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Climate change impact on variability of rainfall intensity in the Upper Blue Nile Basin

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Due to the unprecedented increased concentration of greenhouse gases (GHGs) resulting from industries in developed countries, the developing countries are vulnerable to the changing climate (Linacre 2003). Often researchers define climate and weather in an interrelated way. In a general definition, climate is what is expected and weather is what we get. It is clear that the changing climate has become a huge obstacle for many countries' development, and especially for developing countries like Ethiopia. The IPCC defines climate change as the state of climate identified by changes in the mean and/or variability of its properties for long periods, whether due to natural activity or as a result of human activity. But UNFCCC defines climate change in a way different to the IPCC definition: as change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to the natural climate variability over a comparable time period. Here, the UNFCCC definition is more focused on socio-economic activities than physical changes happening in nature (IPCC 2007, Bates *et al*. 2008, Abdo *et al*. 2009). In most cases, including this study, the climate data used for climate change analysis is usually a time series of more than 30-year length.

The IPCC report shows that extreme rainfall and an increasing frequency of rainfall in most areas are very likely to happen in the 21st century with different emissions scenarios. And major projected impacts of these changes are damage to crops, water logging, soil erosion, flooding, adverse effects on groundwater and surface water quality, water scarcity, contamination of water, disease outbreak, loss of properties, disruption of settlement, and different socio-economic challenges (IPCC 2007). As there are a number of climatic and non-climatic drivers influencing flood and drought impacts, the realization of risks depends on several factors. Floods include river floods, flash floods, urban floods and sewer floods, and can be caused by intense and/or long-lasting precipitation, dam break, and reduced conveyance due to landslides. Floods depend on precipitation intensity, volume, timing, antecedent conditions of rivers and their drainage basins (e.g. soil characteristics, wetness, urbanization, and existence of dikes, dams, or reservoirs). Human encroachment into flood plains and lack of flood-response plans increase the damage potential. Flooding is a familiar event in the Upper Blue Nile basin and did cause a lot of destruction in the past years.

Extreme weather events in Ethiopia significantly affect the agro-socio-economic environment. Droughts in northern, southern and eastern Ethiopia cause great human suffering and loss of life. Such consequences not only result from insufficient total rainfall amount, but also from long dry spells within the rainy season. Occasionally, floods and intense rainfall also cause devastating damage to crops and settlements. It is not, however, known whether the extreme events including drought are becoming more frequent and intense in the light of assumed global warming (Seleshi and Camberlin 2006). This study will focus mainly on the climate change impact on rainfall intensity-duration-frequency in the Upper Blue Nile basin. It is difficult to identify the impact of climate change in the Upper Blue Nile basin due to the uncertainty of projected rainfall patterns in various parts of the basin and the water management structure complexity. However, it is important to use spatially and temporally accurate data and a single station in a catchment does not provide reliable data (Di Baldassarre *et al*. 2011). It is also suggested by Di Baldassarre *et al.* (2011) that to analyse the climate change impact, it is more appropriate to use a framework selecting one or more IPCC emissions scenario, one or more general circulation models (GCM), downscaling GCM climate output for the basin scale, using a GCM model for hydrological modelling and comparing the hydrological modelling result with current and future climate.

This study aims to investigate the impact of climate change on rainfall intensity-duration-frequency (IDF) future projections for the Upper Blue Nile basin. If the rainfall intensity increases, floods are likely to happen and cause damage to irrigation schemes, hydropower plants and any agricultural activities. On the contrary, if flooding decreases there would be a famine, shortage of water and food (Bates *et al*. 2008). In order to investigate climate change impact on the IDF curve, rainfall data are downscaled from two GCMs (HadCM3 and CGCM3) with the A2 emissions scenario and rainfall frequency analysis was carried out. After downscaling and frequency analysis quantile estimation, disaggregation of daily rainfall and finally an IDF curve was developed. Rainfall frequency analysis was carried out to estimate the quantiles with different return periods. The Probability Weighted Method (PWM) was selected for estimation of parameter distributions and L-Moment Ratio Diagrams (LMRDs) were used to find the best parent distribution for each station. The parent distributions derived from frequency analysis are Generalized Logistic (GLOG), Generalized Extreme Value (GEV), and Gamma & Pearson III (P3) parent distribution. After analysing the estimated quantiles a simple disaggregation model was applied to find sub-daily rainfall data. Finally, the disaggregated rainfall was fitted to find the IDF curve.

The IDF curve equation is as follows:

$$i = \exp[(\ln(A) - C \times \ln(B + Td))] \tag{1}$$

where i is intensity (mm/h), Td is time duration (min), A, B, and C are the estimated IDF parameters.

The results show that in most parts of the basin, rainfall intensity is expected to increase in the future. As a result of the two GCM outputs, the study indicates there will likely an increase of precipitation extremes over the Blue Nile basin due to the changing climate. This study should be interpreted with caution as the GCM model outputs for this part of the world have huge uncertainty.

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