28.2	27.28

Source: Author's fieldwork (2016)

From the tillage types on UTRF experimental plots, No till and Traditional heap treatment plots had sediment yield with 10.54 metric tons/ha each followed by Plough/Harrow with 5.31 metric tons/ha and Plough/Harrow/Ridge with 1.81 metric tons/ha. Also at the NCAM site, No till and Traditional heap had 10.46 metric tons/ha each followed by Plough/Harrow/Ridge with 4.79 metric tons/ha and lastly Plough/Harrow with 1.57 metric tons/ha as shown in Table 4. Due to high runoff, sediment yield in the basin is quite high with about 3.67 metric tons/ha lost from the streams annually with a sediment yield upland of 4.16 metric tons/ha as shown in Figure 4. This is in agreement with Johannsen and Armita (2010) reporting that sediment yields were up to ten times greater from agricultural catchments than forested catchments. Coutu and Vega (2007) also reported that SWAT results gotten in their study indicated that implementation of improved tillage practices can reduce sediment yields by almost 20% in the Rock River in Wisconsin. However, the findings from the individual tillage methods contradicts the norm that the use of conservative tillage should reduce sediment yield as proposed by several authors such as Philpset *al.*, (1980), Ainaet *al.*, (1993), Lewandowski *et al.*, (1999), Anthony and Collin (2006), Derpsch, (2007), FAO (2007), Aina (2010), Rejiet *al.*, (2012) among others.

Plough/Harrow/Ridge plot with 283.39mm while Notill and Traditional heap plots had 281.94mm each. This can be attributed both to the elevation of the areas which will increase the movement of surface runoff down slope (see Figure 3) where UTRF has a mean slope of 6.39 and NCAM has a mean slope of 2.74. The mean annual rainfall was higher on UTRF than on NCAM with 1314.21mm and 1113.86mm. According to Salsabilla and Kusratmoko (2017), runoff and sediment are positively related to the land cover in a watershed. More forest cover produces generally less runoff and soil loss. Land with cultivation has more erosion than land with agriculture.

The groundwater (GWQMM) contribution to stream flow for both UTRF and NCAM experimental Site are 687.95mm and 376.34mm respectively. This indicates that UTRF has a high volume contributing into the main channel as compared to NCAM. Among the tillage types on UTRF site, NT and T plots contributed 174.45mm each followed by PH plot with 171.19mm while the lowest is PHR plot with 167.86mm. Also for NCAM, NT and T plot contributed 96.32mm each followed by PHR plot with 93.29mm and PH plot with 90.41mm as shown in Table 4.

Table 4: Surface runoff and Groundwater contribution to stream flow in the main channel in the area

Tillage types	UTRF (SURQmm)	NCAM (SURQmm)	UTRF (GWQmm)	NCAM (GWQmm)
PH	372.91	284.86	171.19	90.41
NT	371.53	281.94	174.45	96.32
T	371.53	281.94	174.45	96.32
PHR	374.42	283.39	167.86	93.29
Grand total	1490.39	1132.13	687.95	376.34

Source: Author's fieldwork (2016)

PHR had the highest value for evapotranspiration on UTRF site with 725.78mm followed by PH with 724.79mm while NT and T plots had the lowest values with 723.6mm each. On NCAM, PH plot had the highest values with 698.1mm followed by PHR plot with 697.47mm

while NT and T treatment plots had the lowest value with 696.6mm each as shown in Table 6. The biomass at both UTRF and NCAM were 54.24mm and 51.24mm respectively. NT and T had 13.57 each followed by PHR with 13.56mm while PH had 13.54mm. For NCAM, all the tillage types had 12.82 BIOM th as shown in Table 5.

Table 5: Evapotranspiration and Biomass in the study area

Tillage types	UTRF (ETmm)	NCAM (ETmm)	UTRF (BIOMth)	NCAM (BIOMth)
PH	724.79	698.1	13.54	12.82
NT	723.6	696.6	13.57	12.83
T	723.6	696.6	13.57	12.82
PHR	725.78	697.47	13.56	12.82
Grand total	2897.77	2788.77	54.24	51.24

Source: Author's fieldwork (2016)

Proper plant growth is key to accurate runoff and sediment predictions. Problems in plant growth are often related to excessive stress due to temperature or the lack of water/nutrients. The data presented here are basin averages, and may not reflect problems with individual. Notill and Traditional plots had 62.62 kg N/ha organic nitrogen at UTRF site followed by Plough/Harrow plot with 50.94 kg N/ha while Plough/Harrow/Ridge plot had 29.83 kg N/ha. For NCAM site, Notill and Traditional heap also had the highest value of 60.79 kg N/ha followed by Plough/Harrow/Ridge with 48.38kg N/ha while Plough/Harrow had the lowest value of 27.41 kg N/ha as shown in Table 6. On UTRF sub-basin, Notill and Traditional heap contributed 5.15 kg N/ha each, followed by Plough/Harrow with 4.41 kg N/ha while Plough/Harrow/Ridge had the lowest value of 3.68 kg N/ha to nitrogen in surface runoff. On NCAM site, Notill and Traditional heap also had the highest contribution of Nitrogen in surface runoff with 4.42 kg N/ha each, followed by Plough/Harrow/Ridge with 3.89 kg N/ha while Plough/Harrow had 3.04 kg N/ha as displayed in Table 6.

