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# WATER QUALITY AND TILLAGE PRACTICES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN A GUINEA SAVANNA ECOLOGICAL ZONE, KWARA STATE, NIGERIA

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***ABSTRACT***

*The study aimed to examine the effects of tillage methods on surface runoff, model the patterns and processes of surface water pollution associated with tillage methods, and predict the highest contributions of different agricultural land uses to the modelled features. The study was carried out at the Unilorin Teaching and Research Farm (UTRF), Ilorin, and the National Centre for Agricultural Mechanisation (NCAM), Idofian, during the 2015 and 2016 maize planting seasons. Traditional heap (T), Notill (NT), Plough/Harrow (PH), and Plough/Harrow/Ridge (PHR) tillage were applied to surface runoff plots. Treatments were replicated three times, yielding 12 plots per location. Samples of surface runoff were collected from experimental plots. Water physicochemical analysis was carried out using standard laboratory procedures. Data were subjected to Analysis of variance, Least Significant Difference, Tukey's test, and Soil Water Assessment Tool (SWAT). The study reveals that 10 surface runoff physico-chemical parameters (e.g., nitrate at 0.001 and 0.001 mg/L in the seasons) were significant for NT and T. In contrast, seven (e.g., magnesium with 0.001 and 0.045 mg/l in 2015, 0.001 and 0.027 mg/l in 2016) were significant for PH and PHR at UTRF and NCAM sites. Also, the SWAT model showed that four of nine biophysical factors examined (sediment yield-10.54 metric tons/ha, groundwater amount-174.45GWQmm, organic nitrogen-62.62kg/ha, and nitrogen in surface runoff -5.15kg/ha) were higher for T, while three (surface runoff amount- 374.42SURQmm, evapotranspiration-752.78ETmm, and soil loss-1.05USLE_LS) were higher for PH and PHR. The study concluded that tillage methods affect water quality. However, PH had a comparatively favourable effect on surface runoff. It is therefore recommended that PH be adopted to reduce water pollution and promote a sustainable environment.*

**Keywords:** Environment, Pollution, Sustainability, Tillage, Water quality

## INTRODUCTION

Agriculture is an essential human activity that facilitates food production. For a long time, the increasing demand for food was met by extending the area under cultivation. One consequence of crop production is the clearing of vegetation, which in turn exposes the land to weathering and degradation. Such weathering activities include soil erosion, nutrient leaching, and changes in soil nutrient profiles, which have increased pollution of freshwater 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 (CA) is an option for maintaining soil health and the surrounding environment for intensive agriculture, especially in the tropical climate (Sayed et al.,2019)

According to Ohu (2011), an essential effect of tillage on soil sustainability is its environmental impact, including soil degradation, poor water quality, and greenhouse gas emissions from soil-related processes, among others. As a subsystem of crop production, tillage can be used to achieve many agronomic objectives, which will eventually lead to the sustainability of the ecosystems. The marked shift in conventional agriculture has brought detrimental effects on natural resources, leading to environmental degradation. Indeed, agricultural practices can be considered both widespread and point sources of pollution, heavily affecting surface and groundwater quality, principally through erosion, runoff, and leaching. Many contaminants (i.e., sediments, nutrients, heavy metals, and agrochemicals) are conveyed by agriculture into surface and groundwater systems (Stagnari et al., 2016). Therefore, Conservation practices must be implemented as a system to increase redundancy and address all loss pathways. Further, planning and adoption must be at a watershed scale to ensure practices are placed in critical source areas, thereby providing the most treatment for the least price (Osmond et al.,2019)

The need for increased production has fostered ecologically unsustainable agricultural intensification in many places, particularly leading to soil degradation. Also, meeting the present and future needs of the population for food, fibre, and shelter, among others, without destroying the soil and water resource base and the environment, remains an important concern. As the population increases and the economy grows, competition for the limited supply of land and water will intensify, leading to conflicts among users. Activities such as bulldozing and inappropriate mechanical tillage subject Nigerian soils to devastating processes, including erosion, hardpan formation, topsoil removal, and sediment generation, which will influence the receiving freshwater body (Ahaneku, 2010). Agriculture, which accounts for 70 per cent of global water abstraction, plays a significant role in water pollution. Farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments, and saline drainage into water bodies. The resultant water pollution poses demonstrated risks to aquatic ecosystems, human health, and productive activities (UNEP, 2016).

Water pollution from agriculture has direct negative impacts on human health; for example, the well-known blue-baby syndrome, in which high levels of nitrates in water can cause *methaemoglobinemia,* a potentially fatal illness in infants. Pesticide accumulation in water and the food chain, with demonstrated adverse effects on humans, led to the widespread ban on certain broad-spectrum, persistent pesticides (such as DDT and many organophosphates). However, some such pesticides are still used in poorer countries, causing acute and likely chronic health effects. Aquatic ecosystems are also affected by agricultural pollution. Eutrophication, caused by nutrient accumulation in lakes, floodplains (*fadama*), and coastal waters, impacts biodiversity and fisheries. Water-quality degradation may also have severe direct impacts on productive activities, including agriculture. In Organisation for Economic Co-operation and Development (OECD) countries alone, the environmental and social costs of water pollution caused by agriculture probably exceed billions of dollars annually (OECD, 2012)

As a result, it is necessary to consider different tillage systems, as some of the studied tillage variations are not adequately described in terms of efficiency and effects (Abulude *et al.,* 2007). This is because most studies focused on nutrient loss in terms of the economics of crop production (i.e., how much Nitrogen (N) or Phosphorus (P) was available for crop intake), rather than on soil degradation, water pollution, or quality concerns (Aina, 2011). In Nigeria, as in many parts of the world, solute transfer or pollution is an acute problem. Several studies on water pollution have focused on water channel pollution (EPA, 1999; Clark *et al*., 1993; Abulude *et al*., 2007; Ifabiyi, 2008), but few have provided information on pollutant sources.

Consequently, efforts to reduce pollution have not been very successful, as there is limited understanding of pollution sources and processes, especially in watershed areas. Though there is much information on tillage studies, the aspects that characterise the complexity of tillage systems and their impact on water quality remain under-researched. Therefore, the study aimed to examine the effects of tillage methods on surface runoff using an experimental design and to model the patterns and processes of surface water pollution associated with these methods.

