RESEARCH PAPER

CHANGES IN LAND USE/ COVER AND WATER BALANCE COMPONENTS DURING 1964–2010 PERIOD IN THE MONO RIVER BASIN, TOGO-BENIN

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ABSTRACT. The Intergovernmental Panel on Climate Change has predicted that sub-tropical regions are more vulnerable to climate change's negative effects (CC). Additionally, to CC, land use and land cover (LULC) changes and dam construction, often neglected, play an important role in the spatial and temporal distribution of water balance components (WBC) for agricultural production and socio-ecological equilibrium. This study aimed to analyze and compare the changes in LULC and WBC for the period before Nangbéto dam construction (1964–1986) and the period after its construction (1988–2010) in the Mono River Basin (MRB). To this end, the study used mainly WBC extracted from the validated Soil and Water Assessment Tool and LULC data of 1975–2000 in the MRB to explore their temporal distributions and the link in their changes. The results showed that mean actual monthly evapotranspiration, percolation, water yield, surface runoff, groundwater, and lateral flow represent 51%, 17.5%, 15.9%, 9.4%; 5.7% and 0.4%, respectively, of total water balance between 1964 and 1986. The same components represented 51%, 9.1%, 20.4%, 6.3%, 10.6% and 2.6%, respectively, between 1988 and 2010. The contribution of these WBC in the mean-annual (1964–1986) period was for actual evapotranspiration (31.3%), water yield (25.9%), percolation (17.7%), groundwater (14.71%), surface runoff (9.94%) and lateral flow (0.40%). Meanwhile, between 1988 and 2010, the contribution of actual evapotranspiration, water yield, percolation, groundwater, surface runoff and lateral flow is 49.8%,19.9%, 11.2%, 10.3%, 6.1%, and 2.5%, respectively. The results showed that the peaks of the actual evapotranspiration, surface runoff, percolation and water yield appeared in September, corresponding to a month after the maximum rainfall in August. However, our more detailed analysis showed that a significant decrease in forest and savanna and an increase in croplands led to a decrease in actual evapotranspiration and lateral flow over the second simulation period compared to the first period of simulation over the MRB scale. These findings showed that sustainable management and conservation of natural vegetation are crucial for integrated water resource management and conservation in MRB.

KEYWORDS: Water balance components, land use/ cover changes, dam construction, temporal analysis, Mono River Basin

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INTRODUCTION

Water is a source of sustainable economic development because it guarantees supply of basic resources to society and ecosystems. Water resources are fundamental to various sectors of activities such as agriculture, industry, domestic water use and sanitation, hydropower generation, health and environmental security (Hanjra and Qureshi 2010). Agriculture, hydropower dams and agricultural land irrigation are the sectors with large water consumption. Actually, water resource management is becoming a more pressing issue due to climate change (CC) impacts (Eusebion and Zong-Liang 2008; Mango et al. 2011). Most researches in water resource management are dealing with complex systems determined by several interactions between natural, socio-economic, political issues and climate change implications (PCCP 2008). As demonstrated by the Intergovernmental Panel on Climate Change (IPCC) in its 2014 report, global climate change, demographic and economic changes will be felt more in tropical and sub-tropical regions (Paeth et al. 2009; Philipp et al. 2018). In most cases, climate variability and human activities are the two major driving factors of hydrological processes and spatial temporal distribution of water balance components (WBC) in any river basin.

In other hand, land use and cover changes (LULCC) usually affect hydrologic cycle through their direct impacts on land surface processes like the amount of evaporation, groundwater infiltration and surface runoff that occur during and after precipitation events (Bronstert et al. 2002; Setyorini et al. 2017). These factors control the water yields of surface streamflow and groundwater aquifers and thus the amount of water available for ecosystem functions and human use (Anderson et al. 2011). For instance, dam construction on a river basin without appropriate management strategies and precautions can induce changes in streamflow with downstream flooding. These LULCC in addition to CC will have consequences on local and regional hydrological regimes. Consequently, the spatial and temporal water resource availability, or in general the water balance, will be significantly affected (Huntington 2006). Therefore, more attention is needed in this sector.

Several studies have investigated the SWAT-simulated hydrological impact of land use change in Iran (Ghaffari et al. 2010). In China, Zuo et al. (2016) assessed the effects of changes in land use and climate on runoff and sediment in China river basin. Others studies assessed future land use changes impacts sed on hydrological process in Canada (Wijesekara et al. 2012) or performed a comparison of hydrological models for assessing the impact of land use and CC on discharge in a tropical catchment (Cornelissen et al. 2013). In Togo, there are few studies on LULCC and water resources in the complex transboundary basin of Mono river (Badjana et al. 2017; Klassou and Komi 2021).

