Modelling of Non-Point Source Pollution Around Lake Victoria Using SWAT Model: A Case of Simiyu Catchment Tanzania

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Abstract: Pollutant loading in Lake Victoria is resulting from a wide range of anthropogenic activities. This study focused on Non-Point Sources (NPS) of pollution and it was carried out to identify and characterize land-use activities and to quantify the sediment and nutrient loads (nitrogen and phosphorus). The study was conducted in Simiyu catchment of Lake Victoria using land-use data of 1975 and 2006 and comparing the relative impact of land-use change on sediment and nutrient load (P and N) into the lake. Possible best management practices were also identified for those sub-basins with the highest pollution yield. Remote sensing using the package ILIWIS 3.0 was used to identify and characterize the land-use and the Soil and Water Assessment Tool (SWAT) model was used to quantify sediment and nutrient load from these two different land-use scenarios. Land use classification according to the SWAT model shows that Agricultural Land-Generic (AGRL) contributes about 73.43%, Range-brush (RNGB) contributes 24.42%, Pasture (PAST), 2.10% Savanna (SAVA) 0.03% and Water (WATR) 0.02% of the total catchment area of Simiyu. It was also found out that there was an expansion of agricultural land from covering 19.33% of the catchment to 73.43% at an annual change rate of 2.9%. However, average Nitrate load was higher for 1975 than 2006. The P load of 1975 was less compared to that in 2006. Model simulation at the catchment outlet for N gave 77.2 kg/km^2.yr while observed values were 146 kg/km^2.yr, simulated P was 47 kg/km^2.yr while observed was 164 kg/km^2.yr. Hence, the model underestimated nutrient yield in the catchment. Therefore, the applicability of the SWAT modelling tool in studying NPS pollution yields poor model performance due to the scantiness of data used for model calibration. More rigorous data campaigns have to be carried out along the two rivers of Duma and Simiyu for purposes of gaining enough information for model calibration and validation. With good model performance, developing management plans to control NPS pollution around Lake Victoria could be achieved using the SWAT model.

Keywords: Land use, model underestimation, non-point source of pollution, nutrients loadings, sediment loadings, SWAT model.

1. INTRODUCTION

Lake Victoria is one of the largest freshwater bodies of the world. Although Lake Victoria is bordered by Kenya, Tanzania, and Uganda, streams and rivers stretching as far as Burundi and Rwanda also feed into it. Needless to mention but vital to note is the fact that Lake Victoria is also the source of the Nile, a river whose waters are greatly committed downstream. In recent years, environmental challenges have beset the Lake. It is not only a source of food, water, employment, transport, hydroelectric power, and recreation, but is also now used as dumping ground for various types of waste [1-3]. According to [4], the once clear, life-filled Lake Victoria is murky and smelly. Furthermore, these days the pollution impact by municipal and industrial discharges is visible in some of the rivers feeding the Lake and along the shoreline, such as the shallow Winam Gulf in Kisumu (Kenya) and near Mwanza (Tanzania) and Kampala City (Uganda).

The ecological health of Lake Victoria has been affected profoundly as a result of a rapidly increasing human population due to migration to the area by plantation workers, clearance of natural vegetation along the shores to establish plantations of coffee, tea and sugar [3] prolific growth of algae [4, 5] and dumping of untreated effluent by several industries [2]. The National Water and Sewerage Corporation charged with treating and supplying water to Kampala City dwellers is complaining of raising treatment costs [6].

A number of studies e.g., [1, 2, 4, 5, 7, 8, 9, 11] have documented pollution as one of the largest problems causing water quality deterioration. In spite of the enormous atten-

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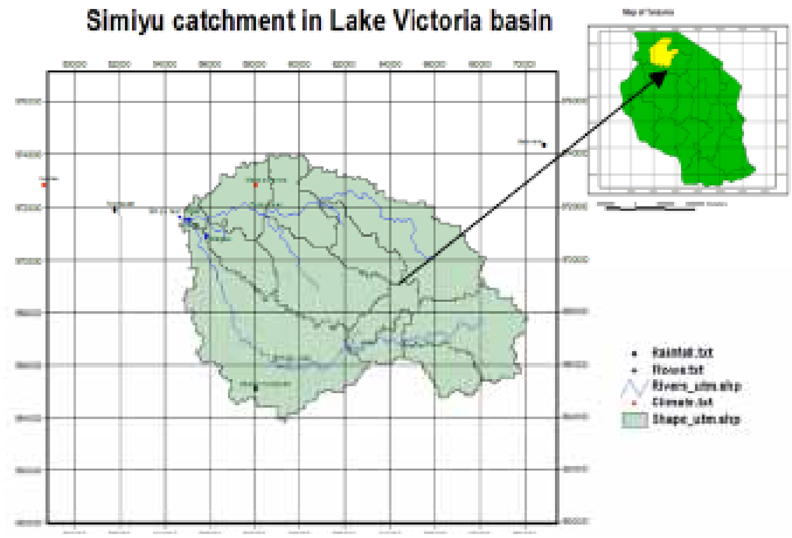

Fig. (1). Location of Simiyu catchment in Mwanza region (Tanzania).

tion that has been invested in tackling the pollution problem during the last three decades, it has persisted though point source pollution has mainly been the focus. Although NPS often affects at a larger scale and some authors such as [7] have reported it in the Lake Victoria, the state-of-the-art literature indicates that no studies aimed at predicting such type of pollution have been carried out in this basin. However, enormous attention has been invested in tackling the pollution problem based on point source pollution, little attention has been paid to NPS yet since they are also part of the major causes of water quality deterioration.

Nitrogen and Phosphorus are the major nutrients of importance as far as lake eutrophication is concerned. These two originate from inorganic and organic fertilizers due to intensive agricultural activity, sewerage from cities, livestock grazing and from the use of disinfectants on farms. As catchment land-use changes to more agricultural land, bare grounds and residential areas, more pollution is produced and directed into the lake. Studying the NPS hot spots and their contribution to lake pollution and relating this to land-use change in the catchment is an important move to set measures for management of the catchment land-uses and reduction in lake water quality deterioration. One of the major catchments that contribute to the non point sources of pollution to Lake Victoria is Simiyu Catchment. The Simiyu catchment in located in the then Mwanza region and is one of the catchments forming the Lake Victoria basin on the Tanzanian side. The study was therefore carried out to assess the non-point sources of pollution in Lake Victoria as a result of land-use change (a case of Simiyu catchment-Mwanza) using SWAT model.

The specific objectives of the study were twofold, namely to identify and characterize land-use activities and to quantify the sediment and nutrient loads (nitrogen and phosphorus).

