H. Djan'na Koubodana, Julien Adounkpe, Kossi Atchonouglo; Komi Agboka, Koffi Djaman,
Kossi Komi, Dambré Koungbanane
Assessing Water Balance Components Contribution Variation in the Mono River Basin,
West Africa
International Journal Water Sciences and Environment Technologies
Vol. (v), No. 2, September 2020, pp.123-130
ISSN Online: 1737-9350; ISSN Print: 1737-6688, Open Access
www.jiste.org
Scientific Press International Limited

Assessing Water Balance Components Contribution Variation in the Mono River Basin, West Africa

H. Djan'na Koubodana[1,2], Julien Adounkpe[1], Kossi Atchonouglo[2]; Komi Agboka[3], Koffi Djaman[4], Kossi Komi[5], Dambré Koungbanane[6,7]

[1]*West Africa Science Service Centre on Climate change and Adapted Land Use, WASCAL-Climate Change and Water Resources, University of Abomey Calavi, 03 PO Box 526 Cotonou, Benin;*

[2] *Faculté Des Sciences, Université de Lomé, B:P 1515 Lomé, Togo;*

[3]*West Africa Science Service Centre on Climate change and Adapted Land Use, WASCAL-Climate Change and Disease Risk Management, University of Lomé, 01 PO Box 1515 Lomé, Togo;*

[4]*Department of Plant and Environmental Sciences,Agricultural Science Center at Farmington,New Mexico State University, P.O.Box 1018, Farmington, NM 87499, USA*

[5]*Laboratoire de Recherche sur les Espaces, les Échanges et la Sécurité Humaine (LaREESH), Département de Géographie, Université de Lomé, BP:1515, Lomé- Togo*

[6]*Centre d'Excellence Africain sur les Changements Climatiques, la Biodiversité et Agriculture Durable (CEA-CCBAD), Université Félix Houphouët-Boigny, Côte d'Ivoire*

[7]*Laboratoire de Recherches Biogéographiques et d'Etudes Environnementales, Département de Géographie, Université de Lomé, BP 1515 Lomé, Togo*

Abstract

This study has investigated and compared the contribution of water balance components over the period before Nangbeto dam installation (1964-1986) and the period after the same dam installation (1988-2010). The datas were mainly water balance component outputs generated from calibrated Soil and Water Assessment Tool over the two periods in the Mono river basin. The results showed that mean monthly actual evapotranspiration, percolation, water yield, surface runoff, groundwater and lateral flow represent 51.05%; 17.53%; 15.93%; 9.43%; 5.67% and 0.42% respectively of total water balance between 1964 and 1986 whereas between 1988 and 2010 the same components represent 51.02%; 9.17%; 20.43%; 6.30%; 10.56% and 2.59% respectively. The contribution of these water balance components during mean annual scale between 1964 and 1986 are actual evapotranspiration (31.33%), water yield (25.95%), percolation (17.67%), groundwater (14.71%), surface runoff (9.94%) and lateral flow (0.40%) while between 1988 and 2010, actual evapotranspiration (49.85%), water yield (19.97%), percolation (11.17%), groundwater (10.34%), surface runoff (6.15%) and lateral flow (2.52%). The peak of actual evapotranspiration, surface runoff, percolation and water yield appears in September corresponding to one month after the maximum of rainfall. The study suggested that land cover change and climate variability have repercussion on water balance components change between 1964-1986 and 1988-2010 over the river basin.

Key Words: Water balance components, land use, climate variability, dam management, streamflow**,** Mono river basin.

