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RESEARCH ARTICLE

IMPACTS OF LAND-USE, LAND-COVER, AND CLIMATE CHANGES ON STREAMFLOW IN THE UPPER LUFIRA CATCHMENT, D.R. CONGO

Mumba Tshanika Urbain[a,b*], Mulungu Deogratias[b], Kasongo Lenge Mukonzo Emery[c], Kalambulwa Nkombe Alphonse[a] and Ilunga Muledi Jonathan[a].

[a]*Université de Lubumbashi, Faculty of Agronomic Sciences, Department of Ecosystem and Biodiversity Management, Research unit in Ecology, Ecological Restoration and Landscapes, Route Kasapa, Campus Universitaire, Box 1825, Lubumbashi, Democratic Republic of the Congo*
[b]*University of Dar es Salaam, College of Engineering and Technology, Department of Water Resources Engineering, Box 35131, Dar es Salaam, Tanzania*
[c]*Université de Lubumbashi, Faculty of Agronomic Sciences, Research unit in Land Evaluation, Soil Conservation and Agro-meteorology, Route Kasapa, Campus Universitaire, Box 1825, Lubumbashi, Democratic Republic of the Congo*
**Corresponding Author Email: Mumba.Tshanika@Unilu.ac.cd, mumbatagro1@gmail.com.*

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ABSTRACT

Hydrological processes are often influenced by the changes in land use, land cover, and climatic variables that negatively or positively affect all the hydrological components. For the Upper Lufira catchment, the factors affecting runoff and its relationship with land use/cover are less known. Thus, this study aims to assess the impacts of climate change and LULC change on streamflow of the Upper Lufira catchment using the powerful Soil and Water Assessment Tool.

This study required three categories of data: a set of historically available climate data from 1990 to 2013, spatial data (DEM, two land use/cover maps respectively for 2000 and 2010, and a soil map), and hydrometric data.

The results showed that streamflow was affected by the changes in LULC and Climate between 1998 and 2013 mainly by reducing it. The changes were also observed for other hydrological components. Lateral flow, base flow, evapotranspiration, and Percolation increased while surface runoff, soil water content, and water yield decreased.

In conclusion, anthropogenic activities do indeed have a significant impact on streamflow as well as on hydrological components in the Upper Lufira catchment. Thus, we have recommended careful control of all human activities in the catchment, mainly by regulating deforestation activities and improving reforestation activities in the context of catchment sustainable management.

KEYWORDS

Climate change, DRC, land-use, land-cover, streamflow and Upper Lufira catchment.

1. INTRODUCTION

River catchments offer many goods and services to the entire humanity (Tickner et al., 2017; Opperman et al, 2018). These can generally be supporting services for sustaining the ecosystem life, recreational services, provisioning services as well as ecological services (MEA, 2005). However, these provided services and advantages from the catchment are not able to meet all human needs; and hence, catchments are facing several threats such as land-use changes on the first hand and climate change on the other hand (Kumar et al., 2021).

Nowadays, due to anthropogenic activities, watershed services and functions are subject to several threats and have been seriously affected (Lake, 2012). Invasive species, overexploitation, pollution, and climate change are some of the threats which exert significant impact on any catchment (Collen et al., 2014). Moreover, other human activities have substantially impacted the hydrological processes such as recurrent deforestation contributes to catchment water losses by increasing the evaporation rate from the soil overgrazing has effect on water quality deterioration and soil compaction changes in farming systems as farmland left in fallow combined with cattle and goats reduce the infiltration rate of rainwater (Sandström et al., 1995; Cassiano et al., 2007; Li et al., 2004). They can also be affected by natural disturbances such as fires, storms, and diseases. Deterioration of catchment functions has considerable detrimental impacts, including erosion and depletion of soil productivity, siltation of rivers, reservoirs and shorelines, increased runoff and flash flooding, reduced infiltration into groundwater, degradation of water quality, and loss of aquatic habitats and biodiversity (Sandström, et al., 1995; Li et al., 2004). Similarly, the impacts of climate change are likely to be significant in the catchment areas, mainly in the modification of river flow regime due to the significant influence on rainfall and temperature which are being affected (Schneider et al., 2013).

In the Democratic Republic of Congo (DRC), the combined effects of land use land cover and climate changes are more evident on the hydrological components especially in domestic water availability (Chishugi et al., 2021). There is a great increase of greenhouse gases (GHGs) due to deforestation, urbanization, population growth, inappropriate land use and allocation, inappropriate industrial processes, lack of awareness, and legal and institutional weaknesses (Kissinger et al., 2012; IPCC, 2019).

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case of increased forest area (Martins et al., 2021). With an overview of our results, forest areas are characterized by a significant decrease of about 6% between 2000 and 2010 while precipitation has increased during the same period and end up with similar results reported by (Martins et al., 2021). Thus, other factors would explain these results in the Upper Lufira catchment. Among them, the remaining vegetation continues to maintain the balance in the catchment and its hydrological cycle. In addition, the important presence of plains as well as the edaphic characteristics of the watershed contribute significantly to the activities of the hydrogeological reserves (Darcis and Soyer, 1983).

4. Conclusion

The overall objective of this paper was to determine the impacts of LULC and Climate changes on streamflow at the catchment scale using the hydrological modelling approach throughout the powerful SWAT model which was recognized as suitable for such analysis. The model was well calibrated and validated for the better simulations. The results have shown that all impacts whether assessed individually or combined have the same impacts on streamflows. These were affected negatively all hydrological components. The climate change assessed separately with only a focus on rainfall assessment, has clearly shown that when rainfall had an upward trend, the streamflow decreased for the Upper Lufira catchment because of the severe LULC changes which have important modifications on vegetation cover and modifying the edaphic properties by increasing the infiltration process for groundwater recharge due to the geomorphology terrain (with plains mainly) of the ULC. LULC change had been observed by an important increase of Urban built-up area, agricultural land, and shrublands over the period from 2000 to 2010 while the natural forests, grassland, and wetlands have decreased. On streamflow, LULC change affected the hydrological cycle. Moreover, the combined impacts of climate change and LULC change on streamflow showed that all water balance components were negatively affected as demonstrated above. In conclusion, the paper tried to demonstrate how the anthropogenic activities have played an important role in affecting the streamflow and all other hydrological cycle components. Thus, we suggest the following aspects to be considered for future studies among others: the implementation of an integrated water resources management plan for the Upper Lufira Catchment and studies focused on groundwater recharge to better understand the phenomenon explaining the performances observed in this component of the hydrological cycle of the Upper Lufira catchment.

Authors' Contributions

Urbain Mumba Tshanika: Conceptualization, methodology development, data collection and analysis, writing.

Alphonse Kalambulwa Nkombe: Support in data collection and analysis and manuscript writing.

Jonathan Ilunga Muledi: Conceptualization, direction, Manuscript reviewing and logistical support.

Deogratias Mulungu: Overall direction of the research, logistical support, reviewed and edited the manuscript.

Emery Kasongo Lenge: Data provider and Manuscript reviewing.

Declaration of Competing Interest

The authors declare no conflict of interests.

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