# Landscape stoichiometry and biological nutrient recycling in the watershed ecosystem

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## 1. Introduction

Nutrient resources have provided us with economic prosperity and human welfare, whereas overexploitation of these resources poses a threat to disturbance of natural biogeochemical cycles of macronutrients, such as nitrogen and phosphorus. Such nutrient imbalances currently cause eutrophication, which in turn lead to drastic changes in community composition and biomass in the watershed ecosystems. Because of its scarcity relative to other macronutrients and its biological requirement, phosphorus plays a key role in controlling aquatic ecosystem processes. Here we will take a new approach, landscape stoichiometry, which links ecological stoichiometry with landscape ecology in order to understand dynamical interactions between nutrients and biological communities in the watershed ecosystems under human disturbances.

## 2. Materials & Methods

We conducted the synoptic research in the whole catchment of Yasu River, which is the largest tributary of the Lake Biwa Watershed. We set 59 monitoring sites at streams, which vary in terms of the land use patter in their catchment areas as well as stream size ranging from 1$^{st}$ to 5$^{th}$ order. For all of these sites, we measured total phosphorous (TP) and nitrogen (TN) concentrations and physical characteristics. We also collected GIS data in this catchment. We used a modified method for spatially referenced regressions of contaminant transport on watershed attributes (SPARROW), according to Smith et al. (1997). We estimated three variables of nutrient spiraling metrics for phosphorous (i.e., $U$: areal uptake which is the microbial uptake rate of phosphorous per unit stream area, $v_f$: uptake velocity as an index of phosphorous removal efficiency in streams, $S_w$: uptake length defined as the average distance taken for a phosphorous atom to be biologically turned over during the upstream-downstream movement), incorporating the above environmental and GIS data into the model.

At 30 out of 59 monitoring sites, we also collected epilithic algae from the river beds to measure their chlorophyll *a*, *b*, *c* concentrations as an index of the whole algal, green algal and diatom biomasses, respectively. We examined how much and which land uses load phosphorous into the streams, using the nutrient spiral metrics. We also examined how the resultant nutrient imbalance alter algal communities and their ability for phosphorous recycling.

## 3. Results

In the catchment of Yasu River, the TP concentration was higher in areas dominated by residential and agricultural land uses. Based on the nutrient spiral metrics, we estimated its non-point source loading (mol/km$^2$*day) from residential and agricultural areas as 1.34 and 0.26, respectively. The nutrient imbalance (TN/TP) due to the phosphorous loadings was the primary factor to determine the green algal biomass.

Our model showed that the $U$ was higher in residential and agricultural areas and lower in forest areas. This trend was the same as the $v_f$. The $S_w$ increased toward the downstream, in which most of phosphorous cannot be taken up by microbes. The $U$ was significantly correlated with the green algal biomass.

4. Discussion

The nutrient spiral metrics revealed that residential and agricultural land uses are the main source of phosphorous pollution, which caused spatial variation in nutrient imbalances on the watershed scale. As previously reported, green algae can linearly respond to the phosphate availability, often dominating in the algal communities under eutrophication. Based on the landscape stoichiometry, we demonstrated that human land uses cause the nutrient imbalances, which can alter algal community composition and thus their ecosystem functioning, especially phosphorous recycling.

Keywords: Nutrient cycling, Nutrient imbalance, Nutrient spiral metrics, Ecosystem function, Phosphorous loading, Epilithic algae

