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Modelling of sediment yield using the soil and water assessment tool (SWAT) model: A case study of the Chanchaga Watersheds, Nigeria

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ABSTRACT

Water erosion poses a threat to agricultural land and water resources and leads to land degradation with river/reservoir sedimentation. Against this backdrop, the soil and water assessment tool (SWAT) model was used to assess the effects of Ridging Across the Slope (RAcS) and Ridge Along the Slope (RAlS) on sediment yield in the Chanchaga basin. The multiple slopes were integrated into SWAT and modified soil textural class in each sub-basin. Observed sediment yield was used to calibrate and validated using SUFI2 for one year each. Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2), PBIAS, P-factor and R-factor for monthly sediment yield in RAcS were 0.77 0.7, 4.5, 0.75 and 1.24 in the calibration. The validated models were 0.56, 0.56, 4.0, 0.92, and 0.61 at the Koropa sub-basin. Similar results were found for sediment yield in RAlS during calibration, but the PBIAS was -2.8. The corresponding values are 0.56, 0.60, 22.4, 0.75 and 0.44 for validation. In the Shatta sub-basin, RAcS was confirmed by NSE and R^2 (0.61 and 0.64) during calibration. Also, the PBIAS, P and R-factors have values of 16.6, 0.75, and 2.21, respectively. The equivalent values were 0.74, 0.75, 13.0, 0.67 and 1.32 during validation. The same results got for sediment yield- RAlS. During calibration, the values of the PBIAS and R-factor were -15.3 and 3.78. The corresponding values for validation include 1.3 and 3.62. The NSE's imply that model validations were satisfactory. Runoff curve number (CN2), soil water storage capacity (SOL_ AWC), and erosion (USLE) are the most sensitive parameters for predicting sediment yield. RAlS is unsuitable as they produced values of 20.32 t/ha/yr in the Koropa and Shatta sub-basins. RAcS is effectual for lessening sediment loads, particularly on very gentle slopes. Designing sediment traps and installation will lessen sediment yield along slope ridging in rivers.

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Introduction

Water erosion harms agricultural land and water resources, resulting in water scarcity, soil infertility issues [8,10,14], and reservoir sedimentation [11,13,14,35] due improper agricultural practices. In addition, the dam capacity and its storage life are reduced by sediment load through either agricultural or management practices [11,35]. Terracing, stripping, and contour ridge are soil and water conservation techniques employed by previous studies to conserve the soil and water [11,20]. The RAcS (Ridging Across the Slope) is perpendicular to the slope. The ridge along the slope (RAlS) is parallel to the slope [17]. RAcS enhances infiltration and decreases eroded soil and water [17]. Contouring is ineffective in the Kalaya River Basin and exacerbated soil erosion, with an average sediment rate of 70 t/ha/yr [11]. Sabo Dagga River had low sediment inflow [29]. The magnitude of soil erosion was classified by Betrie et al. [9].

Tagwai dam has witnessed serious sedimentation problems in the last decades due to improper agricultural practices [31], which has caused surface runoff, eroded soil and siltation issues in the Chanchaga basin [31]. Thus, reducing the volume of water intake for domestic and irrigation purposes of the immediate environment, especially downstream (Koropa).

In the Northern part of Nigeria, some farmers who dwell in the Chanchaga basin were making ridges along the slope (RAlS) and neglect ridge across the slope (RAcS) because it is less expensive and requires little fuel/energy either through soil machine interaction or human. However, RAlS degrades farmland [17]. In addition, both practices cause soil erosion and siltation problems in Dam and riverbank [17]. Specifically, they often contaminate water sources with water-related diseases and give birth to water shortage and inadequate power generation in the dry season [15]. Few studies simulated sediment yield in Tagwai, Shiroro and Jeba dams [3,15,31]. These studies never bothered about simulating the sediment source. Kuti and Ewemoje [17] documented the effect of contour line ridge on sediment yield and found out that planting cowpea could reduce the impact of RAlS on sediment yield at the catchment scale. Tesema and Leta [35] estimated the effect of management practice on sediment yield using the SWAT model at a regional scale [35]. Another study calculated the consequence of terracing, stripping and contouring on sediment loads using the SWAT model at a regional scale [11]. Some studies were silent on reporting HRU analysis, while few works used the same percent (8%) for landcover and soil with zero percent slope to define HRU [16]. In addition, none of the studies has categorised agricultural and river slopes and incorporates them into SWAT to define the HRU. Based on the information available, no study has estimated the effect of RAcS and RAlS on sediment yield using hydrological models (the SWAT model). In addition, there is no sediment data from agricultural land in Africa to build sediment traps for rivers and streams.

The soil and water assessment tool (SWAT) model was used to estimate forecast sediment yield since it is a regionally distributed model that mimics how agricultural and management practices affect sediment yields [10,11,35]. It also could be linked with sequential Uncertainty Fitting (SUFI2) to calibrate, validate, and estimate the sediment yield uncertainty [1,2,25]. Many SWAT applications simulate streamflow and sediment yields [1,11,16,21,23]. Land slope classes were integrated into SWAT HRU, altered the soil textural classes in each sub-basin.

