Exploring the Global Index of Freshwater Eutrophication Potential for the Period 1900-2015

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Background

Human-induced mobilization of nutrients has resulted in elevated nitrogen (N) and phosphorus (P) loadings, while dissolved silicate (DSi) supply to rivers primarily comes from the natural process of rock weathering. The world-wide construction of dams has led to declining Si transport by many rivers. Increasing N and P loads compared to Si may lead to enhanced growth of undesirable non-siliceous algae.

Methods

The Indicator for Freshwater Potential (IFEP)[1] was used to analyze the eutrophication risk in freshwaters. IFEP is an adaptation for freshwaters of the ICEP for coastal waters, based on molar C:N:P:Si (106:16:1:40) composition of diatoms in freshwaters, and converted to carbon to assess N and P independently. The IFEP-N, used if N is in excess over P, is calculated as follows:

IFEP_N=[Flux_N/(14*16)-Flux_Si/(28*40)]*106*12

IFEP<0: DSi in excess over N/P.

IFEP>0: excess N/P over Dsi for diatoms,

conditions prone to harmful non-siliceous harmful algae.

The 0.5 degree resolution IMAGE-DGNM[2-5] (Figure 1) was employed to simulate global changes N, P and DSi export since 1900 until 2015/2020 to compute IFEP. IFEP is calculated from TN, TP and DSi inflow from upstream parts, and delivery and retention within each grid cell; results are aggregated to HYDRO-BASINS level. ICEP calculations for coastal waters with DGNM are presented by Liu et al. at this AGU Fall Meeting.

Validation

The simulated DSi fluxes were tested against "observations" for selected years in the 1990s for 208 rivers (Figure 2a). Simulated TN and TP concentrations were validated for large rivers at the river mouth station (Figure 2b).

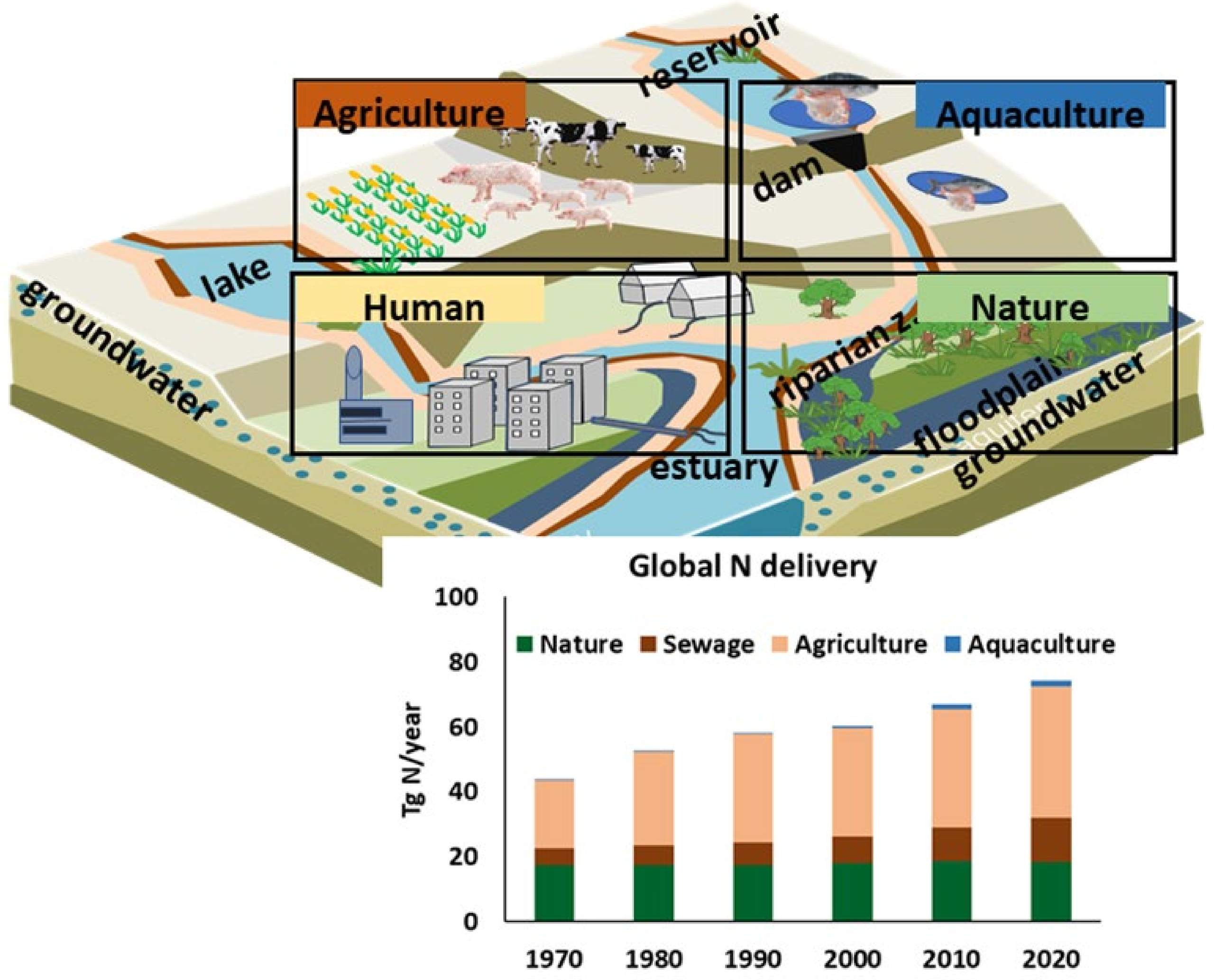
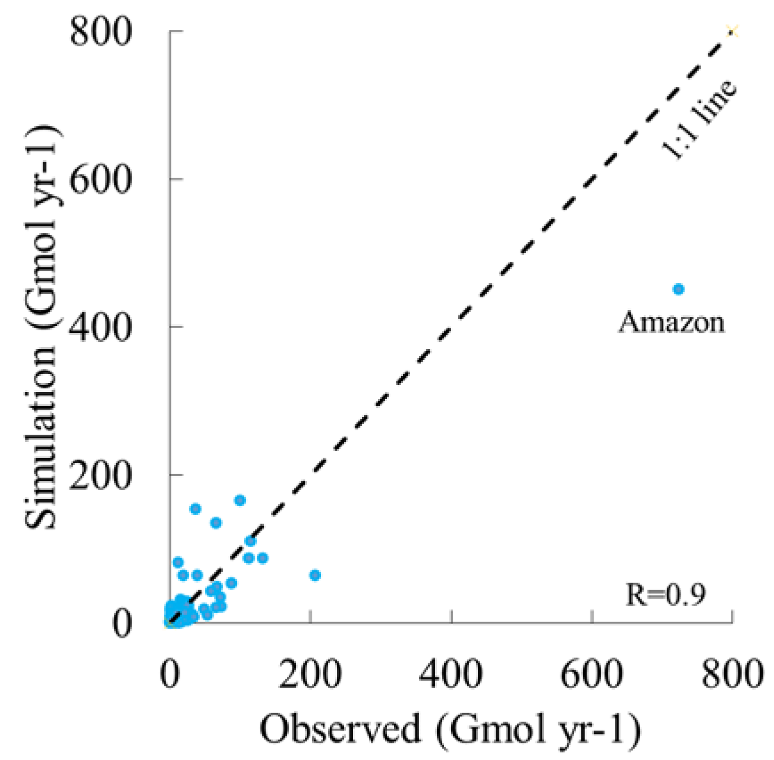