Évaluation de la variation temporelle des composantes du bilan hydrologique dans le bassin du fleuve Mono, Afrique de l'Ouest

Résumé

Cette étude a comparé la contribution des composants du bilan hydrologique sur la période précédant l'installation du barrage de Nangbéto(1964-1986) et la période suivant l'installation du meme barrage (1988-2010) du bassin du fleuve Mono en Afrique de l'Ouest. Les données utilisés sont principalement des sorties de composantes de bilan hydrologique générées à partir d'un outil d'évaluation des sols et de l'eau étalonné et validé dans le bassin du fleuve Mono. Les résultats ont montré que mensuellement, l'évapotranspiration réelle moyenne, la percolation, l'apport en eau, le ruissellement de surface, les eaux souterraines et le débit latéral représentent 51,05% ; 17,53% ; 15,93%; 9,43%; 5,67% et 0,42% respectivement du bilan hydrologique total entre 1964 et 1986 alors qu'entre 1988 et 2010 les mêmes composantes représentent 51,02%; 9,17%; 20,43%; 6,30%; 10,56% et 2,59% respectivement. L'apport de ces composantes du bilan hydrologique à l'échelle annuelle moyenne entre 1964 et 1986 est l'évapotranspiration réelle (31,33%), l'apport d'eau (25,95%), la percolation (17,67%), les eaux souterraines (14,71%), le ruissellement de surface (9,94%) et latéral débit (0,40%) alors qu'entre 1988 et 2010, évapotranspiration réelle représente (49,85%), apport en eau (19,97%), percolation (11,17%), eau souterraine (10,34%), ruissellement de surface (6,15%) et débit latéral (2,52%) . Le pic de l'évapotranspiration, du ruissellement de surface, de la percolation et de l'apport en eau réels apparaît en septembre, correspondant à un mois après le maximum de précipitations. L'étude suggère que le changement de la couverture terrestre et la variabilité du climat ont des répercussions sur les variations des composantes du bilan hydrologique dans le bassin.

Mots clés: Composantes du bilan hydrologique, utilisation des terres, variabilité climatique, gestion des barrages, débit des cours d'eau, bassin du fleuve Mono

---

[1] Corresponding author: koubodana.d@edu.wascal.org

INTRODUCTION

Water resource management is becoming more and more important due to climate change (CC) impacts. CC is resulting from anthropogenic and natural effects (IPCC, 2014; Koubodana, 2015). Water is a source of sustainable and economic developments because it assures safe and supply of the basics resource in a society and ecosystems. Water resource is related to different sectors of activities such as agriculture, industry, domestic water use and sanitation, hydropower generation, health and environmental security (Hanjra and Qureshi, 2010). Among these sectors, agriculture is the largest use of water followed by hydropower dam for electricity generation and agricultural land irrigation. The effects of CC can be seen in water like pollution and river hydrology system modification at the downstream of the reservoir. For instance, dam installation can involve flood at the downstream. These entire domains showed that in water resource management many researchers are mostly dealing with a complex system determined by several interactions between natural, socio-economic and political issues (PCCP, 2008) and elements. Today many challenges that research face are water increase demand vs. water scarcity, water pollution, flood and drought. As proved during IPPC, 2014 global climate change; demographic and economic changes will be more feeling in particular region like tropic and sub-tropical regions of the World. In much case climate variability and human activities are two major driving factors in hydrological processes and spatial-temporal distribution of water availability. In order to give sustainable and adequate solutions on water resource pressed by above cited factors, there is a need to assess water balance components variation over the basin in order to propose somes solutions.

Many studies have been done over Mono river basin particulary on social vulnerability of flood, flood disaster risk mapping, simulation of high streamflow (Amoussou et al.,2014; Kissi et al.,2015) They 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. Recently, (Koubodana et al., 2020a) have successfully run SWAT semi- distributed model to assess streamflow change under the combined impacts of land cover and climate variability for the upstream-downstream stations of the reservoir and for the period before dam installation (1964-1986) and for the period after dam installation (1988-2010). The authors suggested that land cover changes impacts on streamflow and probably on the others water balance components which need to be investigated individually in the catchment which need to be investigated individualy. Therefore, the objective of the study is to investigate the temporal variation of water balance components over two sub-periods of a calibrated and validated SWAT model outputs over the basin.