2. METHODOLOGY

2.1. Description of Study Area

Simiyu Catchment was in the then Mwanza City. Mwanza City is the second largest city in Tanzania after Dar-es-Salaam. The city is located on the southern shores of Lake Victoria in Northern Tanzania (Fig. **1**). It covers 1,325 km^2 that is dry land and 900km^2 is water (Lake Victoria). Simiyu catchment is located between 33^0 15' -35^0 00' E and 2^0 3'-3^0 30'S on the South - Eastern part of Lake Victoria. The Simiyu River drains the Serengeti National Park plains and partly Mau ranges in Kenya to Lake Victoria on the downstream before it discharges its waters to the lake [10]. Simiyu catchment has an area of 10,312.203km^2. It discharges into the lake at the Speke Gulf and is considered as one of the main sources of nitrates and phosphates loads into the lake.

The catchment has a total annual rainfall of 700 to 1000 mm with an average temperature ranging between 22.5^0C and 23°C and it is in the semi-arid part of Tanzania. According to [11], sandy loam soil covers about 60% of the total catchment area. The Simiyu River is a tributary of Lake Victoria, joining the Duma River before the two discharge their waters into the Lake at the Speke Gulf. Other smaller rivers in the same catchment area are Bariadi River and Ngasomo River. Simiyu River is ephemeral, which contain water during and immediately after a storm event and dries up during the rest of the year with exception of some dead channel storage [12]. During the long rainy season, discharge from the river reaches highs of 208 m^3/s [13] and lows of no discharge at all in the dry season.

2.2. Data Collection

The data that was used in this study included spatially distributed information used for elevation, soil and land cover/land-use. Others included climatic data of rainfall, precipitation, wind, and solar radiation and finally observed flow data, which were obtained from Tanzania Meteorological Agency (TMA). Other data used was on the fertilisers and pesticides applied in the catchment. Fig. (**2**) below shows the locations of climatic stations.

Fig. (**3**) below shows the soil type map for Simiyu. The map shows that the produced Sand Loam soils with two layers (FSL and SCL) covers 68.23%, Clay soils with three layers (C, C, C) covers 6.67%, Clay loamy soils with two layers

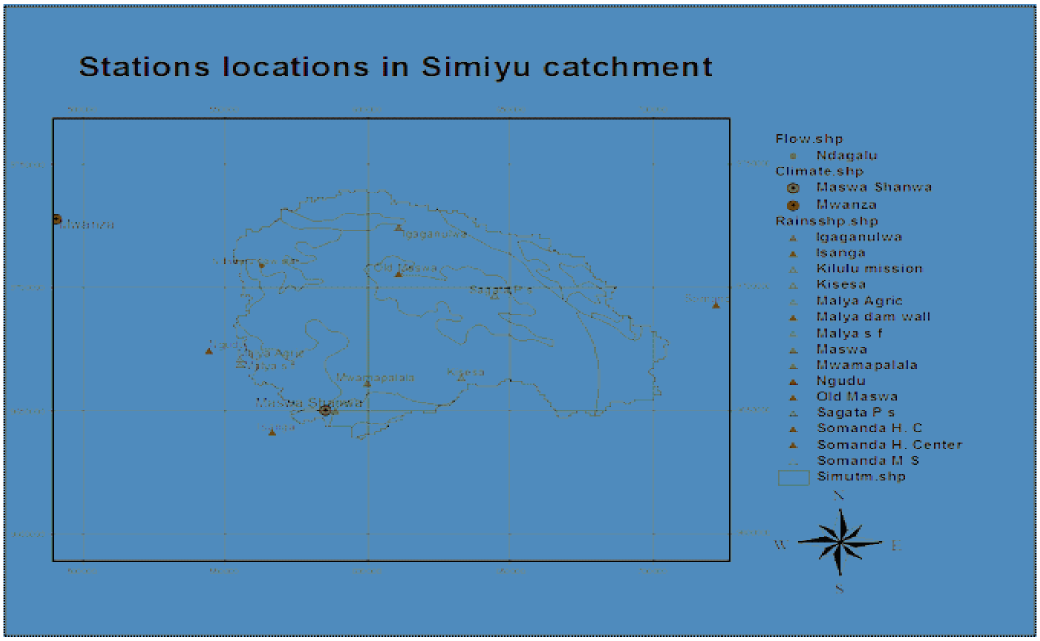

Fig. (2). Climatic stations location in Simiyu Catchment.

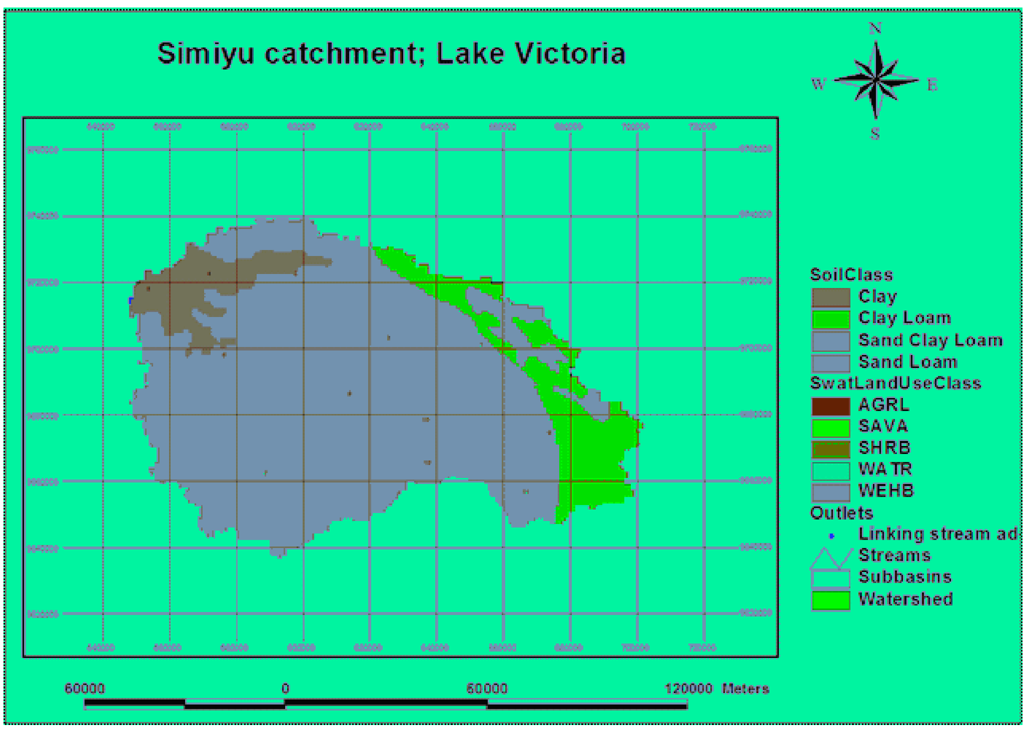

Fig. (3). Soils in Simiyu Catchment.