Figure 1. Scheme of the Integrated Model to Assess the Global Environment (IMAGE)-Dynamic Global Nutrient Model (DGNM) model and simulated global N delivery to inland waters for 1970-2015/2020.

a.



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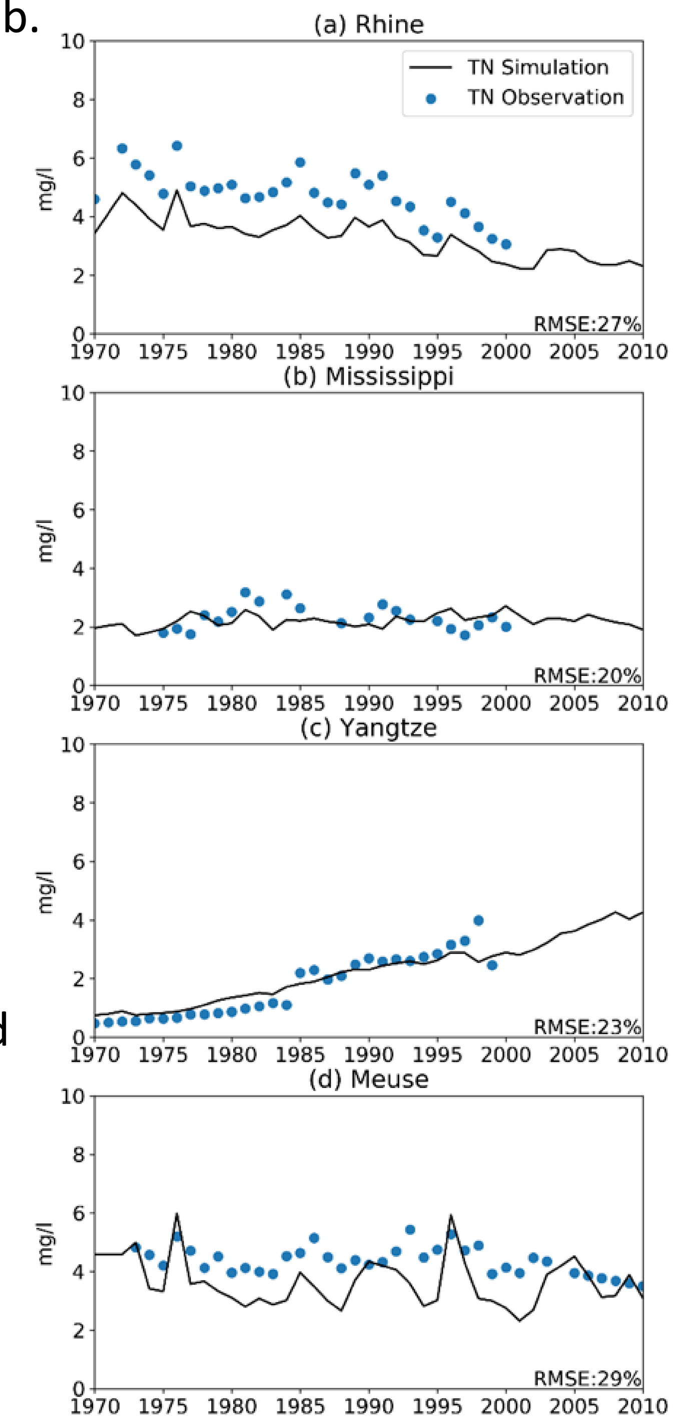