Sediment yield estimation for RAcS and RalS using the SWAT model will reveal the practice that requires modification. Other novelties of this study include sediment source reduction and provide portable water with fewer impurities for domestic and irrigation purposes (Tagwai Dam). The hydropower generation will have water surplus in the dry season by preventing or minimizing sediment loadings into the Zungeru Dam if the recommendations are to use. In addition, the sediment data gotten will be used to construct sediment traps for working dams in the research areas. The main objective of this study is to estimate the effects of RAcS and RAlS on sediment yield using the SWAT model for the Chanchaga basins and recommend the best practice that reduces sediment loads.

Materials and methods

Description of the study

The Niger Basin is situated in West Africa and spans ten countries, covering 7.5 percent of the continent [7]. It can be found in Mali, Niger, and Nigeria. The volume of water entering Mali from Guinea (40 km^3) is greater than the volume entering Nigeria from Niger (36 km^3) [19]. Nigeria has eight hydrological areas (HA) due to topography. Niger central hydrological area is one of them and has 154,600 km^2 in size and receives 1170 mm of rain each year [18]. The land use of the Koropa and Shatta sub-basins in Nigeria's Niger Central Hydrological Area is depicted in Fig. 1.

Hydrology of the study

The river Chanchaga is situated between the latitudes of N 09° 34′00″ and N 09° 42′00″. It also had a longitude between E 06° 29′00″ and 06° 35′ 00″ E. It is a stream with a height of 74 metres above sea level (Fig. 1b).

Soil and vegetation

Koropa and Shatta have sandy loam and loamy sand. Soils have a certain amount of fertility and sandstones are underlined in the soil. The soil drains well. The water reaches the soils at a rapid pace. Thick forests, short and tall grasslands characterise Minna's vegetation.

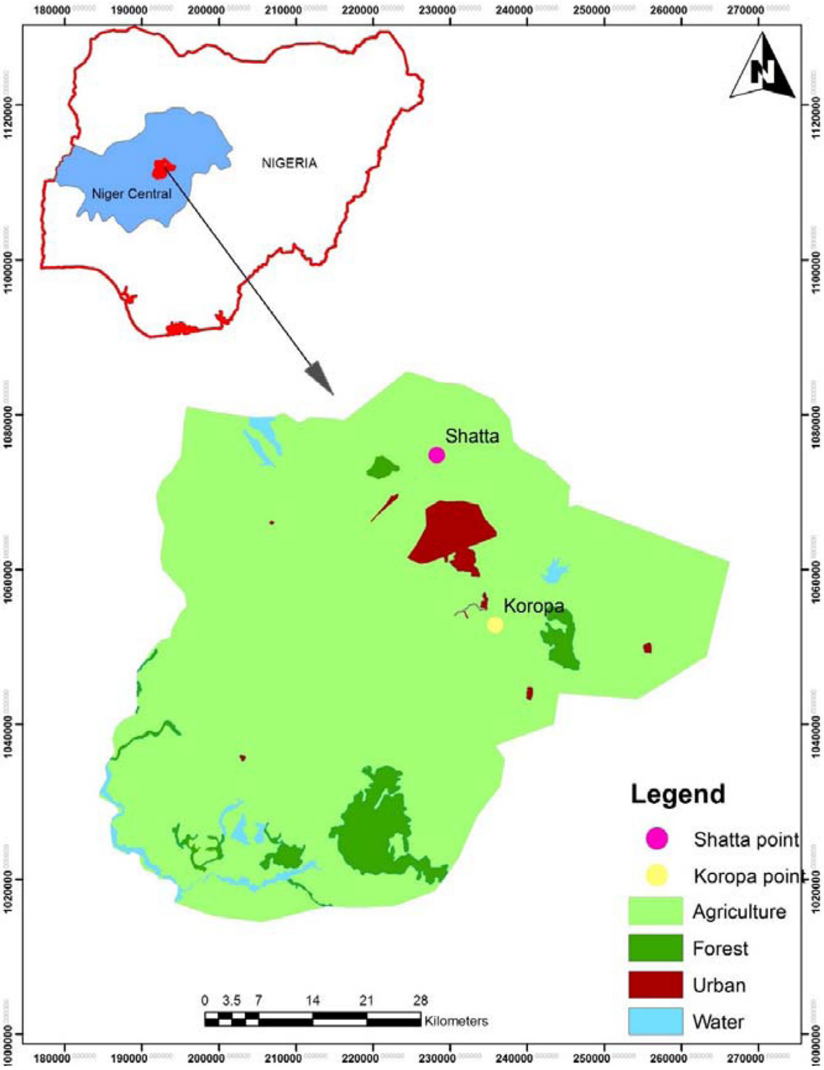

Fig. 1a. Land use of Koropa and Shatta sub-basins.

Climate and agriculture

The rainy season begins in April and ends in October, while the dry season begins in October and ends in March. The annual mean temperature and rainfall were 27.5 °C and 1229 mm, respectively. Groundnut, Cowpea (bean), and Soybean are the most commonly planted crops in these regions.

SWAT theoretical approach for simulations of sediment yield

SWAT is a spatially distributed model that simulates sediment yield and streamflow [23]. SWAT also divides a basin into sub-basins, with each sub-watershed being divided into an HRU based on surface, land use, and slope. According to Khoi et al. [22], the SWAT model uses the water balance equation to simulate sediment yield through the hydrological cycle.

