PBL Netherlands Environmental Assessment Agency

H43C-1351

Exploring changes in nitrogen and phosphorus retention in global rivers in the twentieth century

Introduction

Nutrients are transported from land to sea through the continuum formed by components of river basins (soils, groundwater, riparian zones, floodplains, streams, rivers, lakes, and reservoirs). The hydrology, ecology and biogeochemical processing in each of these components are strongly coupled and result in retention of a significant fraction of the nutrients transported. We analyze the global changes in nutrient retention during the past century (1900-2000).

Model

We use the hydrological PCRGLOBWB model for the period 1900-2000, including the history of dam construction. Global N and P soil budgets for the period 1900-2000 are the starting point to simulate nutrient flows from the soil (via leaching through the groundwater system and surface runoff). The N flows and retention include now a better representation of surface runoff, groundwater transport and denitrification, and the role of riparian zones. Here, we further extend the approach for surface runoff by accounting for residual soil P loss resulting from past surpluses during the 1900-2000 period, and retention in freshwater systems. For in-stream nutrient retention, we use the spiraling concept.

Approach for sensitivity analysis

Since the various processes in the different compartments in terms of delivery to surface water are poorly known, we present a sensitivity analysis of the modeled river export for a number of key variables. The sensitivity of the model was investigated using Latin Hypercube Sampling, with uncertainty ranges for 25 parameters for N and 15 for P, and expressed using the standardized regression coefficient (SRC), to compare to nutrient export at the mouth of the river. SRC is a relative sensitivity measure obtained by rescaling the regression equation on the basis of the standard deviations.

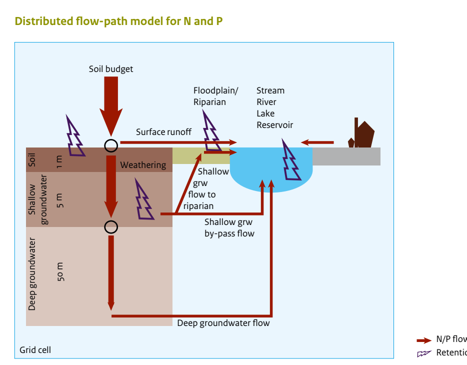

Figure 1. Scheme of distributed N and P flow-path model representing one 0.5 by 0.5 degree grid cell.

Results

The river nutrient export increased from 20 to 40 Tg N yr^{-1} and 1.6 to 6.1 Tg P yr^{-1} over the past century (Figure L4 and R4). The major driver of the increasing river export is the global soil N budget surplus (Figure L1 and R1). In addition, many factors influence in-stream river nutrient retention and thus export, often in different directions (Figure L3 and R3). Increasing residence time resulting from dam construction causes an increase of in-stream retention. For N this is counterbalanced by saturation of retention along with increasing concentrations.

Conclusions

Nutrient delivery to streams and river nutrient export has increased rapidly in the 20th century. However, model results are sensitive to factors determining the N and P delivery, as well as in-stream processes. The most uncertain factors are N delivery to streams by groundwater (denitrification as a function of thickness and reactivity of aquifers), and in-stream N and P retention parameters (net uptake velocity, retention as function of concentration).

Table L.

SRC values of global river N export due to changes in 25 model parameters.

SRC for river N export		
Parameter	**1900**	**2000**
Runoff	0.30	0.31
Temperature	-0.22	-0.23
Budget grassland	0.06	0.09
Budget arable land	0.03	0.23
Budget natural land	0.54	0.30
Runoff fraction		0.07
Deep groundwater fraction		-0.05
N uptake	0.01	0.04
Calibration constant for N in surface runoff	0.05	0.18
water reduction grass	0.03	0.07
water reduction crop		0.05
water reduction natural	0.03	0.02
Thickness of riparian zone	-0.14	-0.15
Thickness of shallow groundwater system	-0.34	-0.34
Thickness of deep groundwater system	-0.05	-0.09
Porosity of aquifer material	-0.10	-0.10
Half-life of nitrate in shallow groundwater	0.17	0.17
Half-life of nitrate in deep groundwater	0.13	0.10
Point sources	0.07	0.28
Net uptake velocity	-0.42	-0.48
Flooding depth	0.15	0.17
water storage surface water	-0.14	-0.16
Area flooding	-0.21	-0.20
N retention modification low concentration	-0.39	-0.22
N retention modification high concentration	-0.03	-0.25

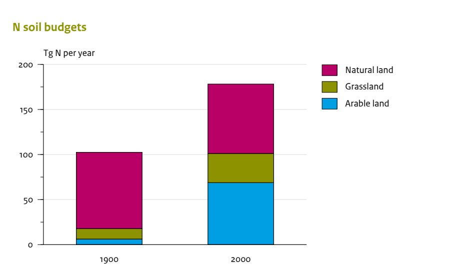

Figure L1. Global Soil N budget for 1900 and 2000.