MATERIALS AND METHODS

Study Area

The study area is Mono River Basin (MRB) in West Africa. It is a main river in Togo, which is shared with Benin country in its last kilometers in the south. This river is located between 06°16' and 9°20'Northern latitude and 0° 42'and 1° 40' Eastern longitude (Figure 1). With a perimeter of 872, 092 km, the basin covers til Athiéme an area of 22,013.14 km² and with 88% of it area in Togo country and the rest (12%) in Benin (PCCP, 2008). It length of 308.773 km, MRB has it source in Alédjo mountains in north of Benin before throwing in Atlantic Ocean by the lagoon system. The elevation of the basin is range from 12 to 948 m *(http://srtm.csi.cgiar.org)*. The watershed shelters the biggest dam of Nangbéto that produce 20% of total hydroelectricity used by the two countries. A second dam of project Adjarala is building on this same river to reduce the problem of electricity of these countries.

The climate is a sub-equatorial climate 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 on 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 months (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 (Arbonnier, 2000). 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 800mm and 1300 mm/year (CILSS, 2016; Speth et al., 2010). Precipitation usually reaches the peaks in May-June and September-October months.

Human activities in the MRB mainly include land use change, the construction the hydroelectricity dam, irrigation activities in the downstream, water withdrawal for population growth, agricultural development and industrial. The rivers shelter the most important reservoir of Nangbéto Dam (Rossi, 1996).

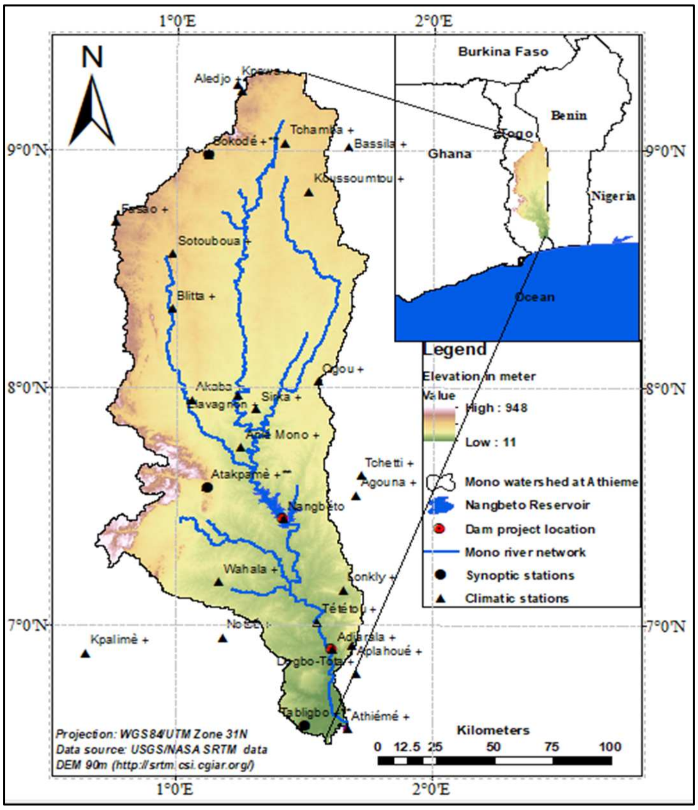

Figure 1: Study Area

Data

Water balance components datasets

The datasets are used in this analysis are the outputs generated by SWAT model from (Koubodana et al., 2020a). The water balance components 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) and were extracted in the calibrated SWAT model of the two period. The values are at daily time step and for each sub basin or reach point between 1964 and 1986 and from 1988 to 2011. The watershed was divided automatically into 24 sub-basins for the first period of simulation (1964-1986) and 23 for the second period (1986-2011). This resulted in an automatic subdivision of109 hydrologic response units (HRUs) (1964-1986) and 111 HRUs (1986-2011) based on the same soil, land use, and slope (Arnold et al., 1998).

Methods

Water balances components temporal contribution

The main water balance components extracted were used to compute the average monthly and mean annual contribution over the whole catchment. Using SWAT Output Viewer (https://swatviewer.com/) it is possible to extract for each water balance component the contribution at mean monthly and annual scale. We have computed mean annual and mean monthly of each water balance components contribution considered over the first period of simulation (1964-1986) and second period of simulation (1988-2010). Therefore, the mean annual and monthly water balance component contributions were used to show the percentage of each water balance components at annual and monthly scale using radars and sectors in excel.