Fig. 1

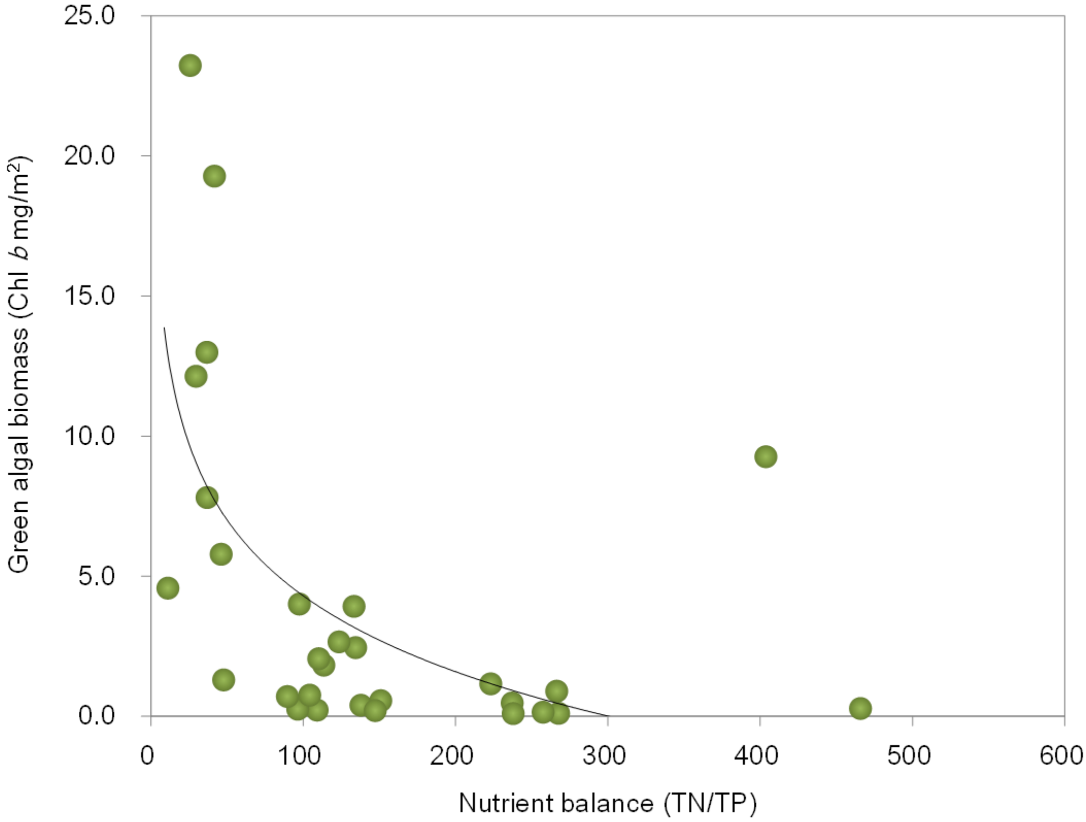
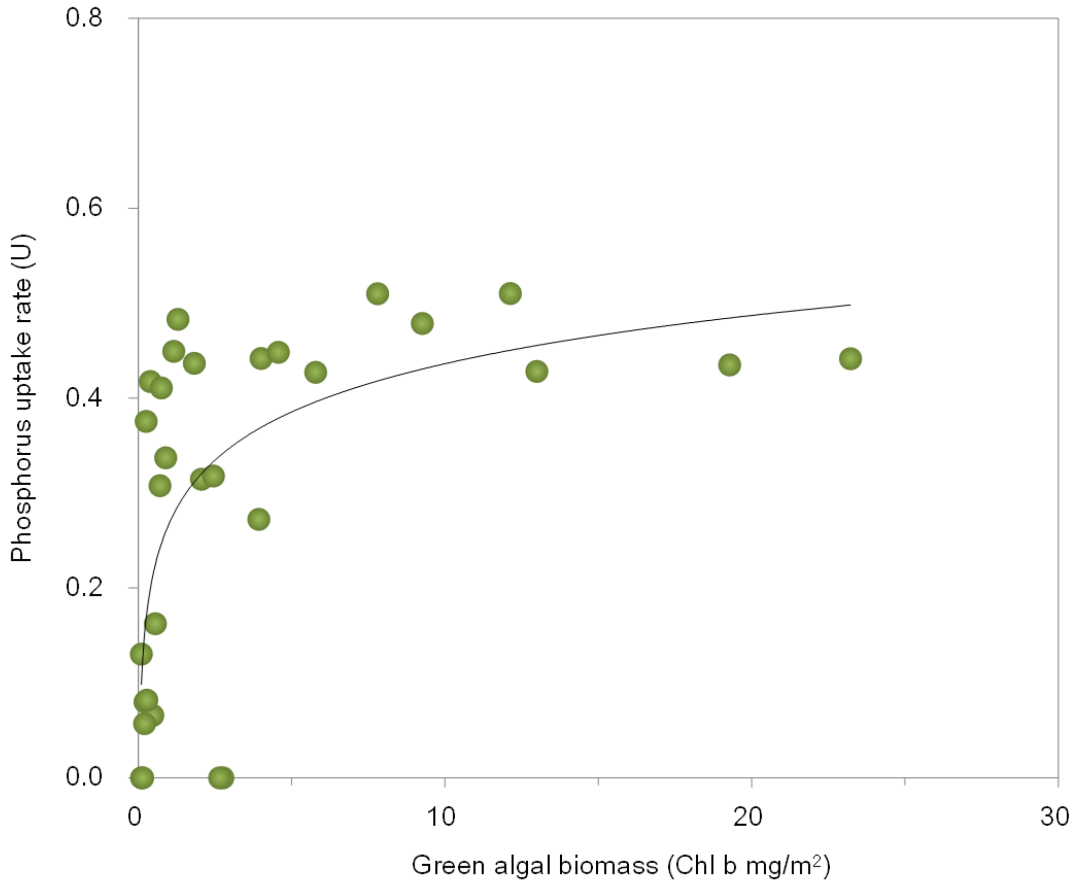

25.0
20.0
15.0
10.0
5.0
0.0
Green algal biomass (Chl b mg/m2)
0
100
200
300
400
500
600
Nutrient balance (TN/TP)

Fig. 2


0.8
0.6
0.4
0.2
0.0
Phosphorus uptake rate (U)
0
10
20
30
Green algal biomass (Chl b mg/m2)