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ASSESSING THE EFFECT OF LAND USE AND LAND COVER CHANGES ON WATER BALANCE IN THE OURIYORI BASIN (BENIN, WEST AFRICA)

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ABSTRACT

This study assessed the hydrological impacts of LULC changes on water resources in the Ouriyori basin, Benin. Two LULC data (1988 and 2016) and Soil and Water Assessment Tool (SWAT) model was used for the hydrological modelling. Sequential uncertainty fitting (SUFI-2) algorithm in SWAT-CUP has been applied for the model calibration and uncertainty analysis. Also, daily climate data and streamflow including digital elevation model, soil characteristics were considered in the model. Climate data for the entire simulation period and the soil datasets being kept constant, the model was run using the land use maps separately. LULC analysis showed that cropland and settlement areas have increased, while savanna areas have decreased from 1988 to 2016. Calibration (2014-2015) and validation (2016-2017) of the simulated streamflow at the basin outlet were achieved with good performance statistics ranging from 0.67 to 0.89 for the R^2, NSE, KGE and PBIAS ranged between 8% to 18%. Results also indicated a decrease in LULC corresponding to an increase in surface runoff followed by a decrease in evapotranspiration (ET). Thus, identifying appropriate strategies in terms of soil and water conservation techniques and effort in improving land management practices are recommended.

Keywords: Land Use and Land Cover, hydrological modelling, SWAT, Benin.

1. INTRODUCTION

Land cover is the biophysical state of the earth surface, whereas land use is considered to be the utilization, inputs made by humans and management of the earth surface by the modification of land cover due to social, political and economic activities (Schulze, 2000). Thus, land use and land cover (LULC) management are definitely linked to the availability and sustainability of water resources. Therefore, any change in LULC may subsequently influence the water quantity through relevant hydrological process, the land topography and soil distribution in the system (Hu *et al.*, 2005).

In West Africa, since the 1990s, there has been extensive land use changes (Aduah *et al.*, 2017). Human activities are known as one of the major driving forces of land cover modifications and hydrologic processes. Also, the rapid population growth has led to the expansion of croplands due to the need to grow more food and thereby meet the rising food demand of the burgeoning population (Forkuor, 2014, Braimoh and Vlek, 2005; Ouedraogo *et al.*, 2010; Bossa, 2012). Between 1990 and 2010, deforestation has resulted in the removal of about 60,000 ha of forest in Benin, representing 20.8 % of its forest cover (FAO, 2010). In order to assess the balance among water demand, its quantity and quality, several studies have investigated both surface water and groundwater in many basins of West Africa. In Benin, Bossa (2012) used SWAT model to investigate the impacts of climate and land use changes on water-sediment-nutrient fluxes in Oueme basin. Results showed surface runoff, groundwater flow, sediment and organic nitrogen loads were the most dominant parameters affected by change in land use (-8% to +2%). In addition, Hiepe (2008) assessed soil erosion in upper Oueme basin (Benin) considering LULC and climate change using SWAT model. The study showed a strong increase in soil erosion rate due to rapid change in LULC. In Volta basin (Ghana), Awotwi *et al.* (2014) investigated the hydrological impacts of LULC changes on water balance using SWAT model and two LULC data and scenarios. They concluded that there is a considerable relationship between change in LULC and the hydrological response of the basin. Indeed, a decrease in LULC has led to a decrease in surface water and baseflow and an increase evapotranspiration. Moreover, Yira (2016) investigated the impacts of climate and land use changes on water resources in the Dano catchment in Burkina Faso (near the Ouriyori basin). This study showed an increase in total streamflow of about 17% and a decrease of actual evapotranspiration of about 5% compared to the status in 1990. In Pendjari basin, the nearest basin to the Ouriyori basin, Ahouansou *et al.* (2015) assessed the water availability basin using J2000 model. Results showed that runoff accounts for 12.53% of annual rainfall and groundwater represents about 9.92% and 21% for the basin water yield. Throughout all these studies, land use change has shown important interests in providing useful information for future land use changes impacts on soil hydrology.

The Ouriyori basin is drained by Houangou, a tributary of Pendjari's river. The basin provides water for small-scale farms, household and pastoralists, and therefore remain crucial for the survival of the communities. A recent population census showed an increase rate of about 2.54% (INSAE, 2015) along with a decrease in forest, shift in major land uses and poor water management (Ahouansou, 2015; Chabi, 2016). However, studies showing the impacts of these recent changes in LULC and population growth on hydrological system are limited, and thus need to be undertaken for improving water management and land use planning in the area. Therefore, the aim of the present study is to assess the impact of LULC changes on hydrology of Ouriyori basin. The results of this research may provide important information for soil and water managers and planners in their efforts. Also, the results may show the capacity of the semi-distributed hydrological model in simulating water balance in a data-scarce African basin affected by climate change.

2. MATERIALS AND METHODS

2.1 Study area

The Ouriyori basin is a small-scale basin located in the semi-arid zone of West Africa (Fig. 1), lies in the North-West of Benin, between latitudes 10°44'12'' N and 10°55'48'' N and longitudes 1°01’30’’W and 1°14’30’’W. The basin covers an area of 14.51 km^2 and is characterized by a hill slope drained by a tributary of the Pendjari river. The average slope of the basin was 4%. The average yearly rainfall was about 1178 mm with the rainy season from May to October and the dry season from November to April. A long-term temperature showed a daily range of temperature between 15ºC to 25ºC (minimum temperature) and 26ºC to 39ºC (maximum temperature) (Chabi 2016). The basin was mainly dominated by croplands and fallow lands and characterized by the tropical ferruginous and hydromorphic soils. The texture of the soil was mostly sandy loam characterized by a lot of gravel.

