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MODELLING THE IMPACT OF TILLAGE ON WATER QUALITY FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN A SAVANNA ECOLOGICAL ZONE, KWARA STATE, NIGERIA

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Abstract

The aim of the study was to examine the effects of tillage methods on surface runoff and model the pattern and processes of surface water pollution associated with tillage methods using Soil Water Assessment Tool (SWAT). This model was designed to predict the impact of land management practices on water, sediment, and varying tillage types in watersheds over two planting seasons. Traditional heap (T), Plough/Harrow (PH), Plough/Harrow/Ridge (PHR) and No-tillage (NT) methods commonly used in the study area were applied to experimental plots at Unilorin Teaching and Research Farm and National Center for Agricultural Mechanization, Idofian (Nigeria). Using Randomized Complete Block Design (RCBD), each treatment had three replicates making 12 experimental plots at each location for the 2015 and 2016 planting season. Nine biophysical parameters were purposively selected, examined and modelled. The study revealed that four of nine biophysical factors (sediment yield: 10.54 t/ha; groundwater discharge: 174.45 mm; organic nitrogen: 62.62 kg/ha, and nitrogen in surface runoff: 5.15 kg/ha) were higher for traditional heaps, while three parameters (surface runoff: 374.42 mm; evapotranspiration: 752.78 mm, and soil loss: 1.05 kg/ha) were higher under plough/harrow and plough/harrow/ridge cultivation practices. The study concluded that tillage methods have impact on water quality. However, plough/harrow has comparatively more favorable effect on the contribution to surface runoff. It is therefore recommended that this type of tillage should be adopted to reduce water pollution and for sustainable environment.

Keywords: tillage, environment, sustainability, water quality, pollution

INTRODUCTION

Agriculture is an essential human activity that facilitates food production. For a long time, the increasing demand for food was met by the extension of cultivated area under cultivation. One of the consequences of crop production is the clearing of natural vegetal cover which in turn exposes the cleared land to weathering processes and degradation. Such weathering processes include soil erosion, leaching of nutrients and change in nutrient profile of the soil, which increase the pollution of fresh water sources. Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation involving activities such as ploughing, digging, overturning, shoveling, hoeing and raking (Aina, 2011) while conservation tillage is an option for maintaining soil health and the surrounding environment for intensive agriculture, especially in the tropical climate (Sayed et al., 2020).

The soil tillage systems influence the soil structure and can have considerable impact on the environment. This substantially affect water quality, nutrient availability, crop yield, sediment transport, pesticide distribution, air quality and greenhouse processes. The effects of soil structure on agricultural production range on scales from soil productivity and sustainability at a local scale, to water quality and landscape at a regional scale, and water and energy balance and greenhouse effect at a global scale (Derpsch, 2007; Hobbs, 2007). Agricultural practices have been a major contributor to water pollution more than any other single source (Gliessman, 1998). Overland flow from farms can contain lots of sediment, pesticides, and fertilizers as well as animal waste products. The leading cause of decreased water quality in lakes and estuaries is agricultural nutrient pollution, whereas agricultural fertilizers are the dominant source of nutrient pollution in any watershed (Mateo-Sagasta et al., 2017). Most crops remove more nitrogen from the soil than any other nutrient, so more nitrogen is applied as fertilizer. About 50% of the nitrogen fertilizers applied to crops is not taken up by the plant and remains as residue in the fields. These residues are carried by runoff and easily leach into groundwater especially when fields are irrigated (Hallberg, 1987). Also, 75% of the sediment in watercourses is estimated to have come from agricultural lands (Anthony and Collins, 2006).

Typically, runoff water contains sediment, dissolved nutrients, and possibly some chemicals from conventional tillage methods. Water runoff could be reduced by conservation tillage, thereby increasing infiltration of water into the soil. One immediate and obvious result of conservation tillage is improved surface water quality. Stimulation and excessive growth of algae and other aquatic vegetation may occur as a result of agricultural runoff, causing severe water quality problems. Overgrowth of algae, in particular, causes oxygen depletion that may kill fish, and also leads to taste and odor problems for drinking water supplies. Sediments from cropland erosion may also increase the turbidity (cloudiness) of water, impairing fisheries (Devlin and Barnes, 2009). Li and Guo (2020) reported that the total nitrogen loads are much higher than the total phosphorus loads from agricultural lands. The land use types showed great pollution loads resulting from various significant spatial differences: agricultural lands have the greatest total nitrate and phosphorus load per unit area, followed by grasslands. Forested lands have the least pollution load per unit area.

Water-borne diseases like diarrhoea has killed more than 100,000 children under five years of age in Nigeria as reported by the United Nations Children's Fund, and 90 % of those deaths were directly attributed to unsafe water and sanitation (Onwuzoo, 2020). Also, Galadima et al. (2011) reported that the most common causes of illness and death are water related diseases affecting mainly poor inhabitants in the local communities. Several cases of death due to water related diseases have been reported: in October 2010, 1191 deaths of cholera from 29115 cases was reported in 15 of the 36 states in Nigeria, including the Federal Capital Territory, Abuja (Galadima et al., 2011). It was observed that the outbreak is still in existence in new areas due to continuous water pollution.

Agricultural diffuse water pollution remains a notable global pressure on water quality, posing risks to aquatic ecosystems, human health and water resources and as a result legislation has been introduced in many parts of the world to protect water bodies. Due to this, water quality models such as Soil Water Assessment Tool (SWAT) have been increasingly applied to catchments to better understand the pattern and process of water pollution from water sheds in different regions which will help identify and provide mitigation options that can be introduced to reduce agricultural diffuse water pollution and improve water quality (Taylor et al., 2016).

