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主　論　文　の　要　旨

論文題目　Assessment of Pollution Load on the Kenyan Catchment of Lake Victoria Basin using GIS Tools

(GIS を活用したビクトリア湖ケニア国側流域からの汚濁負荷解析と評価)

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論　文　内　容　の　要　旨

Abstract

Lake Victoria is a freshwater lake in East Africa and has surface and basin areas of 68,800 km^2 and 194,000 km^2 respectively. The lake is located at an altitude of 1,134 m asl and its average depth is 40 m while volume is 2,760 km^3. It is the second largest freshwater lake by surface area in the world and the largest in Africa. The lake is an economic zone to the three riparian countries, namely, Kenya, Tanzania and Uganda and also a lifeline source of water supply to dry downstream countries. Lake Victoria basin also extends to Burundi and Rwanda. The lake's shoreline is convoluted enclosing

numerous small and shallow bays and inlets in which most are swamps and wetlands. The main gulfs/bays are Winam Gulf on the Kenyan side and Speke Gulf on the side of Tanzania. The only outlet from the lake, River Nile, flows down all the way to Egypt. River Sondu is the third largest by flow volume among the main six rivers on the Kenyan side of Lake Victoria basin and its watershed has the largest forest cover rate. Intensive natural and human activities compounded by ever growing population, poor livelihoods and less investment in sanitation; have accelerated environmental degradation through deforestation, siltation, fishing malpractices, wetland destruction and direct disposal of sewage into the lake. Parts of Sondu catchment have recently been reforested: Koguta hill and Mau forest. Sedimentation limits river carrying capacity and fills irrigation channels/canals with silt deposits and cause flooding downstream. Increased inflow of nutrients has enriched the lake. Lake deterioration is being driven by excessive pollution load: sediments and nutrients (total nitrogen - TN & total phosphorous - TP).

Estimation of pollution load to Lake Victoria has been carried out by several studies in the past. Estimation of pollution load has always been hampered by scarcity of data which adversely affects the accuracy and reliability of results. The methods used borrowed nutrient export coefficients (UAL) to estimate pollution load. The borrowed coefficients were not adjusted to fit local conditions because of lack of relevant data and information. There is need to develop criteria of adjusting borrowed coefficients and or estimating local coefficients based on observed water quality and quantity data. Simulation of hydrology, sediment and nutrients as well as watershed management plans provides useful insights to watershed or lake manager especially on amount of

pollution load and effectiveness of various watershed interventions.

This study was conducted with the main goal to improve pollution load estimation framework and to assess pollution load on the Kenyan side of Lake Victoria by incorporating Geographical Information System (GIS) and Remote Sensing technologies. First, estimation methods of pollution load in Lake Victoria in past studies were reviewed to highlight their strengths and weaknesses in tandem with advancement in technology in watershed modelling. Second, nutrient export coefficients for three land covers on the Kenyan side of Lake Victoria basin were derived using a model equation with land use and rainfall-runoff coefficient as main variables. The land covers are cropland, forest and vegetation/grassland/shrubland. Third, hydrology sediments and nutrients (TN & TP) as well as their spatial-temporal distribution in Sondu watershed were simulated using Soil Water Assessment Tool (SWAT) to identify sediment and nutrients source hot spots. And finally, effectiveness of three watershed management plans aimed at curbing environmental degradation and sediment erosion in Sondu watershed was assessed using SWAT for both space and time distributions. The plans are: maintaining the existing situation, application of 1 m filters on agricultural land covering 54 % of the watershed and 11.2 % addition of forest cover through reforestation.

Past studies on estimation of pollution load to Lake Victoria have different estimates of pollution load which makes it difficult to determine which estimates are reliable and accurate. It demonstrates that in situations of inadequate data varying methods give different results. Estimates show that atmospheric deposition contributes significantly

(30 – 80 %) to the total nitrogen and total phosphorous loads to the lake. Total annual nutrient municipal load of 548 t/yr - TN and 301 t/yr - TP are estimated to be flowing to the Lake from the main six river watersheds on the Kenyan side of the basin. Pit latrines and septic tanks were considered as sources of urban diffuse pollution. The model equation estimated the export coefficients with satisfactory performance for the three land-covers both at validation phase and when matched with those in literature. Nyando watershed had relatively high river nutrient concentration with low rainfall-runoff depth. It suggests that driving factors other than land use and rainfall-runoff coefficient which include loose soil characteristics. However, positive solutions for nutrient export coefficient demonstrated that land use and rainfall-runoff coefficient have significant influence and are usually available and useful variables to explain runoff load.

The SWAT model performance was satisfactory at both phases of stream flow and sediment simulations with scarce observed data notwithstanding. High sediment yield periods were February-April and November-January and directly correlated with high rainfall seasons. Average annual sediment yield from Sondu watershed is 106,200 tons/yr over the 2005 – 2007 calibration periods while TN & TP are 3,388 tons/yr & 312 tons/yr respectively. The nutrients peak periods lagged behind sediments' by one to two months on average. Sediments and nutrients are mainly generated from agricultural crop areas at downstream, central (Sondu) and upstream West (lower Kisii/Nyamira) area of the watershed while the high water runoff yielding areas are upstream (Kericho/Kisii/Kericho) areas. Application of filters on agricultural HRUs reduced the yield from the baseline annual yield of 106,200 tons by 17 % at basin level while addition of 11.2 % forest cover reduced the yield by 28 %. Both filter and reforestation

plans were more effective in wetter months of the year. Months of April-May and November-December which are beginning of high rainfall seasons had high sediment reduction rates for reforestation and filter plans. Reforestation plan consistently ranked higher with respect to sediment yield reduction in all months of the year as monitored at basin outlet. Reforestation was relatively effective in reducing sediment at most upstream sub basins while filters had more impact at most downstream sub basins of the watershed. Sediment yield in sub basins did not show a distinctive pattern whether located upstream or downstream but sediment yield amount corresponded to size of agriculture cover.