## STUDY AREA

The study was carried out at the University of Ilorin Teaching and Research Farm (UTRF), Ilorin, and the National Centre for Agricultural Mechanisation (NCAM), Idofian, both located in Ilorin South Local Government Area and Ifelodun Local Government Area, Kwara State, respectively. University of Ilorin is located between latitude 8º28″N – 8º29' 30″N and between longitude 4º 38' 30″E – 4º40' 30″E, while NCAM is located between latitude 8º22″N- 8º23″N and between longitudes 4º40″E- 4º41″E (Figure 1). The Ilorin-Lokoja trunk A road marks the northern limit from the Oyun river bridge (Ahaneku, 1997).

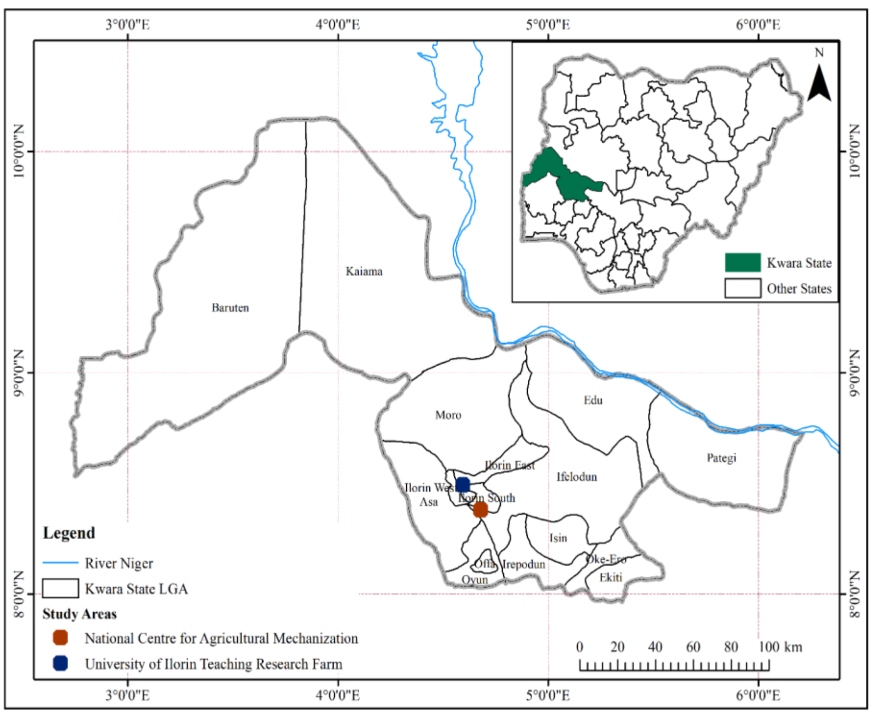


**Fig. 1:** The location of study areas in Kwara State, Nigeria (Source: Kwara State Bureau of Lands and Survey 2002)

The study area falls within the tropical hinterland climatic zone. It is tropical and seasonal, with a dry season from November to April and a rainy season from May to October. Occasionally, the rainy season may begin earlier, and the dry season may be extended (Mustapha, 2008). The dry season is characterised by the absence of rainfall, high temperatures, and a mean monthly rainfall total of about 360mm. The mean annual evaporation is in the range of 1000-1200mm. The humidity ranges from 30% to 80%. Relative humidity is high during the rainy season and low in the dry season. The daily average temperatures are 25 ºC in January, 27.5 ºC in May, and 22.5 ºC in September (Olarewaju & Negedu, 2015). The type of rainfall experienced is convectional storms, sometimes very windy. The heaviest rainfall is often recorded between June and early August. There is a short drought period between August and early September (Olaniran, 2002; Oyegun, 1983). The experimental sites are located in the Guinea Savannah grassland and are characterised by fire-tolerant woody shrubs and trees that are well adapted to dry conditions. The plants are about 12 meters high, with grass about 1.5-2.5 metres in height, while some parts of the study area have rainforest trees (acacia, locust bean, etc.). (Jimoh and Ajao, 2009).

The UTRF experimental site is drained mainly by the Oyun River, which takes its source from Ita-Oregun in Osun State and flows through Otan-Aiyegbaju (also in Osun State) to Offa and finally to Ilorin, where it is dammed at the University of Ilorin main campus. The second experimental site, located in the centre of NCAM, forms part of the lower catchment area of the River Oyun, which bounds it to the West. The catchment of the Oyun River is located between latitudes $9^0$50’ and $8^0$24’ North and Longitudes 4º38' and 4º03' East. Its total area is 800.0 km², with a length of 71.4 km, and it lies within Kwara State.

The drainage pattern is dendritic, with the tributaries joining the Oyun and Asa Rivers obliquely. This defines the topography of the study area. The Oyun and Asa Rivers’ path mark the topographical lows, while the highest portions are to the east and southeast. A cross-section from east to west will show a shallow V-shaped topography (Figure 2). The main River that drains the study area joins the Asa River, which finally empties into the Niger River at Jebba in Niger State (Unilorin Master Plan, 1977). The primary land-use type characterising the two LGAs is agriculture, though some people engage in activities such as trade, commerce, and administration (Kwara State Ministry of Information (KWSMI), 2002; Ahmed, 2009). Typical crops include cassava, yams, melons, groundnuts, sorghum, millet, peppers, tomatoes, and tree crops such as cocoa, kola, oil palm, mangoes, guavas, and citrus.