Recently in the MRB, Koubodana et al. (2019) have shown that the watershed landscape is dominated by cropland, savanna, forest and oil palm plantation. LULCC in the MRB is characterized by losses of savanna and increase of cropland between 1975 and 2013, explained by demographic growth in Togo (Koglo et al. 2018; Koubodana et al. 2019). Over the past years, many projects like the Potential Conflict to Cooperation Potential (PCCP 2008), the Integral Water Resource Management in West Africa (SAWES 2011) and the Integrated Disaster and Land Management Project (PGICT) were implemented for promoting sustainable water resource management in the MRB. Previously, Kissi et al. (2015) have analyzed the social vulnerability of flood in the Bas-Mono prefecture embedded in the MRB. Ntajal et al. (2017) have investigated flood disaster risk mapping and analysis while Houngue (2018) has looked at the simulation of high streamflow using lumped hydrological and climate models in the small area of lower MRB. The authors concluded that the source of high streamflow is not only due to climate change but also to the regulation of the Nangbéto dam, land use and the social factors of the communities living in the catchment. In the previous study, Koubodana et al. (2021) have successfully run, calibrated, and validated a semi-distrubuted Soil and Water Assessment Toold (SWAT) model over the MRB in order to. assess streamflow change before dam installation (1964–1986) and for the period after dam installation (1988–2010). The authors suggested that land cover changes impacted on streamflow and probably on the others WBC which need further investigations.

In this study, outputs from the already calibrated and validated SWAT model in Koubodana et al. (2021) were used to analyze the temporal contribution of WBC for sustainable water resource management in the MRB. The specific objectives of the study are to: (i) assess the temporal distribution of WBC for the periods before and after dam construction; (ii) compare the contribution and changes of WBC in the MRB before and after dam construction, and (iii) determine the link between LULCC and WBC changes in the same basin. The results of this study will allow to elaborate strategies for policy makers better planning and sustainable management of water and land resources in the Transboundary Mono River Basin between Togo and Benin.

MATERIAL AND METHODS

Study Area

The MRB is drained by the Mono River and its tributaries. It is a transboundary basin shared by Togo and Benin Republics in the southern parts of the basin. The Mono River is located between 06°16' and 9°20'Northern latitude and 0° 42'and 1° 40' Eastern longitude (Fig. 1). With a perimeter of 872, 092 km, the basin covers a surface area of 22,013.14 km^2, with 88% in Togo (PCCP 2008). Flowing from its main source in the Alédjo mountains in north Togo, to the Atlantic Ocean in the South, the Mono River has a total length of 308.773 km. The elevation of the basin ranges from 12 to 948 m (http://srtm.csi.cgiar.org , [Accessed 10 Apr. 2019]). The watershed shelters the biggest dam of Nangbéto that produces 20% of total hydroelectricity used by the two countries. To increase the electricity supply capacities, Togo and Benin have co-funded the construction project of a second dam on the same river at Adjarala.

The climate is a subequatorial from 0 to 8°N and with two rainy seasons and two dry seasons. It totals 1200 to 1500 mm/year in the mountainous area of the South-West and only 800 to 1000 mm/ year in the coastal zone. From 8 to 10°N, the climate is tropical humid with one rainy season and one dry season (1000 to 1200mm/year). In the winter (December to March), there is an anti-cyclonic high-pressure area centered over the Sahara. It drives the Harmattan, a desiccating, dusty wind that blows rather persistently from the northeast, drying out landscapes all the way to the coast. However, the hydrograph has one peak that indicates that river discharge is mostly controlled by upstream tributaries. The mean annual temperature ranges from 22°C to 30°C and precipitation varies between 800 mm and 1300 mm/year (CILSS 2016; Speth et al. 2010). Precipitation usually reaches the peaks in May-June and September-October.

Human activities in the MRB mainly include the management of the construction of the hydroelectricity dam, irrigation activities in the downstream, water withdrawal for population needs, agricultural development and fisheries. The rivers shelter the most important reservoir of Nangbéto Dam. The dam is built at 180 km from the mouth of the river and the surface area for water retention that feeds it is 15700 km^2. The second dam under the Adjarala project will be built at 100 km downstream from Nangbéto and, between the two dams, the drained area is 11,000 km^2 (Rossi 1996).

Data

Water balance components datasets

The datasets used in this study are from the validated SWAT model outputs generated by Koubodana et al. (2021). The WBC considered were Precipitation (PCP), actual evapotranspiration (ET), percolation (PERC), surface runoff (SURQ), and groundwater flow (GW_Q), water yield (WYLD) and lateral flow (LAT_Q). These components were extracted from the validated SWAT model for the two periods. The values are provided on daily basis and for each sub-basin or reach point between 1964 and 1986 and from 1988 to 2010. The watershed was divided automatically into 24 sub-basins for the first period of simulation (1964–1986) and 23 for the second period (1986–2010) (Gassman et al. 2007).

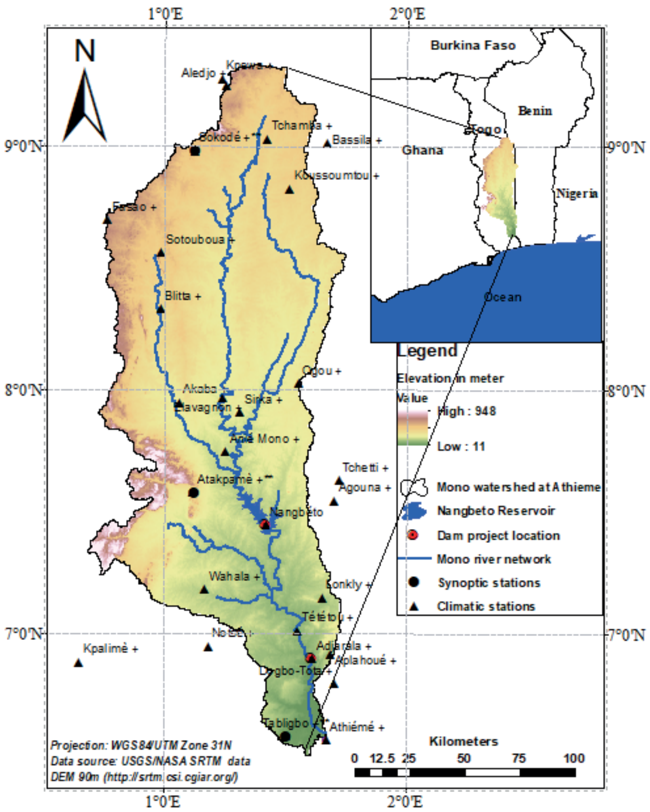


Fig. 1. Study Area (Koubodana et al. 2019)