Figure 2 (a) Comparison of simulated and "observed' DSi fluxes for 208 rivers. (b) Validation of simulated versus observed N concentration at mouth-stations in Rhine, Mississippi, Yangtze and Meuse. Results for P concentrations (not shown) result in RMSE values of 33-73%.

Limitations and future work

The current approach uses an annual time step, and TN and TP delivery, in-stream biogeochemistry and transport. A major step forward will be the full use of the dynamic features of IMAGE-DGNM [3-5], using a monthly or shorter temporal scale, and distinguishing different N and P species. Also, validation for more (inland) stations will be needed.

Acknowledgements

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Literature

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3 Liu, X. et al. Exploring long-term changes in silicon biogeochemistry along the river continuum of the Rhine and Yangtze (Changjiang). Environmental Science & Technology 54, 11940-11950 (2020). https://doi.org:10.1021/acs.est.0c01465

4 Vilmin, L. et al. Modeling process-based biogeochemical dynamics in surface fresh waters of large watersheds with the IMAGE-DGNM framework. Journal of Advances in Modeling Earth Systems 12 (2020). https://doi.org:10.1029/2019ms001796

5 Vilmin, L., Bouwman, A. F., Beusen, A. H. W., van Hoek, W. J. & Mogollón, J. M. Past anthropogenic activities offset dissolved inorganic phosphorus retention in the Mississippi River basin. Biogeochemistry (2022). https://doi.org:10.1007/s10533-022-00973-1

Results

The enhanced nutrient mobilization due to human activities has been dramatic. Global TN export increased 2.3 fold from 1.2 Tmol in the 1900s to 3 Tmol in 2010s, TP export increased by a factor of 1.8 from 80 Gmol in the 1900s to 143 Gmol in the 2010s (Figure 3). In contrast, DSi export decreased from 6.3 Tmol in 1900s to 6.2 Tmol in the 2010s.

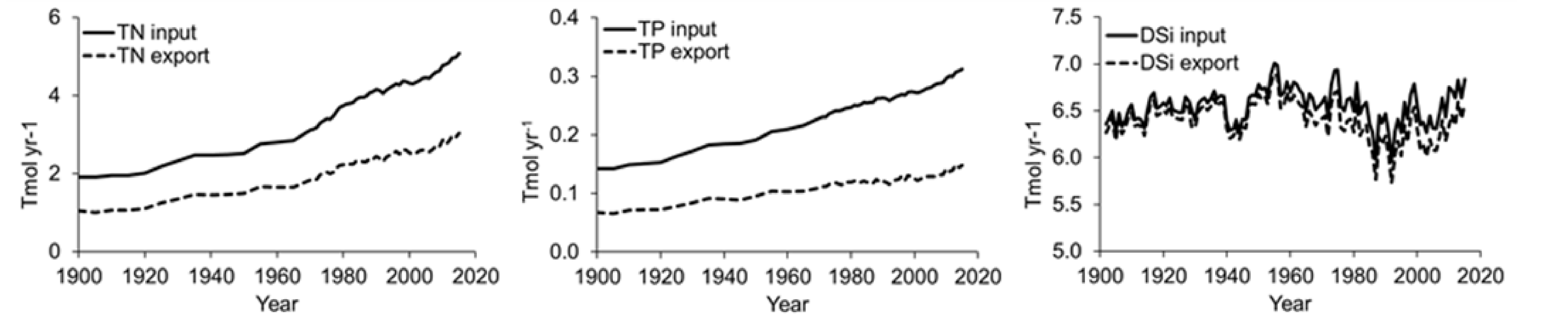

Figure 3. TN, TP and DSi input into the global rivers and export to coastal areas.