RESULTS AND DISCUSSION

Water balance components contribution between 1964 and 1986

Figure 2a-b and Figure 3a-b display the mean inter-annual and intra-annual (seasonal) variability of water balance components. The most important component of water balance selected are precipitation, evapotranspiration, percolation, groundwater, surface runoff, water yield, lateral flow (Begou et al., 2016; Obuobie et al., 2010).

The reported average annual values over MRB of water balance component appearance in (Koubodana et al., 2020a) and maps in Figure 2b show that actual evapotranspiration (31.33%) and water yield (25.95%) have more than 50% of the total average annual water cycle component between 1964 and 1986. The high actual evapotranspiration rate can be explained by the type of land cover and the high temperature in the study area. Lateral flow contribution is the lowest (0.40%) process occurring in the study area in annual average (Figure 2b). The total water yield is the net amount of water that leaves the basin and contributes to streamflow annually is important after evapotranspiration in the basin. The mean water that percolates past the root zone during annually as percolation represents 17.67%; groundwater contribution to streamflow is 14.71% and surface runoff is about 9.94% annually.

Inter-annual average value of water components presented in Figure 2a the variability of these components for each year. Indeed, lateral flow contribution is very low for during each year whereas the others components such as actual evapotranspiration, water yield, percolation, groundwater and surface runoff decrease respectively. During the year of 1968, 1978 and 1980 the annual contribution of water yield is higher that actual evapotranspiration. There are high values of surface runoff in the year 1968, 1979 and 1980 while maximum actual evapotranspiration is observed in 1967, 1975, 1978 and 1984. The same year of high evapotranspiration were also known to have negative annual rainfall variability index (Koubodana et al., 2020b). The change in water cycle components from year to year are due to the variation of climate condition such as temperature, relative humidity and surface land condition which have impacts on any watershed hydrological system (Badjana et al., 2017; Golmohammadi et al., 2014).

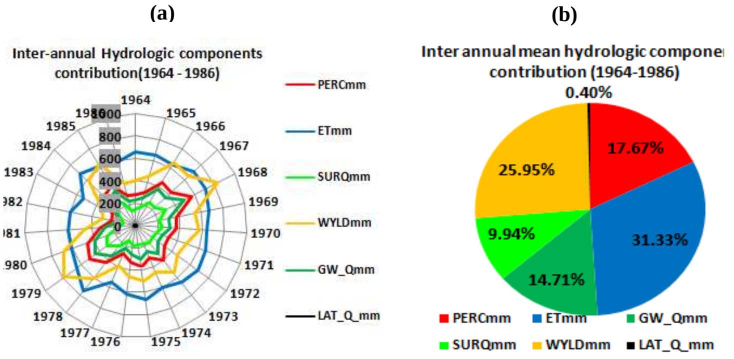
(a) (b)

Figure 2: *Inter-annual variability of hydrological components between 1964 and 1986 with land use map of 1975*

An intra annual mean of water cycle components and the graphs of the temporal changes are observed in Figure 3a&b. It appears that actual evapotranspiration has 51.02% of the global while percolation, water yield, surface runoff, groundwater and lateral flow represent respectively 17.53%, 15.93%, 9.43%; 5.67% and 0.42% of total. The peak of actual evapotranspiration, surface runoff, percolation and water yield are obtained in September and corresponding to the maximum of rainfall which coincides with the rainy season in the region. The lateral flow which depends specifically of the slope of the basin is not important and could be explained the elevation range in the basin. Seasonally, in Figure 3a the maximum of rainfall is ranged from May to October and represent 51.02% of the water balance components.