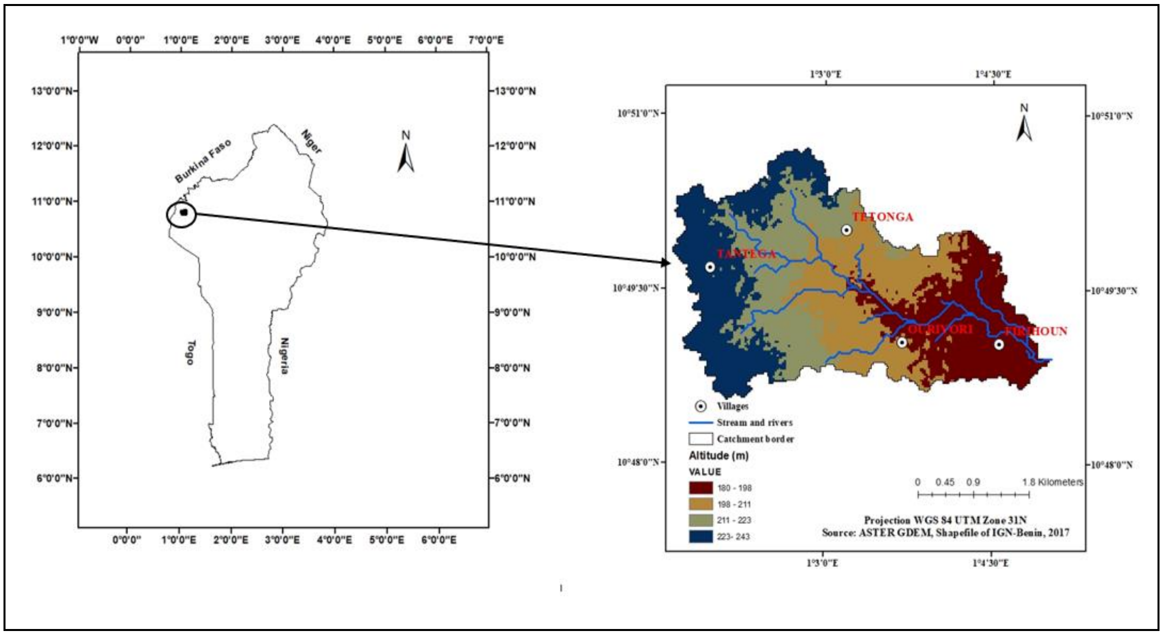


Figure 1: Location of the Ouriyori basin

2.2 SWAT model description

The SWAT model is a physically based semi-distributed and continuous time model that simulates on a daily times series and evaluates the land management practices effect on water, sediments and agricultural chemical in basins (Arnold *et al.* 1998). It is a model developed by Agricultural (USDA-ARS) to help soil and water resource managers in assessing water supplies in basins and large river basins. The model can simulate flows, sediment and nutrient in basin system over a long time period of time. SWAT divides a basin into sub-basins and further into lumped units called hydrological response units (HRUs) based on land use, soil map and digital elevation model (DEM) (Neitsch *et al.* 2011).As a percentage of the sub-basin area, each HRU (combinations of land use, soil and slope) is aggregated at sub-basins level and routed to the main channel for which the basin water balance is calculated. The simulation process is performed in the surface soil, subsurface, shallow and deep aquifers. More details of the model description can be found in the SWAT theoretical documentation.

2.3 Input data

Daily climate and streamflow data were collected from gauge stations for five years (2013-2017). Rainfall, temperature, wind velocity, solar radiation and relative humidity were taken from the synoptic station of Natitingou for the same period. Rainfall and temperature were also taken from four other stations within and close to the basin (Koundri, Nagasega, Pouri, Ouriyori). The DEM was obtained from ASTER GDEM with 30 m resolution. The land use cover maps were used as inputs for the model. Vegetation parameters (e.g. leaf area index, albedo, root depth, plant growth etc.) were derived from field work. In SWAT database with some parameters changes including maximum root depth, Manning's coefficient for the soil surface, maximum stomatal conductance and maximum leaf area index to better represent the tropical conditions. Soil map and soil physical characteristics (Table 1) were used as inputs for the model. Table 1 summarizes the input data into the model.

Table 1: Summary of input data in the hydrological model

Data	Properties of the data	Parameters	Sources
DEM	30 m x 30 m	Slope, aspect, channel, curvature, sub-basin, etc	ASTER GDEM
Climatic	4 weather stations and 1 synoptic station	Daily rainfall, temperature, wind speed, relative humidity, solar radiation	https://wascal-dataportal.org/geonetwork/apps/search/ and Meteorological agency of Benin
Soil	1:200,000	Soil physical and chemical properties (e.g. Ks, θs, θres, bulk density, etc.)	https://wascal-dataportal.org/geonetwork/apps/search/and field works
Land use	5 to 200 m	Land use classes, root depth, leaf area index, albedo, interception factor, etc.	CENATEL-Benin and field works
Streamflow	Daily	Streamflow	https://wascal-dataportal.org/geonetwork/apps/search/and National water agency of Benin

2.4 Model setting up, calibration, validation and sensitivity analysis

Hydrological and meteorological datasets were arranged for the calibration (2014-2015) and the validation (2016-2017) periods. To determine the most sensitive parameters, SWAT-CUP program with SUFI-2 algorithm developed by Abbaspour (2007) was used during the calibration and the validation processes. The observed meteorological data for the entire simulation period and the soil datasets being kept constant, the model was run considering the land use maps separately. In addition, three years data were considered as warm-up period for the models.