Land use and land cover change datasets

The LULC maps of 1975 and 2000 were used to reflect on land use/cover patterns for the period 1964–1986 (named as SIM1) and the period 1988–2010 (called SIM2), respectively. The Nangbéto Dam started operating in 1987, which is selected as the turning point of the climate data, because significant changes of land use may play an important role in local WBC. Land use and land cover datasets were initially analyzed (Koubodana et al. 2019). We define cropland and fallow with oil palm as a crop field and fallow land, farms with crops and harvested croplands whereas agriculture represents cultivated areas with seasonal crops dependent on rainfall. Table 1 shows the areal proportions of the LULC units for the two years.

Methods

SWAT model and water balance component outputs extraction

The SWAT model was setup for the MRB by delineating the watershed was divided automatically into 24 sub-basins for the first period of simulation (1964–1986) called SIM1 and for the second period (1988–2011) called SIM2. This resulted in an automatic subdivision of 109 hydrologic response units (HRUs) and 111 HRUs for SIM1 and SIM2 respectively based on the same soil, land use, and slope (Arnold et al. 1998). More detailed characteristics of the input data used for the SWAT model setup can be found in Koubodana et al. (2021). The surface runoff was estimated using the Soil Conservation Service (SCS) curve number method which is a function of land use, soil permeability and antecedent soil water conditions The Hargreaves's method, which requires only minimum and maximum temperature as input data was used for the

Table 1. LULC datasets (Koubodana et al. 2019)

LULC types	SWAT Code	Area [%]	
		1975	2000
Savanna	RNGE	76.03	63.76
Agriculture	AGRR	6.48	21.83
Forest	FRST	5.38	3.03
Gallery and riparian forest	FRSE	5.2	4.28
Degraded forest	RNGB	3.91	1.98
Cropland and fallow with oil palm plantations	OILP	2.22	3.51
Woodland	FRSD	0.43	0.27
Settlements	URBN	0.31	0.49
Water bodies	WATR	0.02	0.52
Wetland-floodplain	WETN	0.02	0.33

evapotranspiration estimation in the model (Hargreaves and Samani 1982; Koubodana et al. 2021). A detailed description of the model setup, sensitivity analysis, calibration, and validation is presented by Koubodana et al. (2021). The SUFI-2 semi-automatic tools for calibration – validation-sensitivity & uncertainty analysis were then used to generate, and to validate a representative SWAT model over the catchment (Abbaspour et al. 2017).

The main WBC were extracted for both the periods before (SIM1) and after (SIM2) dam construction. These data were used to compute the monthly, and annual averages contributions over over the whole catchment. Using SWAT Output Viewer (https://swatviewer.com/, [Accessed 10 Sept. 2019]), it was possible to extract the contribution of each WBC at mean monthly and annual scales. Mean annual and mean monthly values were computed for each WBC contribution considered over SIM1 and SIM2. Therefore, the mean annual and monthly WBC contributions were used to show the percentage of each water balance component at annual and monthly scales.

Analysis of the temporal distribution of water balance before and after dam construction

The temporal distribution of WBC was assessed using Origin 2018 software. Origin is a powerful and full-featured data analysis software (Deschenes and Bout 2000; Gonzalez-Barahona et al. 2008). Origin offers an easy-to-use interface. The graphs plotted by the software and analysis results can automatically update on data or parameter change (https://www.originlab.com/). This software was been used in many previous studies and it has the advantages to be easy handle, generate graph and update data. First, the SWAT models WBC contribution outputs between 1964 and 1986 or between 1988 and 2010 and distributions were averaged at sub-basin level. Next, the temporal contributions of a selected WBC value for the catchment were averaged using Origin 2018 software. Finally, the same software was used to compute the matrix where the component values of the water balance are listed according to month and year for the periods before and after dam construction.

Changes in land use/cover and water balance components before and after dam construction

The study has established the relationship between LULCC and hydrological components before and after dam construction. The SWAT model simulation was divided into two periods: SIM1 period (1964–1986) and SIM2 period (1988–2010). For SIM1, the land use map of 1975 was used as input and with climate variables extended between 1964 and 1986. Meanwhile, the input data for the SIM2 were the land use data of 2000 and climate variables extended between 1988–2010 and Nangbéto reservoir set in 1987. More details about SWAT model setup model sensitivity analysis, calibration, validation and uncertainty analysis can be found in Koubodana et al. (2021). Based on the validated model outputs after its performances and uncertainties analysis during SIM1 and/or SIM2, modelers were able to deduce the impacts of LULCC on hydrological components before and after dam construction in 1987. Thus, the temporal intensity distribution and related statistics of WBC over MRB for SIM1 and SIM2 were respectively generated. Furthermore, the changes between the two periods of hydrological cycle components were computed and comparative methods allowed giving sustainable information for integral water resource management in MRB.

