Nitrogen and Phosphorous Dynamics and Water Purification Ability of Vegetation and Soil in Uma Oya Catchment

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Abstract
Uma Oya catchment is one of the sub catchments of the Mahaweli watershed which is highly disturbed by the intensive crop cultivation practices. Nitrogen (N) and Phosphorous (P) exported from the catchments end up in the streams and reservoirs causing water quality problems. However, empherical evidence on the levels of nutrient runoff and their association with surface water quality is not available for river catchments in Sri Lanka. Therefore, this study aimed at determining the levels of nutrients (N, P) exported from the Uma Oya catchment and value the ecosystem service provided by the natural vegetation by retaining nutrients. Integrated Valuation of Ecosystem Services and Trade off (In VEST) Nutrient Retention Water Purification Model was used to estimate the amount of N and P exported from 10 sub catchments within the main catchment. The highest N and P export rates predicted by the model were 63.2 kg/ha and 20.3 kg/ha, respectively. Higher nutrient export loads (kg/year) were recorded for sub catchments Boralanda, Kottegoda, Bandarawela, Pahala Ambegoda, Nawela, Erabadda and Horadoruwawa while lower values were recorded for Ohiya, Boragas, and Gangasiri. Calculations showed the ecosystem service for nitrogen retention as LKR million 2.77 and LKR million 1.39 for phosphorous retention per year for all 10 sub catchments.

Keywords: Ecosystem Services, In VEST, GIS Based Modelling, Nutrient Pollution
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Introduction

There is an increasing consensus about the importance of incorporating "ecosystem services" into resource management decisions, but quantifying the levels and values of these services has proven difficult (Erik Nelson *et al.*, 2009). Natural water filtration is a key ecosystem process underlying water quality and is critical for both consumptive water use and in stream water quality that affects fisheries and recreation among other services (Karl and Vigersalstol, 2011). Uma Oya has recently come into discussion due to the Uma Oya multipurpose development project which caused massive land use changes. In addition to that, Uma Oya catchment is an area where vegetable cultivation is practiced in large scale. In the process, soil is disturbed frequently and, N and P containing fertilizers are added to the soil intensively. With the runoff, those nutrients are washed off and transported to water bodies causing water quality deterioration and aquatic ecosystem degradation. Natural vegetation can retain these nutrients to a certain extent. Without quantitative assessments, these services tend to be ignored by those who are making land use and land management decisions. Nutrient wash off degrades agricultural lands causing huge economic losses. Therefore, quantifying this loss and converting it into currency would make it more sensible to the community, which will increase the effort of implementing soil and nutrient conservation measures in their lands. The study aimed at modeling nutrient export and nutrient retention loads by natural vegetation and soil for ten selected sub catchments within the main catchment, value the ecosystem service provided by natural vegetation and field verification of the model.

Materials and Methods

InVEST 3.1.3 version of Water Purification - Nutrient Retention Standalone Beta Model downloaded from www.naturalcapitalproject.org was used for the study. Model needed following GIS raster datasets: Elevation (DEM), Average root restricting layer depth(mm), Average annual precipitation(mm), Plant available water content (PAWC) fraction, Annual average evapotranspiration and Land use map with a LULC code (should be an integer) for each cell. PAWC was determined for soil samples obtained from the study area according to the equation described by Miller and Donahue, (1992). Annual average evapotranspiration was predicted using Blaney-Criddle formula. A shape file of sub watersheds was created using ArcGIS hydrology tool such that each sub watershed contributes to a point of interest where water quality will be analyzed. A table of land use/land cover (LULC) classes (CSV format), containing data on water quality coefficients used in this model was created (bio physical table). Those data included *lucode* (Land use code):same code used in the land use raster map, *LULC_desc*: descriptive name of land use/land cover class (optional), Kc: the plant evapotranspiration coefficient for each LULC class, root depth: the maximum root depth for vegetated land use classes, given in integer millimeters, load_n / load_p: the nutrient loading for each land use(kg $Ha^{-1} yr^{-1}$),*eff_n / eff_p*: the vegetation filtering value per pixel size for each LULC class, as an integer percent between zero and one and LULC_veg: value one or zero is given based on whether each land use type is dominated by vegetation or not. A threshold flow accumulation value of 1000 (default) was used to run the model (Natural Capital Project, 2015). Theissen polygon method was used to interpolate point measurements obtained for precipitation, PAWC and annual evapotranspiration over the catchment. Avoided fertilizer cost due to natural nutrient retention was calculated as the eco system service. Nutrient loss due to wash off was calculated as the economic loss.