(CL-CL) covers 11.96% and Sand Clay Loam soil with two layers (L-CL) covers 13.13% of the catchment.

2.3. SWAT Modelling

2.3.1. Runoff Modelling with SWAT

The SCS curve number method was used in the SWAT model to estimate accumulated runoff for each sub-basin using the method of [14] to estimate the amount of runoff in the different watersheds.

$$Q_{surf} = \frac{(P-0.25)^2}{(P+0.85)} \ldots(1)$$

Where: P is rainfall (mm), S is retention parameter (mm), and Q_{surf} is the accumulated runoff (mm) [14] further defines retention parameter (S) as a function of soil, land-use, slope, management scenarios and is given by;

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \ldots(2)$$

Where; *CN* is the curve number for the decay.

Runoff is a function of many factors like rainfall intensity, soil, vegetation cover, slope, rainfall duration, and the surface moisture content. The SCS curve number is a function of the soil's permeability, land-use and antecedent soil water conditions.

2.3.2. Nutrients and Pesticides Modelling in SWAT

The fate and transport of nutrients and pesticides in a watershed depend on the transformations the compounds undergo in the soil environment. The nutrients and pesticides transformation and transport processes were modeled using the following equations;

Nitrogen

The equation for calculating concentration of nitrate in the mobile water fraction is;

$$Conc\,NO_{3,mobile} = \frac{NO_{3iy} * \exp\left[\frac{-w_{mobile}}{\left(1-\theta_{\varepsilon} * SAT_{iy}\right)}\right]}{w_{mobile}} ...(3)$$

Where; Conc NO_3, mobile is concentration of nitrate in the mobile water for a given layer (KgN/mm H_2O), NO_{3ty} is the amount of nitrate in the layer (Kg N/ha), w_{mobile} is the amount of mobile water in the layer (mm H_2O), θ_{ε} is the fraction of porosity from which anions are excluded, and SAT_{iy} is the saturation rated water content of the soil layer (mmH_2O).

Organic Nitrogen levels are assigned that the C: N ratio of humic materials is 14:1. The concentration of humic organic nitrogen in a soil layer is given by;

$$OrgN_{hum,ly} = 10^4 * \left[\frac{OrgC_{ly}}{14}\right] ...(4)$$

Where $OrgN_{hum,ly}$ is the concentration of humic organic nitrogen in the layer (mg/kg of ppm), and $OrgC_{ly}$ is the amount of organic carbon in the layer (%). The humic organic N is partitioned between the active and stable pools using the following equations:

$$OrgN_{act,ly} = Org_{hum,ly} * fra_{actN} ...(5)$$

$$OrgN_{sta,ly} = OrgN_{hum,ly} * \left(1 - fr_{actN}\right) ...(6)$$

Where, $OrgN_{act,ly}$, is the concentration of Organic Nitrogen in the active organic pool (mg/K), $Org_{hum,ly}$ is the concentration of humic organic nitrogen in the layer (mg/kg), $fr_{act\,N}$ is set to 0.02.

Nitrogen in the fresh organic pool is set to zero in all layers except the top 10 mm of soil. In the top 10 mm, the fresh organic nitrogen pool is set to 0.15% of the initial amount of residue on the soil surface.

$$OrgN_{frsh,surf} = 0.0015 * rsd_{surf} ...(7)$$

Where $OrgN_{frsh,surf}$ is the nitrogen in the fresh organic pool in the top 10mm (Kg N/ha), and rsd_{surf} is material in the residue pool for the top 10 mm of soil (Kg/ha).

Phosphorus

The concentration of phosphorus in the active mineral pool is initialised to;

$$\min P_{act,ly} = P_{solution} * \left[\frac{1-pai}{pai}\right] ...(8)$$

Where $minP_{act,ly}$ is the amount of phosphorus in the active mineral pool (mg/kg), $P_{solution,ly}$ is the amount of phosphorus in solution (mg/kg), and pai is the phosphorus availability index.

The concentration of phosphorus in the stable mineral pool is initialised to;

$$\min P_{sta,ly} = 4 * \min P_{act,ly} ...(9)$$

Where $minP_{sta,ly}$ is the amount of phosphorus is in the stable mineral pool (mg/kg), and $minP_{act,ly}$ is the amount of phosphorus in the active mineral pool.

Organic phosphorus levels are assigned assuming the ratio N: P in humic material is 8:1. The concentration of humic organic phosphorus in the layer of soil is calculated by;

$$OrgP_{hum,ly} = 0.125 * orgN_{hum,ly} ...(10)$$

Where $OrgP_{hum,ly}$ is the concentration of humic organic phosphorus in the layer (mg/kg) and $orgN_{hum,ly}$ is the concentration of humic organic nitrogen in the layer (mg/kg).

Phosphorus in the fresh organic pool is set to zero in all layers except the top 10mm of soil. In the top 10 mm, the fresh organic phosphorus pool is set to 0.03% of the initial amount of residue on the soil surface.

$$OrgP_{frsh,surf} = 0.0003 * rsd_{surf} ...(11)$$

Where $OrgP_{frsh,surf}$ is the phosphorus in the fresh organic pool in the top 10mm (kg P/ha), and rsd_{surf} is material in the residue pool for the top 10mm of soil (kg/ha).

The amount of solution phosphorus in surface runoff is calculated by;

$$P_{surf} = \frac{P_{solution,surf} * Q_{surf}}{\rho_b * depth_{surf} * k_{d,surf}} ...(12)$$

Where P_{surf} is the amount of soluble phosphorus lost in surface runoff (Kg P/ha), $P_{solution,surf}$ is the amount of phosphorus in solution in the top 10mm (Kg P/ha), Q_{surf} is the amount of surface runoff on a given day (mm H_2O), ρ_b is the bulk density of the top 10mm (Mg/m^3) assumed to be the bulk density of the top soil layer, $depth_{surf}$ is the depth of the surface layer (10mm), and $k_{d,surf}$ is the phosphorus soil partitioning coefficient (m^3/Mg).