The degree of uncertainties was quantified by the p-factor which is the percentage of observed data bracketed by the 95% prediction uncertainty (Abbaspour, 2007). Nash-Sutcliffe coefficient was defined as objective function during the process with a minimum of 0.5. The methodology framework adopted for this study is presented in figure 2.

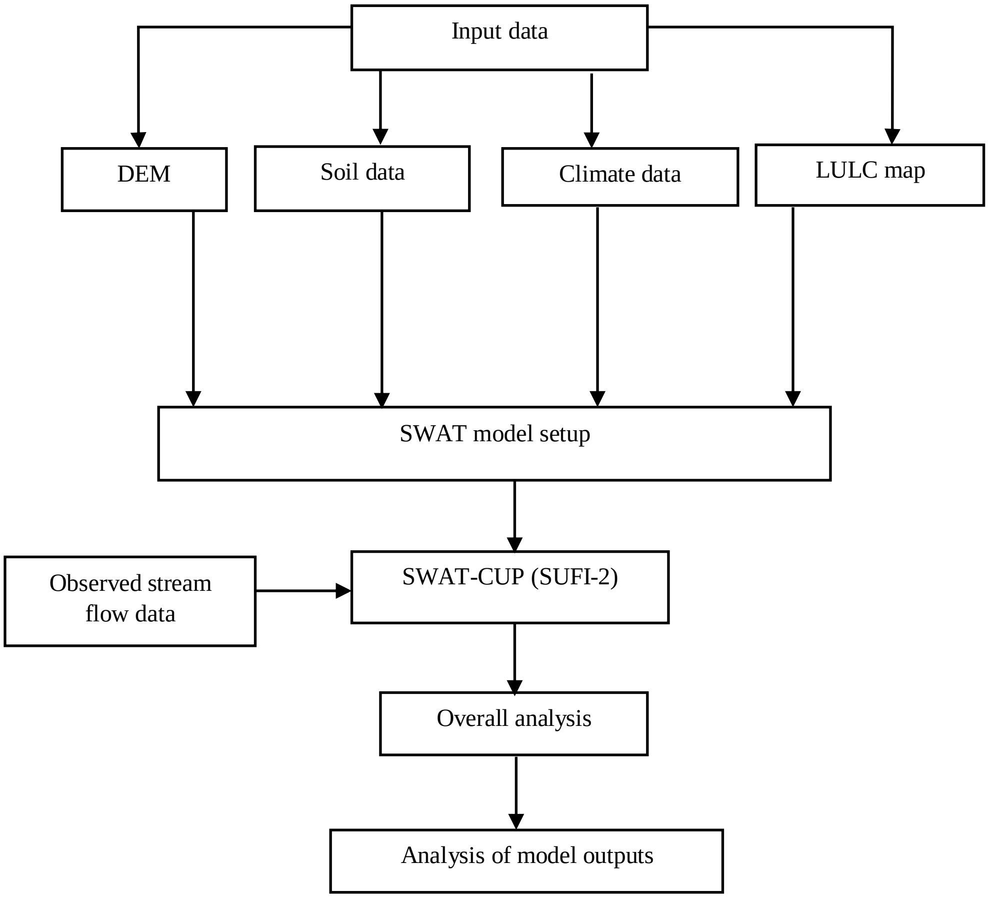


Figure 2: Conceptual framework of the simulation process

After running the model, the sensitivity analysis was performed after each simulation process. The overland flow was estimated by the modified Soil Conservation Service (SCS) curve number method (Neitsch *et al*., 2011). The method takes into account the land use, soil type and antecedent soil moisture content. To estimate the potential evapotranspiration, the Penman-Monteith method was used. The water balance in SWAT is computed using the following equation (1):

$$SW_f = SW + \sum_{i=0}^{t} \left[R_{day} - \left(Q_{surf} + ET + W + Q_{ground} \right) \right] \quad (1)$$

where SW_f is the daily final soil water content (mm); SW is the daily initial soil water content (mm); R_{day} is the daily rainfall (mm); Q_{surf} is the daily surface runoff (mm); ET is the daily evapotranspiration (mm); W is the daily percolation (mm) and Q_{ground} is the daily groundwater flow (mm) and t is the time (day)

The amount of sediment out of the basin reach is calculated with equation (2):

$$Sed_{out} = \frac{V_{out}}{V_{ch}} Sed_{ch} \tag{2}$$

where Sed_{out} and Sed_{ch} are respectively the amount of sediment transported out of the reach and the amount of suspended sediment in the reach (metric tons), V_{out} and V_{ch} are respectively the volume of outflow during the time step ($m^3 s^{-1}$) and the volume of water in the reach segment (m^3).