Table 6: Organic nitrogen and Nitrogen in surface runoff in the study area

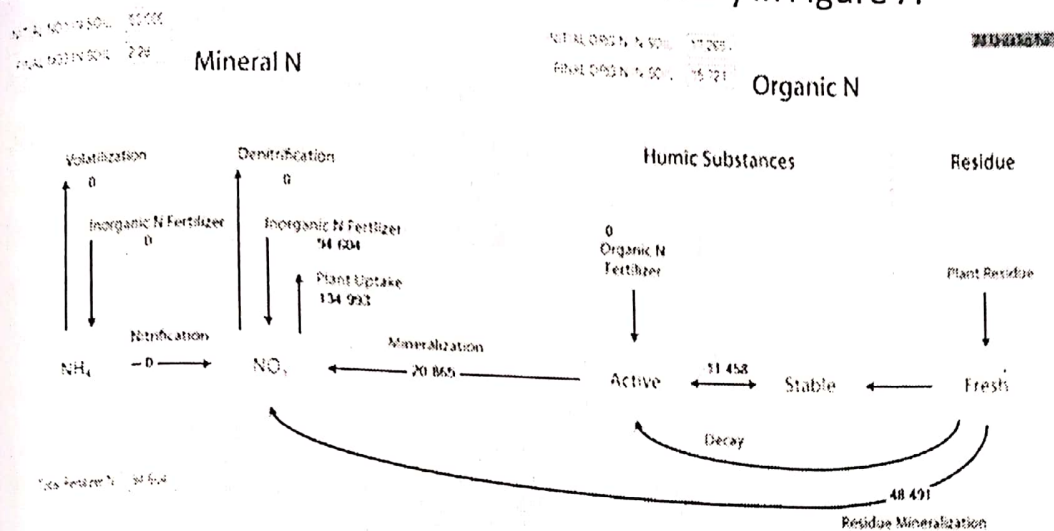
Tillage types	UTRF (kg N/ha)	NCAM(kg N/ha)	UTRF (kg N/ha)	NCAM (kg N/ha)
PH	50.94	27.41	4.41	3.04
NT	62.62	60.79	5.15	4.42
T	62.62	60.79	5.15	4.42
PHR	29.83	48.38	3.68	3.89
Grand total(kg N/ha)	206.01	197.37	18.39	15.77

Source: Author's fieldwork (2016)

The nitrogen cycle is a key to biomass production, which in turn impacts on evapotranspiration, sediment yield and crop yield. It is generally not possible to validate these routines outside a research setting. Of particular importance are the total applied nitrogen fertilizer and losses due to plant uptake, volatilization and denitrification. Soils contain a large amount of organic nitrogen in the form of organic matter. Large changes in initial and final nitrogen contents (in particular organic n) may indicate under or over fertilization during the simulation. All this is indicated in SWAT modelled summary in Figure 6. This is in line with Gassman *et al.*, (2007) reporting that adoption of no tillage, changes in nitrogen application rates, and land use changes could greatly impact nitrogen losses in the Walnut Creek Watershed in central Iowa.

The phosphorus cycle is of particular interest in watersheds with significant agricultural activities. Soils contain a large reservoir of both mineral and organic phosphorus. Large increases in mineral phosphorus content during the simulation often result from over fertilization with either commercial or manure phosphorus sources. This also means that phosphorus concentrations in runoff also increase during the simulation period. Plant uptake is the dominant loss pathway for phosphorus under most conditions. Phosphorus decreased in the soil with both mineral P and Organic P recording losses between initial and final P. This implies that quite an amount of phosphorus is being lost to runoff while the plant uptake is also responsible without any major input of phosphorus to the soil. All

this is indicated in the SWAT modeled summary in Figure 7.



Total nitrogen losses are greater than 40% of applied N
 Organic/Particulate nitrogen losses in surface runoff may be high
 Solubility ratio for nitrogen in runoff is low
 Solubility ratio for phosphorus in runoff is low, may indicate a problem

Nitrogen Losses (kg/ha)	
Total N Loss	59,064
Organic N	39,441
Nitrate Surface Runoff	2,824
Nitrate Leached	15,941
Nitrate Lateral Flow	0.73
Nitrate Groundwater Yield	0.128
Solubility Ratio in Runoff	0.067

Figure 6: SWAT modeling Nitrogen in the study area
 Source: Author's fieldwork (2016)