Water quality was assessed for water samples collected at the river sections at the base of the each sub catchment at monthly intervals. Physical, chemical water quality parameters (NO_3^-,PO_4^{3-}) were estimated for each sampling station. Pearson's correlation test was conducted to assess the correlations between catchment nutrient export and the river water quality.

Results and Discussion

Model outputs were mainly output shape file and export tiff file. Export.tif (kg/pixel) is a pixel level map indicating how much load from each pixel eventually reaches the stream (Figure 1).

Output shape file aggregates the nutrient model results per sub watershed in its attribute table. The fields in the shapefile are dependent on whether the phosphorous, nitrogen or both were simulated in the run. In the attribute table of the shape file*p_ret_adj/n_ret_adj* (kg/watershed) and *p_exp_tot/n_exp_tot* (kg/watershed) were the most important outputs given by the model that were used for this study.

The highest N and P export rate recorded in the sub catchments were 63.2 kg/ha and 20.3 kg/ha, respectively. Higher nutrient export loads (kg/year) were recorded for sub catchments Boralanda, Kottegoda, Bandarawela, Pahala Ambegoda, Nawela, Erabadda and Horadoruwawa while lower values were recorded for Ohiya, Boragas, and Gangasiri. Calculations showed the ecosystem service for nitrogen retention as LKR million 2.77 and LKR million 1.39 for phosphorous retention per year for all 10 sub catchments. Also the economic loss due to N and P wash off was accounted as LKR million 0.29 for nitrogen and LKR million 0.16 for phosphorous(under the fertilizer concession 50 kg bag was prized as LKR 350.00 for both

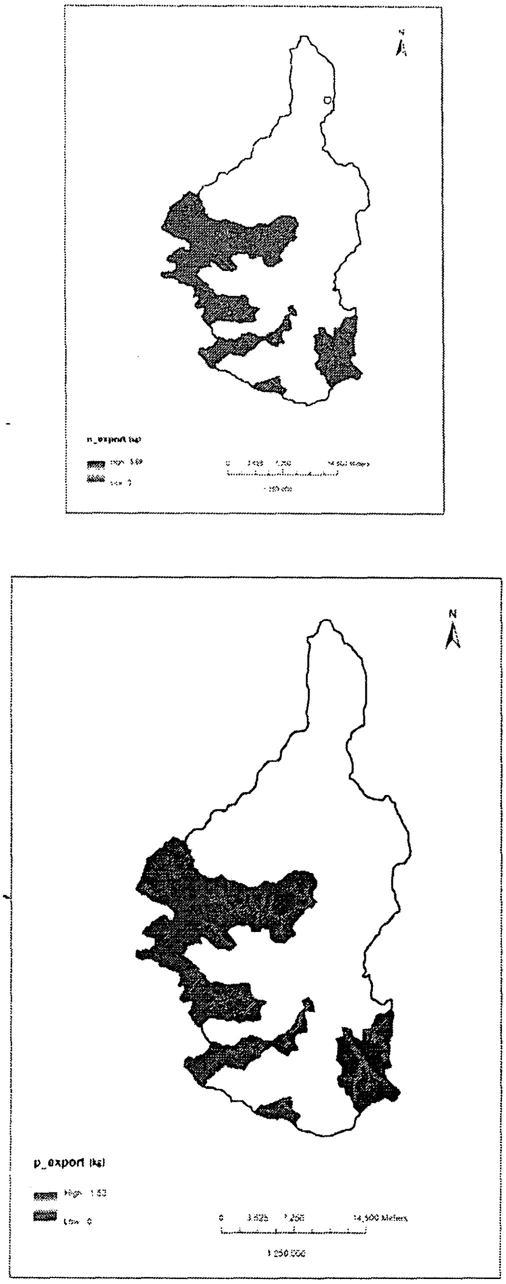

Figure 1: Pixel level maps of nutrient export

urea and tri super phosphate). A weak correlation was observed between nitrogen export loads given by the model for each sub catchment and river nitrate concentration at the base of each sub catchment (R square=0.08).

Correlation was also minimum for phosphorous export values and the river phosphate concentrations (R^2=0.0046).

Because the model results did not correlate well with the water quality data, it is difficult to predict the nutrient pollution in the catchment using obtained results. Nutrient export coefficients used in the bio physical table were not developed for Sri Lankan conditions. They are rather developed for regional scales. Therefore, model needs to re-run using new nutrient export coefficients developed for Sri Lankan land use types and climatic conditions until the results get a considerable correlation with the river water quality data.

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