Soil loss was estimated using Modified Universal Soil Loss Equation (3) (Williams, 1995):

$$Sed = 11.8 \left(Q_{surf} \cdot Q_{peak} \cdot area_{hru}\right)^{0.56} K.C.P.LS.CFRG \tag{3}$$

where Sed is the sediment yield for a given day (metric tons); Q_{surf} and Q_{peak} are the surface runoff rate (mm H_2O/ha) and the peak runoff rate (m^3/s) respectively, $area_{hru}$ is the area of the HRU (ha);K, C, P, LS, $CFRG$ are the soil erodibility (Mg h/MJ/mm), the cover management, the conservation practice factor, the slope length and steepness factor and the coarse fragment factor respectively.

The performance of the SWAT model in simulating daily streamflow in the basin was assessed using statistical indexes to compare the simulated and the measured streamflow at the basin outlet. Coefficient of determination (R^2), Nash-Sutcliffe coefficient (NSE) and the Kling-Gupta efficiency (KGE). Simulations were deemed satisfactory when NSE ≥ 0.5, KGE ≥ 0.5 and $R^2 \geq 0.5$ following Moriasi *et al.* (2007) and Santhi *et al.* (2001). The followings are the statistical indexes equation used:

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \overline{O})^2} \sqrt{\sum_{i=1}^{n}(P_i - \overline{P})^2}} \right] \left[\frac{\sum_{i=1}^{n}(O_I - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n}(O_I - \overline{O})^2} \sqrt{\sum_{i=1}^{n}(P_i - \overline{P})^2}} \right] \tag{4}$$

where O_i and $\overline{O}$ are observed value and mean of the observed values respectively, P_i and $\overline{P}$ are simulated value and mean of the simulated values and n is the number of observation.

- NSE is expressed by the following equation (4) and ranges between -∞ and 1. A value closed to 1 gives a best performance.

$$\mathrm{NSE}=1-\left[\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\overline{O})^2}\right] \quad (5)$$

- KGE has that advantage to consider model calibration as a multi-objective problem and therefore takes in consideration the correlation, the variability error of the flow and the bias error during the optimization. KGE is used to overcome some shortcomings of the NSE which is the propensity to underestimate flow (Gupta *et al.*, 2009). The range values of the following equation (5) of KGE is -∞ and 1 with 1 as a best value.

$$\mathrm{KGE}=1-\sqrt{(r-1)^2+(\alpha-1)^2(\beta-1)^2} \quad (6)$$

where r is the linear correlation coefficient between observed and simulated flows (mm.day^{-1}); α is the standard deviation of simulated over observed and β is the ratio between the mean simulated and mean observed flows.

- The Percentage bias (PBIAS) describes the tendency of the simulated data to be greater or smaller than the observed data over the simulation period. The lower or closer the value of PBIAS is to 0%, better is the model simulation performance.

$$\mathrm{PBIAS}=\frac{\sum_{i=1}^{n}(O_i-P_i)}{\sum_{i=1}^{n}(Q_i)} \quad (7)$$

3 RESULTS AND DISCUSSION

3.1 LULC distribution

Table 2 shows the distribution of LULC in the basin from 1988 to 2016. The change analysis showed that cropland and fallow land have increased of about 42% while shrub and grass savanna decreased of about 29% and 13%, respectively. Increase in cropland and fallow areas was due to the removal of the natural vegetation for the establishment of new croplands areas.

Table 2: Summary of LULC distribution in the Ouriyori basin

LULC	1988	2016
	Area (ha)	Area (ha)
Shrub savanna	502	7
Grass savanna	669	451
Cropland and fallow land	478	1184
Agroforestry	5	5
Water bodies	2	2
Settlements	9	16

3.2 Simulation of streamflow

During the simulation of the streamflow (2014-2015), among the 13 parameters selected for the calibration, only 8 parameters were more sensitive with different degree of sensitivity. Based on p-value and t-test, the Curve Number (CN2), the time required for water leaving the bottom of the root zone to reach the shallow aquifer (GW_DELAY),the baseflow alpha factor characterizing the shallow aquifer recession curve (ALPHA_BF) and the deep aquifer percolation coefficient (RCHRG_DP) were found to be the most sensitive parameters. The percentage of the prediction uncertainty(95PPU) enveloped only fifty percent of the estimated flow during the simulation. These coefficients revealed a good simulation even though the model was not able to capture enough the observation as shown by the p-factor (from 45% to 55%).

3.2.1 Streamflow simulation during the calibration period

The SWAT model was calibrated at daily time scale. The water balance components during the calibration period (Table 3) showed the contribution of the rainfall to surface runoff of about 9% with the land use conditions in 1988 and 14% with the land use conditions of year 2016. The groundwater flow, the total aquifer recharge (shallow and deep), and the actual evapotranspiration were respectively 21%, 37% and 70% for the total rainfall with the land use condition of 1988 whereas in 2016 land use conditions, these water balance components were 17%, 28% and 73% respectively (Table 4).These differences can be explained by the difference in land use over the time (Awotwi *et al.*, 2014).

