NS/05

LUSI - Results

Land Use Changes and Si Transport through the Scheldt River Basin

DURATION OF THE PROJECT
01/01/2007 - 31/01/2011

BUDGET
653.782 €

KEYWORDS
Biogenic silica; eutrophication; land use; deforestation; Scheldt river basin.

CONTEXT

Nutrient concentrations in the North Sea and adjacent estuaries are the end-result of basin-wide input, retention, mobilization and transport of N, P and Si. Traditionally, eutrophication has been approached as a problem of increased human inputs of N and P. In contrast, dissolved Si concentrations have mostly been considered as not anthropogenically influenced. Transfer of dissolved Si (DSi) to rivers has usually been considered to result from a pure geochemical process, involving only direct chemical weathering of soil minerals. As such, the DSi emission from terrestrial systems affected by human activities into water bodies has been considered relatively constant compared to pristine natural systems. Uptake by diatoms in the river continuum was the main factor used to explain DSi profile changes through time. Current research has clearly pointed out that vegetation cover can have a strong impact on the fluxes of Si through terrestrial ecosystems. It has become clear that ecosystems can store a large amount of Si as amorphous, biogenic Si (amorphous SiO2nH2O, BSi), both in soil and vegetation. BSi is far more soluble than mineral Si, and terrestrial Si fluxes are thus potentially strongly controlled by biota. As a result, land use changes and concurrent changes in vegetation cover, have a strong potential impact on the fluxes of Si through river basins.

OBJECTIVES

This project aimed to answer the question if Si fluxes through a river basin, and ultimately towards the sea, can change because of land use changes. These changes were budgeted for the Scheldt basin, taking into account surface runoff, subsurface drainage and storage and cycling through vegetation.

The results will be used to evaluate the effect of land use changes over historical times on Si fluxes. Moreover, it is the aim to formulate recommendations towards land planning with respect to the reduction of eutrophication, working from the viewpoint of Si in the nutrient ratios. As such, this study of Si can provide a mirror image for the N and P side of the eutrophication problem, and provide invaluable, new insights in our evolving concept of eutrophication.

CONCLUSIONS AND DISCUSSION

Our habitat and small catchment scale research shows that in agricultural catchments BSi is an important component of total Si fluxes, which is in contrast to forested catchments. Transport of BSi mostly occurs during rainfall events. Erosion induces a significant mobilization of topsoil and hence BSi from cropland ecosystems. During peak events, a clear trade-off existed between DSi and BSi concentrations, and BSi often became the dominant form of transported bio-reactive Si in croplands.

Based on our results, we propose a novel conceptual model for Si fluxes with deforestation. Initial forest development is characterised by small amounts of DSi released from the soil BSi pool, compared to the amount that is annually added to the vegetation and to the soil BSi pool. Developing forests form net sinks for DSi: unfortunately, little or no research is currently addressing Si dynamics in developing forests. An equilibrium state will eventually be reached: this stage is characterised by a large, slowly growing soil BSi stock. The forest vegetation stimulates bedrock weathering of silicates through increases in soil CO2 content, production of organic acids and stabilization of organic soil cover. Trees take up the weathered dissolved Si (DSi) and deposit it as BSi plant-bodies (phytoliths) in their biomass. The major part of the weathered DSi passes through biomass before it is eventually released to rivers.

The eventual export fluxes of Si from the climax forest soils are controlled by the dissolution of soil phytoliths. With deforestation, the amount of DSi exported from the forest soils drastically increases as BSi stocks dissolve. However, DSi fluxes may be expected to gradually decrease again over time as there will be a fundamental imbalance: the production of biogenic BSi no longer balances the total amount of ASi dissolved, as harvesting of crops prevents replenishment of the soil BSi stock. Soil erosion will increase and BSi will be physically removed from the soils, especially during precipitation events. Increased TSi fluxes will only last until the soil reaches a new climax cultivation state, characterised by lower export TSi fluxes. The absence of deep-rooting vegetation and the absence of a significant soil organic layer restrain vegetation stimulated weathering mechanisms.

Our results proof that worldwide massive agricultural Si harvest, and in- and export of food from countries, are reducing potential bio-control and bio-stimulation mechanisms in river basins worldwide. The agricultural silicon harvest is thus a new and important loop in the silica cycle, and its sink function adds and potentially exceeds other important anthropogenically created Si sinks, such as BSi deposition in lakes and reservoirs and reduced weathering stimulation after deforestation. We strongly recommend to start research focusing on this new loop in biogeochemical Si cycling, by the detailed life cycle assessment of harvested BSi, and research focusing on soil Si depletion and biogeochemical consequences in agricultural river basins worldwide.

