Land Use Change Impacts on the Peak Flood Discharge and Sedimentation in the Upper Awash Basin, Ethiopia

Mr. Alemayehu Abate Shawul (2014CEZ8253)

Abstract

Quantitative assessment of the impact of land use/land cover (LULC) changes and climate variability on water resources, extreme hydrologic events and sedimentations are important for efficient decisions on sustainable water resources management. Most studies on the effect of LULC change focused mainly on the mean streamflow conditions. However, the effects of LULC on extreme high flow have received less attention. Assessment of data quality, precipitation concentration index (PCI), Mann-Kendall (MK) trend test, and extreme climate change indices analyses were performed. Standard statistical tools were used for the homogeneity test, and most of the climate stations exhibited homogenous annual precipitation series. The supervised image classification method was used to determine the historical LULC changes based on historical series of Landsat imageries. Future LULC change scenarios were developed using the machine-learning approaches in the Land Change Modeler (LCM). The Soil and Water Assessment Tool (SWAT) model was validated at five subbasins for runoff and sediment yield simulations. Moreover, the performance of global precipitation databases were evaluated for hydro-climatic studies in the data scarce regions. Comprehensive assessment of LULC change effect on the water balance components using integrated approaches of hydrologic modeling and partial least squares regression (PLSR) provides better understandings of the impact of recent development activities on water resources. The impact of LC change on the flood frequency was analyzed by fitting the annual maximum daily (AMD) discharge simulated for each LULC change scenarios with log Pearson type (LP) 3 probability distribution function.

The annual mean and dry season PCI values demonstrated higher spatial and temporal variability, whereas PCI in the wetter seasons indicated low precipitation concentration. The MK trend test exhibited a significantly increasing trend of maximum temperature; however, the trend of mean annual and extreme precipitation indices was insignificant for the majority of climate stations. The LULC change detection analysis revealed significant increments in the areal extent of the cropland and urban areas, conversely decreasing trends in the pasture, forests

and shrubland coverage. The modelled future LULC change scenarios of the year 2025 and 2035 exhibited significant expansion of cropland and urban areas at the expense of forest, pasture and shrubland areas. The SWAT model performed well for simulation of daily and monthly streamflow and monthly sediment yield at main gauged subbasins. The performance of global precipitation estimates for hydrologic simulation was found to be encouraging. The CPC-NOAA precipitation data was found superior in capturing the hydrologic variability. In relatively smaller watersheds, the suitability of global precipitation was lower due to the limited number of data points resulted from the coarse resolution of the data sources.

The monoplot of PLSR components for LULC change impact on mean annual basin values exhibited that groundwater is highly correlated with the forest areas and lateral flow is strongly correlated with pasture. Whereas surface runoff is significantly attributed to the change in urban and cropland, sediment yield is mainly attributed to cropland area. The Variable Importance for the Projection (VIP) and PLSR weight (w) revealed that the decline of groundwater is mainly due to urban (VIP=1.34 and w=-0.55), whereas, the change in forest area enhanced groundwater flow. PLSR is effective statistical tool for assessment of the relative impacts multiple land management practices on hydrologic variability. The effect of LULC change on sediment yield is higher at the subbasins level. In addition to watershed morphometric parameters, hydrologic parameters such as surface runoff, runoff coefficient and total water yield can be used to infer sediment source areas. Prioritization of sub-watersheds for best management practices (BMPs) can be effectively performed by integrating GIS, hydrologic modelling and statistical tools. Riparian zone and steep slope reforestation significantly reduce the peak flood discharges and sedimentation.

The dynamics in the historical LULC largely increased the frequency and magnitude of extreme flood events. The increase in peak runoff is marginally varied for higher year return periods such as 200- or 100-year than the 5- or 2-year return period floods. The main reasons for a marginal increase in the percent change of peak flow for the higher return periods could be due to a high saturation level resulting in less infiltration for the larger return periods. The effect of LULC deterioration on the hydrologic response is more pronounced in the smaller subbasins. Moreover, the magnitude and trends of 24 extreme climate change indices for baseline and future scenarios (RCP 4.5 and RCP 8.5) were computed. Unlike the extreme precipitation indices, most of the temperature indices demonstrated significantly increasing trends. The hydrologic impact of climate change would be much pronounced when accompanied by probable future LULC change. The impact of LULC and climate change is more significant on extreme hydrologic events than average values. Therefore, future land management plans should consider appropriate vegetative conservation measures in the upland and flood plain areas to reduce the impact of LULC change on peak flood events and sedimentation.