According to [15] while SWAT allows nutrient levels to be input as concentrations, it performs all calculations on

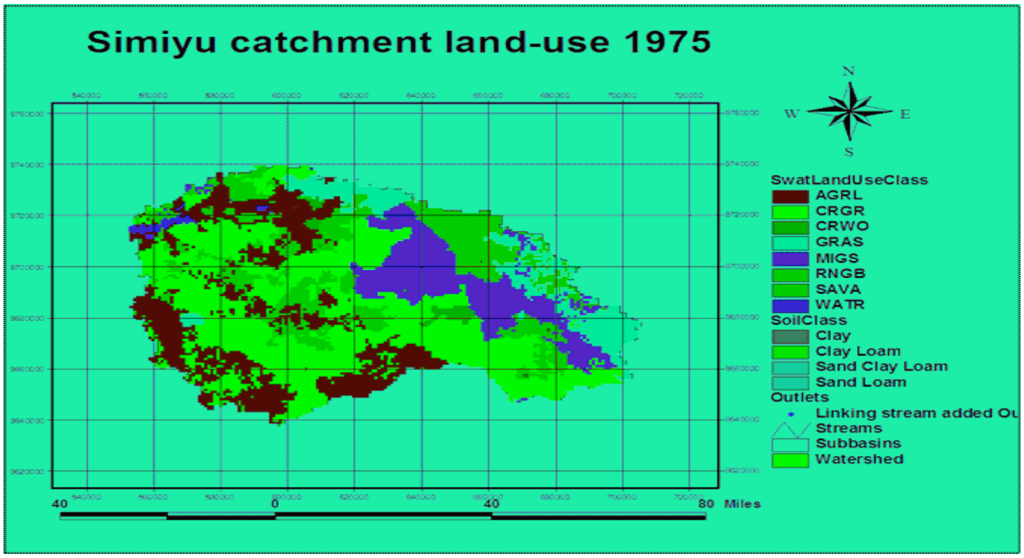

Fig. (4). Simiyu catchment land use in 1975.

mass basis and to convert a concentration to a mass, the concentration is multiplied by the bulk density and depth of the layer and divided by 100;

$$\frac{Conc_n * \rho_b * depth_{ly}}{100} = Kg\,of\,n\,per\,ha ...(13)$$

Where $Conc_n$ is the concentration of the nutrient in a layer (mg/kg or ppm), ρ_b is the bulk density of the layer (Mg/m^3) and $depth_{ly}$ is the depth of the layer.

The modified universal soil loss equation [16] is given by,

$$sed = 11.8 * \left(Q_{surf} * q_{peak} * area_{hru}\right)^{0.56}$$
$$* K_{USLE} * C_{USLE} * P_{USLE} * LS_{USLE} * CFRG ...(14)$$

Where; sed is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm H_2O/ha),q_{peak} is the peak runoff rate (m^3/s), $area_{hru}$ is the area of the HRU (ha), K_{USLE} is the USLE soil erodibilty factor (0.013),C_{USLE} is the USLE cover and management factor, P_{USLE} is the USLE support practice factor, LS_{USLE} is the USLE topographic factor and CRFG is the coarse fragment factor.

2.4. Land-use Characterisation

Actual land-use data was obtained from Landsat TM satellite images for the year 2006. Two scenes were acquired to complete the study area in the images. For the 1975 land-use, which was base year for the comparison, a copy was obtained already processed from Water Resources Department. All image processing was done using ILWIS software version 3.0.

2.5. Checking Model Performance

Three criteria were included in the statistical analysis for hydrology. These criteria are the deviation of water yields, the Nash-Sutcliffe coefficient, and the coefficient of gain from the daily mean. In addition to these three, the coefficient of determination (R^2) is also calculated as part of the hydrologic analysis. The Nash-Sutcliffe coefficient, E_{ns}, measures how well the daily simulated and measured flows correspond. This coefficient is calculated;

$$E_{ns} = 1 - \frac{\sum_{i-n}^{n}\left(Q_i - P_i\right)^2}{\sum_{i-n}^{n}\left(Q_i - Q_{mean}\right)^2} ...(15)$$

where Q_i is the measured daily discharge, P_i is the computed daily discharge, and $\bar{O}$ is the average measured discharge. A Nash-Sutcliffe value can vary between 0.0 and 1.0 where a value of 1.0 indicates a perfect fit while a value of 0.0 indicates that the model is predicting no better than the average of the observed data.

With the water quality parameters the model evaluation is based on Normal Root Mean Square Error (NRMSE);

$$\frac{\sqrt{\dfrac{\sum_{i}^{n}\left(Q_i - P_i\right)^2}{n}}}{meanQ} ...(16)$$

NRMSE value can vary between 0 and ∞ with the value 0 indicates a perfect fit between the observed and measured data while the value of 1 an acceptable value for concentration simulation.

3. DISCUSSIONS OF RESULTS

3.1. Land use Identification and Characterisation

Land-use/cover information is of critical importance in hydrological modelling, as it helps determine model variables that account for the volume, timing and quality of runoff. The amount of expected runoff from vegetated land-use types is influenced not only by the surface and soil physical properties but also by the uptake capacity of the flora present. Below is the land-uses/cover (Figs. **4** and **5**) that were used in the model to study catchment pollution contribution.

The above land-use (Table **1**) was obtained from image processing as explained in the methodology section above while the former, (Table **2**) was obtained from the Depart-

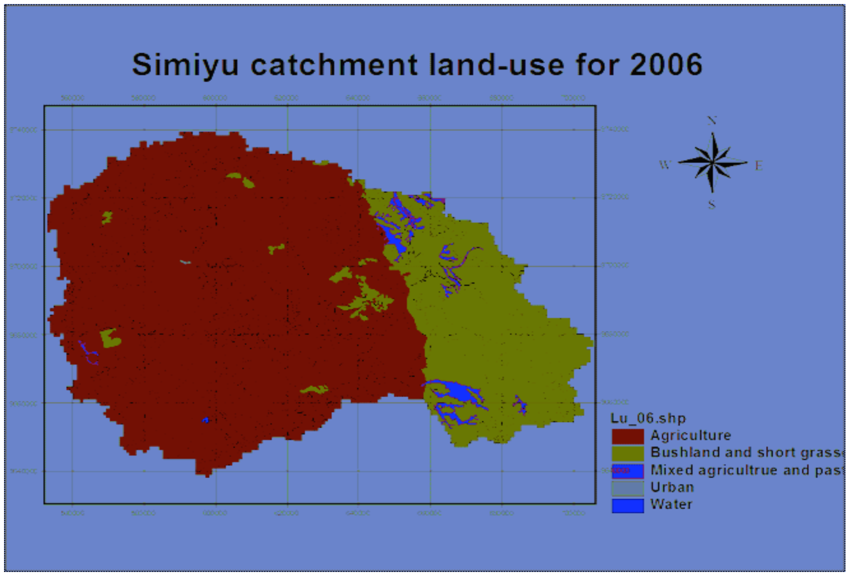

Fig. (5). Land use for Simiyu Catchment in 2006.