RESULTS

Precipitation temporal distribution and changes before and after dam construction

Fig. 2 underscores the temporal distinction of wet and dry seasons and shows the monthly rainfall patterns for the whole basin between 1964 and 1986 (a) and between 1988 and 2010 (b). The onset of the rainy season is May/June for both periods. The cessation of rains occurs in September/October and October/November for the period before and after dam construction, respectively.

The peak of rainfall is reached in between June and September during SIM1 and July and October during SIM2. The dry season always starts from November/December to March/ April of the following year in the two simulations. There is an alteration of unimodal years (1966, 1968, 1979, 1980, 1985 & 1989, 1991, 1993, 1995, 1999, 2002, 2003, 2010) and bimodal years (1964, 1974, 1976, 1978 & 2007, 2009). Rainfall magnitude

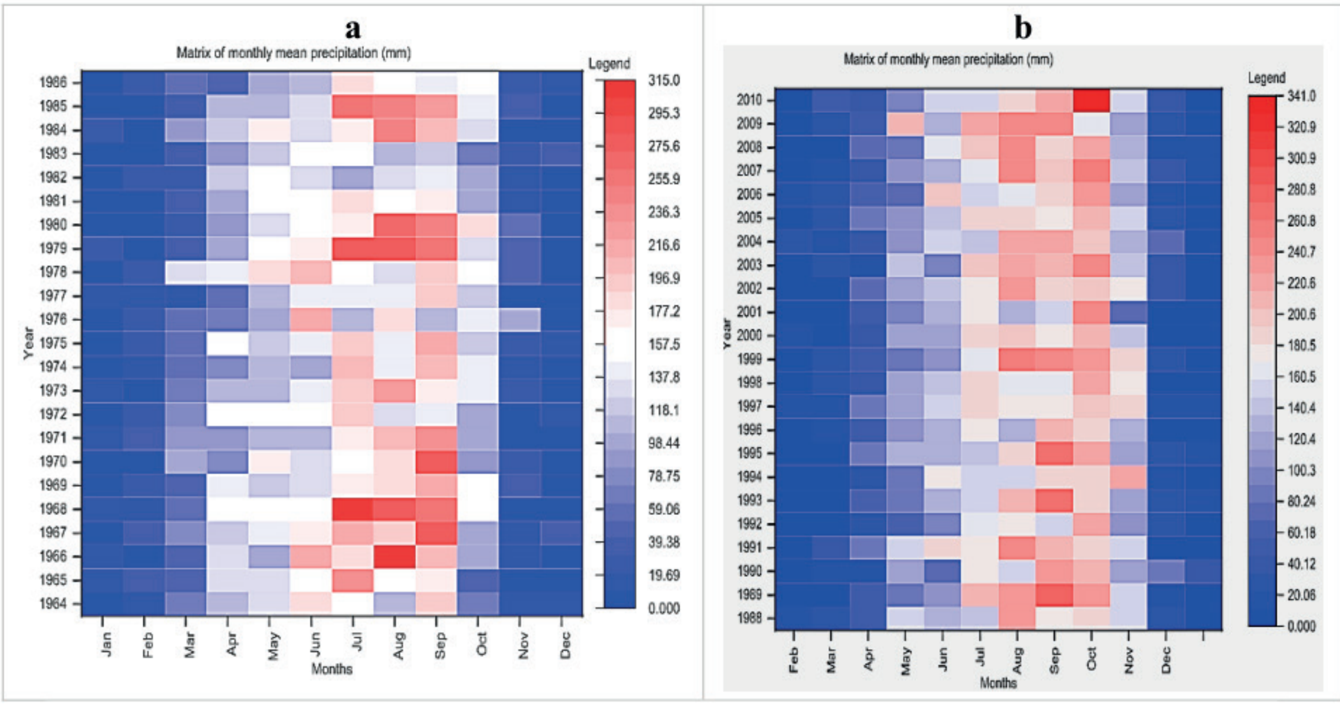


Fig. 2. Matrix [Month-Year] average rainfall evolution over MRB for SIM (a), SIM2 (b)

intensity between 1988–2010 has considerably decreased compared to the period 1964–1986 where there is the inverse situation.

Matrix illustration of water balance components before dam construction (1964-1986)

Fig. 3a to Fig. 3f show the influence of individual water cycle components between 1964 and 1986. These figures showed the distinction between wet and dry months and years over the entire basin. Particularly, actual evapotranspiration (Fig. 3b) ranges from 3.5 to 135 mm/year and the maximum are observed for each year between April and October corresponding to the rainy season. Contrariwise, the minimum of actual evapotranspiration was displayed between November and March which is the dry season. For the other water cycle components such as percolation, surface runoff, groundwater water yield and lateral flow (Fig. 3a, 3c and 3f), the maximum values are observed between August and October which is the period of peak of rainfall over the study area. Some years underline the pronounced lowest value of these variables during this season.