According to Gassman et al., (2014), one of the most widely used water quality watershed- and river basin-scale models worldwide is the SWAT model. It can be useful extensively for a broad variety of hydrologic and/or environmental problems. Some of the major advantages of the use of SWAT and its wide acceptance internationally can be attributed to its flexibility in addressing water resource problems comprehensive online documentation and supporting software can be adapted for use for specific application needs.

Shen et al. (2013) applied the SWAT in the Three Gorges Reservoir basin (China) to estimate nitrogen and phosphorus loads and identify causal factors. They found the paddy (rice) fields and non-irrigated cultivated areas to be the most important sources of both nutrients. Einheuser et al. (2012) simulated nutrient concentrations in the Saginaw River (USA) with SWAT, and linked them to indicators of stream health. The results of the study suggest that nutrient concentrations have the highest influence on stream health. This combined modelling system was used to predict the effect of various conservation practices on stream health.

Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation, such as ploughing, digging, overturning, shoveling, hoeing and raking. 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 conventional tillage and conservation tillage. Conventional tillage is any tillage and planting system that leaves less than 15% residue cover after planting or less than 560 kg/ha of small grain residue equivalent throughout the critical wind erosion period as proposed by CTIC (2004). Firstly, it includes systems such as mechanized tillage involving the mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowing. The degree of soil disturbance depends on the type of implement used, soil and intended crop type. Secondly, traditional tillage is practiced mostly by manual labor in the humid and sub-humid regions of West Africa, and in some parts of South America. 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 as observed by Aina (1993).

The second type of tillage is Conservation tillage which is any tillage and planting system that covers 30% or more of the soil surface with crop residue after planting, to reduce soil erosion by water is conservative tillage (CTIC, 2004). There are many variations of conservation tillage systems covering abroad spectrum of farming methods primarily aimed at reducing soil disturbance, conserving and managing crop residue to reduce erosion. Ohu (2011) divided conservation tillage practices into no-tillage, ridge tillage, strip tillage and the mulch tillage having varying practices and application but with the focus of conserving the resources on the soil.

Alternative land management practices such as conservation or no-tillage, contour farming, terraces, and buffer strips are increasingly used to reduce nonpoint source and water pollution resulting from agricultural activities. Models are useful tools to investigate effects of such management practice alternatives on the watershed level. However, there is a lack of knowledge about the sensitivity of such models to parameters used to represent these conservation practices (European Environment Agency, 2005, as cited by Taylor et al., 2016). Consequently, the effort at reducing pollution has not been too successful since a little understanding exists on sources and processes of pollution especially in watershed areas.

Though there is a lot of information on tillage studies, the aspects that characterize the complexity of tillage systems and its impact on water quality is yet to be fully researched. Therefore, the aim of the study was to examine the effects of various tillage methods on surface runoff and to model the pattern and processes of surface water pollution associated with tillage methods using 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 Kwara State (Nigeria) respectively (Fig. 1).

The climate of the study area falls within the tropical hinterland climatic zone, having a dry season occurring between November to April while the rainy season is between May and October. Occasionally, there could be an earlier beginning of the rainy and the dry season (Mustapha, 2008). The dry season is characterized by low amount of rainfall, high temperature and mean monthly rainfall total of about 360 mm. The mean annual evaporation is in the range of 1000-1200 mm, the humidity ranges between 30-80%. Relative humidity is high during the rainy season and low in dry season. The temperature ranges between 20-30 oC (Adelana and Olasehinde, 2004). The type of rainfall experienced is convectional storms, sometimes very windy. The heaviest rainfall is usually recorded between June and early August. There is a short spell of drought between August and early September (Oyegun, 1983; Olaniran, 2002).

The experimental sites are located in the Guinea Savannah grassland and characterized by the presence of fire tolerant woody shrubs and trees which are biologically suited to withstand dry conditions. The plants are about 12 m high with grass of about 1.5-2.5 m in height while some parts of the study area have some rainforest trees (such as acacia trees, locust bean etc; Jimoh and Ajao, 2009).

The type of soil is ferruginous tropical soil and the parent material consists of Micaceousschists and genesis of basement complex origin which are rich in ferro-magnesian minerals. The soil formation is characteristic of the geology of the study area exhibiting Jurassic, pan African and Precambrian geological structure (Ahaneku, 1997).

The UTRF and NCAM experimental sites are drained mainly by Oyun River (Fig. 2), which takes springs at Ita-Oregun (in Osun State) and flows through Otan-Aiyegbaju (in Osun State) to Offa and finally to Ilorin where it is dammed at the University of Ilorin main campus. The catchment of Oyun River is located between latitudes 9º50’ and 8º24’ North and Longitudes 4°38' and 4°03' East. Its total catchment area is 800 km^2 with a length of 71.4 km and it lies within Kwara State. The first experimental site (NCAM) is located at the upper catchment area of the river, while the second experimental site (UTRF) is located at the lower catchment area of River Oyun that bounds it to the west (Fig. 2).