Table1. Land-use Classification of 1975

Processed Land-use	SWAT Class	Percentage of Catchment Area
Grassland with scattered cropland	Cropland / Grassland Mosaic (CRGR)	38.28
Mixed cropping and cultivation with herbaceous crops	Agricultural land-Generic (AGRL)	19.33
Bush land with emergent trees	Range-brush (RNGB)	18.77
Bushed grassland	Mixed grassland/shrubs (MIGS)	13.25
Open grassland and urban	Grassland (GRAS)	8.73
Wooded with scattered cropland	Cropland / woodland mosaic (CRWO)	1.03
Inland Water	Water (WATR)	0.58
Urban	SAVA	0.03

ment of Water resources Engineering database produced from previous research. The chart showing the land use changes between 1975 and 2006 is shown in Fig. (**6**).

For the 1975 land-use, agriculture was practiced on 19.33% of the catchment area while in 2006; it covered up to 73.43% of the catchment. In 1975, major activity was in sub basin 7 (also the outlet sub-basin) which was 33.23% of the catchment and agriculture was done in 11.62% in the sub-basin. Similarly, in 2006, sub-basin 7 covered 32.23% of the catchment area and of this agriculture covered up 32.35%. Nutrient load from sub-basin 7 was therefore of major interest since this took up a large percentage of the catchment area in both land-use scenarios (1975 and 2006). Hence all analysis below was targeted to this sub-basin which was also the outlet in the catchment. From the above land use changes it shows that there is close relationship between the land use changes and the non point source of pollution. Land use changes destroy the land cover and therefore intensify the surface runoff. Moreover the agricultural land use because of its release in agrochemicals (nitrogen, phosphorus, pesticides and herbicides) they contribute to the pollution into Lake Victoria. Because of these pollutants then the surface water quality of the Lake Victoria is impaired.

3.2. Model Results

3.2.1. Hydrological Modelling

For the hydrology, the model was run and a plot of the simulated and observed flows was made using the model's default values. Figs. (**7** and **8**) below shows the model results for 1975 and 2006 land use scenarios respectively.

Following this, a sensitivity analysis was carried out and the resulting parameters were ranked according to their importance on model performance. Table **3** below shows the model parameters used.

Starting with the 1975 land-use, manual calibration was done and efforts were made to adjust the parameters till the Index of Volumetric Fit (IVF) of 0.88 for the long-term water balance was obtained. The ranges used were between 85-70 for CN_II all land-uses, SURLAG of 1, CH_K2 of 3, ALPHA_BF of 0.02, ESCO of 0.001 and SOL_AWC of

Table 2. Land-Use Classification for 2006

Processed Land-Use	SWAT Class	Percentage of Catchment Area
Cultivated	Agricultural Land-Generic (AGRL)	73.43
Mixed Agriculture and pastures	Range-brush(RNGB)	24.42
Bush-land and short grasses	Pasture (PAST)	2.10
Short grasses/Urban	Savanna (SAVA)	0.03
Water	Water (WATR)	0.02

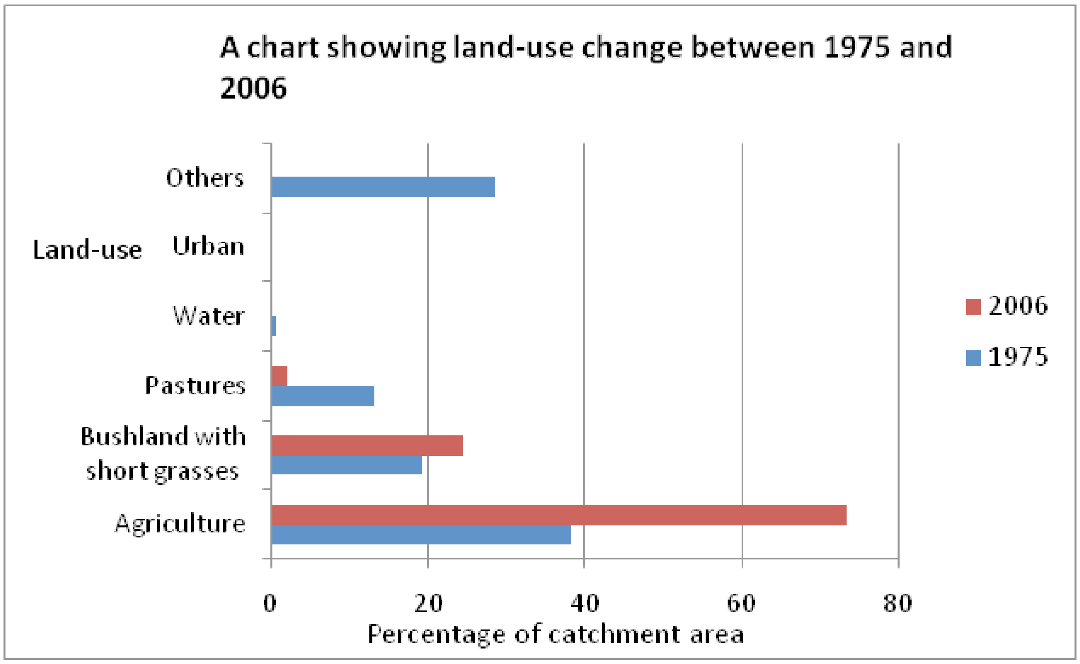

Fig. (6). Land use changes between 1975 and 2006.

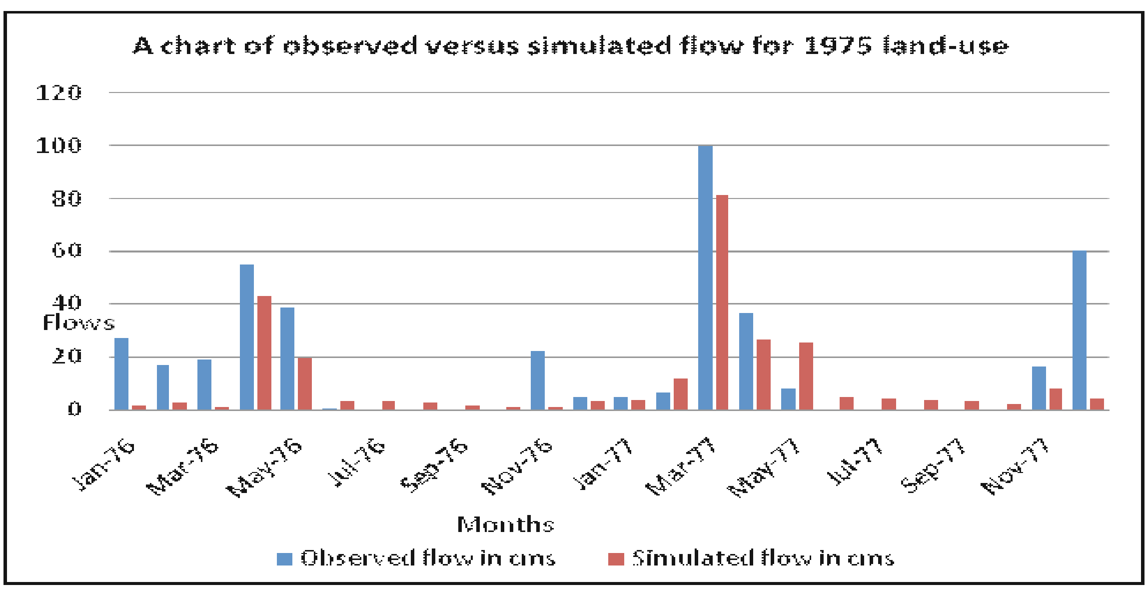

Fig. (7). Flow results for 1975 land use scenarios.