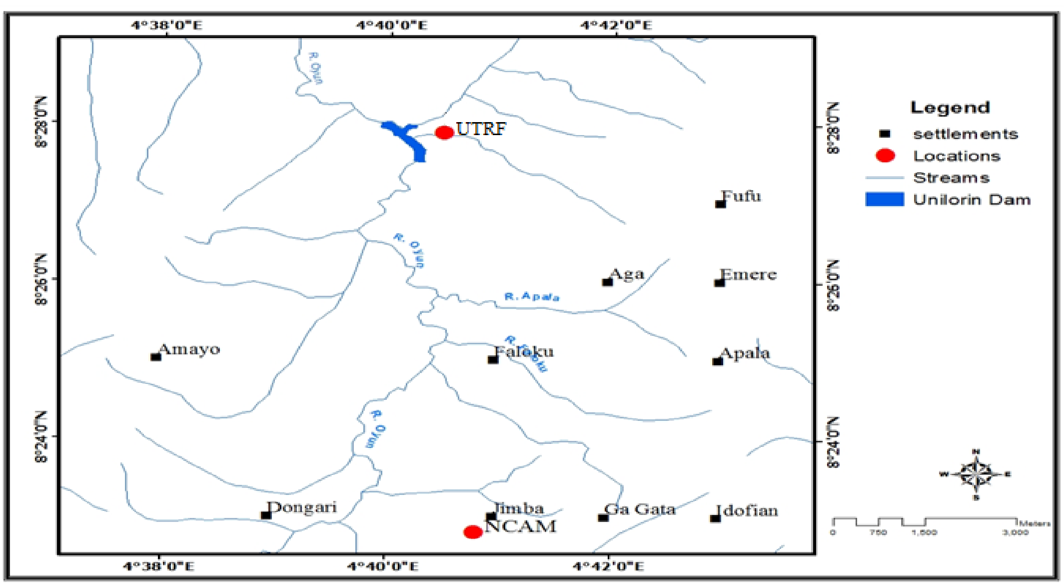


**Figure 2:** Drainage pattern for the Study Area
**Source:** National Space Research and Development Agency (2016)

## METHODOLOGY

Data were collected by collecting water (surface runoff) samples from constructed experimental plots using different tillage methods and subjecting the samples to laboratory testing. The results obtained were used for subsequent analysis. Maps and satellite images showing land use types, soil, climate, relief, and drainage were sourced. Data was complemented with information from relevant books, journals, internet sources, and literature.

The study employed a purposive sampling technique to determine tillage practices, following a reconnaissance survey of available tillage methods in the study area and consultation with an Agronomist. The availability of mechanical equipment, personnel to operate it, and the extent of land influenced the choice of the experimental sites. The construction of the runoff plot was to enable the collection of surface runoff samples. The plot size was 5 x 5 $m^2$, with 2m inter-plot spacing, for a total area of 300 m2 per experimental plot at each location (Figure 3). This plot size is suitable for surface-flow and soil-erosion research projects conducted in limited space and can be used to monitor natural or simulated rainfall events (William, 1988; William & Buckhouse, 1991). Each plot was bounded to prevent runoff from entering or escaping into the surrounding field. A slot was created at the lower end of each plot to collect runoff, and the slot was covered to prevent debris from falling into the collection outlet. The water samples were collected from selected runoff plots in plastic bottles and immediately sent to the Biochemistry Laboratory at the University of Ilorin for laboratory analysis. The runoff samples were collected during the maize (Zea mays L. Suwan I) cropping seasons (i.e., 2015 and 2016) under natural rainfall conditions.

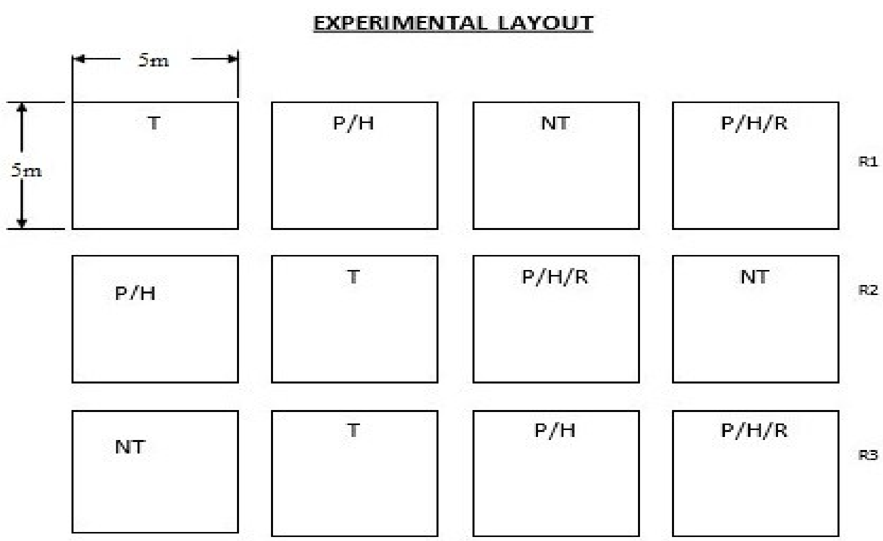


**Figure 3:** Experimental layout at UTRF and NCAM Site to evaluate the effects of various tillage methods on Water quality

NOTE: Tillage methods: T: traditional heap; P/H: plough and harrow; P/H/R: plough, harrow and ridge; NT: No tillage; R1-R3: replications

Four treatments with three replicates were applied using a Randomised Complete Block Design (RCBD). They were treatments A (zero or no-tillage), B (plough and harrow), C (plough, harrow, and ridge), and D (traditional heap farming), shown in Figure 3. These covered both conventional and conservative tillage methods commonly used in the study area. NPK (15:15:15) fertiliser was applied at 4 and 8 weeks after planting, while pre-emergence and post-emergence herbicides (Glyphosate and Atrazine) for weed control were applied in the experimental plots as part of everyday agronomic practices among farmers in the study area. To avoid bias, a Table of Random Numbers was used to select the location of each tillage method/plot (replicates) as shown in Figure 3.

Three replicates of each tillage method were constructed, giving a total of 12 experimental plots at each location for a thorough comparative study. Therefore, a total of 24 water samples were collected from all the experimental plots after a rainfall event. A total of 9 runoff-across tillage methods experimental plots across each farming season (i.e., 2015 and 2016 planting seasons). This was dependent on the amount of rainfall and the amount of overland flow accumulated at the collection outlet after each rainfall event.

Laboratory analytical methods were used to determine the physical, chemical, and biological composition of the water. Sixteen parameters closely related to agricultural practices were examined (Table 1). This enabled the determination of variation in water concentration parameters across tillage methods. A standard laboratory analytical method from the Association of Official Analytical Chemists (AOAC, 1990) was used to analyse all selected parameters. Data were subjected to Analysis of variance, Least Significant Difference enabled direct comparisons, and the Soil Water Assessment Tool (SWAT).