The drainage pattern is dendritic with the tributaries joining Oyun and Asa River obliquely. This defines the form of the topography of the study area. The Oyun and Asa Rivers are located on topographical low lands, while the higher elevations are located to the east and south-east. (Fig. 2). The main river that drains the

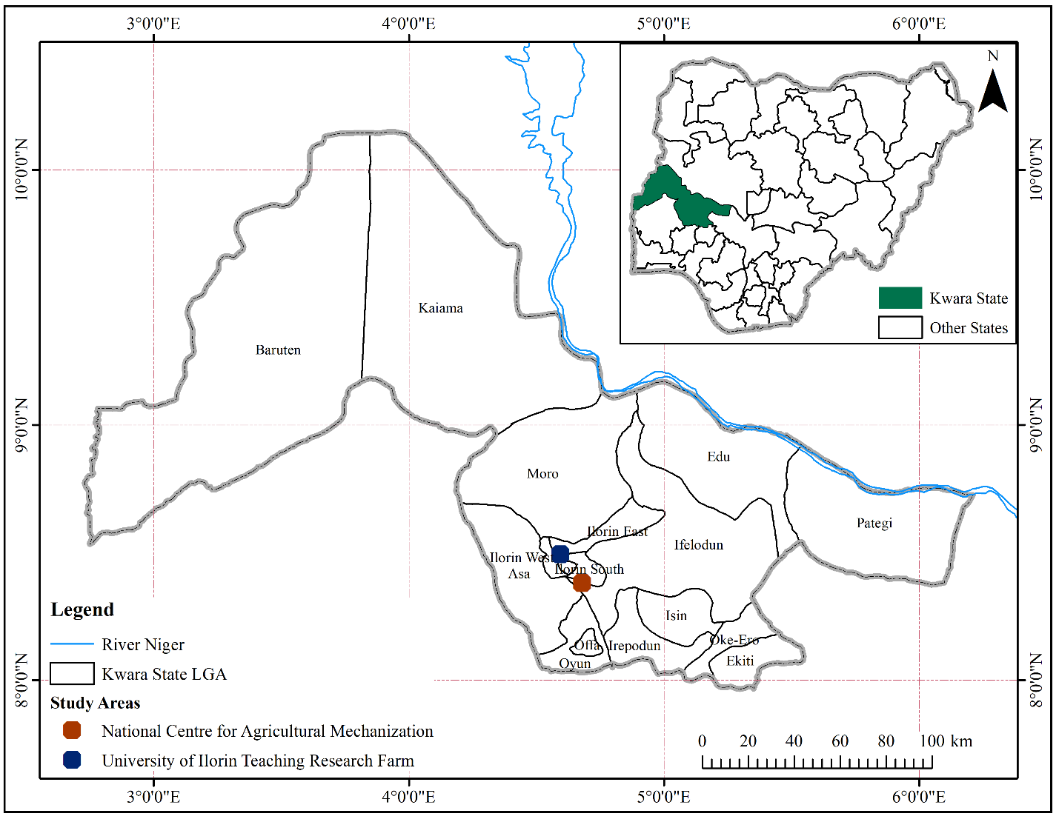

Fig. 1 The location of study areas in Kwara State, Nigeria
(Source: Kwara State Bureau of Lands and Survey 2002)

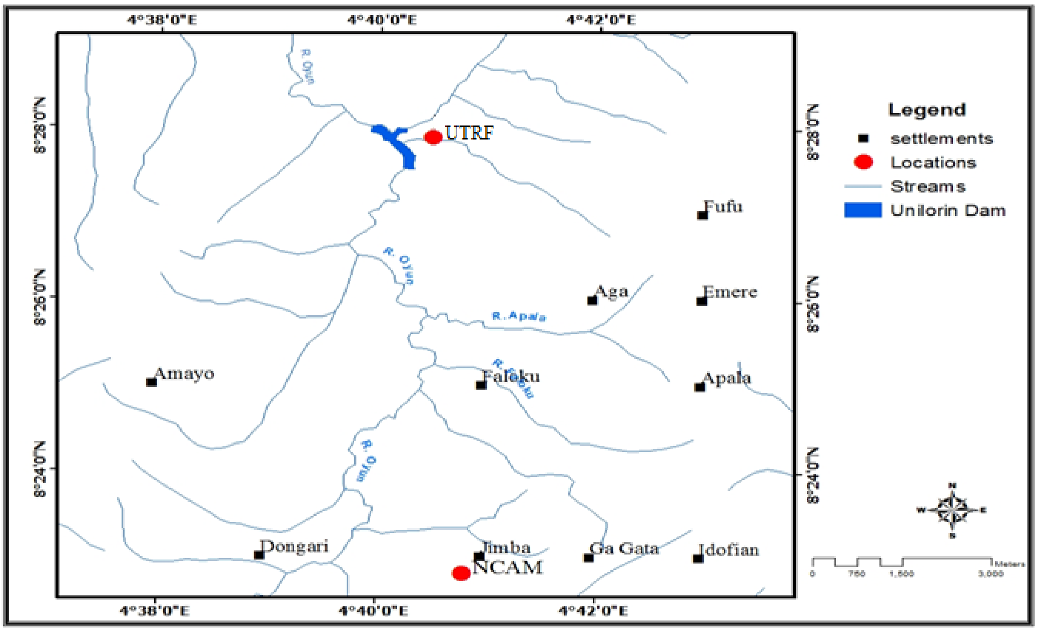

Fig. 2 Drainage pattern and settlements in the study area
(Source: Nigerian National Space Research and Development Agency 2017)

study area joins the Asa River which finally empties its water into the Niger River at Jebba in Niger state (KWSMI, 2002). The major land use type characterizing the Oyun drainage basin is agricultural land use though some other people engage in activities like trading, commerce, administration among others (KWSMI, 2002; Ahmed, 2009). The crops commonly grown include cassava, yam, melon, groundnut, sorghum, millet, pepper, tomato, and tree crops such as cocoa, kola, oil palm, mango, guava and citrus.