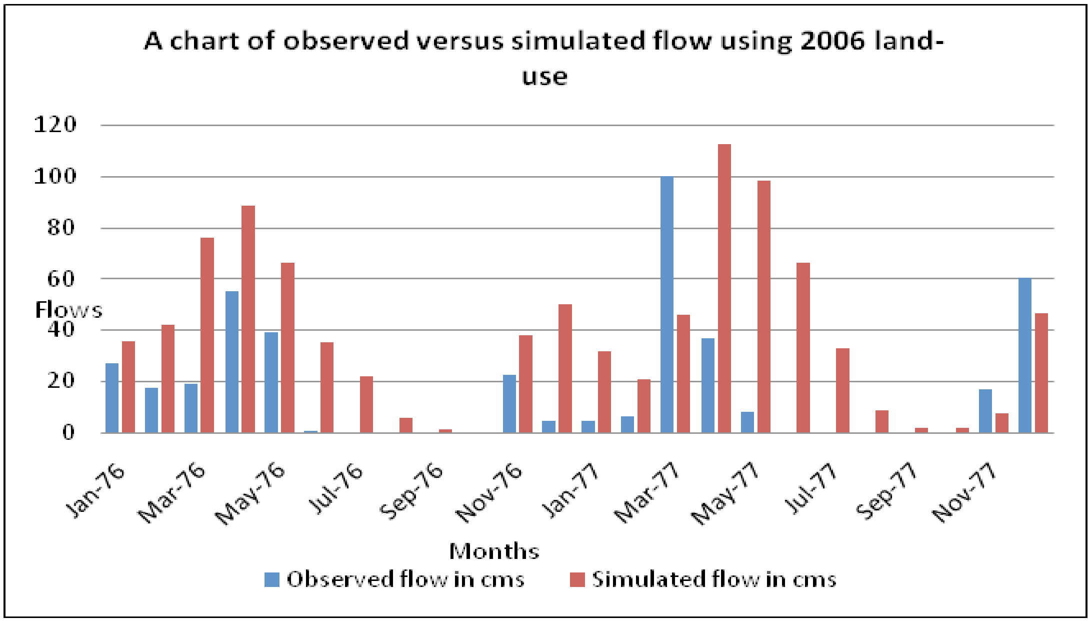

Fig. (8). Flow results for 2006 scenarios.

Table 3. Model Parameters for Hydrology Model Calibration

Parameter	Description	Range Given in Model
CN2 (.mgt)	Initial SCS Curve Number II value	Varied with land-use between 55 and 98
SURLAG (.bsn)	Surface runoff lag time (days)	4 days
CH_K2 (.rte)	Channel effectiveness hydraulic conductivity (mm/hr)	0.00mm/hr
ALPHA_BF (.gw)	Base-flow alpha factor	0.048 day
ESCO (.hru)	Soil evaporation compensation factor	0.00
SOL_AWC (.sol)	Available water capacity	0.17 and 0.18mm/mm

0.17. Although RCHRG_DP (gw) ranked 14 on the sensitivity analysis, adjusting it gave good model performance. It was maintained at 0.5 from 0.05.

Changes in the land-use have an impact on the hydrology of the catchment. This meant, the model had to be calibrated again using the 2006 land-use map. However, due to lack of observed flow data for 2006, the model was calibrated only once for 1975. The landuse was changed to that of 2006 using the same model parameters as those of 1975. Using the available flow data at Ndagalu station for period 1977 to 1983, only five years were considered wet years i.e. the annual rainfall average of was above the average of the time step from 1976 to 1983. Hence these five years were used for the long-term water balance. Model performance indices were an IVF of 88% and Nash-Sutcliffe efficiency, E_{ns} of 34.5% (for the 1975 land-use map) and IVF 72.4% and E_{ns} 30.1% (for 2006 land-use). From the hydrology, there was increase in the average surface runoff between 1999 and 2000 with 1975 having an average of 14.14 m^3/s/month and 2006 having 20.16m^3/s/month. Fig. (**9**) below shows the runoff for 1975 and 2006.

This can be attributed to the change in vegetation cover that has an impact on surface runoff.

3.2.2. Nutrients Quantification

3.2.2.1. Model Parameters for Nutrient Calibration

The model parameters that were used to model nutrients are shown in Table **4** below:

Sensitivity analysis for water quality gave the most sensitive parameter as SOL_ORGN because it has an impact on the amount of nutrient, both organic N and organic P leached into the stream i.e. ($OrgP_{hum,ly} = 0.125*orgN_{hum,ly}$)). Second is the CN2 as it was for the hydrology because a small change for runoff will result into a change for nutrients at the catchment outlet. The next sensitive parameter is SOL_Z (Soil depth) because as the depth of the soil increases, the amount of nutrient lost in the surface runoff decreases mainly for the soluble phosphates. BIOMIX is another sensitive parameter because as the microbial activity in the soil increases the soil constituents are made more liable to erosion. SLSUBBSN and other catchment physical features are sensitive parameters because with a steeper slope, there is a tendency of increasing the surface runoff rate and hence the amount of nutrient carried into the stream.