SWAT input model

SWAT is an ArcGIS add-on (10.5). Digital elevation model, soil, land use/land cover are the required maps for the models. Daily rainfall and temperature are the climatic data needed. others were relative humidity, wind speed, and solar radiation.

Collection of data

Raster data

A 90 m digital elevation model was downloaded from the Shuttle Radar Topography Mission (SRTM) (link: http://srtm.csi.cgiar.org). The Land-use map produced by the United States Geological Survey was extracted for this study.

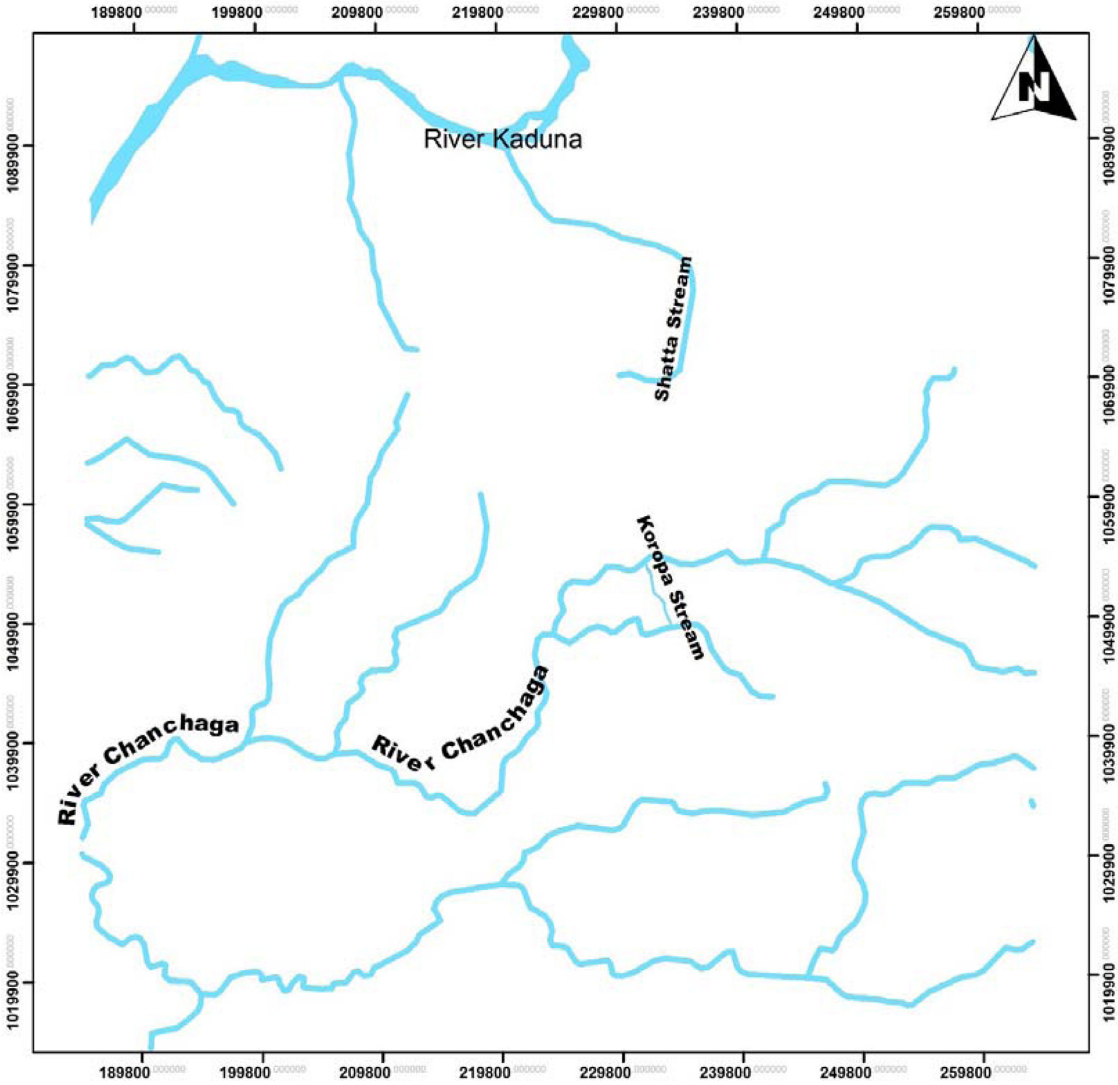

Fig. 1b. River channel of Chanchaga.

(https://www.usgs.gov). Besides, soil data were removed from the harmonized digital soil map of the world that was developed by the Food and Agriculture Organization (FAO) (link: http://www.fao.org).

Climatic data

Rainfall, temperature and evaporation were obtained from the Upper Niger River Basin Authority. Others are wind speed, relative humidity and solar radiation and releases by the Nigeria Hydrological Services Agency, and Solcast API. The data covers a period of seven (7) years (2013–2019).

Sediment data

The earlier study [17] measured monthly sediment yields downstream of Tagwai dam in the Koropa area (River Chanchaga) and Shatta stream, which flow to the Zungeru river (ongoing Zungeru dam), respectively. The records were kept from 2018 to 2019.