Table 3: Annual average water balance components of the basin during the calibration period (top: land use 1988; down: land use 2016)

Components of water balance (2014-2015)	Values (mm)
Rainfall	915.1
Surface runoff	78.1
Lateral flow	23.5
Groundwater flow	194.5
Total aquifer recharge (shallow + deep)	340.9
Deep aquifer recharge	7.4
Total flow/ water yield	257.2
Actual Evapotranspiration	637.2
Potential evapotranspiration	1907.5
Change in water storage	1.9

Components of water balance (2014-2015)	Values (mm)
Rainfall	915.1
Surface runoff	126.5
Lateral flow	20.9
Groundwater flow	153.2
Total aquifer recharge (shallow+ deep)	260.8
Deep aquifer recharge	6.1
Total flow/ water yield	262.4
Actual Evapotranspiration	672.8
Potential evapotranspiration	1907.5
Change in water storage	1.6

Table 4: Ratio of each water balance component related to the total rainfall during calibration period

Water balance components	Proportion of water balance component related to the total rainfall (%)	
	Land use 1988	Land use 2016
Surface runoff	9	14
Groundwater flow	21	17
Total aquifer recharge	37	28
Actual evapotranspiration (ET)	70	73

These results showed the potential of the basin in terms of surface and groundwater. The contribution of the rainfall that returns to the atmosphere through evapotranspiration was closet those obtained by Sintondji *et al.* (2013)in Oueme basin at Save outlet, Sintondji *et al.* (2017)in Couffo catchment at Lanta outlet and Bossa (2007) in Zou catchment at Atcherigbe outlet with respective values of 73% 72% and 72.4%.In contrary, the value is higher than that obtained by Awoye *et al.* (2007) in Klou basin (68.9%).The contribution of rainfall to surface runoff are relatively close to those found by Sintondji *et al.* 2013, Awoye (2007) and Giertz *et al.* (2006) with a value ranging from of 9.5% to 18.7%. However, the basin showed a higher rate of the aquifer recharge. This may be due to the geomorphology and the gravelly aspect of the basin as the area is a bedrock region covered by hills in Northern Benin. The difference found in surface runoff and in evapotranspiration can be explained by the difference in land use management from 1988 to 2016 particularly the continuous conversion of natural vegetation to croplands and settlement areas (Chabi, 2016).

The comparison of simulated and observed streamflow is showed in Figures3 and 4 with their corresponding performances. The performance of the model in simulating daily streamflow is showed by the statistical indexes where R^2 was 0.89; NSE was 0.88; KGE ranged between 0.81 and 0.83 and PBIAS between 8.3% and9.8%.The coefficients R2, NSE and KGE are greater than 0.5, and the percentage of bias are close to 15%.Therefore,we can state that the calibration of the model was good according to Moriasi *et al.* (2007) and Santhi *et al.* (2001).

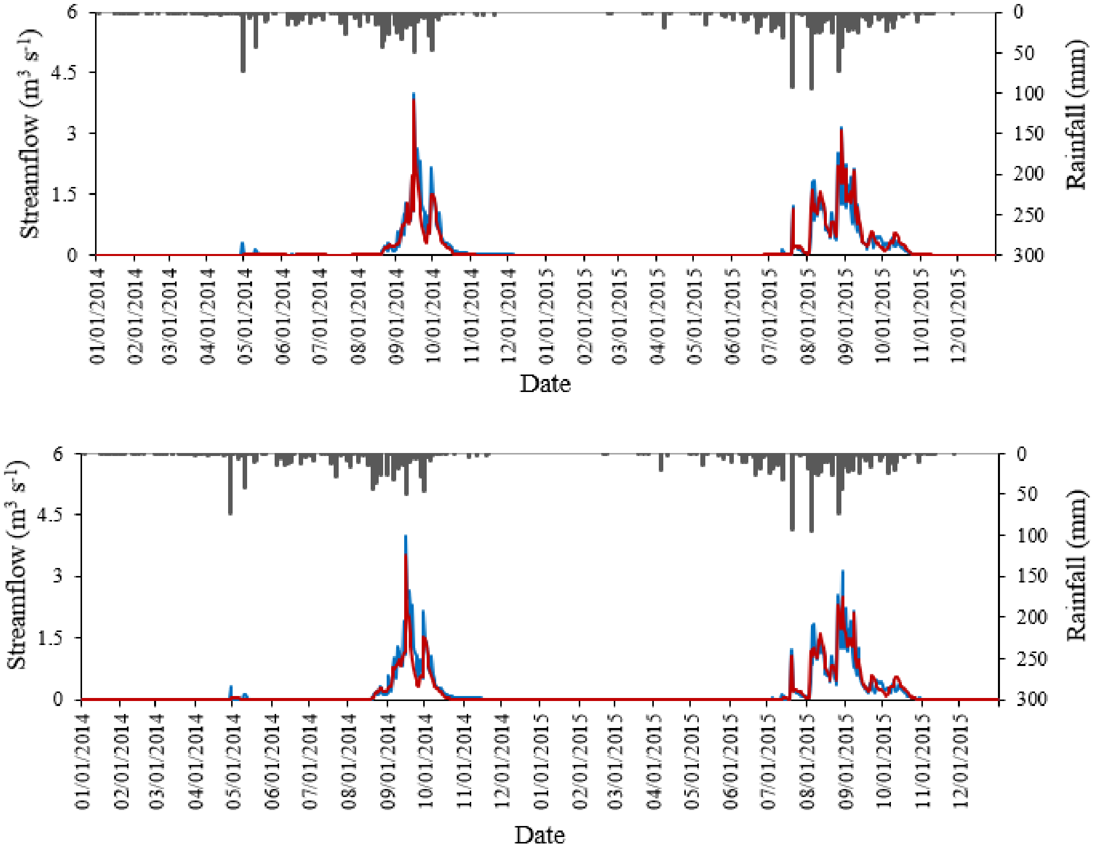


Figure 3: Daily average simulated and observed streamflow for the calibration period; top figure for land use 1988 and down figure for land use 2016