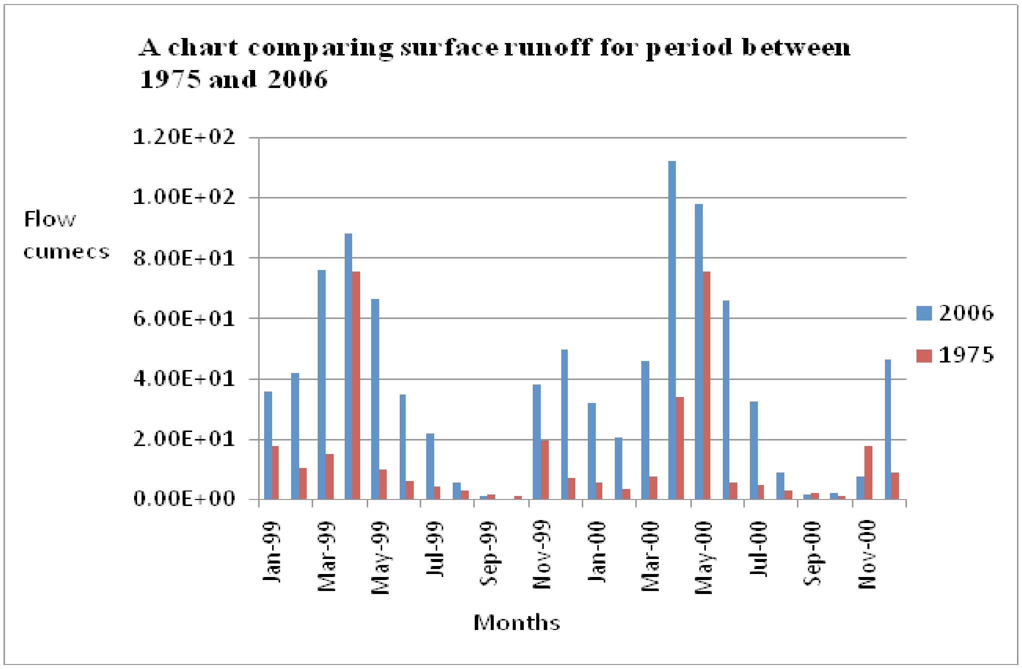

Fig. (9). Runoff for 1975 and 2006 periods.

Table 4. Model Parameters for Nutrients

Parameter	Description	Default	Values Used
SOL_ORGN (.chm)	Initial Organic N concentration	0.00	500mg/kg
CN2(.mgt)	Initial SCS CN II value	45 and 55	45 and 55
SOL_Z (.sol)	Soil depth	609 (Sand loam) and 228 (sand clay loam soil)	442mm
BIOMIX(.mgt)	Biological mixing efficiency	0 to 1	0.2
SURLAG (.bsn)	Surface runoff lag time	4	1day
SOL_AWC (.sol)	Available water capacity	0.17 and 0.18	0.17mm/mm

Model efficiency after calibration for nutrients gave a Normal Root Mean Square Error (NRMSE) of 0.61 for the nutrients calibrated at the outlet.

3.2.2.2. Nitrogen Quantification

The model parameters obtained above were then used to quantify the nitrogen load. Fig. (**10**) below shows the nitrogen load for 1975 and 2006 scenarios.

With application of pesticides and fertilizers set on in the model, there were shooting values for the nitrates load from the 2006 land-use. Average nitrate load went up to 92.2kgNO_3/km^2/yr for 2006 from 77.2 kg/km^2/yr like shown in figure above. The 1975 land-use had an average of 52.03kgNO_3/km^2/yr. This shows how in the 2006 land-use, the increased agricultural activity in the catchment with application of manure and other fertilizers to increase crop production increased nutrient yield in the catchment. Analysis of organic nitrogen levels in the catchment with emphasis on sub-basin 7 showed the average load increased 0.112-0.237kg/ha/yr to 1.003-1.339kg/ha/yr in 1975 and 2006 land-uses respectively.

3.2.2.3. Phosphorus Quantification

The model parameters obtained above were then used to quantify the phosphorus load. Fig. (**11**) below shows the phosphorus load for 1975 and 2006 scenarios.

Mineral phosphorus levels were higher for the 2006 land-use compared to 1975. This gave an average 54.5286 KgMin.P/Km^2/yr and 33.5KgMin.P/Km^2/yr respectively. It was observed that due to less consumption of phosphorus-containing fertilizers in the catchment, the ranges of mineral phosphorus for the two periods were almost close. Organic phosphorus pool is set to 0.03% of the initial amount of residue on the soil surface while Organic N is 0.15% of the initial amount of residue on the soil surface. Therefore high levels of organic P and N in the 2006 land-use can be attributed to large biomass due to agricultural activity than it appears in the 1975 land-use. From the above results it shall be observed in all cases that the nutrient loads reduce in the catchment between July and October because Simiyu River passing through sub-basin7 (which was of major interest in the above analysis) is characterized as an ephemeral river.

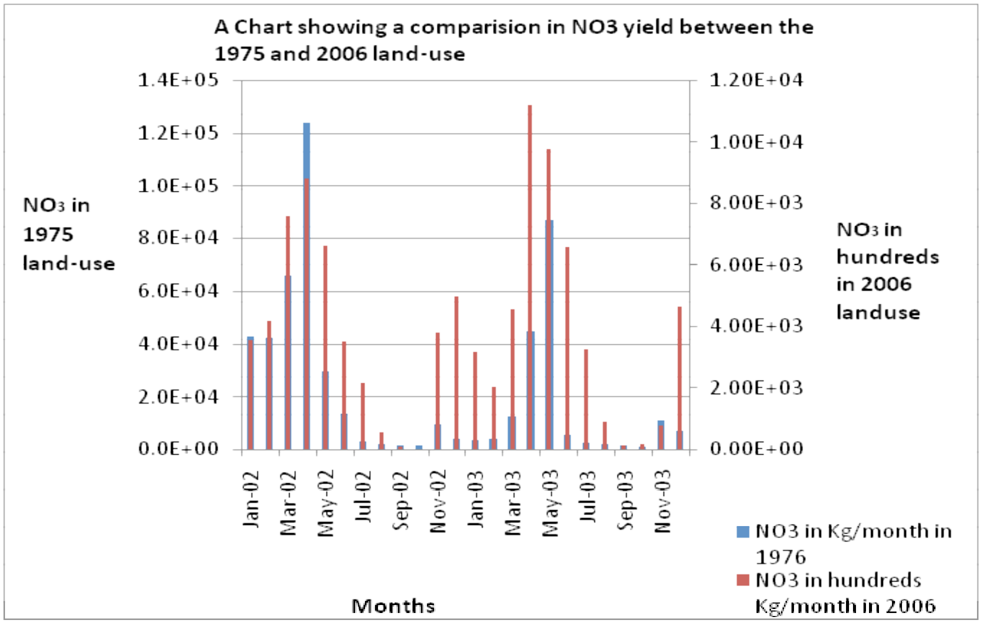

Fig. (10). Nitrogen load for 1975 and 2006 scenarios.