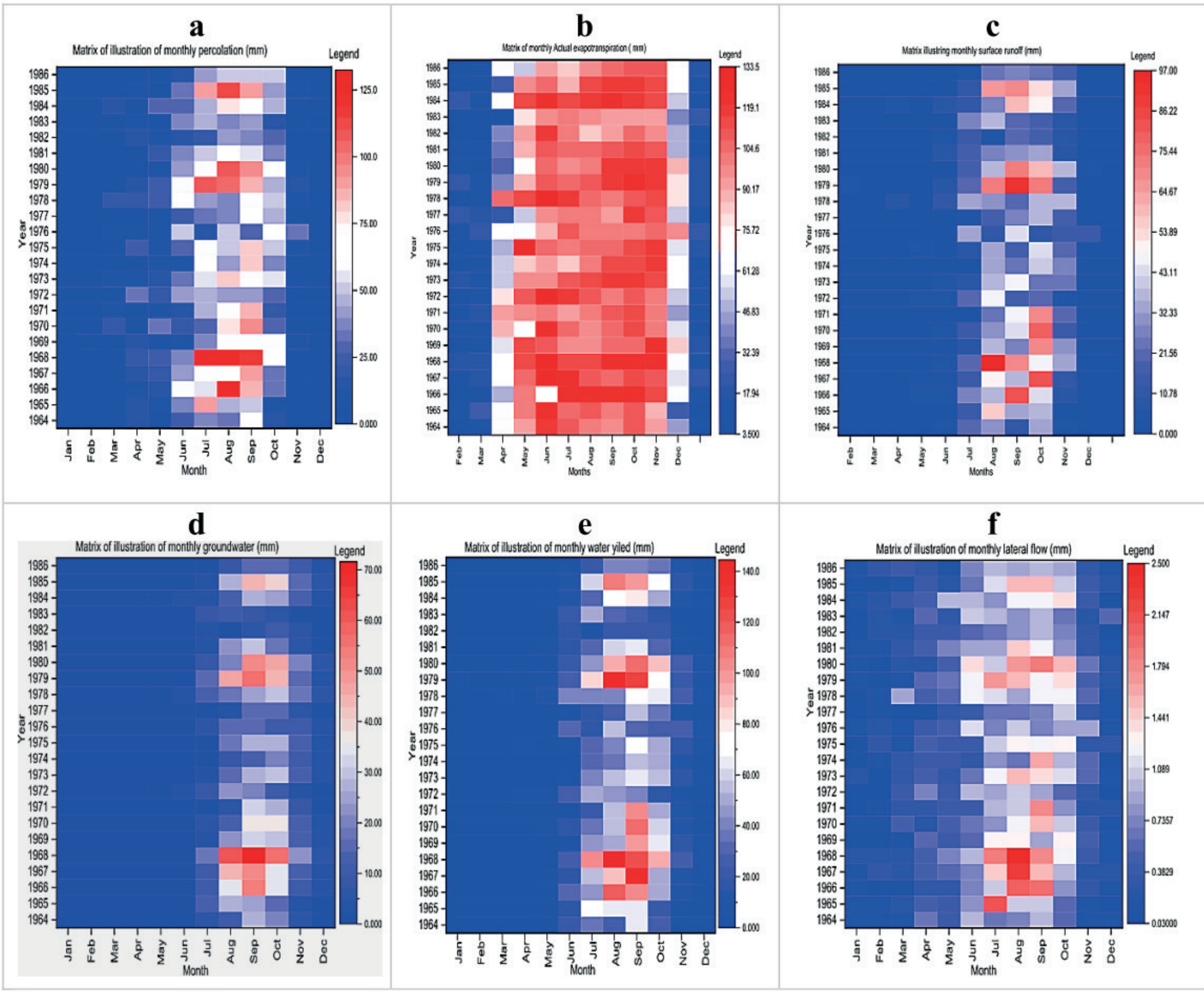
Matrix illustration of water balance components after dam construction (1988–2010)

Over the second period of simulation (SIM2) between 1988 and 2010, the monthly variability of water cycle components per year is presented in Fig. 4. These figures revealed that the high values of actual evapotranspiration are seen between May and October of the year and the other months (November to April) are characterized by the low actual evapotranspiration. For the other components of the hydrological cycle, the maximum is obtained between July and October. There are years with lowest surface runoff over the years of 1988, 1992, 1996, 1997, 2000, 2001, 2002, 2004 and 2005 which are known as drought years in the region.

Land use/cover and water balance component changes before and after dam construction in the Mono River basin