Slope categorization

The complete land slopes of Koropa and Shatta were categorised and determined using a levelling device, tripod stand, and pegs. The steepness of the slopes varied from 2% to 5% (very gentle slope). The formula for the slope is as follows:

$$slope = \frac{hd}{d} \times 100 \tag{1}$$

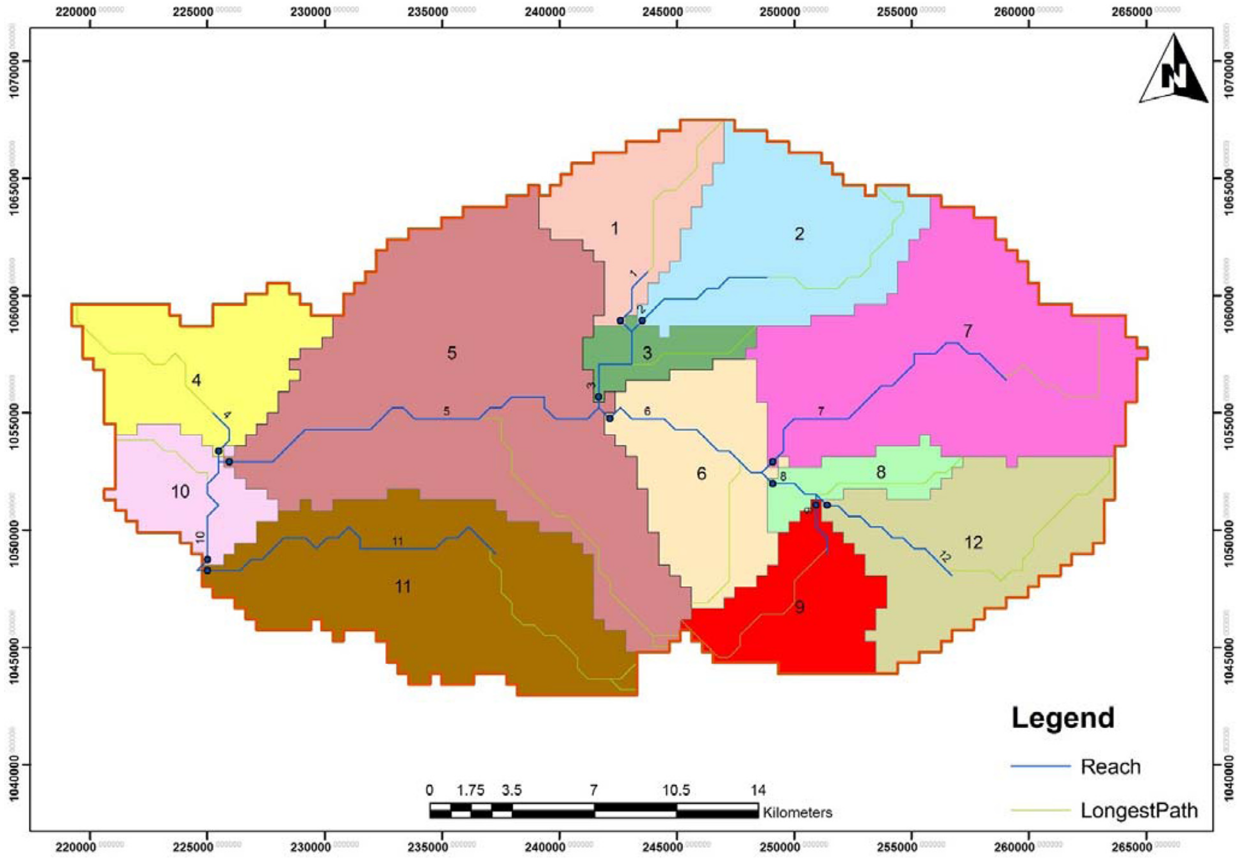

Fig. 2. Delineation of Koropa sub-basins of the Chanchaga basin.

Where,

$Hd = height\ difference\ along\ the\ slope\ length\ (m)$

$d = slope\ length\ distance\ (m)$

Model setup and configuration

Abbaspour et al. [1] detailed how to build up the model. Watershed delineation was done by clipping digital elevation models (raster format) to the boundary of each location in the ArcGIS interface to calculate each subbasin [11]. Figs. 2 and 3 show the delineation of the Koropa and Shatta sub-basins. Slope categorisation was carried out in Koropa and Shatta and was ranged from 2% to 5% within the agricultural land near the river/stream. The incorporation of 2%, 3%, 5% slopes into SWAT defines the land slopes of the Koropa and Shatta, which is different from existing studies in Niger State. Multiple slope classes change the soil textural classes under each subbasin to represent their agricultural activities and provided a far more accurate physical description of the water balance. Both soil and slope layers are reclassifying and overlayed land use, soil, and slope layers. The write command is enabled now for creating the SWAT table, simulation menu displays to set the timeframe and run the SWAT simulation.

Calibration, validation and sensitivity analysis

Sensivity analysis

Sensitivity analysis is a technique that determines the influence of 17 chosen parameters (Table 1) on predicting sediment yield [2,22]. Sequential Uncertainty Fitting algorithms (SUFI2) was employed for this study and is an optimization algorithm that calibrates and validates the model using a Bayesian system [22].