**Table 1:** Details of Water Quality Parameters Determined and Nigerian Drinking Water Standard

| S/N | Water quality | Laboratory methods | NDWS Maximum permitted levels (2007) |
|---|---|---|---|
| 1 | Turbidity | Nephelometric Method | >5 TU |
| 2 | Conductivity | Conductivity method | 0.4-0.85 millimoles per centimetre |
| 3 | Total Dissolved Solids(TDS) | Conductivity method | 500mg/l |
| 4 | Carbon (C) | Titrimetric method | NIL |
| 5 | Sodium (Na) | Atomic absorption spectrophotometer | 200 mg/l |
| 6 | Potassium (K) | Atomic absorption spectrophotometer | NIL |
| 7 | Nitrate ($NO_3$) | Nitrate colourimetric method | 50 mg/l |
| 8 | Phosphorus(P) | Standard curve and calibration of the spectrophotometer | >0.1 mg/l |
| 9 | pH | Glass electrode pH meter | 6.5-8.5 |
| 10 | Calcium(Ca) | Titrimetric method | NIL |
| 11 | Magnesium (Mg) | Titrimetric method | 0.20 mg/l |
| 12 | Dissolved Oxygen (DO) | Titrimetric method | 5-6 mg/l |
| 13 | Chloride (Cl) | Argentometric Method | 250 mg/l |
| 14 | Copper (Cu) | Atomic absorption spectrophotometer | 2 mg/l |
| 15 | Zinc (Zn) | Atomic absorption spectrophotometer | 3 mg/l |
| 16 | Lead (Pb) | Atomic absorption spectrophotometer | 0.01 mg/l |
| 17 | Iron (Fe) | 1% EDTA Entraction method | 0.3 mg/l |

**Source:** Association of Official Analytical Chemists -AOAC (1990)

The Soil and Water Assessment Tool (SWAT) were used to model pollution patterns and processes associated with tillage types using ARCSWAT 2012.10.19 for ArcGIS 10.2, 10.3, and 10.4. SWAT is a hydrologic model that uses the following components: weather, soil, land use, and other variables to generate data for the Hydrologic Response Unit (HRU). Some of the features modelled in the SWAT environment are stated in Table 2. The SWAT was chosen because it can simulate the model with limited data and helps describe the relationship between land use and watershed hydrology.

**Table 2:** Features Modelled in SWAT

| UNITS | DESCRIPTION |
|---|---|
| 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 is 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) |

**Source:** Author's Fieldwork (2016)

## RESULTS AND DISCUSSION

### Impact of Tillage Methods on Surface Runoff Water Quality on the Experimental Plots

The 17 variables examined in the study showed that tillage methods significantly affected surface runoff in 2015, except for turbidity, sodium, zinc, phosphorus, conductivity, total dissolved solids, and calcium at the UTRF site. This, however, is not the case in 2016, as only six (nitrate, chlorine, calcium, magnesium, lead, and iron) out of the seventeen examined were significant, as shown in Table 4. On the NCAM site, 17 variables showed significant differences in concentration in 2015, except for turbidity, potassium, zinc, phosphorus, conductivity, chlorine, total dissolved solids, calcium, dissolved oxygen, and iron. On the other hand, seven variables (carbon, nitrate, chlorine, copper, total dissolved solids, calcium, and lead) out of the seventeen studied were significantly impacted by the tillage methods in 2016 (Table 3).

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**Table 3:** Tillage Impact on Surface Runoff Quality Parameters at UTRF and NCAM Experimental plots for 2015 and 2016 planting season using ANOVA

| SN | | Experimental Sites | Sum of Squares | | Df | | Mean Square | | F | | Sig. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| 1. | Turbidity | UTRF | 0.056 | .106 | 3 | 3 | 0.019 | .035 | 1.609 | 1.665 | 0.191 | .179 |
| | | NCAM | 0.051 | .049 | 3 | 3 | 0.017 | .016 | 2.236 | 1.446 | 0.088 | .234 |
| 2. | Carbon (C) | UTRF | 0.132 | .076 | 3 | 3 | 0.044 | .025 | 2.711 | 1.910 | 0.048* | .132 |
| | | NCAM | 1.487 | .282 | 3 | 3 | 0.496 | .094 | 3.46 | 8.541 | 0.019* | .001* |
| 3. | Sodium ($Na^{2+}$) | UTRF | 0.036 | .027 | 3 | 3 | 0.012 | .009 | 2.062 | 2.326 | 0.109 | .079 |
| | | NCAM | 0.03 | .018 | 3 | 3 | 0.01 | .006 | 3.105 | 2.223 | 0.029* | .090 |
| 4. | Potassium (K) | UTRF | 0.117 | .056 | 3 | 3 | 0.039 | .019 | 14.142 | 1.871 | 0.001* | .139 |
| | | NCAM | 0.005 | .004 | 3 | 3 | 0.002 | .001 | 0.838 | .779 | 0.476 | .508 |
| 5. | Zinc ($Zn^{2+}$) | UTRF | 0.005 | .005 | 3 | 3 | 0.002 | .002 | 0.912 | 1.482 | 0.438 | .224 |
| | | NCAM | 0.003 | .001 | 3 | 3 | 0.001 | .000 | 0.521 | .241 | 0.669 | .868 |
| 6. | Nitrate ($N^{2+}$) | UTRF | 298.265 | 232.907 | 3 | 3 | 99.422 | 77.636 | 62.152 | 56.922 | 0.001* | .001* |
| | | NCAM | 274.927 | 268.532 | 3 | 3 | 91.642 | 89.511 | 7.351 | 110.951 | 0.001* | .001* |
| 7. | Phosphorous (P) | UTRF | 0.134 | .079 | 3 | 3 | 0.045 | .026 | 2.616 | 1.508 | 0.054 | .217 |
| | | NCAM | 0.071 | .014 | 3 | 3 | 0.024 | .005 | 1.347 | .516 | 0.262 | .672 |
| 8. | pH | UTRF | 0.245 | .013 | 3 | 3 | 0.082 | .004 | 6.237 | .757 | 0.001* | .521 |
| | | NCAM | 0.122 | .019 | 3 | 3 | 0.041 | .006 | 4.27 | 1.004 | 0.007* | .394 |
| 9. | Conductivity | UTRF | 14.205 | 24.546 | 3 | 3 | 4.735 | 8.182 | .425 | 1.421 | .735 | .241 |
| | | NCAM | 54.242 | 4.667 | 3 | 3 | 18.081 | 1.556 | 1.363 | .938 | .257 | .425 |
| 10 | water quality across tillage types | UTRF | 4.233 | 2.817 | 3 | 3 | 1.411 | .939 | 6.97 | 10.049 | 0.001* | .001* |
| | | NCAM | 2.019 | 2.088 | 3 | 3 | 0.673 | .696 | 0.003 | 8.241 | 1.00 | .001* |
| 11. | Copper ($Cu^{2+}$) | UTRF | 3.558 | .003 | 3 | 3 | 1.186 | .001 | 15.23 | 1.871 | 0.001* | .139 |
| | | NCAM | 0.002 | .107 | 3 | 3 | 0.001 | .036 | 9.004 | 18.028 | 0.001* | .001* |
| 12 | Total Dissolved Solids | UTRF | 0.003 | .010 | 3 | 3 | 0.001 | .003 | 1.245 | 2.023 | 0.297 | .115 |
| | | NCAM | 0.008 | .010 | 3 | 3 | 0.003 | .003 | 1.526 | 4.470 | 0.211 | .005* |
| 13. | Calcium ($Ca^{2+}$) | UTRF | 0.049 | 3.089 | 3 | 3 | 0.016 | 1.030 | 1.941 | 14.200 | 0.127 | .001* |
| | | NCAM | 0.007 | .307 | 3 | 3 | 0.002 | .102 | 1.894 | 2.783 | 0.134 | .045* |
| 14. | Magnesium ($Mg^{2+}$) | UTRF | 0.027 | .272 | 3 | 3 | 0.009 | .091 | 5.622 | 25.855 | 0.001* | .001* |
| | | NCAM | 0.013 | .001 | 3 | 3 | 0.004 | .000 | 3.172 | 1.302 | 0.027* | .278 |
| 15. | Dissolved Oxygen (Do) | UTRF | 161.267 | 1130.028 | 3 | 3 | 53.756 | 376.676 | 7.171 | 2.162 | 0.001* | .097 |
| | | NCAM | 14.20 | 76.185 | 3 | 3 | 4.733 | 25.395 | 0.591 | .111 | 0.622 | .953 |
| 16. | Lead($Pb^{2+}$) | UTRF | 0.08 | .083 | 3 | 3 | 0.027 | .028 | 15.481 | 3.893 | 0.001* | .011* |
| | | NCAM | 0.033 | .041 | 3 | 3 | 0.011 | .014 | 6.81 | 9.206 | 0.001* | .001* |
| 17. | Iron ($Fe^{2+}$) | UTRF | 15.079 | 7.276 | 3 | 3 | 5.026 | 2.425 | 34.773 | 12.871 | 0.001* | .001* |
| | | NCAM | 0.283 | .275 | 3 | 3 | 0.094 | .092 | 0.565 | .572 | 0.639 | .634 |