Finally, we have also made distinct advances in our knowledge of techniques to analyze for BSi in soils and suspended sediments. We have found threshold concentrations where traditional alkaline extraction methods are applicable for terrestrial soils, and are developing novel continuous extraction techniques to gain better insight in lithological interference and reactivity of BSi. We also tested the conceptual model by studying land use and Si fluxes in land use age gradients (in cooperation with Lund University, Sweden) in Southern-Sweden. The age gradients in land use studied here indicated that our conceptual model holds true in other environments. Finally, we summarized current understanding of the effect of ecosystems on terrestrial Si fluxes in a set of scientific recommendations for the future.

Our results emphasize the necessity of increasing our understanding of land use impacts on biogeochemical Si cycling, with a millennium of soil disturbance after deforestation leading to 2-fold to even 3-fold decreases in TSi flux from a watershed where the adjacent coastal zone has experienced significant coastal eutrophication problems due to changes in Si/P and Si/N river deliveries in the three last decades.

OUR RESULTS AND SUSTAINABLE DEVELOPMENT

- Incorporation of our findings in models will improve their quality with respect to eutrophication in rivers and the coastal zone: the prediction capacity for eutrophication events will increase. As such, organizations such as OSPAR and the EU in general can benefit from our results. We will provide all data in ready-to-use datasets to MUMM (Management Unit of the North Sea Mathematical Models) for public archiving.

- Implementation of the Water Framework Directive will benefit from this project as the effect of land use on Si can be used in the construction of reference conditions. The results can also have an impact on Conservation Objectives, as silica cycling was imbedded in the construction of conservation objectives of certain habitats such as tidal marshes.

- Measures to reduce erosion also will change Si delivery to aquatic systems. The project will provide knowledge to link these two aspects. Reforestation has an effect on Si storage. As such, the effect of reforestation of changing nutrient ratios can be evaluated.

- Our observations showed the importance of land use and land cover as regulating factors of riverine Si transport, both BSi and DSi. Once implemented in biogeochemical models, our data will provide valuable input for the integrated management of watersheds.

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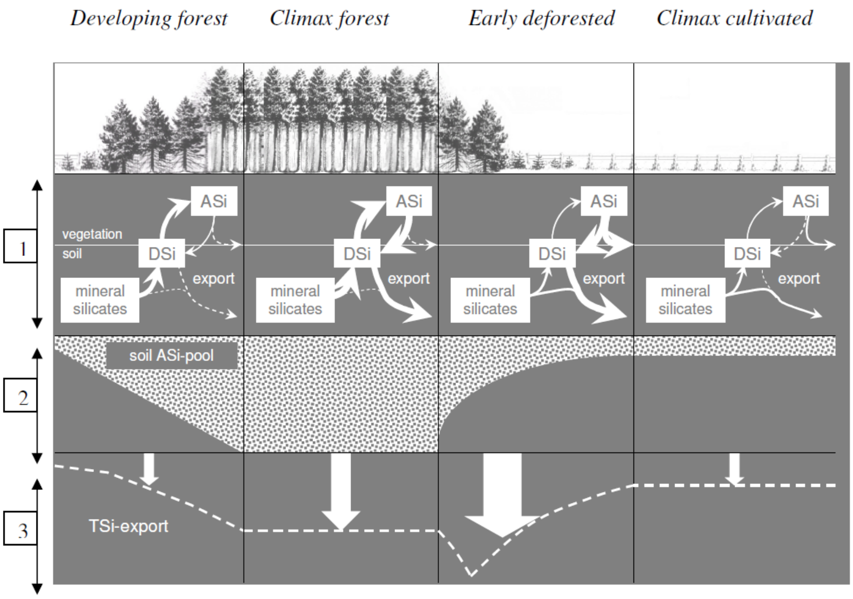

Summary figure: A new conceptual model for changes in Si cycling with long-term soil disturbance. (1) Hypothesised Si cycling in developing forest, climax forest, early deforested areas and equilibrium cultured areas, the associated soil ASi stock (2) and the resultant magnitude of TSi export (3). In (1), boxes represent stocks of Si. Arrows represent fluxes: the thickness of arrows is representative for flux size. Dashed arrows represent irrelevant fluxes. In (2), the dotted area represents the size of the soil ASi pool. In (3) the sizes of the arrows represent relative TSi fluxes. The dashed line represents the hypothesized evolution of the size of the TSi fluxes.

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