Impacts of Climate and Land use/cover change on Mini-hydropower generation in River Kyambura watershed in South Western part of Uganda

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1. Introduction

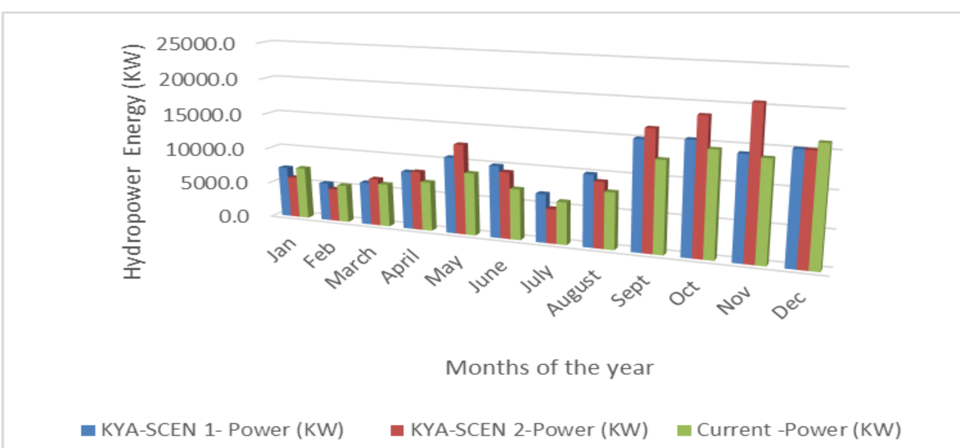
Both climate change and land use/cover change have an impact on water resources. On a global scale, many studies have been carried out on assessing the effect of land use change on river flows (Amini *et al*., 2011; Guzha *et al*., 2018; Bosmans *et al*. 2016; Welde & Gebremariam 2017) and climate change on river flows (Taye *et al*. 2015; Ogiramoi, 2011; Duong, 2016; Kangume, 2016; Taylor et al. 2014). To mitigate climate change impacts, several solutions have been proposed to reduce greenhouse gas emissions. Hydropower is so far the most lucrative option due to its renewability, lower emissions, and longevity of infrastructure. Electricity is very important for national development. Though the hydropower sector makes a significant effort to cope with today's rising world energy demands, this is difficult due to climate and land use/cover change effects. Madani (2011) stated that climate change will have a variety of effects on streamflow, involving quantity and timing, sediment load, temperature, and ecosystem changes. This affects hydropower generation. In Uganda, such trends have been experienced in several watersheds such as the river Mpanga watershed. The flow of river Mpanga has been dwindling with time. This has negatively affected the hydropower production capacity of the Mpanga mini-hydropower station to an extent that it is sometimes shut down due to low power generation (Taylor et al.,2015). This study aimed at modeling the impacts of climate and land use/cover change on Mini-hydropower generation in River Kyambura watershed in South Western part of Uganda. To assess the possible impact of climate and land use/cover change on hydropower generation, analysis of the river flow related to climate and land use variability is required, as it will help planners and managers operate the hydropower plant efficiently as well as help in developing decision support systems to maintain the integrity of river Kyambura.

2. Methodology

In this study, ArcSWAT which is an ArcGIS/ArcMap extension, was used as the main modeling software. The SDSM software version 4.2 was used to downscale meteorological data and project future climatic conditions. ArcMap 10.5 was used to process and classify land use images whereas Terrset software was used to project land use changes within the catchment by the year 2050. Spatial, meteorological, soil, ground trothing, daily river flow and land use/cover data which were prerequisites for developing the SWAT model for the Kyambura catchment, were obtained, tested for trends, consistency, analyzed and used in this study. Daily time series of hydro-meteorological data of Rubirizi-saza-quarter weather station for a 31-year period (1989 – 2019) was obtained from the NASA website. Landsat 5, 7, and 8 data were obtained for the years 1989, 2009 and 2019. They were enhanced, and classified into four classes (Vegetation, Urban, Open water and Barren Land) using the maximum likelihood classifier in ArcMap. A future Land Cover map for the year 2050 was developed using the Land Change Modeler of TerrSet software. SDSM software was then used to downscale meteorological data and project mean temperatures and rainfall of the Kyambura watershed for the year 2050. Two study scenarios were then created i.e KYA-SCEN 1 and KYA-SCEN 2. In KYA-SCEN 1, Land Use and Land Cover (LULC) for 2019 was assumed to be constant until the year 2050, whereas climate was allowed to vary. In KYA-SCEN 2, both climate and LULC were allowed to vary as predicted by SDSM and TerrSet software. The two scenarios were run in the validated ArcSWAT model and the simulated flow output files were compared with the simulated flow for 2019. Hydropower potential for the Kyambura mini-hydro power station was then calculated for the three datasets.

3. Results

In the year 2050, it was predicted that there would a 7% increase in precipitation and an increase in temperature by 0.5^{o}C. LULC was predicted as follows; there was to be an increase in urban land by 11.89%, barren land by 25.78%, water by 0.49% and a reduction in the vegetation coverage by 38.17%. This resulted into an increase in the simulated streamflow by 12 % and 18% for KYA-SCEN 1 and KYA-SCEN 2 respectively.



Hydropower potential comparisons

In comparison with the present/current power potential there will be a general increase in the amount of power produced in 2050. Total annual Power generated was predicted to increase by 10.6% and 17.7% for KYA-SCEN 1 and KYA-SCEN 2 scenarios respectively. It was also evident that high power loads were generated during wet seasons and very low in dry seasons. During the two dry seasons, the amount of power generated was lower than the 7600KW plant design capacity in February and July.

4. Conclusion and recommendations

In conclusion, this study has shown that climate and Land use/cover change have an impact on hydropower generation in the Kyambura catchment. LULC has been and will continue changing. The SWAT model for the Kyambura catchment was setup and Correlation coefficients (R^2) of 0.788 and 0.688 were obtained during ArcSWAT model calibration and validation respectively. From the climate prediction and analysis, the total annual rainfall was predicted to increase by 7% and temperature by 0.5^{o}C by the year 2050. This therefore implies that there is evidence of climate change within the catchment. There was a streamflow increase in both study scenarios which inturn affected the hydropower generation potential of the Kyambura mini-hydropower station. The study therefore reveals that there is a strong relationship between climate, LULC change, stream flows and eventually hydropower generation.

I therefore recommend that National Environmental Management Authority (NEMA) develops a catchment-based environmental protection program through re-afforestation and enforcing buffer zones alongside the Kyambura River and employ all other catchment-based management practices to keep the integrity of the catchment. This study did not take into consideration of sedimentation impacts on the hydropower station. It is therefore recommended that future studies be carried out in this regard.

5. **Experience/lessons learnt** in the CAWESDEA internship programme

I have learnt the following during this program;

- Modeling future climate change using SDSM
- Land Use and Land Cover classification using ArcMap/ArcGIS
- Modeling Land Use and Land Cover for the future using LCM in TerrSet software
- Analysis and statistical downscaling of meteorological data
- Modeling hydrological response to Land use and climate changes
- Calibration and validation the ArcSWAT model
- Hydropower potential design basics and principles
- Modeling impacts of climate and Land cover change on hydropower generation potential of any mini-hydro power station

Apart from the scientific and engineering experience, I have learnt how to manage a project from the beginning to the end, engaging many stake holders in order to get the required data and information, and I have been able to appreciate that I can actually add knowledge to the engineering sector through continuous research and innovation. I am a better engineer than I was before this program.