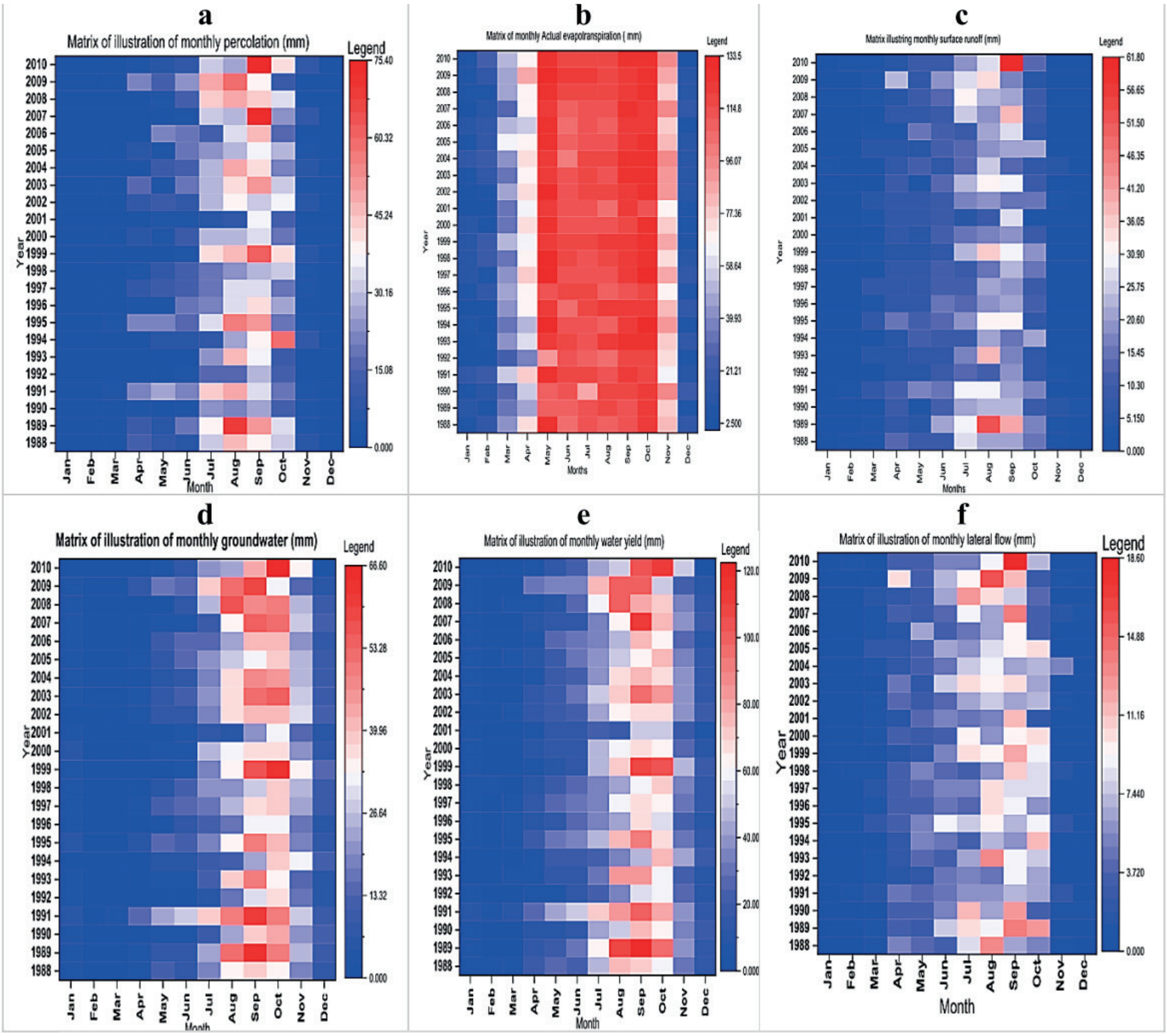
Knowledge about land use and land cover dynamics is of high importance for integral water resource management in a given watershed. Therefore, LULCC were estimated between 1975 and 2000. The major land use changes are observed in savanna, forest, agriculture and cropland (Table 2). Between 1975 and 2000, there is 12.27% of decrease of savanna estimated at 2701.08 Km^2 of losses savanna, 2.35% (517.32 Km^2) of decrease of forest, 15.35% (3379.10 Km^2) increase of agriculture land, 1.29% (283.98 Km^2) increase of Cropland with oil palms as majors land cover over Mono river basin.

LULCC between 1975 and 2000 had repercussions on WBC over the study area (Table 3). Consequently, the results showed that there were significant decreases of forest, savanna and increases of agricultural land involve a decrease of precipitation (PRECIPmm), actual evapotranspiration (ETmm) and lateral flow (LAT_Q_mm) over the second period of simulation compared to the



(a) Percolation, (b) actual evapotranspiration, (c) surface runoff, (d) groundwater, (e) water yield and (f) lateral flow

Fig. 3. Matrix [Month-Year] of water balance components contribution between 1964 and 1986



(a) percolation, (b) actual evapotranspiration, (c) surface runoff, (d) groundwater, (e) water yield and (f) lateral flow.

Fig. 4. Matrix illustration of water balance components contribution between 1988 and 2010

Table 2. Statistics of LULC and changes for the period 1975–2000

LULC types	SWAT Code	Year 1975		Year 2000		Change area 1975–2000	
		[Km²]	[%]	[Km²]	[%]	[Km²]	[%]
Forest	FRST	1,184.34	5.38	667.02	3.03	-517.32	-2.35
Savanna	RNGE	1,6737.02	76.03	1,4035.94	63.76	-2,701.08	-12.27
Wetland-floodplain	WETN	4.40	0.02	72.65	0.33	68.24	0.31
Plantation/Agriculture	AGRR	1,426.49	6.48	4,805.59	21.83	3,379.10	15.35
Water bodies	WATR	4.40	0.02	114.47	0.52	110.07	0.50
Settlements	URBN	68.24	0.31	107.87	0.49	39.62	0.18
Gallery and riparian forest	FRSE	1,144.71	5.20	942.19	4.28	-202.53	-0.92
Degraded forest	RNGB	860.74	3.91	435.87	1.98	-424.86	-1.93
Woodland	FRSD	94.66	0.43	59.44	0.27	-35.22	-0.16
Cropland and fallow with oil palms	OILP	488.70	2.22	772.68	3.51	283.98	1.29
-	Total	22,013.70	100.00	22,013.70	100.00	0.00	0.00

first period of simulation. The other components such as percolation (PERCmm), groundwater (GW_Qmm), surface runoff (SURQ_mm) and water yield (WYLDmm) show an increase in the second period of simulation.