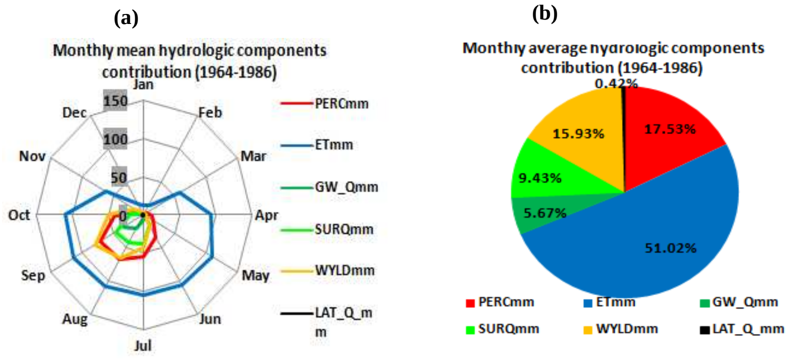

***Figure 3**: Intra-annual variability of hydrological component between 1964 and 1986 with land use map of 1975*

Water balance components contribution between 1988 and 2010

Figure 4a&b and Figure 5a&b show the inter-annual and intra-annual evolution of water balance components over MRB. The maximum runoff value is displayed in 1991, 1993, 1997, 1999, 2002, 2005 and 2009.