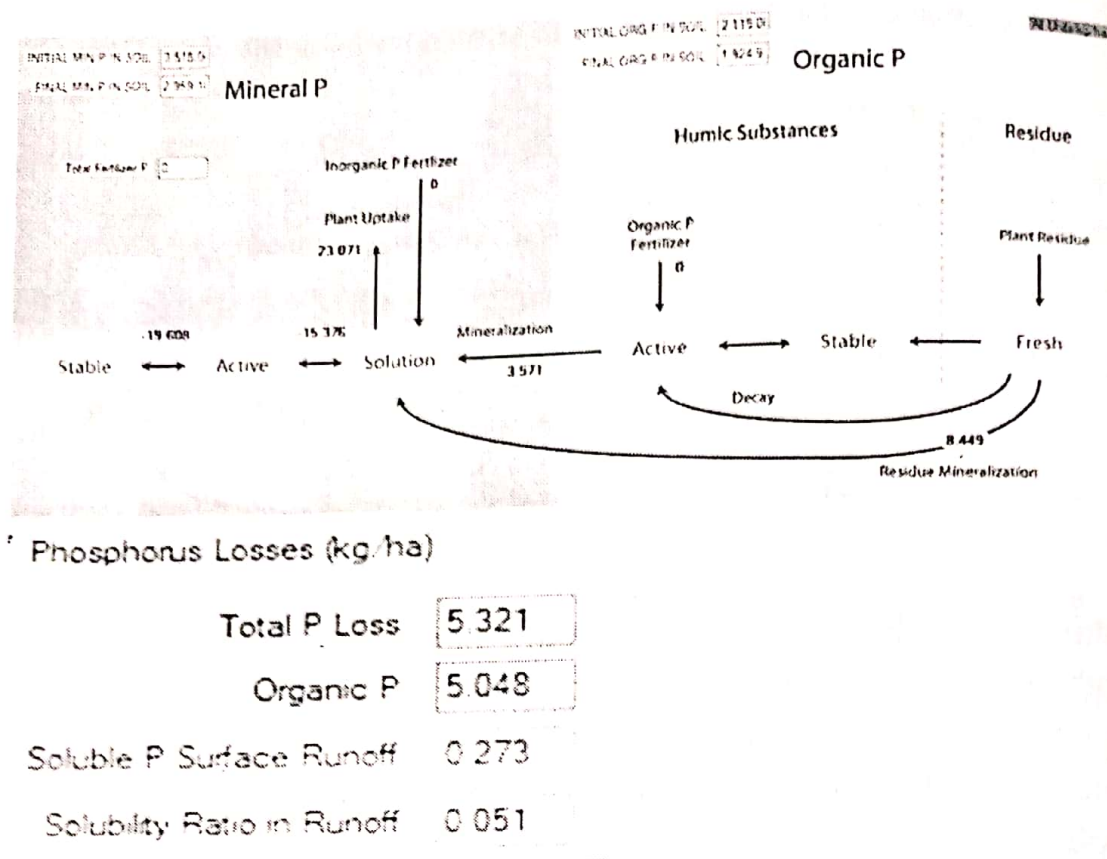


Figure 6: SWAT modeling Phosphorus in the study area
Source: Author's fieldwork (2016)

The observations from the SWAT model revealed that UTRF sub-basin contributed more to all the features modelled than NCAM sub-basin expect for soil loss where NCAM site generated more soil loss than UTRF site with 6 and 1.661 USLE_LS respectively. Notill and Traditional heap tillage contributed more to sediment yield, groundwater amount, organic nitrogen, and nitrogen in surface runoff water than the other tillage types at both locations as shown in Tables 3, 4 and 6 while Plough/Harrow and Plough/Harrow/Ridge tillage contributed more to surface runoff amount and evapotranspiration at both locations has shown in Tables 4 and 5. Plough/Harrow tillage contributed more to soil loss on UTRF subbasins than the other tillage types while Notill and Traditonal heap contributed more in NCAM subbasins as shown in Table 3. NT, T and PHR tillage had the same values for crop yield in UTRF subbasins

while all the tillage types had the same values in NCAM subbasins as shown in Table 5. For the biomass, NT and T tillage contributed more in the UTRF subbasins than the other tillage types while NT contributed more in NCAM subbasins as shown in Table 5. Thus, conservative tillage contributed more to the features as against the opinion of it been the most suitable tillage type for attaining the best environmental conditions for growing maize giving rise to a sustained land resources as highlighted by several reference (Lewandowski *et al.*, (1999), Anthony and Collin (2006), Derpsch, (2007), FAO (2007), Aina (2010), Rejiet *al.*, (2012) among others.). Therefore, farmers must be conscious of the agricultural land management activities such that the best tillage method that is suitable for such an environment is applied to have optimum crop yield yet conserving the water and soil quality.

Conclusion and Recommendations

In conclusion, Soil and Water Assessment Tool (SWAT) model has proven to be an effective tool for assessing the impact of tillage types and non-point pollution problems for a wide range of scales and environmental conditions across the globe and has enabled in this study the quantification of the impact of land management practices, predict the impact of man-made changes and management practices as well as natural changes. It has also allowed assessment of various physical phenomena such as water, sediment, nutrient and crop yields in complex watersheds with varying soils, land use and management conditions over a period of time with accuracy and also generate alternate scenarios. The study recommends the need for appropriate technology for monitoring over time how farm management practices affect water and soil degradation and also a call for cooperation in research and in the establishment of data banks operating on a unified information system, the eminence of education, training, and extension to farmers in Nigeria.

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