R: A global data analysis of sediment and organic carbon yield for modeling riverine biogeochemistry

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Objective

◆ Recent studies have rejected the hypothesis that aquatic ecosystems only play a passive role like a “pipe” in transporting organic carbon from land to ocean but rather suggested that a considerate fraction of the transported carbon would be degraded. Thus it becomes important to estimate the magnitude and timing of the loss of the land carbon pool (mainly soil organic carbon) in earth system models. The top priorities should include the parameterization of soil erosion, a chain of processes transferring a huge amount of soil particulate organic carbon into river systems.

◆ But two major issues (scale and heterogeneity) exist there, making model soil erosion at global scale a big challenge. The scale issue is that the contribution of different processes (e.g., interrill erosion, rill erosion, gully erosion, bank erosion, landsliding and deposition) for soil erosion vary with catchment size. The heterogeneity issue is that soil erodibility and the contribution of different processes for soil erosion vary with the land use, topography, lithology, geology, tectonics and human activities of catchments.

◆ By making statistical analysis on sediment yield data of over 1000 small catchments (less than 200 km²) across the globe, we aim to figure out the dominant processes and the significant environmental factors controlling soil erosion at the spatial scale of ACME. Additionally, by analyzing POC yield data from dozens of small catchments, we also try to build a relationship between POC yield and sediment yield.

Table 1. Partial correlation coefficient (partial r) and corresponding p-value for each considered variable with the natural logarithm of the catchment sediment yield, ln(SY). Each partial correlation was calculated by controlling for all variables that relate to different factors than the considered variable.

Variable	partial r	p-value
ln(Q_{peak})	0.52	< 0.0001
ln(Q)	0.33	< 0.0001
RE	0.32	< 0.0001
P	0.23	< 0.0001
Crop	0.23	< 0.0001
Wood	-0.20	< 0.0001
Frag	-0.20	< 0.0001
ln(SLP)	0.17	< 0.0001
Silt	-0.14	< 0.0001
SOC	-0.11	< 0.0001
Grass	-0.08	0.0014
ln(POP)	0.08	0.0015
ln(CA)	-0.06	0.0094
VarSM	-0.06	0.2986
Sand	0.01	0.8248
PGA	0.00	0.8762
LITH	0.00	0.9160

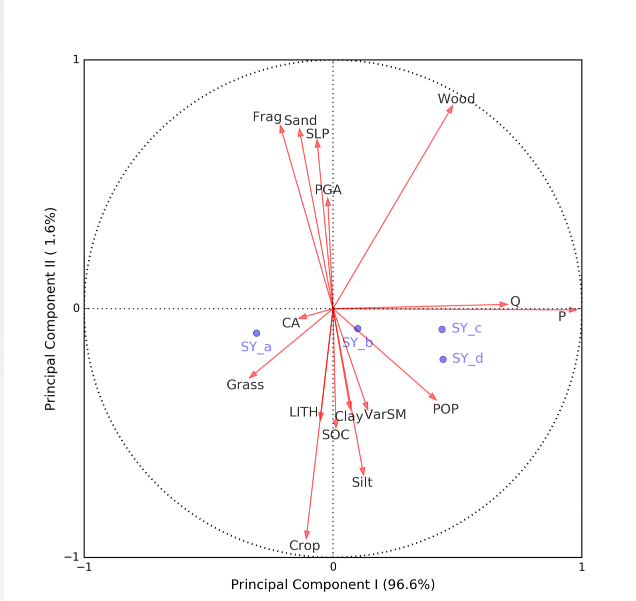

Figure 2. Principal Component Analyses (PCA) of environmental factors as active ables and sediment yield as supplementary variables.

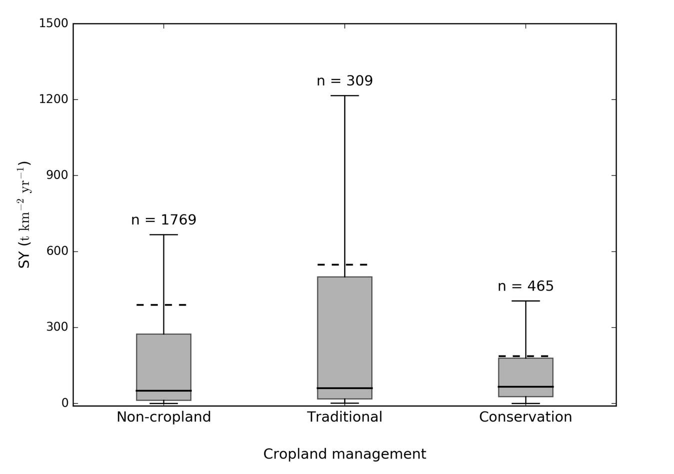

Figure 3. Distribution of SY between land use classes.

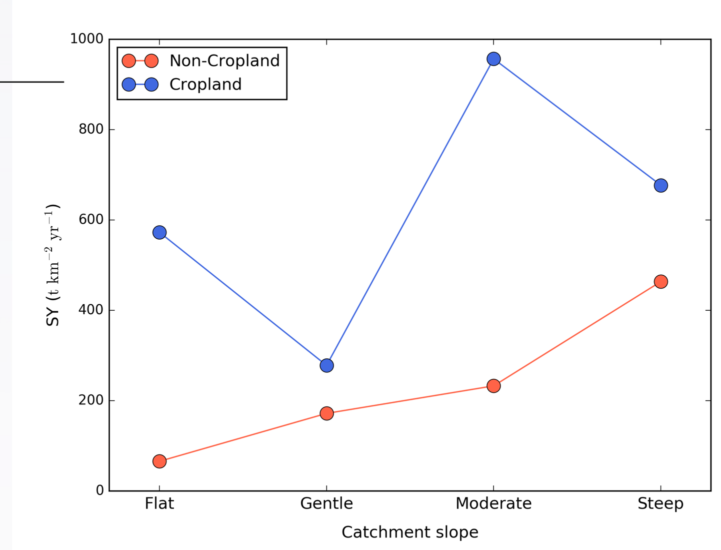

Figure 4. Median of SY between catchment slope classes (Flat: less than 0.01 m m^{-1}; Gentle: between 0.01 and 0.1 m m^{-1}; Moderate: between 0.1 and 0.2 m m^{-1}; Steep: larger than 0.2 m m^{-1}) for cropland and non-cropland.