Calibration and validation analysis

Calibration compares simulation results with observed sediment data for a specific time (Jan 2018 - December 2018). The objective function compares predicted and observed values to determine whether they are satisfactory or not for validation (Jan 2019 - December 2019). In an iterative method, this software analyses and takes calculated data within the 95 percent

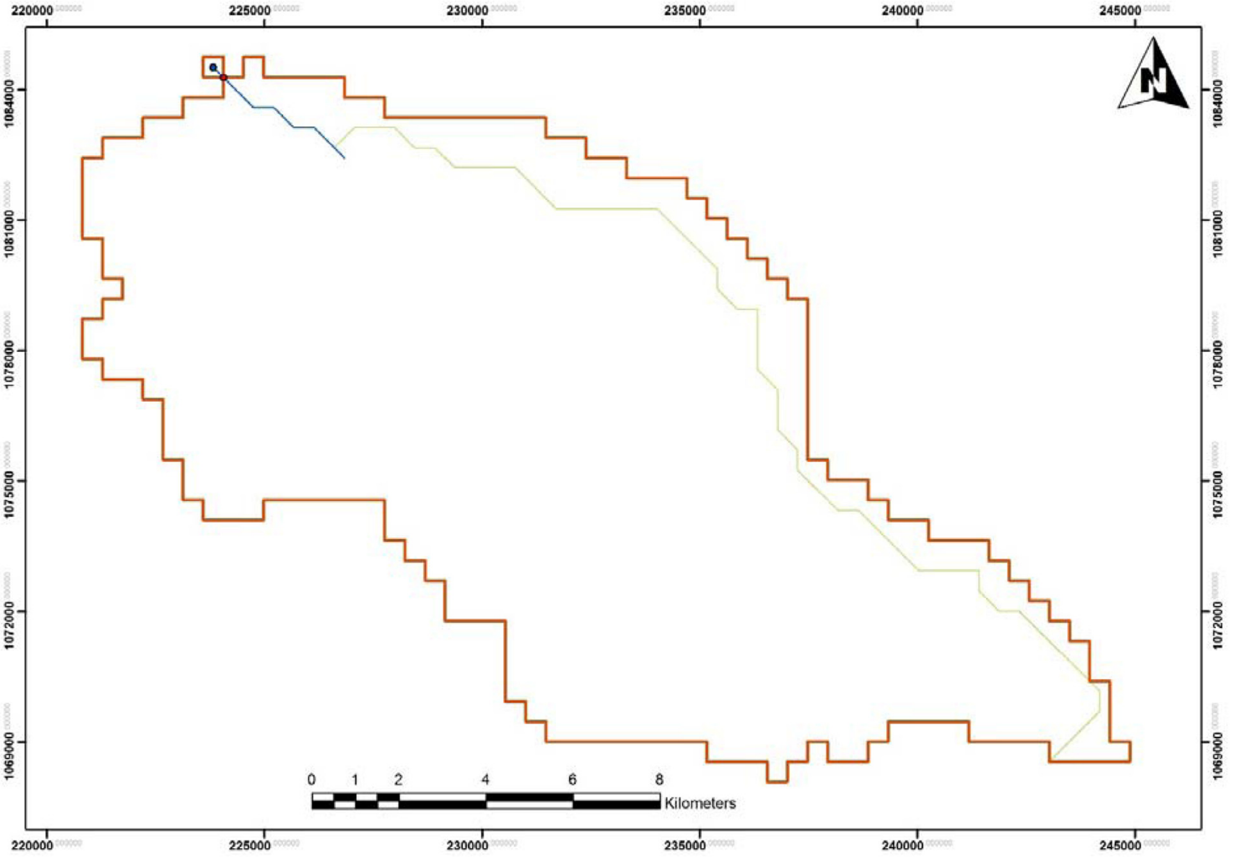

Fig. 3. Delineation of Shatta sub-basin of the Chanchaga basin.

Table 1
Chosen input parameter of the SWAT model.

S/N	Input Parameters	Definition of Parameter	Minimum	Maximum
1	r__CN2.mgt	SCS runoff curve number for moisture condition	−0.2	0.2
2	v__ALPHA_BF.gw	Baseflow alpha factor for groundwater	0	1
3	a__ESCO.hru	Soil evaporation compensation factor	0	1
4	a__EPCO.hru	The factor of compensation for water consumption by plants	0.01	1
5	a__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur	0	2
6	a__GW_REVAP.gw	Groundwater “revamp” coefficient	0.02	0.2
7	v__CH_N2.rte	Manning’s n value for the main channel	0	0.3
8	a__GW_DELAY.gw	Groundwater delay time	30	450
9	r__SOL_AWC().sol	Soil water storage capacity	0	1
10	v__CH_K2.rte	Effective hydraulic conductivity in the main channel	0.01	500
11	v__ALPHA_BNK.rte	Baseflow alpha factor for bank storage	0	1
12	r__SOL_K().sol	Soil conductivity	0	2000
13	v__CH_COV1.rte	Channel cover factor	0	1
14	v__CH_ERODMO.rte	Channel erodibility factor	0	0.6
15	v__SPCON.bsn	Parameters used to calibrate sediment yield SPCON Linear parameters for calculating the channel sediment rooting	0.0001	0.01
16	v__SPEXP.bsn	Exponent parameter for calculating the channel sediment routing	1	1.5
17	r__USLE_K().sol	USLE equation soil erodibility (K) factor	0	0.65

Where r = ratio (this means the existing parameter is multiplied by (1 + given value)); v = value (this means the given value will replace the existing parameter value); a = addition (this means the value is added to the existing parameter values).

prediction uncertainty (95PPU) for the model [1]. The research followed the steps outlined by Khoi et al. [22]. The P-factor, which ranges from 0 to 1, is the percentage of calculated data plus error brackets in the 95PPU band. In addition, the R-factor is the ratio of average width (95PU band) to standard deviation of the variables being measured. For the P-factor, a value of $>$ 0.7 or 0.75 was appropriate due to the flow discharge. The R-factor estimates the power of models. It should be less than 1.5 [1,12]. The percent bias (PBIAS) calculates the average tendency of the simulated data compared to the observed sediment yield, with zero being the best value. PBIAS with a low value means better simulations. High positive values above 25% also indicate a model of overestimation [10,12]. Negative values mean that the model is underestimated [10,12].