METHODS

Randomized Complete Block Design (RCBD) was applied with four different treatments replicated thrice. They were treatment NT (zero or no-tillage), treatment PH (plough and harrow), treatment PHR (plough, harrow and ridge), and treatment T (traditional heap farming). In the study area, these are the conservative and conventional tillage types used. Simulation of the tillage methods was made from the experimental plot for the entire Oyun drainage basin. Maize (Zea mays. L. SWAM 1 variety) was planted for 2015 and 2016 farming years on a 5m x 5m plot size at spacing of 75 cm between rows and 50 cm within row. Nitrogen, Phosphorus and Potassium i.e NPK (15:15:15) fertilizer was applied at 4 weeks and 8 weeks after planting while a normal agronomic practice such as pre-emergence and post emergence herbicide for weed control were administered on the sets of the experimental plot (Fig. 3).

Soil Water Assessment Tool (SWAT) was used to model the pattern and process of pollution from the tillage types through an ARCSWAT 2012.10.19 for ARCGIS software 10.2, 10.3 and 10.4. SWAT is a hydrologic model using the following components: weather, soil, land use as well as other variables to generate data on Hydrologic Response Unit (HRU). Some of the features modeled in the SWAT environment are described in Table 1. The SWAT was chosen because it can simulate the model with limited data and helps to describe the relationship of activities on land with the watershed hydrology.

SWAT model involved various kinds input data for simulation of the watershed. The Flow chart of the steps in the SWAT model application for the study area are shown in Figure 4. The input data included Digital Elevation Model (DEM), and maps of land use/land cover, soil cover, and precipitation. All these data were collected, processed and converted into the SWAT input format. The software was run by giving these data as inputs. The various steps involved in the software are watershed delineation, HRU analysis, and write input tables, edit input data and SWAT simulation. Afterwards, the software executed the command and the output file was printed. This output file was used to plot the graphs and maps. These graphs and maps show the characteristics of watershed.

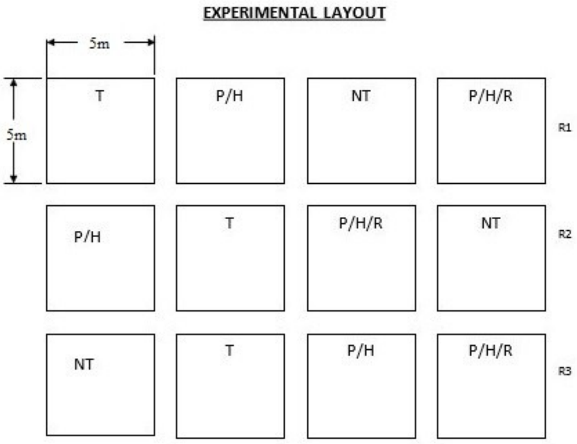

Fig. 3 Experimental layout at UTRF and NCAM Site to evaluate the effects of various tillage methods on soil erosion. Tillage methods: T: traditional heap; P/H: plough and harrow; P/H/R: plough, harrow and ridge; NT: No tillage; R1-R3: replications

Table 1 Features modelled in SWAT

PARAMETERS	DESCRIPTIONS
Hydrologic Response Unit (HRU)	The hydrologic response unit (HRU) is the smallest spatial unit of the model, and the standard HRU definition approach lumps all similar land uses, soils, and slopes within a subbasin based upon user-defined thresholds.
Sub-basin	A sub-basin (SUB) is a structural geologic feature where a larger basin is divided into a series of smaller basins with intervening intra-basin highs.
Precipitation (PREC)	Precipitation (mm) is any liquid or frozen water that forms in the atmosphere and falls back to the Earth. It comes in many forms, like rain, sleet, and snow.
SURQGEN	Amount of surface runoff (mm) contribution from streamflow from HRU during simulation. (Amount generated before transmission pothole, wetland and pond losses.)
Sediment yield (SED)	Sediment yield can be defined as the amount of sediment reaching or passing a point of interest in a given period of time, and sediment yield estimates are normally given as t/year or kg/year.
SURQ	Surface runoff (mm) generated in watershed for the day, month or year
Soil loss	Soil loss (kg/ha) during the time step calculated with the USLE equation (USLE_LS)
GWQ	Amount of lateral flow and ground water flow contribution (mm) to main channel from HRU during simulation
ET	Actual evapotranspiration (mm) in HRU during simulation
NO_3	Nitrate in surface runoff and lateral flow in HRU during simulation (kg N/ha)
ORGN	Organic Nitrogen in surface runoff in the HRU during simulation (kg N/ha)

RESULTS AND DISCUSSION

The hydrological cycle of the study area depicts the way and manner water and nutrients interact with the environment of the study area. The incoming amount of rainfall across the study area was 1230.9 mm and this number is distributed across runoff, infiltration and flow. The rate of surface runoff in this model shows a higher infiltration (distributed among the return flow, lateral flow as well as the percolation to the aquifer). The evapotranspiration rate shows a high rate of return which indicates that a deficit in precipitation would almost be certain to impact on the health of vegetation considering the rate of water loss through evapotranspiration (Fig. 5).