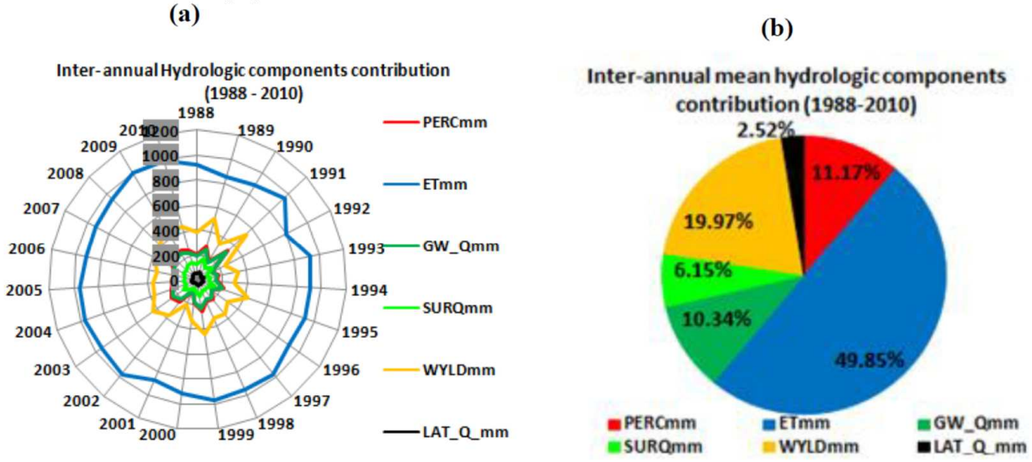

***Figure 4:** Inter-annual variability of hydrological component between 1988 and 2010 with land use map of 2000*

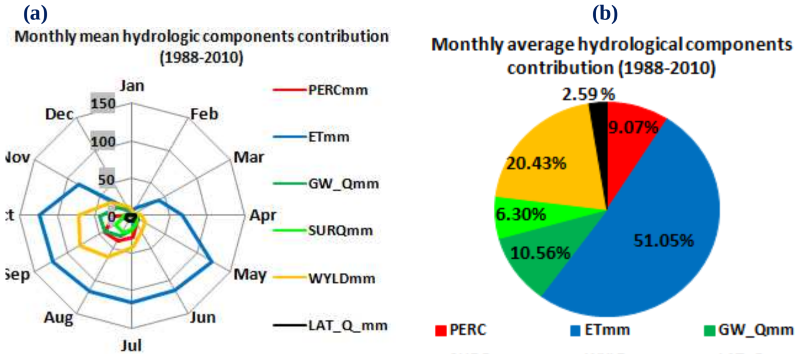

***Figure 5**: Intra-annual variability of hydrological component between 1988 and 2010 with land use map of 2000*

The percentages of each water cycle components for inter-annual and intra-annual scale are actual evapotranspiration (49.85%), water yield (19.97%), percolation (11.17%), groundwater (10.34%), surface runoff (6.15%) and lateral flow (2.52%). Consequently, actual evapotranspiration and water yield components represent more than 60% of the total. The average actual evapotranspiration between 1988 and 2010 is around 900mm/year. Annual mean percolation and groundwater have similar to high value displayed in 1991, 1995, 1999, 2003 and 2008.
By comparison of inter-annual components in the second simulation, there is an increase of actual evapotranspiration and lateral flow whereas a decrease of water yield, surface runoff groundwater and percolation were observed. In contrary to the intra-annually observations there is decrease of percolation, surface runoff and increase of groundwater, lateral flow and actual evapotranspiration.

For water management strategy planning, analysis of individual water balance component contribution at temporal and spatial scales is required. Sathian and Symala (2009) indicate that precipitation, actual evapotranspiration, percolation, groundwater, surface runoff, water yield and lateral flow are the most important components of water balance in a watershed. Within these components, precipitation is an input variable in hydrological models and the others need to be predicted because of inexistent observation data (Ghoraba, 2015). Actual evapotranspiration and water yield components contribution are important over the two periods of inter-annual and intra-annual scales as displayed in Figure 2, Figure 3, Figure 4 and Figure 5. Actual evapotranspiration is the highest amount of water loss by the watershed in annual and monthly mean scale. The high amount of actual evapotranspiration can be explained by the various type of vegetation and also by the increase of temperature in the study area (Koubodana et al., 2019b; 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 from 51.02% (1964-1986) to 51.05% (1988-2010) for intra-annual period.

This increase of water actual evapotranspiration from the pre-dam period to post-dam installation period is due to the increasing CO_2 concentrations in the atmosphere, land-use and land cover changes or decreasing wind speed (Koubodana et al., 2020b, 2019). The second major water component 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 of all case is lost as streamflow. The amount percentage is ranging from 0.40% (1964-1986) to 2.52% (1988-2010). According to Figure 2b and Figure 4b, water yield decreases from 25.95% between 1964 and 1986 to 19.97% between 1988 and 2010 at inter-annual scale whereas Figure 3b and Figure 5b show in intra-annually the amount has decreased from 15.93% (1964-1986) to 20.43% (1988-2010). Lateral flow is the lowest (1988-2010) for inter-annual average and from 0.42% (1964-1986) to 2.59% (1988-2010) for intra-annual average. 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 uniform in the basin and ranges from 12 to 948m.

The results of water cycle components contribution confirmed most analysis performed in West Africa (Akpovi et al., 2016; Awotwi et al., 2015; Begou, 2016; Hounkpè, 2016). Over inter-annual analysis of the two sub-periods, 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 contribution is higher and with positive rainfall index (Koubodana et al., 2019b). The years of 1977, 1982, 1983, 1986, 1990 and 2002 present the period with lowest surface runoff and associated with negative rainfall variability index in section 5.2 and confirmed the years of drought in West Africa (Koubodana et al., 2019b; Oguntunde et al., 2006; Yabi and Afouda, 2012).

CONCLUSION

The analysis of water balance component contribution variation over Mono riber basin indicated that its changes depend of the period of SWAT model simulation. At seasonnal sacle actual evapotranspiration, percolation, water yield represented more than 75% of total water balance between 1964 and 1986 and between 1988 and 2010. The contribution of these water balance components at annual mean scale between 1964 and 1986 are actual evapotranspiration (31.33%), water yield (25.95%), percolation (17.67%), groundwater (14.71%), surface runoff (9.94%) and lateral flow (0.40%) while between 1988 and 2010, actual evapotranspiration (49.85%), water yield (19.97%), percolation (11.17%), groundwater (10.34%), surface runoff (6.15%) and lateral flow (2.52%). The peak of actual evapotranspiration, surface runoff, percolation and water yield appear in September corresponding to one month after the maximum of rainfall and while the periode of flooding and drought are represented by high of low surface runoff in the baisn. These results are important in order to support policies, decision-making and relevant authorities for a sustainable water resource management at watershed level.