Model performance evaluation

The Nash-Sutcliffe efficiency (NSE) was the model's objective function. The power of the models is determined by the coefficient of determination (R^2) and percent bias (PBIAS) [12,37]. Using Eqs. (2)-4, the output of the models is evaluated as follows [37].

$$\text{Nash} - \text{Sutcliffe (NSE)} = 1 - \frac{\sum_{=i}^{n}\left(\mathrm{O_i} - \mathrm{P_i}\right)^2}{\sum_{=i}^{n}\left(\mathrm{O_i} - \mathrm{O_{avr}}\right)^2} \tag{2}$$

$$\text{Coefficient of determination } (\mathrm{R}^2) = \left[\frac{\sum_{=i}^{n}\left(O_i - O_{avr}\right)\left(P_i - P_{avr}\right)}{\sum_{=i}^{n}\left(O_i - O_{avr}\right)^2 \sum_{=i}^{n}\left(P_i - P_{avr}\right)^2}\right]^2 \tag{3}$$

$$\text{Percent bias (PBIAS)} = \left[\frac{\sum_{=i}^{n}\left(O_i - P_i\right) \times \ 100}{\sum_{=i}^{n}\left(O_i\right)}\right] \tag{4}$$

Where,

$\mathrm{O_i} = i^{th} observed\ value,$
$\mathrm{O_{avr}} = average\ observed\ value\ of\ the\ entire\ study\ period,$
$\mathrm{P_i} = i^{th} simulated\ value,$
$\mathrm{P_{avr}}$ = average of simulated value.

Results and discussions

Watershed and hydrological response unit of the sub-basins

Koropa and Shatta

The Koropa sub-basin was 758.98 km^2 in size (Fig. 3). It was divided into 12 sub-basins with a total of 63 hydrological response units (Fig. 2). Fig. 2 indicates that agricultural land (95.31%) is the most extensive land use, followed by water (3.14%), forest (0.90%), and residential land (0.90%). (0.65 percent). The most common soils are lithosols and plinthic luvisols.

Shatta's sub-catchment area is approximately 207.78 km^2. There was one (1) sub-basin with six hydrological response units at this site (Fig. 3). In the sub-basin, agricultural land was the only land use. The soil is covered by ferric and plinthic luvisols.

Sensitivity analysis

Koropa and Shatta sub-basins

Runoff curve number (CN2), soil water storage potential (Sol AWC), and erosion (USLE K) have t-stat values of 43.40, 6.55, and 4.47, respectively, in the validation periods. The p-values for these models are 0.0000 in the Koropa sub-basins. Other parameters in the ridging across slope had higher values than 0.05, as shown in Table SM1. The t-stat for curve number in ridging along slope was 8.38, with p-values of 0.0000, followed by soil water storage capacity (5.99) and erosion (3.14). At the Koropa sub-basins, the other input parameters had p-values greater than 0.05 (Table SM2).

At the Shatta sub-basin, the available soil water storage capacity (SOL AWC) and erosion (USLE K) had t-stat values of −22.14 and −4.94, respectively, and p-values of less than 0.0000. In the ridging across the slope, the p-values for the remaining parameters were higher by 0.05. (Table SM3). In the along slope ridges (Shatta sub-basin), −9.92 and −7.33 are the t-stat of soil water storage capacity (SOL AWC) and erosion (USLE K), and p-values of 0.0000, as shown in Table SM4.

Calibration, validation and uncertainty analysis

Koropa and Shatta sub-basins

The sediment yield - across slope ridge possessed NSE and R^2 values of 0.77 and 0.77. Other parameters include P-factor, R-factor and PBIAS with values of 0.75, 1.24 and 4.5 for calibration (Figures SM1). Similar results were discovered for sediment yield- along slope ridge (Figure SM3). The simulated monthly sediment yields represent the observed data with NSE and R^2 values of 0.56 and 0.56. Other parameters included P-factor, R-factor and PBIAS with values of 0.92, 0.61 and 4.0 during validation (Figures SM2). The same trend was observed for sediment yield- along slope ridge, as shown in Figures SM4. Finally, the model's sediment load output is satisfactory, with NSE, R-factor, R^2 and PBIAS values of 0.56, 0.61, 0.56 and 4.0.

The sediment yield - across slope ridge had NSE, R^2, P-factor, R- factor, PBIAS values of 0.61, 0.64, 0.75, 2.21 and 16.6 (Figures SM5). Similar results were discovered for sediment yield -across slope ridges, as shown in Figures SM7.