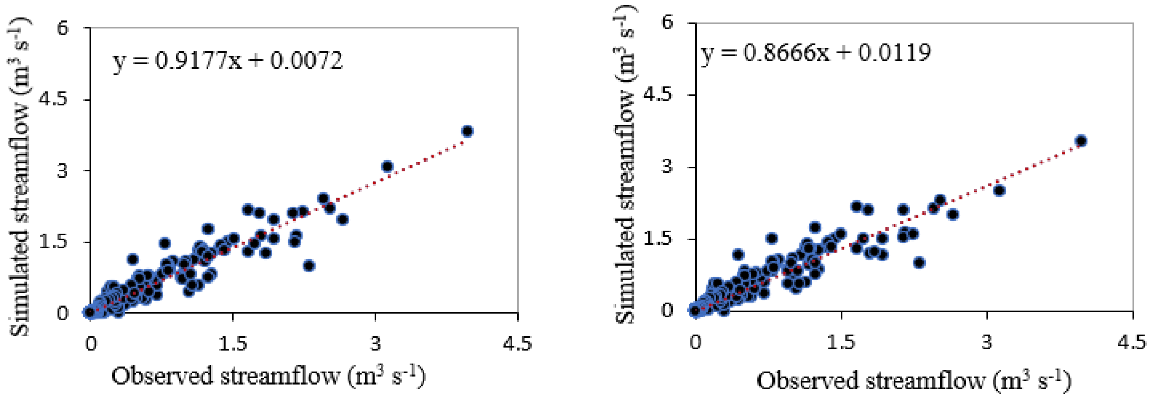


Figure 4: Scatter plot of simulated and observed streamflow for the calibration period; left for land use 1988 and right for land use 2016

3.2.2. Stream flow simulation during the validation period

Tables 5 shows the annual average values of each water components during the validation period (2016-2017). The surface runoff coefficient was about 6% and 11% for land use condition of 1988 and 2016 respectively, while the groundwater flow, the total aquifer recharge and the actual evapotranspiration were respectively 15%, 29% and 88% for the land use condition of 1988, and 11%, 18% and 89% for land use condition of 2016 (Table 6). These ratios are close to those obtained during the calibration step.

Table 5: Annual average water balance components of the basin during the validation period (top: land use 1988; down: land use 2016)

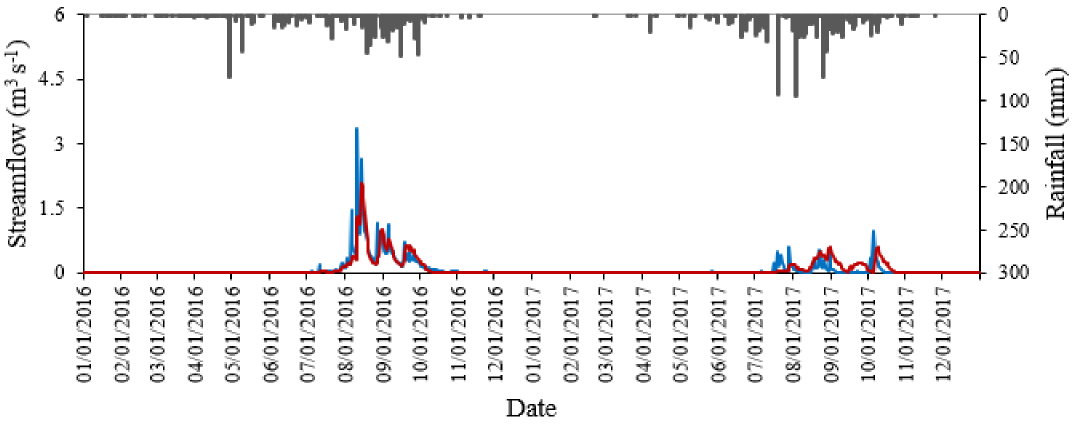
Components of water balance (2016-2017)	**Values (mm)**
Annual rainfall	698
Surface runoff	44.1
Lateral flow	17.4
Groundwater flow	101.4
Total aquifer recharge (shallow+ deep)	201.6
Deep aquifer recharge	7.4
Total flow/ water yield	134.2
Actual Evapotranspiration	615.2
Potential evapotranspiration	1748.3
Change in water storage	-1

Components of water balance (2016-2017)	**Values (mm)**
Annual rainfall	698
Surface runoff	76.2
Lateral flow	15.9
Groundwater flow	78.5
Total aquifer recharge (shallow+ deep)	124.6
Deep aquifer recharge	5.6
Total flow/ water yield	143.7
Actual Evapotranspiration	627.4
Potential evapotranspiration	1748.3
Change in water storage	-1.5

Table 6: Ratio of each water balance component related to the total rainfall during validation period

