Journal of Hydrology: Regional Studies 4 (2015) 333–348

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

# Uncertainty of runoff projections under changing climate in Wami River sub-basin

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## ARTICLE INFO

*Article history:*
Received 26 December 2014
Received in revised form 25 May 2015
Accepted 29 May 2015
Available online 28 July 2015

*Keywords:*
Delta method
Fuzzy extension principle
Sensitivity
Skill score
Uncertainty
Wami

## ABSTRACT

**Study Region:** The Wami River sub-basin is among the river sub-basins with a vital ecosystem in Tanzania. It comprises the Saadani National park and it has the very great potential of irrigation and rain fed agriculture.
**Study Focus:** The objective of this study was to evaluate the uncertainty of future streamflow in respect of increasing water demands and uncertain projected climate inputs, General Circulation Models (GCMs). The water demands were projected to the year 2039 and GCM precipitation was selected as the changing climatic variable. The CMIP5-GCMs were evaluated for their skills and those with the minimum skill scores above 75% were downscaled and used in projection of scenario RCP 8.5 precipitation. Then uncertainties of RCP 8.5 precipitation were estimated using a fuzzy extension principle and finally used to simulate uncertainties of future runoff using a rainfall-runoff model, Soil and Water Assessment Tool (SWAT).
**New Hydrological Insights for the Region:** The results of projected streamflow shows that the baseline annual climatology flow (ACF) is 98 $m^3/s$ and for the future, the median ACF is projected to be 81 $m^3/s$. At 100% uncertainty of skilled projections, the ACF from the sub-basin is projected to range between −47% and +36% from the baseline ACF. However, the midstream of the sub-basin shows reliable water availability for foreseen water uses expansion up to the year 2039.


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http://dx.doi.org/10.1016/j.ejrh.2015.05.013
2214-5818/

## 1. Introduction

Rigorous studies on climate change impact on streamflow in Tanzania were conducted in the Pangani basin (Notter et al., 2013), Ruvu River sub-basin (Mwandosya et al., 1998) and the Wami River sub-basin (Wambura, 2014). In the Pangani basin, Notter et al. (2013) studied climate change impact on streamflow using two individual GCMs representing the extremes of available IPCC predictions (i.e. the driest and wettest conditions). On the other hand in the Ruvu River sub-basin, Mwandosya et al. (1998) researched on the impact of climate change on streamflow using individual GCM showing the lowest Root Mean Squared Error (RMSE) in predicting the historical climate. In the Wami River sub-basin, Wambura (2014) studied the response of streamflow under changing climate using individual GCM showing the highest skill score in predicting the historical climate.

However, in the case of climate change, the use of the RMSE statistic (Mwandosya et al., 1998) for selection of GCMs does not compare corresponding dates and thus does not test GCMs' season variability capability. Without testing GCMs' spatial skill across the sub-basin, the reliability of the selected GCM in predictions cannot be guaranteed (Wambura, 2014). However, projections of future climate without uncertainty resulting from GCMs having similar performances in control period, but very different future predictions, compromises the credibility of a single GCM predictions (Nóbrega et al., 2011; Todd et al., 2011; Wambura, 2013). The point estimates are very uncertain because different GCMs often disagree, even in the direction of change on precipitation, although temperature can be relatively consistent between GCMs (Randall et al., 2007; Wambura, 2013). Therefore, there is a need to address the important issue of skilled GCM uncertainty using uncertainty bounds from several different skilled GCMs projections. Thus the technique (fuzzy set analysis) which includes all GCMs in estimating uncertainty at various levels from the median projection of the downscaled GCMs is preferred.

Fuzzy set theory is a powerful tool for analysing the kind of uncertainty associated with a lack of information regarding a particular element of the problem at hand. In fuzzy set theory an element may have the degree of applicability, rather than simply being true or false. Another advantage of fuzzy set theory is that it allows for continuous values of membership between the full certainty and full uncertainty (Gonzalez et al., 1999). Since most of the GCMs project different future climate and there is a lack of information on which GCM is reliable, therefore fuzzy set analysis is the right approach in analysing that vagueness (Guyonnet et al., 2003; El-Baroudy and Simonovic, 2006; Wambura, 2013). The technique includes selected GCMs in estimating uncertainty at various levels of confidence. In a family of fuzzy set theory, the triangular fuzzy number (fuzzy extension principle) is one of the most common fuzzy number. It solves many practical and complex problems(Liang et al., 2005). The selection of fuzzy numbers seems not very essential because they have no significant difference in the performance (Chen et al., 2008). However, even with the use of fuzzy set analysis in constructing uncertainty of various GCMs, the resolution scale of GCMs still affects the representation of local climate, thus downscaling of GCMs to the point or region of interest is also preferred.

The GCMs have coarse resolution of about $1.3^\circ \times 2.7^\circ$ latitude and longitude scale, therefore it is important to downscale them. There are many methods available for downscaling GCM projections to the specific region or study area of interest, for discriminating between mean changes and changes in climatic variability and for ensuring consistency between climate change scenarios. The common methods are dynamic downscaling, statistical downscaling and simple approaches like bias correction methods. Dynamic downscaling involves extraction of local scale information by developing limited area models or regional climate models with coarser resolution GCM data used as boundary conditions. But the demerit with this method is that the downscaling process requires computing faculties with very high computing efficiency (Wilby and Wigley, 1997). Statistical downscaling involves developing a quantitative relationship between large scale atmospheric variables and local surface variables. The local climate information is derived by determining a statistical model which relates large scale climatic variables to local climatic variables. Then the large scale output of a GCM simulation is fed into the statistical model to estimate the corresponding local climate characteristics. The simplest statistical downscaling technique is application of GCM-scale projections in the form of the delta method (Fowler et al., 2007). However, Fowler et al. (2007) argued that simple methods for downscaling GCMs projections are effective in simulating hydrological systems.