In the validation, an NSE, R^2, P-factor, R-factor and PBIAS values with values of 0.74, 0.75, 0.67, 1.32 and 13.0 were simulated for monthly sediment yield - across slope ridges (Figures SM6). A similar result was found for sediment yield -along slope ridges, as shown in Figures SM8. During validation, the simulated sediment yields are okay, with NSE, R-factor, R^2 and PBIAS values of 0.74, 1.32, 0.75 and 13.0.

Sediment yield prediction

Calibration

In the Koropa sub-basins, monthly sediment yield -across and along slope ridge with mean values of 5.24 and 14.86 tons/ha (Figures SM1 and SM3). Highest monthly simulated sediment yield with a value of 57.51 tons/ha. 6.09 and 19.41 tons/ha are the averages predicted sediments- across and along slope ridges in the Shatta sub-basin (Figures SM5 and SM7). The highest monthly predicted sediment yield obtained in the Shatta sub-basin, with a value of 63.10 tons/ha.

Validation

The average monthly predicted sediment yields -across and along slope ridges with values of 14.94 and 28.24 tons/ha (Figures SM2 and SM4). Koropa sub-basin (5) had the highest monthly sediment yield with 89.56 tons/ha. Monthly sediment yields - across and along slope ridges averaged 10.17 and 18.77 tons/ha (Figures SM6 and SM8). The Shatta sub-basin (1) had the highest sediment, with a value of 61.07 t/ha.

Discussion of results

Sensitivity analysis

The sensitivity of CN2, SOL AWC, and USLE K was discovered (Table SM1). The results are in line with previous studies [4,12,15]. Sediment yield was higher when the t-stat value was higher [26]. Other parameters were insensitive to simulated sediment yield (Table SM1).

The insensitivity of CH EROD and CH COV has been discovered. This study's results are in line with previous studies [30]. The same results as in Tables SM2, SM3 and SM4 were obtained. The remaining parameters had no impact on the sediment yield (Table SM2, SM3 and SM4).

SOL AWC, CN2, and USLE K were the most sensitive variables for estimating forecasted sediment yield. The outcomes were in tandem with previous studies [4,12,15]. The undue sediments were changed by the models (USLE K, CN2, and SOL AWC). With NSE >0.5 and PBIAS ± 25%, the models are adequate [1,2,11,25] in the Koropa and Shatta sub-basins.

Calibration, validation and uncertainty analysis

The SWAT model performance is measured with three methods: calibration, validation and uncertainty analysis [10,32,35]. The monthly sediment yields - across and along slope ridges with NSE values of 0.77 and 0.81 (Figures SM1 and SM3). Similar results were obtained in the Shatta sub-basin (Figures SM5 and SM7). The monthly predicted sediment yield matches the observed data as PBIAS values equal 4.5 and −2.8 at the Koropa sub-basins. In the Shatta sub-basin, a similar pattern was observed. 16.6 and −15.3 are the values of PBIAS during calibration (Figures SM5 and SM7). The findings corroborate the previous research [1,5,12].

The percent Bias (PBIAS) for monthly sediment yield shows a better model, though it overestimates sediment yield-across and along slope ridges at the Koropa. The same results were noticed in the Shatta sub-basin. The findings back up previous research [1,15], which was different from earlier studies who worked on dam sediment yield and flow discharge predictions. Farmers used along slope ridges to raise crops and engaged in sand mining immediately after each rainfall. These activities explained sediment yield mismatch in sub-basin 5 and 1. The simulated sediment yield- across slope ridges was better than that of the along slope ridges, but there is little or no study available in the literature.

The Percent Bias is a function of data loss in the model, which is satisfactory since the NSE >0.5 and the PBIAS values are less than 25% [1,2,11,25]. The existing studies were comparatively different from sediment yield in RAcS and RAlS.

A good agreement existed between simulated and observed sediment yield -across and along slope ridges. They also have NSE values of 0.56 and 0.56 during validation. 4.0 and 22.4 are the values of PBIAS in the Koropa sub-basins (Figures SM2 and SM4). In the Shatta sub-basin, the same was obtained (Figures SM6 and SM8). The results are consistent with previous studies [1,5,12,15]. Although, the sediment yield in RAcS and RAlS was relatively different from previous research.

Both P and R factors had a good fit during validation at Koropa sub-basins for simulated and observed sediment yield-across and along slope ridges [1]. The Shatta sub-basin also yielded the same results. Farmers engaged in sand mining after each rainfall event and caused sediment yield uncertainty (Figures SM5, SM7, and SM8). The ridge along the slope is another factor that affects the model and was different from the existing studies. There are no works available in the literature to compare with.

Sediment yield predictions

The SWAT models simulate sediments yield -across and along slope ridges. Annual sediment loads are calculated in the Chanchaga basin using this model. Figures SM1–SM8 demonstrate sediment yield- across and along slope ridges in each sub-basin.