DISCUSSION

Temporal analysis of water balance components

In water management strategy planning, the analysis of individual water balance component contribution is a requirement. Sathian and Symala (2009) indicated that precipitation, actual evapotranspiration, percolation, groundwater, surface runoff, water yield and lateral flow were the most important components of water balance in a watershed. Among these components, precipitation is an input in hydrological models such as SWAT while other inputs are predicted due to the paucity of observation data (Ghoraba 2015). Actual evapotranspiration, percolation and water yield component contriburions were the highest components over the two periods of average annual and seasonal timescales as displayed in Table 3.

Actual evapotranspiration is the highest amount of water loss by the watershed in annual and seasonal average scales. The high amount of actual evapotranspiration can be explained by the various types of vegetation and also by the global increase of temperature and particularly in the study area (Koubodana et al. 2021; Lawin et al. 2019). Meanwhile, it is important to note that actual evapotranspiration has increased from 31.33% (1964–1986) to 49.85% (1988–2010) in inter-annual time scale and slightly from 51.02% (1964–1986) to 51.05% (1988–2010) for intra-annual period. This increase of water actual evapotranspiration from the period (1964–1986) to the period (1988–2010) is due to the increase of global land surface temperature since 1970, LULCC or decreasing wind speed (Koubodana et al. 2020, 2019).

The second major WBC is water yield which is net amount of water that leaves the sub-basin or the basin and contributes to streamflow in the reach during the time step. It is computed as WYLD = SURQ + LATQ + GWQ − TLOSS − pond abstractions. Therefore, an important amount of precipitation percentage received by the watershed is lost as streamflow. The percentage amount is ranging from 0.40% (1964–1986) to 2.52% (1988–2010). According to Fig. 2b and Fig. 4b, water yield decreases from 25.95% between 1964 and 1986 to 19.97% between 1988 and 2010 at -average annual timescale whereas Fig. 3b and Fig. 5b show on average seasonal timescale, it amounts has increased from 15.93% (1964–1986) to 20.43% (1988–2010). Lateral flow is the lowest (1988–2010) for average annual time scale and from 0.42% (1964–1986) to 2.59% (1988–2010) for average seasonal timescale. This can be due to the low infiltration rate and also that lateral flow depends on the watershed local slope (Cornelissen et al. 2013) which is not constant in the basin and ranges from 12 to 948m. The results on water cycle components contribution confirmed most analysis performed in West Africa (Akpoti et al. 2016; Begou et al. 2016; Hounkpè 2016;

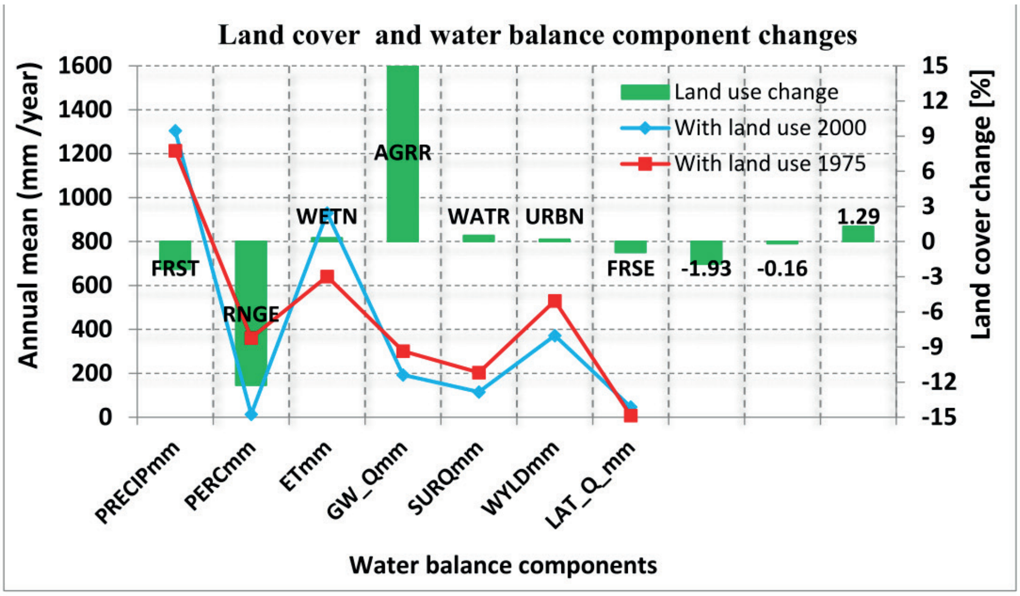


Fig. 5. Land use/cover and water balance components changes between SIM1 and SIM2

Table 3. Water balance component contribution at different time scales

Components	Annual average [%]		Monthly average [%]	
Period	1964–1986	1988–2010	1964–1986	1988–2010
PERCmm	**17.67**	**11.17**	**17.53**	**9.07**
ETmm	**31.33**	**49.85**	**51.02**	**51.05**
GW_Qmm	14.71	10.34	5.67	10.56
SURQmm	9.94	6.15	9.43	6.30
WYLDmm	**25.95**	**19.97**	**15.93**	**20.43**
LAT_Q_mm	0.40	2.52	0.42	2.59
Total	100.00	100.00	100.00	100.00

Kumi M. 2015). For average annual timescale analysis, many years are associated with high and low contribution of surface runoff compared to the average over the period. For example, 1968, 1979, 1980, 1995, 1999 and 2003 runoff contributions are higher and with a positive rainfall index. The years of 1977, 1982, 1983, 1986, 1990 and 2002 present the period with lowest surface runoff and associated with negative rainfall variability index and confirmed the years of drought in West Africa (Koubodana et al. 2020; Oguntunde et al. 2006; Yabi and Afouda 2012).