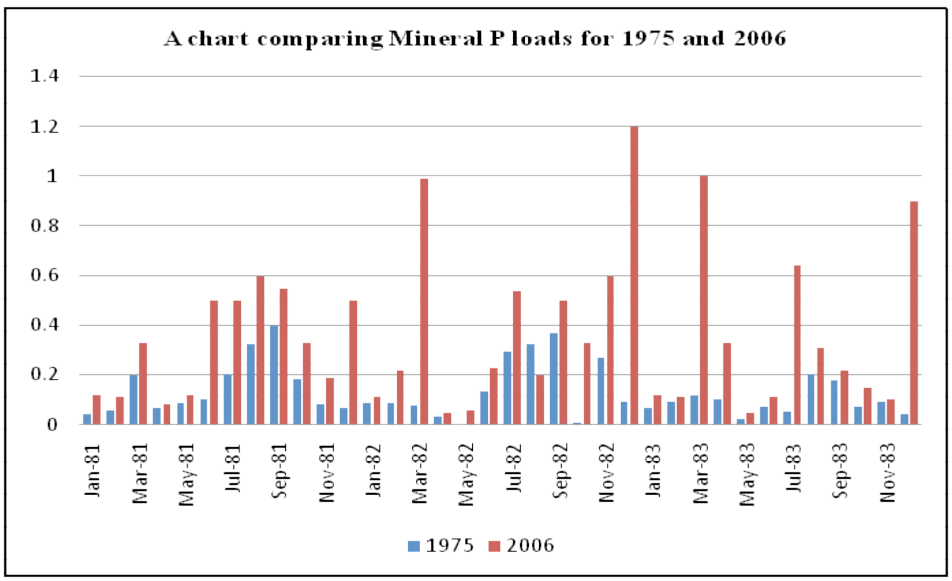

Fig. (11). Phosphorus load for 19975 and 2006 scenarios.

The Fig. (**12**) below shows the comparison between nitrogen and phosphorus loads.

The amount of nitrate nutrient in the water is higher than that of phosphorus due to the initial 8:1; N: P ratio in the soil. The correlation above gave a logical meaning, so the model was then applied for comparing the land-uses.

4. CONCLUSIONS

From the study is can be concluded that Land use classification according to the SWAT model shows that Agricultural Land-Generic (AGRL) contributes about 73.43%, Range-brush (RNGB) contributes 24.42%, Pasture (PAST), 2.10% Savanna (SAVA) 0.03% and Water (WATR) 0.02% of the total catchment area of Simiyu. It was also found out that there was an expansion of agricultural land from covering 19.33% of the catchment to 73.43% at an annual change rate of 2.9%. However, average Nitrate load was higher for 1975 than 2006. The P load of 1975 was less compared to that in 2006. Model simulation at the catchment outlet for N gave 77.2 kg/km^2.yr while observed values were 146 kg/km^2.yr, simulated P was 47 kg/km^2.yr while observed was 164 kg/km^2.yr. Hence, the model underestimated nutrient yield in the catchment. Therefore, the applicability of the SWAT modelling tool in studying NPS pollution yields poor model performance due to the scantiness of data used for model calibration. More rigorous data campaigns have to be carried out along the two rivers of Duma and Simiyu for purposes of gaining enough information for model calibration and validation. With good model performance, develop-

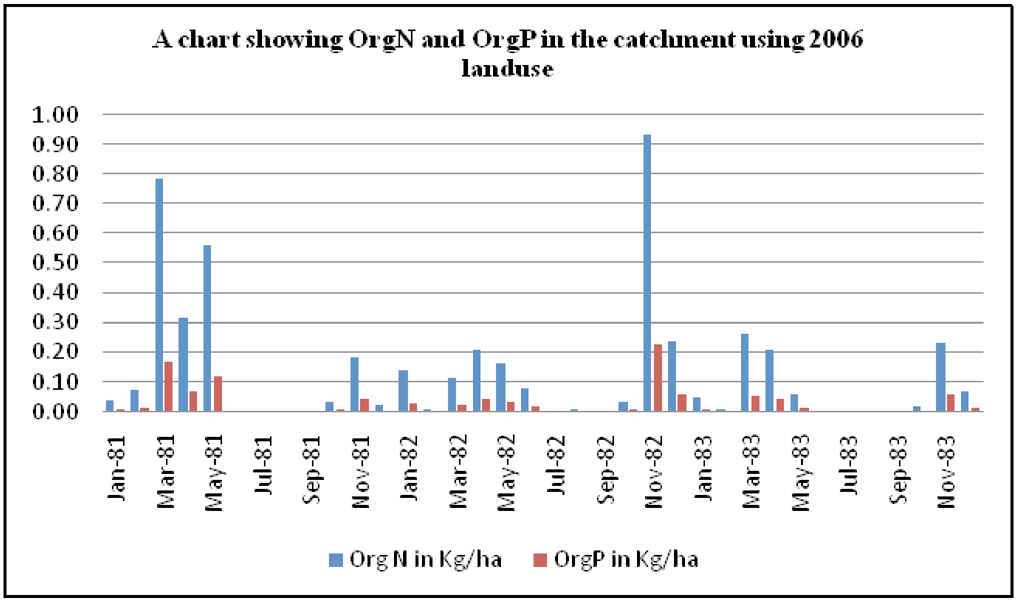

Fig. (12). orgN and orgP Loads using the 2006 land use.

ing management plans to control NPS pollution around Lake Victoria could be achieved using the SWAT model.

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NOMENCLATURE

AGRL	=	Agricultural Land-Generic
ALPHA_BF	=	Base-flow alpha factor
BIOMIX	=	Biological mixing efficiency
CH_K2	=	Channel effectiveness hydraulic conductivity
CN	=	the curve number for the decay.
CN2	=	Initial SCS Curve Number II value
Concn	=	concentration of the nutrient in a layer
ESCO	=	Soil evaporation compensation factor
IVF	=	Index of Volumetric Fit
NO3,	=	Nitrate
NPS	=	Non-Point Sources
OrgNact,ly,	=	the concentration of Organic Nitrogen
OrgNfrsh,surf	=	the nitrogen in the fresh organic pool
OrgNhum,ly	=	the concentration of humic organic nitrogen
OrgPfrsh,surf	=	the phosphorus in the fresh organic pool
OrgPhum,ly	=	the concentration of humic organic phosphorus in the layer
Pact,ly	=	amount of phosphorus in the active mineral pool (mg/kg),
PAST	=	Pasture
Psurf	=	the amount of soluble phosphorus lost in surface runoff
Qsurf	=	the accumulated runoff (mm)
RNGB	=	Range-brush
SAVA	=	Savanna
SOL_	=	AWC Available water capacity
SOL_	=	ORGN Initial Organic N concentration
SURLAG	=	Surface runoff lag time
SURLAG	=	Surface runoff lag time (days)
SWAT	=	Soil and Water Assessment Tool
TMA	=	Tanzania Meteorological Agency
USLE	=	Universal Soil Loss Equation
WATR	=	Water

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