Across the slope ridging

Ridge across the slope has minimised soil degradation, nitrogen depletion, sediment levels, and other contaminants in rivers and streams [11,13]. In the Koropa and Shatta sub-basins, Figures SM1, SM2, SM5, and SM6 display the sediment yield across the slope ridging. The values of PBIAS were 4.5 and 4.0 for sediment yield -across slope ridge during and validation. The SWAT model also showed a better simulation with R-factors of 1.24 and 0.61 (Figure SM1 and SM2). During calibration and validation, PBIAS values of 16.6 and 13.0 for sediment load -across slope ridges (Figure SM5 and SM6) were obtained. With R-factors of 2.21 and 1.32, the SWAT model, on the other hand, predicted sediment yields were okay by 16.6 and 13.0% (PBIAS). As a result, the monthly sediment yield mismatch may be caused by factors, but it is most likely due to loamy sand and sand mining activities in the Shatta sub-basin. Average monthly simulated sediments vary between 5.24 and 14.94 tons/ha. Koropa and Shatta sub-basins have the highest monthly predicted sediment yield with values of 49.64 and 45.47 tons/ha. Water erosion is a problem in sub-basins 5 and 1. The average eroded sediment- RAcS was 9.12 t/ha/yr. The findings were not in tandem with previous studies [11]. Although, the sediment yield in RAcS and RAlS was relatively different from previous research. As a result, ridging across the slope is one of the best conservation methods that reduce erosion and sediment yield in the Chanchaga basin, and it backs up previous studies [27], but the existing study differs from this study in term of factors.

Along the slope ridging

The eroded sediments are removed quickly by RAlS (Ewemoje and Kuti, 2021). In the Koropa and Shatta sub-basins, the average monthly simulated sediment yields ranged from 14.86 to 28.24 tons/ha. During and validation, the PBIAS values for sediment yield -along slope ridge were −2.8 and 22.4. In the Koropa sub-basins, the SWAT models were satisfactory, with R-factors of 0.83 and 0.44. (Figure SM3 and SM4). It also shows model underestimation (2.8%) and the model was satisfactory (22.4 percent). PBIAS values of −15.3 and 1.3 for sediment load- along slope ridge (Figure SM7 and SM8) were obtained during calibration and validation. The SWAT model, on the other hand, underestimated sediment yield by 15.35 percent with R-factors of 3.78 and 3.62. As a result, the monthly sediment yield mismatch may be due to causes, but it's most likely due to loamy sand and sand mining in the Shatta sub-basin. At the Koropa and Shatta sub-basins (Figures SM3, SM4, SM7, and SM8), 89.56 and 61.07 tons/ha are the maximum monthly sediment yield and was affected by water erosion. The 5 and 1 sub-basins are the ones most affected by water erosion. Plate SM1 showed that sediment accumulation on the riverbank was very high. The findings disagree with existing studies [29]. This was supported by the average annual sediment yields -along slope ridge, which was 20.32 t/ha/yr. Along-slope ridging exacerbates sediment yield, implying that the percentage increase of sediment loads - ridge along the slope equals 55%. The findings back up previous research [11,36], but the sediment yield in RAlS was relatively different from existing studies.

The consequences of ridge along slope include soil infertility and dam/river silting, comparing these results to existing studies, there is no work available on effect of RAlS on sediment yield. Due to this activity, the sediment loads traverse from river chanchaga to Jebba dam might be high as predicted by Adeogun et al. [3]. Because river chanchaga traverse a lot of rivers before reaching Jebba dam and these study neglects sediment source: the effect of agricultural practices on sediment load.

Assessing the impact of sediment deposition along riverbanks

Ridging along the slope greatly decreased the amount of water available for plant growth, resulting in food shortages. The findings corroborate previous study [34,38], but the earlier work did not identify whether RAcS or RAlS cause erosion and sediment yield. This menace cause river siltation [33]. soil erosion is low in both sub-basins [9]. Ridging along the slope reduces the number of nutrients available for plant growth, which was in tandem with previous studies [24,28], but with different factors for determining sediment load.

Implications of sediment yield modelling on water resources planning and management

Since the ridge runs parallel to the slope, the dam's lifetime and water supply for animals and humans are both limited [15,31]. Sediment yield can increase the cost of water treatment, causing water odour and taste. In both surface and sub-surface irrigation systems, it can cause primary clog in the lateral pipes. Eroded sediment degrades natural ecosystems, and subjected river/stream to the risk of flooding. Sediment load alters river depth and make navigation and recreational activities more difficult [6].

Limitations of the study

This research provides a deeper understanding of how the soil and water assessment tool (SWAT) model was used to assess the effects of ridging across and along the slope on sediment yield in the Chanchaga basin. In the future, more methods like EPIC, APEX, ANN etc., will be combined with the SWAT model to make sediment yield- along slope ridges more applicable to more places. Owing to a lack of data, the model ran for two years.

Conclusion

The SWAT model was used to assess the impact of contour line ridge on sediment yield. The observed data and the monthly simulated sediment yield were consistent. The use and adaptation of across-the-slope ridging reduce the basin's sediment yield. On the other side, along- slope ridging is increasing sediment yield. Hydrologists and water engineers use the best management practices (BMPs) to minimise erosion and sediment accumulation in sub-basin outlets. Sediment data will be used in future studies to build sediment traps for the Koropa and Shatta sub-basins. As a result, in the study field, ridging across the slope is recommended as the best management practice. There is a need to improve the SWAT model in the future to capture the uncertainty associated with sediment yield -along slope ridges.

Declaration of Competing Interest

The authors affirm that they have no conflict of interest.

CRediT authorship contribution statement

I.A. Kuti: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Software, Validation, Visualization, Investigation, Writing – review & editing. **T.A. Ewemoje:** Conceptualization, Supervision, Visualization.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sciaf.2021.e00936.

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