IFEP values were mostly negative in 1900 (Figure 4), except a few river basins show slightly positive values in Western Europe. From 1900 to 1970, the number of areas with IFEP>0 has increased, especially in Japan, South Korea and Western Europe (Figure 4). During 1970-2015, IFEP changed from - to + due to the increasing N and P loads (Figure 3), especially in Eastern China and Northern India. Meanwhile, there has been improvement in many European rivers, and some basins even shift from + to -.

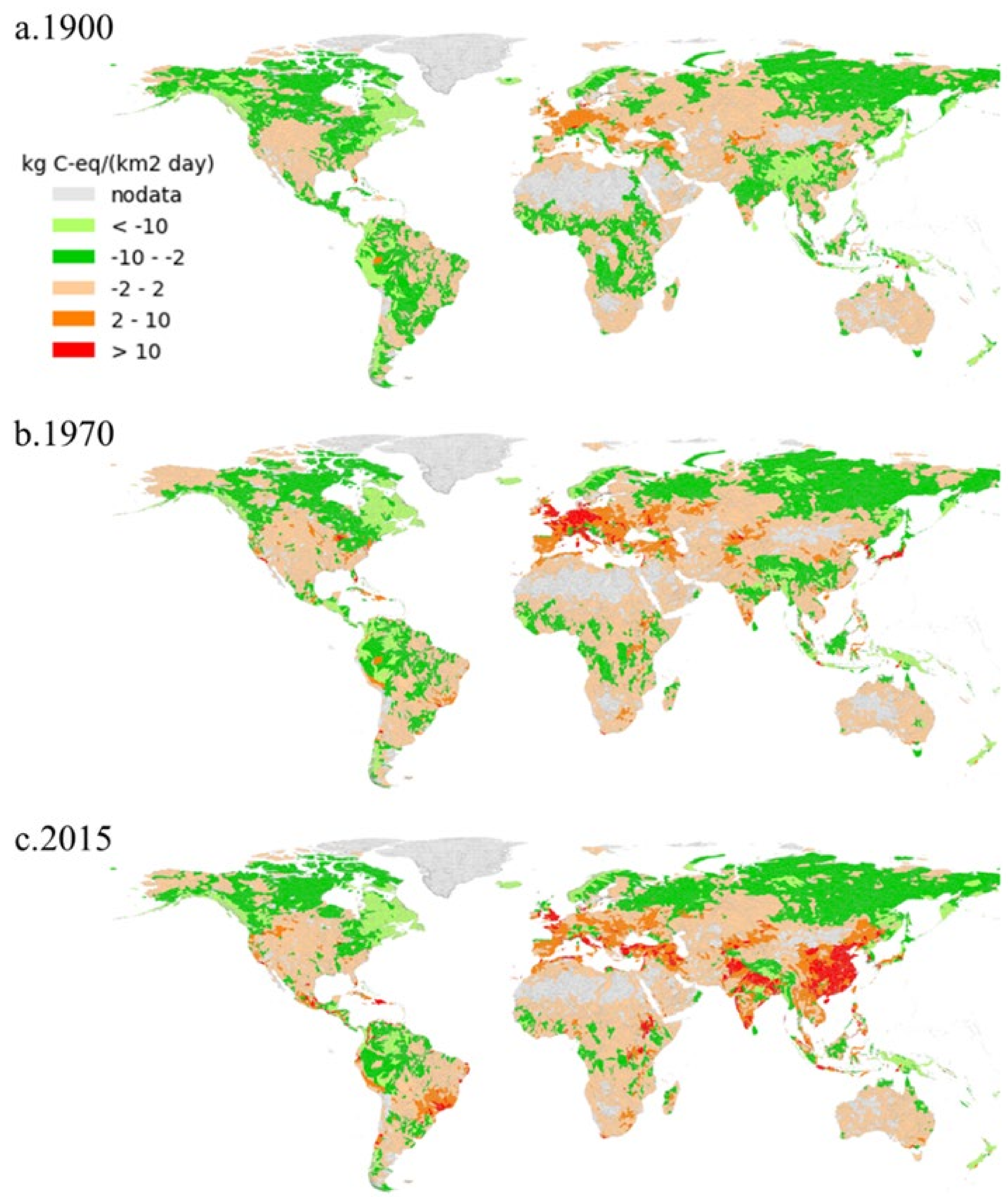

Figure 4. Simulated global IFEP for 1900, 1970 and 2015. IFEP = IFEP_N if N:P ratio < 16 (N limiting), IFEP = IFEP_P if N:P ratio > 16 (P limiting).