Water balance components	**Proportion of water balance component related to the total rainfall (%)**	
	Land use 1988	Land use 2016
Surface runoff	6	11
Groundwater flow	15	11
Total aquifer recharge	29	18
Actual evapotranspiration (ET)	88	89

In validation phase, figures5 and 6indicated that the model underestimated the streamflow and performed lightly worse during the validation phase compared to the calibration phase. However, the statistical indices of the validation phase indicated that R2and NSE was between 0.67% and 0.71% while KGE was 0.76 and PBIAS ranged between 8% and 18% (Fig. 5). It is common for the statistical indexes to show worst indexes in validation period compared to the calibration period because the simulation parameters are optimized only in the calibration period (Lelis *et al.*, 2012; Pinto et al., 2013; Aragao *et al.*, 2013). Moreover, the validation period may have different conditions leading the calibrated parameters to be less optimized in validation period. SWAT validation showed also a better agreement despite that the peak flows values were reduced after the calibration. This may due be to the fact that the rainfall trend was reduced during the validation period.



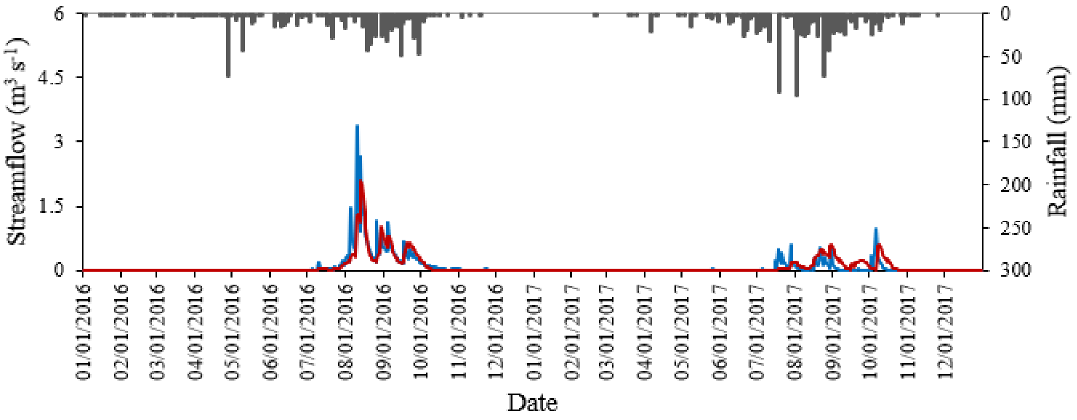


Figure 5: Daily average simulated and observed stream flow for the validation period: top figure for land use 1988 and down figure for land use 2016

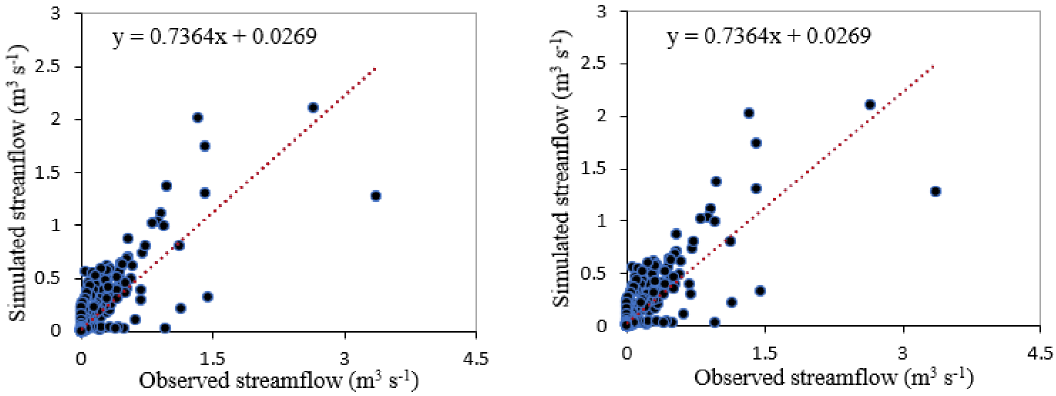


Figure 6: Scatter plot of simulated and observed streamflow for the validation period; left for land use 1988 and right for land use 2016

3.2.3. Hydrological response to LULC change

3.2.3.1. Effect of LULC change on blue water

The observed meteorological data for the entire simulation period and the soil datasets being kept constant, SWAT was run for 1988 and 2016 land use maps separately and the two simulated hydrographs were compared. As LULC changes from 1988 to 2016, with the cropland and fallow land increasing and savanna areas decreasing, surface runoff increased from 9% to 14%, while groundwater and the total aquifer recharge decreased from 21% to 17% and 37% to 28%, respectively. This difference can be related to the effect of changes in LULC mainly induced by various anthropized activities such as agriculture which was the dominant activity in the basin area.

3.2.3.2. Effect of LULC change on green water

As for the blue water, LULC changes have a considerable effect on the spatial distribution on the average annual evapotranspiration across the basin. Cropland and fallow areas depicted the high value of ET while the low values were found in savanna areas. The average ET of the land use for year 2016 was larger than the one of the land use for year 1988. The difference in ET is due to the increasing in croplands areas while savanna areas decreased. This may be explained by the difference in leaf area index and the stomatal conductance of the various LULC controlling the evapotranspiration. The results concord with the findings in neighboring basins (Awotwi *et al.*, 2014, Sintondji *et al.*, 2014; 2017).