Note: * Significant at 0.05 between water quality across tillage types. Source: Authors' Fieldwork (2016)

The tillage methods had a significant impact on nitrate and lead at both locations (UTRF and NCAM site) and across both planting seasons (2015 and 2016), while there was no significant impact of the tillage methods on turbidity, sodium, zinc, phosphorus, and conductivity at both locations and across the planting seasons. In 2015, carbon, pH, copper, and magnesium were significantly affected by tillage methods at both UTRF and NCAM sites, while in 2016, chlorine and calcium were significantly affected by tillage methods at both locations. There was no significant impact on total dissolved solids or calcium at the sites in 2015, whereas in 2016, sodium, potassium, dissolved oxygen, and pH were not significantly affected by the tillage methods at both locations. Between the locations, the UTRF site showed that carbon, potassium, pH, copper, sodium, and dissolved oxygen were significantly affected by tillage types in 2015 but not in 2016. Calcium was not significant in 2015 but was significantly affected in 2016, while only magnesium was significantly affected by tillage type in both 2015 and 2016 (Table 4).

On the NCAM site, tillage methods significantly affected carbon, potassium, nitrate, and lead in both years. At the same time, sodium, pH, and magnesium were significant in 2015 but not in 2016. In addition, chlorine, total dissolved solids, and calcium were not significant in 2015 but were significant only in 2016. The tillage methods had no significant impact on turbidity, zinc, phosphorus, conductivity, dissolved oxygen, or iron in either 2015 or 2016. From the foregoing, it is evident that location and time play a significant role in determining the concentration of these parameters, due to weather variability, topography, soil type, and other factors.

Surface runoff is one of the diffuse sources of elements and chemical substances exported into water bodies. According to Klimaszyk and Rzymski (2011), significant loads of nitrogen, phosphorus, and 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 depend on many factors, but the catchment area's morphology is among the most important. The most significant nutrient loads are exported from agriculturally used catchments. As a result, surface runoff from agricultural lands is a major contributor to eutrophication in lakes and rivers. Therefore, the concentration of these parameters in overland flow can eventually contaminate freshwater sources around the catchment area. As a result, there is a need for an appropriate tillage method that reduces the concentration of these parameters in surface runoff.

Climatic variations have caused unusual weather conditions. In recent times, average air temperatures and sunshine hours have increased, while precipitation has decreased. Notably, the 2015 rainy season was longer than that in 2016. This has caused variability in the amount of water available for runoff, infiltration, and percolation of nutrients into the soil. Consequently, this has affected the water properties and the amount of sediment carried along in the overland flow to the receiving river. This is not far from Busari et al. (2015), who reported that climate change mitigation and adaptation processes found zero tillage (ZT) to be the most environmentally friendly among different tillage techniques. Therefore, conservation tillage practices such as ZT and minimum tillage, which have the potential to break the surface compact zone and reduce soil disturbance, offer a better soil environment and higher crop yields with minimal impact on surface runoff.

Also, the LSD significance test revealed that NT and T (conservative tillage) contributed significantly to turbidity, carbon, potassium, nitrate, pH, iron, chlorine, copper, magnesium, phosphorus, sodium, and calcium in the water. In contrast, PH and PHR (mechanised tillage) contributed significantly to lead, dissolved oxygen, sodium, and conductivity at the UTRF site in 2015 (Tables 4, 5, and 6). In 2016, Conservative tillage samples had higher levels of carbon, sodium, potassium, dissolved oxygen, conductivity, copper, calcium, magnesium, and lead, while mechanised tillage samples had higher levels of turbidity, nitrate, phosphorus, pH, chlorine, and iron. In addition, T and NT contributed significantly to carbon, nitrate, pH, iron, and phosphorus. In contrast, PH and PHR contributed significantly to turbidity, carbon, chlorine, and dissolved oxygen only on the NCAM site in 2015. In 2016, T and NT contributed significantly to carbon, nitrate, turbidity, dissolved oxygen, iron, and calcium, while PHR and PH contributed significantly to chlorine, phosphorus, pH, and conductivity. There was no significant difference in the contribution from the tillage types to zinc and total dissolved solids on UTRF for both years, and also to sodium, potassium, zinc, magnesium, total dissolved solids, lead, and copper on NCAM for both years (Tables 4, 5, and 6). This is in line with Giller *et al. (2009), who reported that Zn, Co, and Pb showed higher concentrations in topsoil under zero tillage. In contrast, Cu, Fe, Mn, and Ni showed higher concentrations* under conventional tillage.