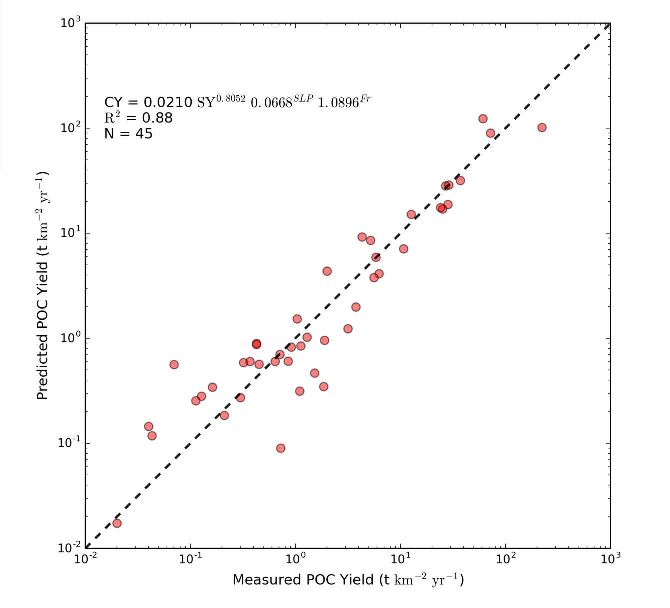

Figure 5. Observed catchment POC yield (CY), versus the corresponding predicted value. Black dash line is 1:1 reference.

Approach

Sediment and POC yield data:

◆ The sediment yield data were collected from the published data from journal papers, personal communication, and three national datasets. The POC yield data were collected from 18 journal papers. Figure 1 shows the distribution of these catchments.

◆ Environmental variables involved are related to scale (CA), climate (Q, Q_{peak}, RE, VarSM), topography (SLP, RSLP), land use (Wood, Grass, Crop), soil (Clay, Silt, Sand, SOC), lithology (Frag, LITH), tectonics (PGA), population (POP).

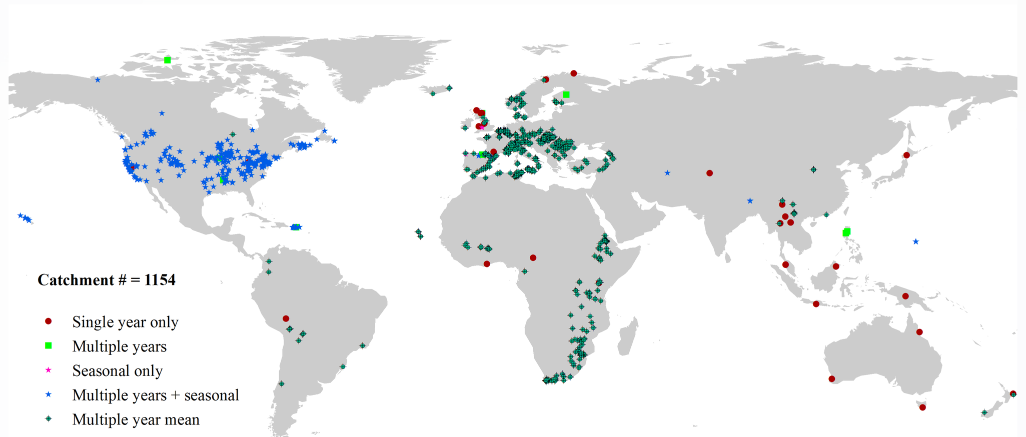

Figure 1. Spatial distribution of the studied catchments.

Statistical analysis:

◆ Spearman correlation is for the main effect of variable correlation. PCA is for the major drivers of the variability of predictors and the loading factors of sediment yield on them. Partial correlation is for the main effect of predictors on sediment yield. One-way and two-way ANOVA are for the difference of sediment yield groups. Multiple linear regression is for the regression model between sediment yield and POC yield. All variables are transformed if normality is required and outliers are pre-filtered. The predictors in regression are selected by F-statistics.

Impact

Soil erosion processes:

◆ At the spatial scale of ACME, soil erosion caused by concentrated flow is more important than interrill erosion. Soil deposition causes the reduction of sediment yield and must be included in soil erosion models. Threshold-based methods, e.g. unit stream flow, are needed to account for the order-scale increase of sediment yield in short time.

Soil erodibility:

◆ Vegetation cover, rock fragment fraction and slope are the important important factors for soil erodibility. Meanwhile, soil erodibility is largely disturbed by agricultural practice. Conventional agriculture would make soil vulnerable for erosion. But proper soil reservation management can alleviate soil erosion.

POC yield:

◆ POC yield can be estimated under the same framework for sediment yield. In other words, a soil erosion model can help estimate the disturbance of the SOC pool.

Soil erosion modeling:

◆ This sediment yield dataset can be used for the development and validation of a soil erosion model at the global scale. The relationship between POC yield and sediment yield can be used for the estimate of POC loss in earth system models. The study also indicates that soil erosion in earth system models needs to be modeled at event-scale for better performance.

ACME Accelerated Climate Modeling for Energy

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