The model simulation is daily time step based. The values in Table 2 are real figures for the UTRF and NCAM watersheds according to the input data used in the SWAT model. Plough, harrow and ridge (PHR) tillage contributed the most to the amount of surface runoff to stream flow in the main channel, surface runoff generated in HRU during time step

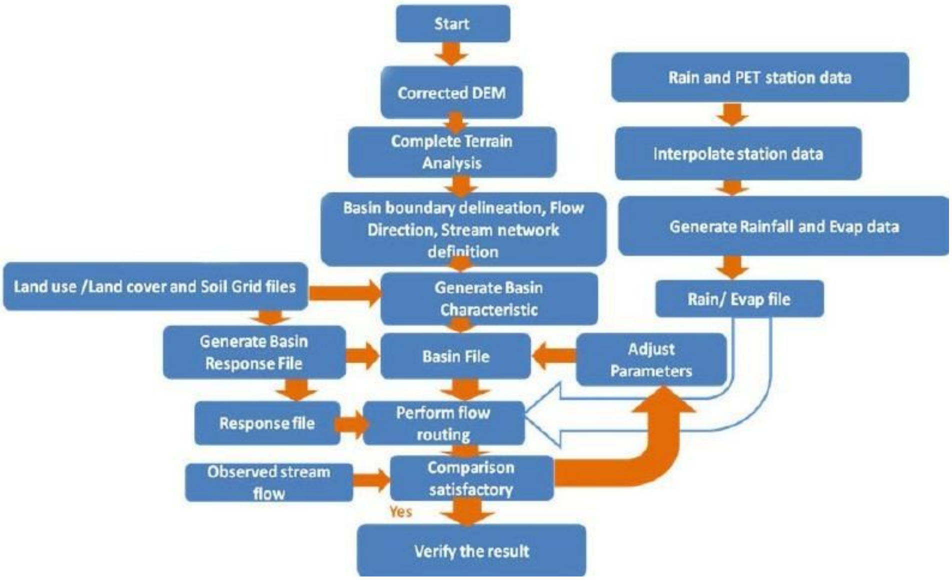

Fig. 4 Flow chart of the steps in the SWAT model to evaluate the soil erosion for the study area (adopted from Akpoti 2015)

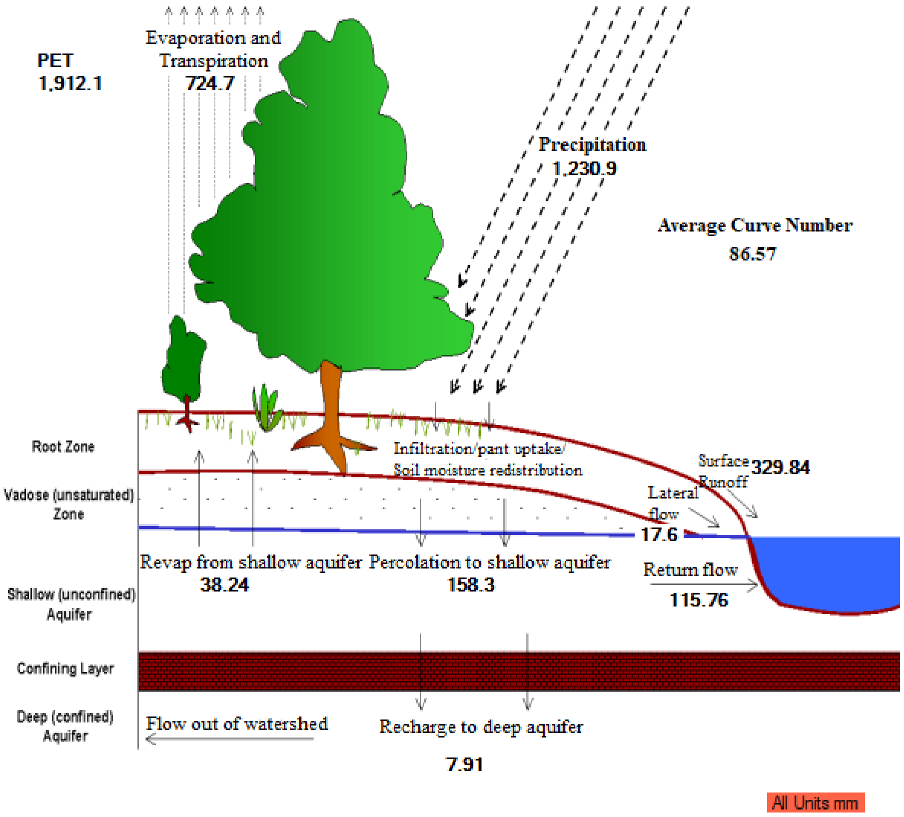

Fig. 5 Flow chart of the steps in the SWAT model to evaluate the soil erosion for the study area (adopted from Akpoti 2015)

and actual evapotranspiration generated from the UTRF site with 374.42 mm, 374.42 mm and 725.78 mm respectively; while highest in plough and harrow (PH) tillage on NCAM site with 284.86 mm, 284.87 mm and 698.1 mm respectively. No-till (NT) and traditional heap (T) generated the highest nitrate (5.15 and 4.42 kg/ha), organic nitrate (62.62 and 60.79 kg/ha), sediment yield (10.54 and 10.46 t/ha), soil loss (2.24 and 2.31kg/ha) and groundwater amount (174.45 and 96.32 mm) on UTRF and NCAM site respectively as shown in Table 2 and Figure 6, 7 and 8. The representation of the hydrological cycle reveals the mean values of some of features modelled for the entire study area.

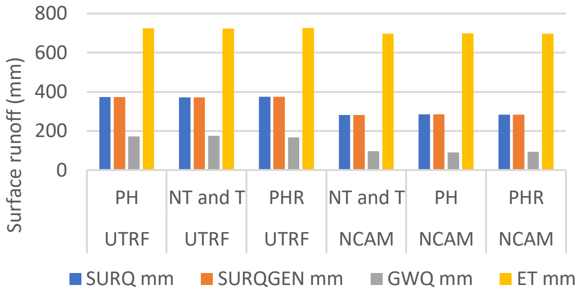

Fig. 6 Amount of surface runoff contribution from streamflow. Surface runoff generated in the watershed, lateral flow and ground water flow contribution to main channel from HRU during simulation, evapotranspiration in UTRF and NCAM sites.