Field observations in this study showed that Conservative tillage contributed more to the concentration of some water parameters than mechanised tillage across locations and time. Some parameters were not affected by either tillage method, regardless of location. These are turbidity, potassium, zinc, phosphorus, pH, conductivity, magnesium, dissolved oxygen, and iron. This is not far-fetched from the findings of several authors, among them Hernanz et al. (2009), who showed that runoff water from no-tillage had higher calcium and magnesium concentrations than that from conventional tillage. Moreover, calcium and magnesium can be readily transported and adsorbed onto suspended sediments in surface runoff. Also, Lal (1989) reported that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanised farming and 12 maize crops. In contrast, the decline in soil and water properties was decidedly less in the no-tillage watershed. Minase *et al.* (2016) also reported that carbon levels could be increased in both soil and water through minimum tillage. The findings for calcium does not tally with Bertol *et al.,*(2005) reporting that an important factor that may have influenced the low calcium and magnesium concentrations in surface runoff under no-tillage was the fact that these elements, especially calcium, can complex with organic matter, which has neutral charge and is soluble, be leached with water down in the soil profile, and thus be reduced in the surface runoff. This phenomenon is favoured under no-tillage because of greater accumulation of organic matter and, consequently, organic carbon in this soil, in comparison to conventional soil tillage.

**Table 4:** Turbidity, Carbon. Sodium, Potassium, Zinc, and Nitrate LSD values from the Experimental sites

| Tillage type | Turbidity | | | | Carbon | | | | Sodium | | | | Potassium | | | | Zinc | | | | Nitrate | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | |
| | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| Traditional | 0.4 | 0.44 | 0.42 | 0.48 | 3.14 | 3.25 | 3.14 | 3.3 | 0.36 | 0.38 | 0.35 | 0.37 | 0.6 | 0.59 | 0.34 | 0.36 | 0.27 | 0.31 | 0.26 | 0.32 | 38.79 | 38.89 | 38.17 | 38.31 |
| Plough/Harrow | 0.41 | 0.44 | 0.46 | 0.43 | 3.18 | 3.22 | 3.14 | 3.2 | 0.32 | 0.34 | 0.35 | 0.37 | 0.52 | 0.53 | 0.35 | 0.37 | 0.25 | 0.29 | 0.271 | 0.33 | 37.98 | 38.33 | 38.04 | 38.19 |
| No-Till | 0.45 | 0.39 | 0.42 | 0.45 | 3.22 | 3.27 | 3.14 | 3.25 | 0.35 | 0.38 | 0.38 | 0.4 | 0.58 | 0.56 | 0.34 | 0.38 | 0.25 | 0.29 | 0.26 | 0.33 | 34.6 | 35.06 | 34.44 | 34.51 |
| Plough/Harrow/Ridge | 0.4 | 0.48 | 0.4 | 0.42 | 3.14 | 3.2 | 2.88 | 3.16 | 0.36 | 0.38 | 0.38 | 0.4 | 0.58 | 0.58 | 0.35 | 0.36 | 0.26 | 0.29 | 0.26 | 0.32 | 37.38 | 39.95 | 36.41 | 37.93 |
| LSD (0.05) | 0.08 | 0.11 | 0.06 | 0.08 | 0.09 | 0.08 | 0.26 | 0.08 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.07 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.88 | 0.85 | 2.45 | 0.66 |

*Any difference larger than the LSD value is considered a significant result.

**Table 5:** Total dissolved solids, Calcium, Magnesium, Dissolved oxygen, Lead, and Iron LSD values from the Experimental sites

| | Total Dissolved Solids | | | | Calcium | | | | Magnesium | | | | Dissolved Oxygen | | | | Lead | | | | Iron | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | |
| Tillage Type | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| Traditional | 0.56 | 0.6 | 0.57 | 0.61 | 1.04 | 1.63 | 1.094 | 1.68 | 0.191 | 0.25 | 0.178 | 0.29 | 68 | 89.48 | 62.9 | 81.96 | 0.14 | 0.17 | 0.14 | 0.14 | 1.79 | 1.83 | 1.75 | 1.75 |
| Plough/Harrow | 0.56 | 0.58 | 0.55 | 0.59 | 1.07 | 1.34 | 1.11 | 1.73 | 0.17 | 0.17 | 0.18 | 0.3 | 68.23 | 84.7 | 62.7 | 81.4 | 0.12 | 0.13 | 0.11 | 0.11 | 1.45 | 1.54 | 1.7 | 1.71 |
| No-Till | 0.56 | 0.57 | 0.55 | 0.59 | 1.09 | 1.79 | 1.09 | 1.81 | 0.16 | 0.3 | 0.2 | 0.29 | 65.4 | 86.66 | 63.4 | 83.59 | 0.07 | 0.09 | 0.13 | 0.14 | 1.72 | 1.74 | 1.81 | 1.82 |
| Plough/Harrow/Ridge | 0.55 | 0.57 | 0.55 | 0.58 | 1.08 | 1.7 | 1.1 | 1.8 | 0.15 | 0.21 | 0.19 | 0.3 | 67.96 | 80.59 | 63.53 | 82.88 | 0.1 | 0.13 | 0.16 | 0.17 | 2.42 | 2.25 | 1.68 | 1.7 |
| LSD (0.05) | 0.02 | 0.03 | 0.03 | 0.02 | 0.06 | 0.20 | 0.02 | 0.14 | 0.03 | 0.05 | 0.02 | 0.00 | 1.90 | 9.66 | 1.96 | 11.05 | 0.03 | 0.06 | 0.03 | 0.02 | 0.26 | 0.32 | 0.28 | 0.29 |

