Effects of Landscape Attributes and Climate Variables on Catchment Hydrology

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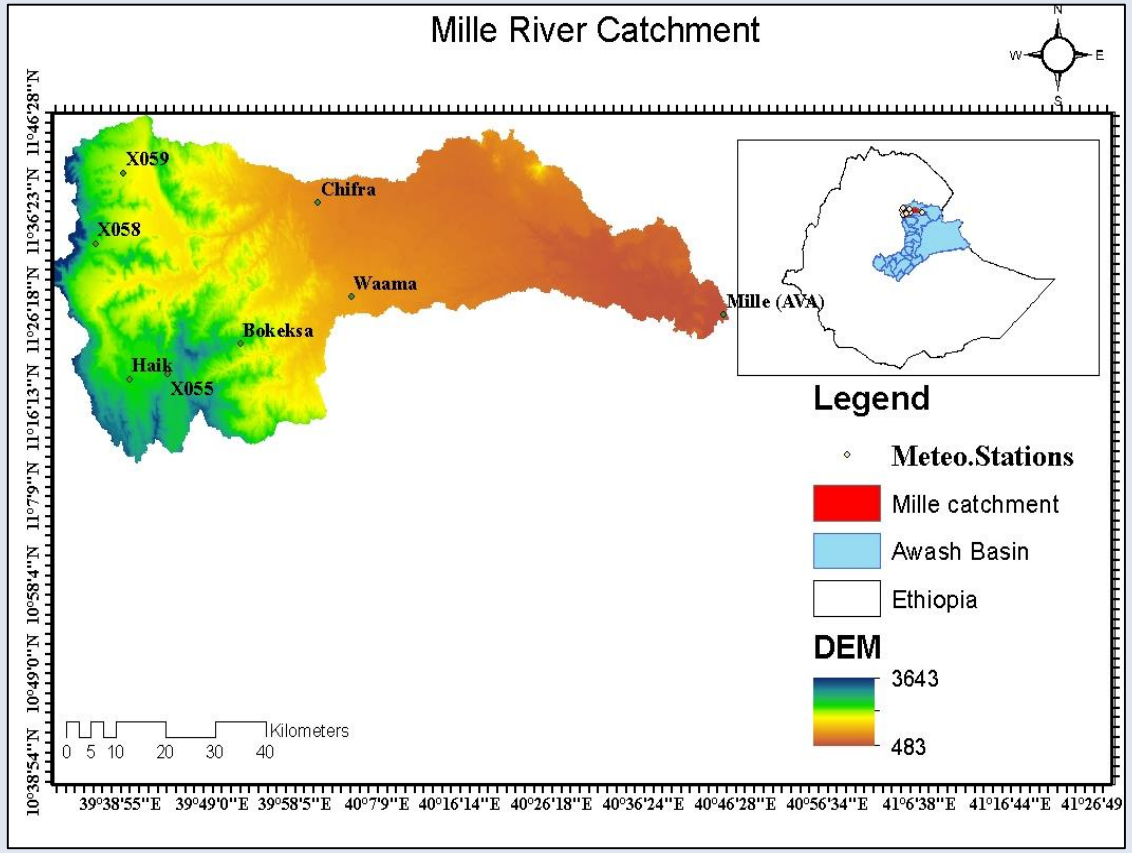
Introduction

- Water resources and hydrology's spatiotemporal variation are extremely disturbed by catchments characteristics (DeFries & Eshleman, 2004; Zhu & Day, 2009; Mao & Cherkauer, 2009), specifically, developing countries like Ethiopia, where water is a stressed resource (Chatterjee, 2018; Kassas, 1976).
- So, evaluating the impacts of landscape-climate descriptors on catchments' hydrological regime response is important for the management and development of catchments (Chiverton et al., 2015; Ersi et al., 2022; Hatfield & Prueger, 2014; Xiao et al., 2019).

- This chapter aims to analyze mean monthly streamflow and potential evapotranspiration (PET) with limited landscape-climate descriptors.
  - Via answering the following questions regarding streamflow-potential evapotranspiration and limited landscape-climate predictors at the catchment scale:
    (1) Which landscape-climate descriptors are likely to affect the streamflow temporal variation?
    (2) Which landscape-climate descriptors are the factors that drive spatiotemporal variation of potential evapotranspiration within the Mille catchment? and
    (3) Which landscape or climate predictor has the dominant impact on streamflow and potential evapotranspiration?

Study Area

- Lies between 11°26′ to 11°46′N latitude and 39°38′ to 40°46′E longitude.
- Covers an area of 4,390.1 km2.
- Complex mountainous terrain and various climatic conditions characterize the catchment.



Datasets

- Daily meteorological datasets were acquired from NMA (1983-2002).
  - Include rainfall, maximum and minimum air temperature, relative humidity, solar radiation, and wind speed.
- Potential evapotranspiration at each meteorological station was estimated using the Hargreaves method stated as:

$$ET_0 = 0.00023 * RA * TD^{0.50}(T^0C + 17.8)$$

- The mean monthly areal R (mm), T (°c), and PET(mm) were estimated using kriging with external drift (KED) (Goovaerts, 2000; Hirpo et al., 2022; Webster, 2015).
- The potential dryness index (PDI) was calculated as the ratio between mean monthly areal potential evapotranspiration and mean monthly areal rainfall.

Datasets…contd.

- Average daily stream flow (1983-2002) was provided by the MoWE, Ethiopia.
- Average soil water content (SWC) (mm) extracted from SWAT+ model calibrated dataset.
- Monthly point and spatial areal NDVI was extracted from MOD13A1-006 MODIS/Terra using AppEEARS software.
  - 500m spatial and 16 days temporal resolution
  - The monthly mean NDVI was averaged.
- Base flow (mm) was estimated from total stream flow records using the Base flow Digital Filter Program.
- Base flow index (BFI) was calculated as the ratio of base flow to total streamflow.
- Elevation and Easting were extracted from 30m SRTM DEM.

Statistical Analysis and Modeling Technique

- Regression analysis was computed to examine relationships between hydrological regime responses, and landscape-climate descriptors using R programming software.
- The analysis procedure involved the following two steps:
  - A multiple linear regression analysis using :

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_i x_i + \varepsilon$$

  - Checking multicollinearity:

$$\mathbf{VIF_i} = \frac{\mathbf{1}}{(\mathbf{1}-\mathbf{R_i^2})}$$

Results

- The multiple linear regression analysis of mean monthly stream flow with limited landscape attributes and climate variables was analyzed.
  - Among all the explanatory variables, only rainfall is strongly significant for explaining the temporal variation in stream flow (P-value = 0.0005753 < 0.001 significance level).
- The regression model depicts that the mean monthly temperature is the most significant contributor to mean monthly potential evapotranspiration deviation ($p < 0.001$).
- The spatial pattern of mean annual PET within the Mille catchment is strongly significant, and the mean annual NDVI was the most significant contributor on the spatial distribution of PET.

Conclusions

- Overall, understanding factors causing spatio-temporal variation in hydrological regime response like total streamflow and potential evapotranspiration will lead to improving capabilities for water management in various water use systems.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