Acknowledgments: Authors like to thank the German Ministry of Education and Research (BMBF) for their financial through the West African Science Service Center on Climate Change and Adapted Land use (WASCAL) and the Graduated Research Programme on Climate Change and Water Resources at the University of Abomey Calavi Benin.

References

Akpovi, K., Antwi, E.O., Kabo-bah, A., 2016. Impacts of Rainfall Variability , Land Use and Land Cover Change on Stream Flow of the Black Volta. Hydrology 3, 1–24. https://doi.org/10.3390/hydrology3030026

Amoussou, E., Tramblay, Y., Totin, H.S. V, Mahé, G., Camberlin, P., 2014. Dynamique et modélisation des crues dans le bassin du Mono à Nangbéto (Togo / Bénin). Hydrol. Sci. J. 59, 2060–2071. https://doi.org/10.1080/02626667.2013.871015

Arbonnier, M., 2000. Arbres, Arbustes et Lianes des Zones Sfleches d'Afrique de l'Ouest, vol. 2. Edition CIRAD-MNHN-UICN, Montpellier, France.

Arnold, J.G., Srinivasan, R., Muttiah, R.S., Williams, J.R., Arnold, J.G., Bednarz, S.T., Srinivasan, R., 1998. Large Area Hydrologic Modeling and Assessment Part I: Model Development. J. Am. Water Resour. Assoc. 34, 73–89. https://doi.org/10.1111/j.1752-1688.1998.tb05961.x

Awotwi, A., Kumi, M., Jansson, P.E., Yeboah, F., Nti, I.K., 2015. Predicting Hydrological Response to Climate Change in the White Volta Catchment, West Africa. Earth Sci. Clim. Chang. 6, 1–7. https://doi.org/10.4172/2157-7617.1000249

Badjana, H.M., Fink, M., Helmschrot, J., Diekkrüger, B., Kralisch, S., Afouda, A.A., Wala, K., 2017. Hydrological system analysis and modelling of the Kara River basin (West Africa) using a lumped metric conceptual model. Hydrol. Sci. J. 62, 1094–1113. https://doi.org/10.1080/02626667.2017.1307571

Begou, J.C., 2016. Hydrological Modeling of the Bani Basin in West Africa: Uncertainties and Parameters Regionalization. PhD of Graduate Research Program on Climate Change and Water Resources (GRP-CCWR) of the University of Abomey-Calavi (Benin Republic), Public defense on: 26/10/2016.

Begou, J.C., Jomaa, S., Benabdallah, S., Bazie, P., Afouda, A., Rode, M., 2016. Multi-Site Validation of the SWAT Model on the Bani Catchment: Model Performance and Predictive Uncertainty. Water (Switzerland) 8, 1–23. https://doi.org/10.3390/w8050178

CILSS, 2016. Landscapes of West Africa- A Window on a Changing World. 47914 252nd St, Garretson, SD 57030, UNITED STATES.

Cornelissen, T., Diekkrüger, B., Giertz, S., 2013. A comparison of hydrological models for assessing the impact of land use and climate change on discharge in a tropical catchment. J. Hydrol. 498, 221–236. https://doi.org/10.1016/j.jhydrol.2013.06.016

Ghoraba, S.M., 2015. Hydrological modeling of the Simly Dam watershed (Pakistan) using GIS and SWAT model. Alexandria Eng. J. 54, 583–594. https://doi.org/10.1016/j.aej.2015.05.018

Golmohammadi, G., Prasher, S., Madani, A., Rudra, R., 2014. Evaluating Three Hydrological Distributed Watershed Models: MIKE-SHE, APEX, SWAT. Hydrology 1, 20–39. https://doi.org/10.3390/hydrology1010020

Hanjra, M.A., Qureshi, M.E., 2010. Global water crisis and future food security in an era of climate change. Food Policy 35, 365–377. https://doi.org/10.1016/j.foodpol.2010.05.006

Hounkpè, J., 2016. Assessing the climate and land use changes impacts on flood hazard in Ouémé River Basin, Benin (West Africa). Doctor of Philosophy (Ph.D) thesis in Climate Change and Water Resources at University of Abomey Calavi (Benin Republic); Date of defense: 05 September 2016.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; Technical Report. IPCC, Geneva, Switzerland.