*Any difference larger than the LSD value is considered a significant result

**Table 6:** Phosphorus, pH, Conductivity, Chlorine, and Copper LSD values from the Experimental sites

| | Phosphorous | | | | pH | | | | Conductivity | | | | Chlorine | | | | Copper | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | | UTRF | | NCAM | |
| Tillage type | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** | **2015** | **2016** |
| Traditional | 2.31 | 2.25 | 2.19 | 2.3 | 6.67 | 6.7 | 6.65 | 6.68 | 0.8 | 81.62 | 0.799 | 80.4 | 48.53 | 48.28 | 43.52 | 48.26 | 0.51 | 0.119 | 0.11 | 0.101 |
| Plough/Harrow | 2.21 | 2.32 | 2.21 | 2.33 | 2.33 | 6.65 | 6.7 | 6.7 | 0.8 | 81.62 | 0.987 | 80.88 | 48.33 | 48.48 | 43.64 | 48.54 | 0.12 | 0.116 | 0.11 | 0.138 |
| No-Till | 2.27 | 2.31 | 2.26 | 2.31 | 6.76 | 6.69 | 6.74 | 6.7 | 0.8 | 81.7 | 1.39 | 80.77 | 48.01 | 48.16 | 43.3 | 48.19 | 0.11 | 0.106 | 0.1 | 0.082 |
| Plough/Harrow/Ridge | 2.27 | 2.3 | 2.21 | 2.32 | 6.74 | 6.72 | 6.69 | 6.72 | 0.8 | 80.55 | 1.38 | 80.44 | 48.37 | 48.57 | 43.38 | 48.43 | 0.11 | 0.108 | 0.1 | 0.162 |
| LSD (0.05) | 0.09 | 0.10 | 0.09 | 0.07 | 0.08 | 0.06 | 0.07 | 0.06 | 0.02 | 1.76 | 0.96 | 0.94 | 0.31 | 0.22 | 10.03 | 0.21 | 0.19 | 0.02 | 0.02 | 0.03 |

The values presented in Table 7 are actual results for the UTRF and NCAM watersheds based on the input data used in the SWAT model. At the UTRF site, the PHR land preparation method contributed the most to surface runoff (SURQ: 374.42 mm), surface runoff generation (SURQGEN: 374.42 mm), and evapotranspiration (ET: 725.78 mm). In contrast, at the NCAM site, the PH land preparation method recorded the highest values for SURQ (284.86 mm), SURQGEN (284.87 mm), and ET (698.1 mm). The NT and T land preparation types resulted in the highest levels of nitrate ($NO_3$: kg/ha), organic nitrogen (ORGN: kg/ha), sediment yield (SED: tons/ha), soil loss (USLE_LS), and groundwater discharge (GWQ: mm) across both sites (Table 7). These patterns can be attributed to differences in elevation, which influence surface runoff—UTRF has a steeper mean slope of 6.39, while NCAM has a gentler slope of 2.74 (Figures 4 and 5). According to Salsabilla and Kusratmoko (2017), runoff and sediment are positively associated with land preparation practices. Areas with greater forest cover typically experience lower runoff and soil loss, while cultivated land tends to suffer more erosion than managed agricultural fields. The hydrological model also presents average values for key variables across the entire study area.

**Table 7:** Distribution of the Hydrological Response Unit (HRU) and the SWAT modelled Parameters in UTRF and NCAM sub catchments

| Name | HRU | SUB | Tillage method | Land Area Covered ($m^2$) | SURQ mm | NO3 kgh | ORGN kgh | PREC mm | SURQ GEN mm | SED th | USLE_LS | GWQ mm | ET mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UTRF | 44 | 18 | PH | 0.463 | 372.91 | 4.41 | 50.94 | 1314.21 | 372.91 | 5.31 | 1.05 | 171.19 | 724.79 |
| UTRF | 45 | 18 | NT and T | 0.201 | 371.53 | 5.15 | 62.62 | 1314.21 | 371.53 | 10.54 | 2.24 | 174.45 | 723.6 |
| UTRF | 46 | 18 | PHR | 0.209 | 374.42 | 3.68 | 29.83 | 1314.21 | 374.42 | 1.81 | 0.44 | 167.86 | 725.78 |
| NCAM | 103 | 42 | NT and T | 0.872 | 281.94 | 4.42 | 60.79 | 1113.86 | 281.94 | 10.46 | 2.31 | 96.32 | 696.6 |
| NCAM | 104 | 42 | PH | 2.19 | 284.86 | 3.04 | 27.41 | 1113.86 | 284.87 | 1.57 | 0.38 | 90.41 | 698.1 |
| NCAM | 105 | 42 | PHR | 2.56 | 283.39 | 3.89 | 48.38 | 1113.86 | 283.39 | 4.79 | 1 | 93.29 | 697.47 |

NOTE: T-Traditional heap, PH-Plough/Harrow, PHR-Plough/Harrow/Ridge, NT-No Till,
**Source:** Author's fieldwork (2016)

