Hydrologic Analysis of Malewa Watershed as a basis for Implementing Payment for Environmental Services (PES)

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ABSTRACT

The Malewa River Basin is important to development and livelihoods, supporting tourism, floriculture, small-scale farmers, dairy and pastoralism. The area faces key threats such as declining water levels in the Lake Naivasha, catchment degradation, pollution, water conflict, poverty and inequitable access to natural resources and markets. The research was aimed at undertaking situation analysis and hydrological baseline studies focusing on land-use and water relationships. The main study objective was to evaluate the impact of different land use and farming systems on the water, sediment and nutrient yield of River Malewa and to identify target sub-basins for implementing Payment for Environmental Service (PES) on a pilot basis. The following were identified as the major possible buyers of PES; Nakuru water and sewerage company, Naivasha water and sewerage company, Olkaria Geothermal plant (OGP), flower farmers and large scale water abstractors such as Manera farm, Delemare farm, the lake Naivasha riparian owners association, etc. The major sellers in PES scheme would be the small scale upstream landowners around Geta, and Wanjohi locations farmers around Kipipiri range, amongst others.

Land-use changes over a timeframe of thirty years were studied using satellite images. The trends in land-use were analyzed using IDRIS Kilimanjaro software. Landsat images for 1973, 1987, and 2003 were used to determine land cover and land cover change. A criterion was developed based on parameters such as annual rainfall, water yield, population density, water conflicts, and pressures on vegetation and water bodies to select the target areas for PES implementation. Hydrological effects of specific land use changes and best management practices in the selected priority catchment were analyzed using the Soil and Water Assessment

Tool (SWAT) model run on a monthly time step. Extensive continuous flow data over 10-year period from three locations within the basin were used for model calibration and validation. Sensitive model parameters were adjusted within their feasible ranges during calibration to minimize model prediction errors for monthly flows. A modeling framework was developed to represent the Best Management Practices (BMPs) with the Soil and Water Assessment Tool (SWAT) model and evaluate their impact on the water quantity and quality of the target watersheds.

Over the thirty years timeframe of study, it was noted that there has been spatio-temporal change in landuse. There has been expansion in agricultural lands and built-up areas with reduction of forests and grasslands which are fragile ecosystems. These changes exert influence on the ecosystem as a whole, because they affect water cycle, biodiversity, radiation budgets and many other processes. Based on the parameters, two sub-catchments with areas of 121 km^2 and 112 km^2 respectively within the upper catchment near GETA and Wanjohi were identified to be suitable for PES implementation.

At the main gauging station 2GB01; monthly calibration resulted in model prediction of average flow within 19% of the measured average flow while the monthly Nash-Sutcliffe (E_{NS}) measure was 0.58. These results indicated acceptance level of the model to predict monthly flow in the basin. The model was then used to run scenario analyses for the selected target areas. Six scenarios were tested namely 100 % horticultural crops (carrot, cabbage, sweet potatoes and onions distributed equally), 100% high density residential areas, 100% forest, a combination of forest and range brush in the ratio of 53% to 47%, Best Management Practices (BMPs) i.e. 1, 5

and 10 m filter strips and conservation farming with USLE_P values of 0.1, 0.5 and 1.0). The P values of 1.0 indicate no erosion control, 0.65 indicates contour farming and 0.1 indicates terraces. Land management practices with these P values were tested for their effect on streamflow and sediment load.

The results from land-use indicate that there has been land-use change mainly conversions from forest to agriculture and from range brush to agriculture. From the scenario analyses, it was observed that forest cover is the best with regards to water quantity and quality. The implementation of BMPs indicated that water quality can be greatly improved for example, the BMPs decreased the average monthly sediment yield at Wanjohi sub-basin outlet from 457.16 kg/ha (without BMPs) to 11.73 kg/ha for the best BMP (USLE_P=0.1.Without the BMPs, total organic N yield predicted by the SWAT were 2891 Kg/ha for Wanjohi and 472 Kg/ha for Geta. After the implementation of the BMPs, there was a significant decrease in organic N in both sub-basins. The decrease for Wanjohi sub-basin was from 2891 kg/ha to 77.18, for contour terrace (USLE_P=0.5), the decrease for Geta was from 472.34 kg/ha to 167.06 kg/ha for contour terrace (USLE_P=0.1) and 358.78kg/ha and 240.1kg/ha for filter width of 5m and 10m respectively

From the study, it is recommended that a filter strip of 5m should be implemented in Geta and Wanjohi sub-basins as a start for PES implementation. Implementation of 5 m vegetated filter strips in the pilot watersheds would reduce sediment yield from 457.16 kg/ha (without BMPs) to 11.73 kg/ha at Wanjohi sub-basin and from 424.56 kg/ha with no best management practices (BMPs) to 18.9 kg/ha in Geta sub-basin with BMP installed.

There is need for further research on impacts of different agricultural land-use systems if they are to form part of PES implementation, also basin wise studies from upstream to downstream basins

need to be undertaken to show the impact of BMPs on water quality and streamflow at the Malewa river mouth into the Lake Naivasha.