Table 2 Distribution of the Hydrological Response Unit (HRU) and the SWAT modelled Parameters in UTRF and NCAM sub catchments

Tillage method	**Name**	**HRU**	**SUB**	**SURQ [mm]**	**NO_3 [kg/h]**	**ORGN [kg/h]**	**PREC [mm]**	**SURQGEN [mm]**	**SED [t/ha]**	**Soil loss [kg/ha]**	**GWQ [mm]**	**ET [mm]**
PH	UTRF	44	18	372.91	4.41	50.94	1314.21	372.91	5.31	1.05	171.19	724.79
NT and T	UTRF	45	18	371.53	5.15	62.62	1314.21	371.53	10.54	2.24	174.45	723.6
PHR	UTRF	46	18	374.42	3.68	29.83	1314.21	374.42	1.81	0.44	167.86	725.78
NT and T	NCAM	103	42	281.94	4.42	60.79	1113.86	281.94	10.46	2.31	96.32	696.6
PH	NCAM	104	42	284.86	3.04	27.41	1113.86	284.87	1.57	0.38	90.41	698.1
PHR	NCAM	105	42	283.39	3.89	48.38	1113.86	283.39	4.79	1	93.29	697.47

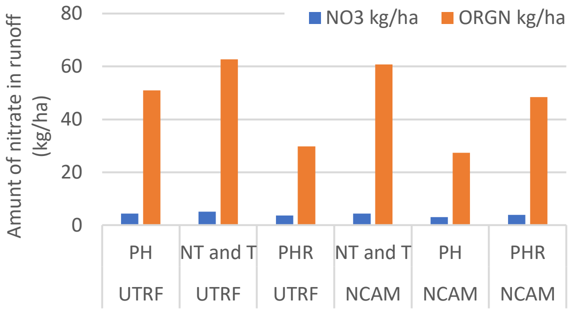

Fig. 7 Amount of nitrate and organic nitrate in surface runoff in the HRU during simulation in UTRF and NCAM sites

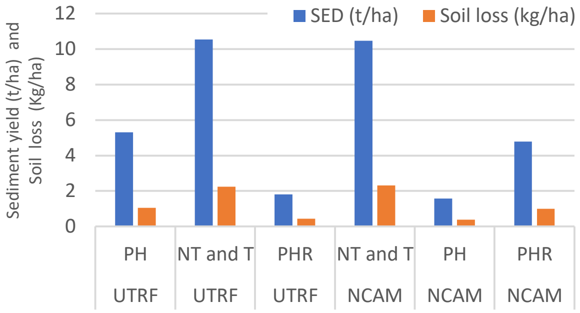

Fig. 8 Sediment yield and soil loss in surface runoff in the HRU during simulation

Effect of tillage methods on runoff

Non-point or diffused pollutants can enter into a river or lake through various points or locations whereas contamination from point source pollutant can be linked to specific discharge points of waste water treatment plants, sewers and factories. Drainage water from agricultural farm land is a major example of contamination from non-point source. The major pollutant from agricultural non-point solution (NPS) that is a product of these activities are sediment, pesticides, nutrients, salts and pathogens. The National Water Quality Inventory according to EPA (2012) reported that the leading source of impairment of water quality to surveyed lakes and rivers is agricultural nonpoint source (NPS) pollution, the third largest source of impairments to estuaries, and also a major contributor to the contamination of ground water as well as degradation of wetlands. Physical, chemical, and biological properties of soil are influenced by tillage systems and have a major impact on the productivity of soil and water quality at a wider scope.

Typically, runoff water contains nutrients that are dissolved, sediment and possibly some chemicals from conventional tillage methods whereas conservation tillage decreases runoff of water, thereby increasing penetration of water into the soil. Surface water quality improvement is one obvious and immediate result of conservation tillage. Runoff from Agricultural land may result in encouragement and excessive growth of algae and other aquatic plants, causing severe problem in water quality. Algae overgrowth in particular, causes odor and taste problems for drinking water supplies and the depletion of oxygen may kill aquatic animals. Sediment from cropland erosion may also increase the turbidity (cloudiness) of water, impairing fisheries (Devlin and Barnes (2009). This is because according to Cheikh et al., (2020), suspended sediments can influence light penetration into the column of water and will likely carry nutrients and pollutants which will affect the smooth functioning of the river ecosystems. Also, Abebe (2019) reported that Intensive agricultural practice such as tillage practices in Ethiopian highlands can results in increased soil erosion rates and sedimentation in the reservoir.

The result findings in this study revealed that No-till (NT) and Traditional heap (T) generated the highest nitrate loss (5.15 and 4.42 kg/ha) which is in line with Alam et al. (2014) reporting that the highest total N, P, K, and S in their available forms were recorded in zero tillage as compared to minimum tillage, conventional tillage, and deep tillage. Drainage water from watershed having conventional tillage is usually brown in color and carry a lot of sediments. However, in a Brazilian watershed area researcher adopted no-tillage, and found out that clear water is drained from the farmland even in times of heavy rainfall (Phillips et al., 1980). Turbidity and siltation levels are amplified in areas where conventional tillage practices still occur during various sampling of water quality and events of habitat assessment. The implication is that implementation of conservation tillage practices is likely to reduce fine clay particulates loading and materials from surface erosion that are delivered to adjacent waterways. Therefore, perhaps the greatest water quality benefit from conservation production systems is the resulting reduction sediment loss through soil erosion and runoff (Phillips et al., 1980).