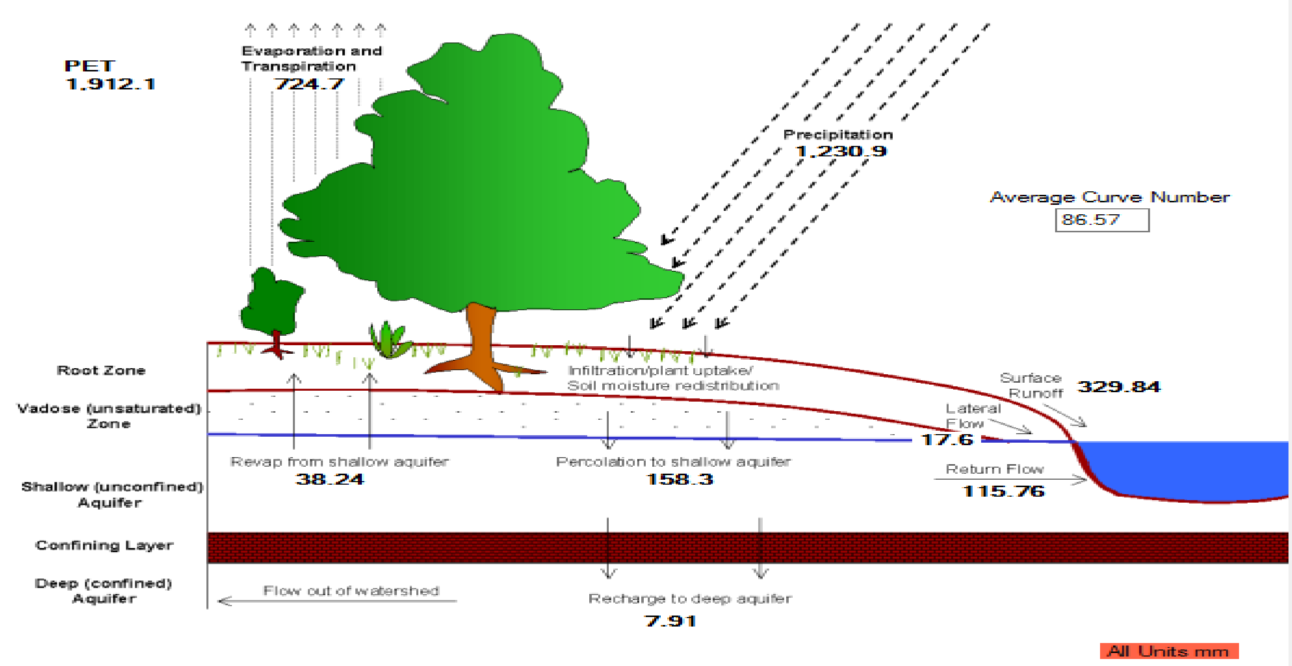


**Figure 4:** Schematic Representation of the Hydrologic Cycle of the study area.
**Source:** Adopted from Akpoti 2015

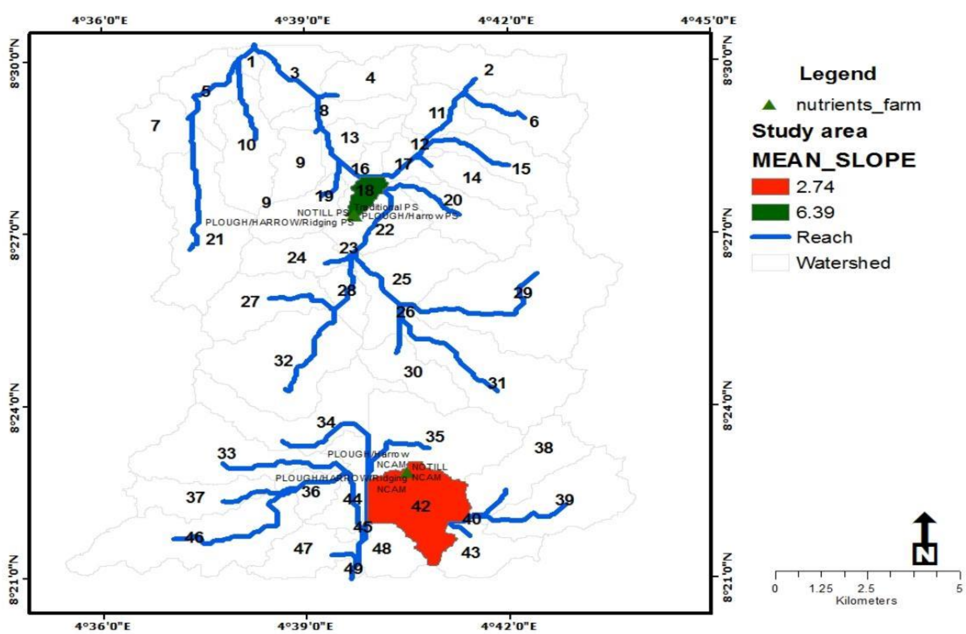


**Figure 5:** SWAT model showing the study area watershed delineated into Hydrological Response Units and the Mean slope of the study area. Source: Author's fieldwork (2017)

**Agricultural Land Use Predictions and Contribution to Modelled Features**

The SWAT delineated the subbasins into three land-use types. They are agricultural cropland, areas of thick vegetation, and bare surfaces. Each of these land uses has a distinct impact on the modelled variables. A few important predictions, summarised by land use, for each of these variables are shown in Table 8. The areas indicated the most significant land-use contribution to the modelled variables. From Table 8, agricultural cropland had a greater contribution to the total of groundwater quality, sediment yield, and organic nitrogen than the other land use (i.e., bare surfaces and forested area) in the study area, with values of 139.56mm, 4.72 kg/ha, and 44.72 kg N/ha, respectively. Also, bare surface contributed more to the total of surface runoff, precipitation, nitrogen, and crop yield in the study area than the agricultural and forested areas, with values of 447.08mm, 1,314.21mm, 4.94 kg N/ha, and 9.40, respectively. Furthermore, the forested areas contributed more to soil loss, evapotranspiration, and biomass than the agricultural and barren surfaces with values of 1.00, 800.80mm, and 22.62 bioth, respectively.

**Table 8:** Land Use Predictions on Features Modelled for the Study Area

| **Land Use** | Area | Curve No (CN) | Average Water Capacity (AWC) | USLE (Soil Loss) | Precipita-tion | Surface Runoff (SURQ) | Ground water Quality (GWQ) | Evapotran-spiration (ET) | Sediment Yield (SED) | N03 | Organic Nitrogen | Bio-mass | Yield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural cropland | 166.07 | 87.00 | 175.77 | 0.92 | 1,235.15 | 338.02 | 139.56 | 714.23 | 4.72 | 3.90 | 44.72 | 13.27 | 4.21 |
| Grasslands/ Shrubs/Bare surface | 6.75 | 86.22 | 175.77 | 0.69 | 1,314.21 | 447.08 | 64.50 | 766.85 | 2.29 | 4.94 | 20.45 | 13.40 | 6.40 |
| Thick cluster of trees (Dense Vegetation) | 19.15 | 83.00 | 175.77 | 1.00 | 1,165.00 | 217.66 | 103.87 | 800.80 | 0.02 | 0.08 | 0.34 | 22.62 | 4.24 |

**Source:** Author's fieldwork (2017)

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 Philps *et al*., (1980), Aina *et al.,* (1993), Lewandowski *et al*., (1999), Anthony and Collin (2006), Derpsch, (2007), FAO (2007), Aina (2010), Reji *et al., (*2012) among others. The findings from the land use prediction are in line with Arnold and Fohrer (2005), Coutu and Vega (2007), and Gassman *et al.* (2007), reporting that bare surfaces contribute more to surface runoff and that there is a significant relationship between forested surfaces and the amount of runoff generated through the application of SWAT. 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 studies (Junge et al., 2008, Lewandowski *et al*., (1999), Anthony and Collin (2006), Derpsch, (2007), FAO (2007), Aina (2011), Reji *et al.,(*2012) among others.). Therefore, farmers must be conscious of agricultural land management activities, ensuring the best tillage method suitable for such an environment is applied to achieve optimal crop yield while conserving water quality.

## CONCLUSION AND RECOMMENDATIONS

In conclusion, Traditional Heap and No tillage contributed more to the surface runoff parameters than Plough/Harrow and Plough/Harrow/Ridge, Plough/Harrow and Plough/Harrow/Ridge contributed more to soil loss and surface runoff amount flowing to the nearest river/drainage than Traditional Heap and No tillage. Therefore, the study recommends integrating tillage planning into watershed management programs as a key strategy to minimise agricultural water pollution, and applying PH as a preferred tillage method to promote sustainable agricultural practices and reduce nutrient and sediment loss through runoff.

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