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Modeling Optimal Operation Of Nashe Hydropower Reservoir Under Land Use Land Cover Changes In Blue Nile River Basin, Ethiopia

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The availability and distribution of water resources for economic development in the watershed have been affected by land use land cover (LULC) changes. The LULC changes have significant effects on hydrology and reservoir operations by altering the hydrological components of the watershed. The Nashe watershed is the upstream part of the Blue Nile River basin and one of the most significant potential areas for various socio-economic developments. The purpose of the study was to analyze the impacts of historical and future LULC change on hydrological components and optimal reservoir operations for managing water resources in relation to hydropower generation. The historical and future LULC scenarios were developed using the ERDAS Imagine model and Land Change Modeler respectively. In this study, agricultural land was the largest LULC occupying an area of 44% in 1990, 50.4% in 2005, and 61.2% in 2019 over the past thirty years and predicted to occupy an area of 73% in 2035 and 73.2% in 2050 over the coming thirty years. Therefore, according to the transition probability matrix, the largest LULC change in the Nashe watershed was the conversion of forest land, range land, and grass land to agricultural land and urban area.

The Soil and Water Assessment Tool (SWAT) model was applied to assess the impacts of LULC change on the hydrological processes under varying LULC changes. The findings of the study demonstrated that the SWAT model performance indicators were within an acceptable range, and the model performed well in simulating the hydrological processes of the watershed. In the Nashe watershed, the development of agricultural land and the reduction of forest cover were the major contributors to the increase in surface runoff and decline in groundwater flow. Compared to the baseline, the wet and dry season surface runoff have increased by 6.96% and 11.17%, respectively, under the current LULC. The potential future LULC change scenarios were predicted to result in moderate increases in surface runoff while decreasing groundwater flow, lateral flow, and evapotranspiration in comparison to the baseline scenario.

To model and optimize the operation of the Nashe hydropower reservoir, a modeling framework that integrates the SWAT model and the HEC-ResPRM optimization model was used. The HEC-ResPRM reservoir operation optimization model was utilized to reproduce the optimal hydropower reservoir storage, release, water level, and hydropower generation. In comparison to the status of the Nashe actual hydropower reservoir operation, the current optimized operation demonstrated a significant increase in power storage, pool level, release, and power generation. Similar results indicate that under the 2035 and 2050 LULC scenarios, the optimized hydropower reservoir operation policy shows an increasing trend compared to the current actual and optimized reservoir operations. In general, the findings demonstrated the importance of using an integrated simulation-optimization approach to investigate the effects of LULC changes on hydrological processes and consequently available water resources in the optimal operation of hydropower reservoirs. Therefore, decision-makers and land use planners should pay close attention to LULC change as one of the major drivers of change in the watershed's hydrology and reservoir operation.