Kissi, A.E., Abbey, G.A., Agboka, K., Egbendewe, A., 2015. Quantitative Assessment of Vulnerability to Flood Hazards in Downstream Area of Mono Basin, South-Eastern Togo: Yoto District. J. Geogr. Inf. Syst. 7, 607–619. https://doi.org/10.4236/jgis.2015.76049

Koubodana, H.D., 2015. Mecanismes de connexions entre les modes de varaibilités internannuelle equatorial et meridien de l'Atlantique tropical. These de Master, Chaire Internationale en Physique Mathématique et Applications (CIPMA-Chaire UNESCO), Université d'Abomey-Calavi (UAC), Benin, Soutenu en Octobre 2015.

Koubodana, H.D., Adounkpe, J., Atchonouglo, K., Djaman, K., Larbi, I., 2020a. SWAT-Simulated Streamflow Response to Land Use, Climate Variability and Dam Management in the Mono River Basin, Togo- Benin, West Africa. Int. J. River Basin Manag. 52.

Koubodana, H.D., Adounkpe, J., Tall, M., Amoussou, E., Atchonouglo, K., Mumtaz, M., 2020b. Trend Analysis of Hydro-climatic Historical Data and Future Scenarios of Climate Extreme Indices over Mono River Basin in West Africa. Am. J. Rural Dev. 8, 37–52. https://doi.org/10.12691/ajrd-8-1-5

Koubodana, H.D., Diekkrüger, B., Näschen, K., Adounkpe, J., Atchonouglo, K., 2019. Impact of the Accuracy of Land Cover Data Sets on the Accuracy of Land Cover Change Scenarios in the Mono River Basin, Togo, West Africa. Int. J. Adv. Remote Sens. GIS 8, 3073–3095. https://doi.org/10.23953/cloud.ijarsg.422

Lawin, A.E., Lamboni, B., Manirakiza, C., Kamou, H., 2019. Future Extremes Temperature: Trends and Changes Assessment over the Mono River Basin, Togo (West Africa). J. Water Resour. Prot. 11, 82–98. https://doi.org/10.4236/jwarp.2019.111006

Obuobie, E., Diekkrüger, B., Reichert, B., 2010. Use of chloride mass balance method for estimating the groundwater recharge in northeastern Ghana. Int. J. River Basin Manag. 8, 245–253. https://doi.org/10.1080/15715124.2010.505895

Oguntunde, P.G., Friesen, J., Giesen, N. Van De, Savenije, H.H.G., 2006. Hydroclimatology of the Volta River Basin in West Africa: Trends and variability from 1901 to 2002. Phys. Chem. Earth, Parts A/B/C 31, 1180–1188. https://doi.org/10.1016/j.pce.2006.02.062

PCCP, 2008. PROGRAMME PCCP -From Potential Conflict to Cooperation Potential: cas du basin du Mono (Togo-Benin). Lomé-Togo.

Rossi, G., 1996. L'impact des barrages de la vallée du Mono (Togo-Benin). La gestion de l'incertitude. Géomorphologie Reli. Process. Environ. 2, 55–68. https://doi.org/10.3406/morfo.1996.878

Sathian, K., Symala, P., 2009. Application of GIS integrated SWAT model for basin level water balance. Indian J. Soil Cons 37, 100–105.

Speth, P., Christoph, M., Diekkrüger, B., 2010. Impacts of Global Change on the Hydrological Cycle in West and Northwest Africa, Springer S. ed. Springer Heidelberg, Germany. https://doi.org/10.1007/978-3-642-12957-5_1

Yabi, I., Afouda, F., 2012. Extreme rainfall years in Benin (West Africa). Quat. Int. 262, 39–43. https://doi.org/10.1016/j.quaint.2010.12.010