In this study, Plough, harrow and ridge (conventional tillage) contributed more to the amount of surface runoff contribution to stream flow in the main channel, surface runoff generated in HRU during time step and Actual evapotranspiration generated from the UTRF site with 374.42 mm, 374.42 mm and 725.78 mm respectively; while No-till and Traditional heap generated the highest soil loss (2.24 and 2.31kg/ha). This is in contrast to the findings of Chowaniak et al. (2020) reporting that runoff was 4.3 ± 0.6% higher under No-till than under Conventional tillage, while soil loss was 66.8 ± 2.7% lower under No-till than under Conventional tillage.

In addition, Bertol et al. (2005) reported that Cu, Fe, Mn and Ni concentrations were higher under conventional tillage than under zero tillage on topsoil and runoff. Therefore, the application of tillage method can be used to achieve production, environmental and sustainable objective due to the fact that it can determine how much nutrient is available in the soil for plant growth as well as how these nutrients disintegrate into runoff and contaminate surface water.

Surface runoff is one of the diffused sources of the export of elements and chemical substances in water bodies. The findings of this study showed that No-till and Traditional heap generated the highest organic nitrate (62.62 and 60.79 kg/ha), soil loss

(2.24 and 2.31 kg/ha) and groundwater amount (174.45 and 96.32 mm) which is in line with Klimaszyk and Rzymski (2011), who stated that significant loads of nitrogen, phosphorus, organic matter among others can be transported in overland flow from the catchment area to freshwater. They also reported that the quality and quantity of surface runoff depends on many factors but some of the most important factors are tillage practices and the morphology of the catchment area. As a result, surface runoff from agricultural lands is a major contributor to the eutrophication in lakes and rivers. Therefore, the concentration of these parameters in overland flow can eventually contaminate fresh water sources around the catchment area. As a result, there is a need for appropriate tillage method that will contribute less to the concentration of the parameters to surface runoff. 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 sustained land resources as highlighted by several references (Anthony and Collins, 2006; Derpsch, 2007; Aina, 2011; Onwuzoo, 2020). 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 quality.

CONCLUSION

In conclusion, the different tillage methods had impact on water quality. The traditional heap and no-tillage methods contributed more to the surface runoff parameters than plough / harrow and plough / harrow / ridge, plough / harrow and plough / harrow / ridge contributes more to soil loss and surface runoff amount flowing to the nearest river/drainage than traditional heap and no-tillage. Therefore, the study recommends that plough/harrow should be adopted for a sustainable environment due to its comparatively favorable effect on its contribution to surface runoff in this ecological zone.

References

Abebe, T. A. 2019. Calibration, Validation and Performance Evaluation of Swat Model for Sediment Yield Modelling in Megech Reservoir Catchment, Ethiopia. *Journal of Environmental Geography* 12 (3–4), 21–31. DOI: 10.2478/jengeo-2019-0009

Adelana, S. M. A., Olasehinde, P. I. 2004. Assessment of aquifer system in parts of South-Western Nigeria using isotope techniques. *Proc. International Workshop on the Application of Isotope Techniques in Hydrological and Environmental Studies, Paris,* September 6-8.

Ahaneku, I. E. 1997. Comparative Evaluation of Some Tillage Systems for Effective Moisture Conservation. In: Oni, K. C. (Ed.) Proceedings of ISTRO - Nigeria: Tillage Research and Agricultural Development in Sub-Saharan Africa. 233–243.

Ahmed, Y. A. 2009. Settlements pattern and functional distribution in emerging communities: A case of a local government Area of Kwara State, Nigeria. *The Social Sciences.*4 (3), 256–263.

Aina, P. O. 2011. Conservation tillage for sustainable agricultural productivity, 'Tillage for Agricultural Productivity and Environmental Sustainability' Lead Paper. *International Soil Tillage Research Organization (ISTRO)-Nigerian Symposium Conference*, Ilorin, Nigeria, February 21-23 2011.

Aina, P. O. 1993. Rainfall runoff management techniques for erosion control and soil moisture conservation. In: FAO Information Division (Ed.) *Soil Tillage in Africa: Needs and Challenges. FAO Soils Bulletin, 69*. Food and Agricultural Organization of the United Nations, Rome, Italy.

Akpoti, K., Antwi, E., Kabo-bah, A. 2016. Impact of rainfall variability, land use and land cover change on stream flow of Black Volta Basin, West Africa. *Hydrology* 3 (3), 26. DOI: 10.3390/hydrology3030026

Alam, K., Islam, M., Salahin, N., Hasanuzzaman, M. 2014. Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. *The Scientific World Journal* 2014, 437283, DOI: 10.1155/2014/437283

Anthony, S., Collins, A. 2006. Sediment gap analysis to support water framework directive, *Defra project WQ0106, Final report, 136 pp*

Bertol, I., Guadagnin, J. C., González, A. P., Amaral, A. J., Brignoni, L. F. 2005. Soil tillage, water erosion, calcium, magnesium and organic carbon losses. *Scientia Agricola (Piracicaba, Braz.),* 62 (6), 578–584. DOI: 10.1590/S0103-90162005000600011

Cheikh, F., Manuela G., Laurent, K., Elodie, R. 2020. Investigating the drivers of total suspended sediment regime in the senegal river basin using landsat 8 satellite images. *Journal of Environmental Geography* 13 (1–2), 31–42. DOI: 10.2478/jengeo-2020-0004

Chowaniak, M., Głąb, T., Klima, K., Niemiec, M., Zaleski, T., Zuzek, D. 2020. Effect of tillage and crop management on runoff, soil erosion and organic carbon loss. *Soil Use and Management* 36 (4), 581–593. DOI: 10.1111/sum.12606

CTIC 2004. National Survey of Conservation Tillage Practices. Conservation Technology Information Center, West Lafayette, IN.