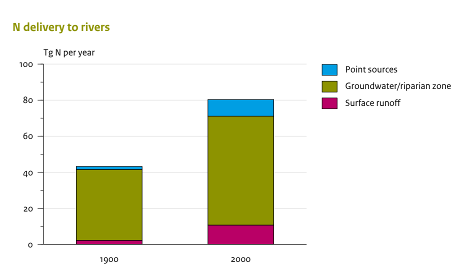

Figure L2. N delivery to streams and rivers.

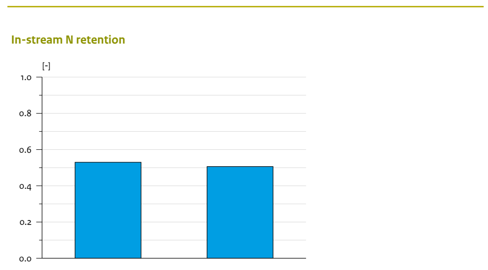

Figure L3. Global in-stream N retention as a fraction of the N delivery.

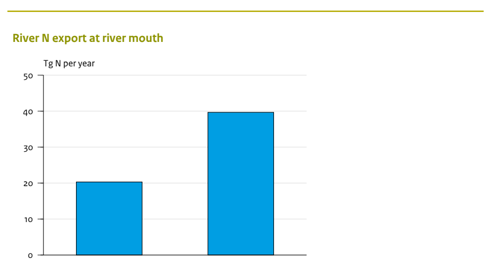

Figure L4. Global N export to coastal seas at the river mouth.

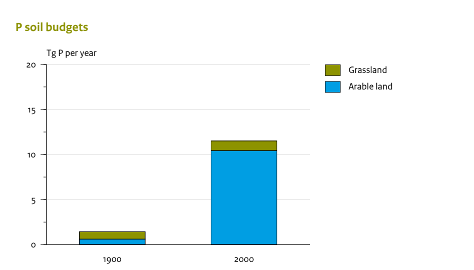

Figure R1. Global Soil P budget for 1900 and 2000.

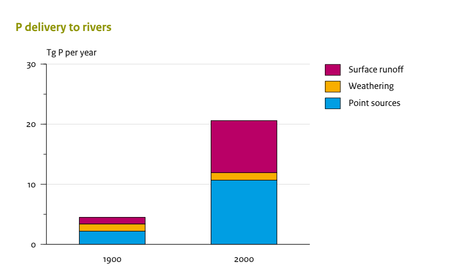

Figure R2. P delivery to streams and rivers.

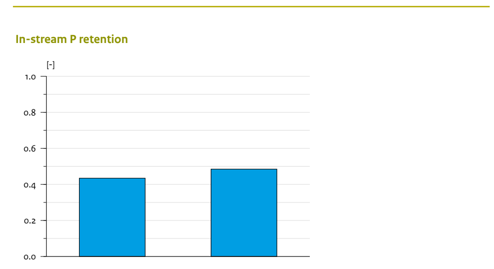

Figure R3. Global in-stream P retention as a fraction of the P delivery.

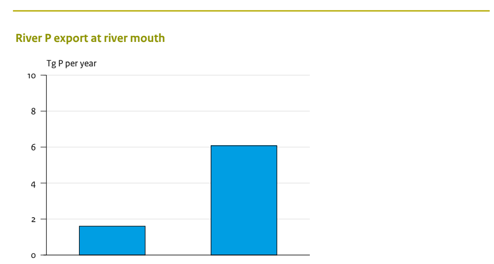

Figure R4. Global P export to coastal seas at the river mouth.

Table R.

SRC values of global river P export due to changes in 15 model parameters.

SRC for river P export		
Parameter	**1900**	**2000**
Runoff	0.52	0.23
Temperature	0.17	-0.02
Budget grassland	0.06	0.01
Budget arable land	0.09	0.20
Budget natural land		
Runoff fraction	0.10	0.22
P uptake	0.06	0.10
weathering	0.38	0.09
Time period for residual soil P		-0.12
Fraction residual soil P loss	0.42	0.74
point sources	0.39	0.32
net uptake velocity	-0.32	-0.31
Flooding depth	0.14	0.13
water storage surface water	-0.14	-0.13
Area flooding	-0.22	-0.19

Footnote Table L and R: Cells with values show significant SRC, green and brown colors indicate values exceeding +0.2 and -0.2, respectively. An SRC value of 0.2 indicates that the parameter concerned has an influence of 0.2^2= 0.04 (4%) on the model variable considered. The sum of squares of SRC_i values of all parameters equals the coefficient of determination (R^2), which for a perfect fit equals 1.

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