3.2.4. Sediment transportation in the basin during the calibration period

The Ouriyori basin is an anthropized area with a high rate of overgrazing. This situation leads to change in land surface, especially the structure of the soil. However, the basin may face soil erosion problems in some sub-basins. The soil loss assessment of the basin showed a high soil loss in sub-basins 3, 4, 12, 22 and 23 for 1988 land use; and in sub-basins 2, 4, 8, 11, 13, 15 for land use 2016 (Fig. 7). Considering both land uses, the sub-basin 4 including Tantega village had high soil loss amount for the two land use conditions. The soil loss varied between 0.01 ton/ha/y and 7.67 t/ha/y with land use of 1988, and varied between 1.01 t/ha/y and 20.62 t/ha/y. This difference depicts the change in LULC from 1988 to 2016. Previous studies found an amount ranging between 4.8 t/ha/y and 18.4 t/ha/y in Soudano-sahelian areas (Diallo *et al.*, 2002) and an amount of 21 t/ha/y in the Terou-Igbomakoro basin (Sintondji, 2005).

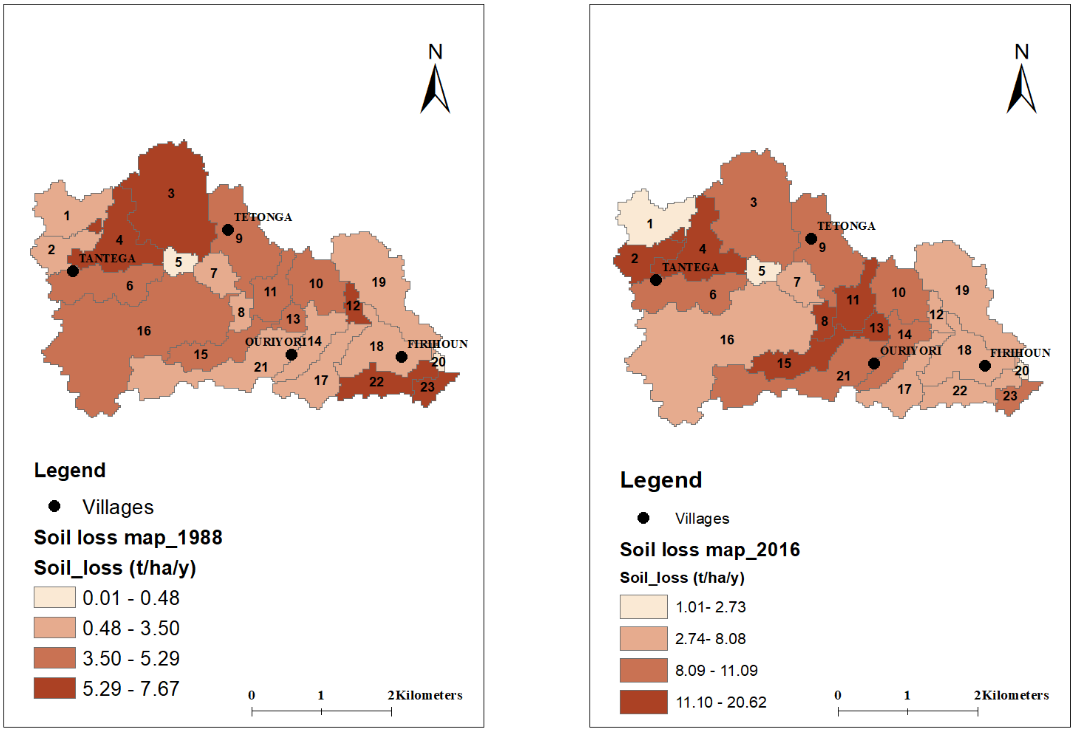


Figure 7: Annual average soil loss per sub-basin (left: land use 1988; right: land use 2016)

4. CONCLUSION

SWAT hydrological model, despite limited data availability, provided satisfactory results in simulating streamflow in the Ouriyori basin. Thereby, the model has the potential to be used as tool for soil and water resources planning and management. In this basin, results indicated that cropland and fallow land increased by 42% whereas savanna areas decreased up to 29% from 1988 to 2016. The hydrological response of LULC changes in the basin indicated that different LULC changes have a direct effect on the basin water balance (water yield and ET). Changes in LULC from 1988 to 2016 showed that when cropland and fallow land increased and savanna areas decreased, surface runoff increased from 9% to 14%, while groundwater and the total aquifer recharge decreased from 21% to 17% and 37% to 28% respectively. The average ET considering land use for 2016 was larger than the one of land use of 1988. This is explained by the increase in cropland areas along with a decrease in savanna areas. Regarding the variation in the amount of soil loss across the basin, appropriate and suitable soil and water conservation systems including anti-soil erosion techniques are needed to provide more access to water for crop and domestic water supplies. Indeed, effective land and water management practices are recommended to meet the needs of the actual generation while protecting the natural resource for the future generation.

Some uncertainties may be related to this study. The missing data in observed streamflow, climate data and the length of available data used for this study may induce some uncertainty during the simulation. Despite these limitations, the outputs of this research are satisfactory and can be used to further investigate the impacts of climate and LULC change in future water balance of the basin.

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