Derpsch, R., 2008. No-tillage and Conservation Agriculture: A Progress Report. In: Goddard, T., Zoebisch, M. A., Gan, Y. T., Ellis, W., Watson, A. and Sombatpanit, S. (eds) No-Till Farming Systems. Special Publication Nº3, World Association of Soil and Water Conservation, Bangkok, ISBN:978-974-8391-60-1, 7–9

Devlin, D., Barnes, P. 2009. Impacts of no-till on water quality. *No Till Series,* Kansas State University, Online available at https://bookstore.ksre.ksu.edu/pubs/MF2907.pdf

Einheuser, M. D., Nejadhashemi, A. P., Sowa, S. P., Wang, L., Hamaamin, Y. A., Woznicki, S. A. 2012. Modeling the effects of conservation practices on stream health. *The Science of the Total Environment* 435-436, 380–391. doi:10.1016/j.scitotenv.2012.07.033

Galadima, A., Garba, Z. N., Leke, L., Almustapha, M. N., Adam, I. K. 2011. Domestic water pollution among local communities in Nigeria: causes and consequences. *European Journal of Scientific Research* 52 (4), 592–603. Online available at: https://nairametrics.com/wp-content/uploads/2013/03/2012-08-30-124334_5321.pdf

Gassman, P. W., Sadeghi, A. M., Srinivasan, R. 2014. Applications of the SWAT model special section: Overview and insights. *Journal of Environmental Quality* 43, 1–8, DOI: 10.2134/jeq2013.11.0466.

Gliessman, S. R. 1998. Agroecology: Ecological processes in sustainable agriculture. Ann Arbor Press, Chelsea, MI.

Hallberg, G. R. 1987. The impacts of agricultural chemicals on groundwater quality. *Geojournal* 15 (3), 283–295. DOI: 10.1007/BF00213456

Hobbs, P. R. 2007. Conservation agriculture: what is it and why is it important for future sustainable food production? *Journal of Agriculture Sciences* 145, 127–137. DOI: 10.1017/S0021859607006892

Jimoh, H. I., Ajao, L. I. 2009. Problems of suspended sediments loads in Asa River catchment, Ilorin, Nigeria. *Pakistan Journal Of Social Science*. 6, 19–25.

Klimaszyk, P., Rzymski, P. 2011. Surface runoff as a factor determining trophic state of Midforest Lake. *Polish Journal of Environmental Studies* 20 (5), 1203–1210.

KWSMI 2002. Kwara State Diary, Kwara State Ministry of Information, 1–10.

Li, M., Guo, Q. 2020. SWAT model simulation of non-point source pollution in the Miyun Reservoir Watershed. *IOP Conference*

Series: Earth and Environmental Science 428, 012075, DOI:10.1088/1755-1315/428/1/012075.

Mateo-Sagasta, J., Zadeh, S. M., Turral, H. 2017. Water pollution from agriculture: A global review. *Executive Summary*, 35. Online available at: http://www.fao.org/3/a-i7754e.pdf

Mustapha, K. M. 2008. Assessment of Water Quality of Oyun Reservoir, Offa, Nigeria, using Selected Physic-Chemical Parameters. *Turkish Journal of Fisheries and Aquatic Sciences* 8, 309–319.

Ohu, J. O. 2011. Tillage for Environmental Sustainability. In: Tillage for Agricultural Productivity and Environmental. *Proceedings of the Nigerian Branch of International Soil Tillage Research Organization (ISTRO)*, University of Ilorin, Ilorin, (2011), 1–10.

Olaniran, J. O. 2002. Rainfall anomalies in Nigeria: The contemporary understanding. 55th Inaugural Lecture, University Press, Ilorin. 66 p. Online available at: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.734.1395&rep=rep1&type=pdf

Onwuzoo, A. 2020. Over 100,000 under-five Nigerian children die from water-borne diseases annually-UNICEF. *The Punch Health Wise*, Online available at: https://healthwise.punchng.com/over-100000-under-five-nigerian-children-die-from-water-borne-diseases-annually-unicef/

Oyegun, R. 1983. Water Resources in Kwara State Nigeria. Matanmi and Sons Printing and Publishers, Ilorin, Nigeria

Phillips, R. E., Blevins, R. L., Thomas, G. W., Frye, W. W., Phillips, S. H. 1980. No-tillage agriculture. *Science* 208, 1108–1113. DOI: 10.1126/science.208.4448.1108

Sayed, A, Sarker, A, Kim, J, Rahman, M., Mahmud, G. A. 2020. Environmental sustainability and water productivity on conservation tillage of irrigated maize in red brown terrace soil of Bangladesh. *Journal of the Saudi Society of Agricultural Sciences* 19 (4), 276–284. DOI: 10.1016/j.jssas.2019.03.002

Shen Z, Chen, L., Hong, Q., Qiu, J., Xie, H., Liu, R. 2013. Assessment of nitrogen and phosphorus loads and causal factors from different land use and soil types in the Three Gorges Reservoir Area. *Science of The Total Environment* 454-455, 383–392, DOI: 10.1016/j.scitotenv.2013.03.036

Taylor, S. D., He, Y., Hiscock, K.M. 2016. Modelling the impacts of agricultural management practices on river water quality in Eastern England. *Journal of Environmental Management* 180, 147–163. DOI: 10.1016/j.jenvman.2016.05.002