Rainfall matrix of Fig. 2 shows the average seasonal precipitation from 1964 to 1986 and also from 1988 to 2010 sub-periods. These results confirmed that the climate in the MRB, is unimodal and bimodal according to the past studies (Koubodana et al. 2020; Tramblay et al. 2014).

Fig. 3 and Fig. 4 show the matrix illustration of water cycle components between 1964 and 1986 and from 1988 and 2010 sub-periods. These figures illustrate the dry and wet months and years over the entire basin. It also displays the nature of the season assigned in the basin. The results reported that most of WBC reach their peak between July and October, which is exactly the period of the rainy season in the sub-tropical zone (Djaman et al. 2017; Giertz et al. 2006; Laux et al. 2009). The period of 1964, 1984,1982, 1981, 1977, 1976,1973, 1972, 1988, 1992, 1996, 1997, 2000, 2001, 2002 and 2004 characterized by a very low amount of surface runoff and precipitation are justified by the year where drought occurred in West Africa (Laux et al. 2009; Omotosho and Abiodun 2007; Sylla et al. 2016). For example, 1984, 1982, 1981, 1977, 1976,1973,1972 and 1964 are known in previous analysis as drought years with negative annual rainfall variability index (Descroix et al. 2009; Yabi and Afouda 2012).

Land use/cover and water balance components changes before and after dam construction

Land use and land cover changes are significant between 1975 and 2000 and justified by drivers such as population growth (Ahmad and Quegan 2012; dos R. Pereira et al. 2016). Nevertheless, Koubodana et al. (2019) concluded that the decrease of forest and savanna flowed by an increase of cropland and settlements has occurred in MRB between 1975 and 2000. The combined impacts of land use changes and climate variability induce the increase of precipitation intensity, actual evapotranspiration and lateral flow whereas decrease in percolation, groundwater, surface runoff and water yield were found. One of the reasons for this situation is that the conversion of forest and savanna in cropland caused the change in surface soil layer and vegetation canopy (Wagner et al. 2009). This confirms that LULCC plays an important role in the changes in WBC, water infiltration, evaporation and water movement at local level (Hagemann et al. 2014). The results confirmed the analysis of Koubodana et al. (Koubodana et al. 2019) over the basin. Fig. 5 showed LULCC between 1975 and 2000 have affected water components annual mean for (1964–1986) and (1988–2010) periods respectively. Forest and savanna decreased and could be explained by agriculture expansion, bush fire, timber extraction in response to population needs (Atsri et al. 2018; Koglo et al. 2018; Koubodana et al. 2019). Togo and Benin experience an increase of population which involve more demands for agricultural lands and habit, energy wood consumption. According to Verstraeten et al. (2008), the actual evapotranspiration (ET) is the process from which water is transferred from the soil compartment and/or vegetation layer to the atmosphere. Therefore, any change in land cover (leaf index area) or land use will affect ET intensity. Soil characteristics and climate condition also impacted on water balance components variation (Sciuto and Diekkrüger 2010).

Sources of uncertainty influencing the results of this analysis

Indeed, there are many sources of uncertainty which could affect the results of this study. Some of these include: uncertainty associated with the hydrological modelling and input data quality. In many cases, the analysis of these predictive uncertainty helps in capturing the overall range of expected uncertainty propagated through modelling (Liu and Gupta 2007; Nonki et al. 2021; Zhong-min et al. 2010) . But this study was already subject of uncertainty analysis in Koubodana et al. (2021) . Other studies prefer an ensemble hydrological modeling in order to reduce uncertainties (Gaba et al. 2015; Huisman et al. 2009). The ensemble of the hydrological models could therefore encompass the effects of model uncertainties, because the mean result is a more reliable estimation of hydrology characteristics and increases the confidence of the modeling. In fact, the multi-model approach has been proven to be more robust and exhibits better performance than individual models (Huisman et al. 2009). All these limitations will be considered in furthers analysis in order to minimize uncertainties for formulation of better policies strategies measures at local scale.

CONCLUSION

In this study, outputs on water balance components from a SWAT hydrological model and land use dataset of the years 1975 and 2000 were analyzed in the Mono River Basin over the period before Nangbeto dam construction (1964–1986) and the period after its construction (1988–2010). The results showed that mean monthly actual evapotranspiration, percolation and water yield represent 70% of total water balance in mean monthly and annual time scale. In detail, actual evapotranspiration, surface runoff, percolation and water yield peaks appeared in September corresponding to one month after the maximum rainfall in August. However, more detailed investigation showed that a significant decrease of forest, and savanna and increases of cropland involve an increase of actual evapotranspiration and lateral flow over the second period of simulation compared to the first period of simulation. Therefore, from this analysis it can be concluded that water balance component contribution, the runoff, evapotranspiration and water yield evolution depend strongly on different land-use type change, climate conditions and also on the presence or not of reservoir in the watershed. Finally, there is a strong need to develop sustainable adaptation measures in future studies including ensemble modeling to reduce uncertainties, particularly at local scale where the impact occurs, to mitigate the possible impacts of the projected change in climate. ■

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