Natural and Anthropogenic Influences on Nutrient Export from Tropical Mountainous Rivers into the Arabian Sea

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Abstract

The land-sea connection of nutrients via rivers is an essential component in the global nutrient biogeochemistry. Rivers alone transport approximately 80% of the dissolved nutrients from land to ocean and play a vital role in nourishing riverine, coastal and oceanic ecosystems. During the past decades, global scale investigations have estimated the riverine nutrient flux to the oceans along with the significant drivers. However, most of the previous estimations are based on nutrient discharge by a few major rivers. Despite being large in number and high yields, the tropical coastal/mountainous rivers have received less attention. To fill the gap, we have investigated 70 west-flowing coastal rivers, draining the Western Ghats (WG), for their Dissolved Inorganic Nutrient (DIN) transport characteristics and influencing factors. Previous studies in the selected estuaries along the WG coast are combined to update the land-sea fluxes estimation to understand the spatial pattern of DIN over the WG rivers-the Arabian sea coast continuum. Altogether, the DIN fluxes from entire WG (including non-sampled rivers) region to the estuaries are 664, 241 and 6277 Tg yr^{-1} for Nitrate (N), Phosphate (P) and Silicate (DSi) respectively. The natural factors, such as discharge, cropland, and forest cover each explain 30–85% of the spatial variation in DIN levels at the basin scales. DIN concentrations of rivers reduces to ˜ 90% after reaching the respective estuaries. Based on Redfield ratio of C:N:P (106:16:1), annual export of 66.4 Tg of dissolved inorganic N from the WG rivers would support 439.9 Tg of new carbon production in the Arabian Sea coast. The humid tropical climate and high population density ($>$ 300 people per km^2 among the bio-diversity hotspots) of the WG region favour the high DIN export, thus, making the Arabian sea coast highly productive among the global coastal regions. Keywords: Dissolved Inorganic Nutrients; Rivers-Coast Continuum; Influencing Factors; Small Mountainous Rivers; Western Ghats.

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Context

Coastal seas receive nutrient inputs via rivers, groundwater, and atmospheric sources where rivers are treated to be the dominant external sources. Together 8.5% (12.7×10^{6} km^{2}) of the global land area is drained by about 24,500 first and second-order independent mountainous rivers and contributes over 12% of global freshwater discharge (Milliman and Farnsworth, 2013). The high runoff is one of the prominent features of these catchments nevertheless of the climatic conditions of regions. These catchments are marked by considerable heterogeneity in basin parameters (i.e. lithology, topography, soils, vegetation cover, and climate). It implies that

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Study Area

Indian landmass separates the North Indian Ocean into the Arabian sea and the Bay of Bengal lies on either side of the west and east coasts. Though the Bay of Bengal receives much freshwater discharge from the large perennial rivers, around 600 small west-flowing rivers originate from the Western Ghats (WG) and subsequently discharges into the Arabian Sea. The WG is a continuous tropical mountainous chain running parallel to the western coast of India for a distance of 1,600 km and covers a 1,40,000 km^{2} area (Fig. 1). The WG is experiencing a tropical humid climate with average annual rainfall and temperature of 3554 mm (highest in peninsular India) and 27 °C, respectively (Reddy

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Materials and methods

An extensive sampling of 70 coastal mountainous rivers, draining the WG of India was carried out (Fig. 2). At the end of each day sampling, a temporary laboratory was set up in the halting hotel room for filtration of samples. About 100 ml of the sample was filtered through 0.45 µm nylon membranes at a gentle vacuum, the filtered water was collected in pre-cleaned high-density polyethylene (HDPE) bottles and instantly poised with the $HgCl_2$ to arrest the biological activity. During the field, the filtered water samples were stored in a portable car chiller (~4 °C) later, shifted to laboratory refrigerators till the analysis.

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Results and Discussions

The seasonal concentrations of DIN, DIP, and DSi for the WG rivers range from 0.05 to 6.8, 0.01 to 0.39, and 6.2 to 55.1 mg l^{-1}, and the discharge weighted mean concentrations of DIN, DIP, and DSi are 1.05, 0.05, 19.4 mg l^{-1}, respectively (Fig. 3).

The entire WG region supplies 0.31 Tg of DIN, 0.014 Tg of DIP, and 5.65 Tg of DSi every year to the Arabian Sea. This accounts about 1% of each DIN, DIP and DSi of global riverine loads. The mean annual yields of DIN, DIP, and DSi for the entire WG region are 27, 1.3, and 501 kg ha^{-1}, respectively. The mean DSi yield of the WG (501 kg ha^{-1} yr^{-1}) is remarkably higher

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Controlling factors

The fluxes of DIN, DIP, and DSi are showing significant linear correlations with catchment area and length for SGT, WDC, DT, and whole WG rivers (Fig. 4). It advocates the strong influence of catchment size and length of the WG rivers, despite the concentrations are showing strong variability among the three regions. Further, no other factor from hydrological (except discharge), climatic and land use and land cover (LULC) patterns have shown any variability. Similar to Krishna et al. (2016), the yields of DIN, DIP, and DSi are also independent of the basinal, climatic, and

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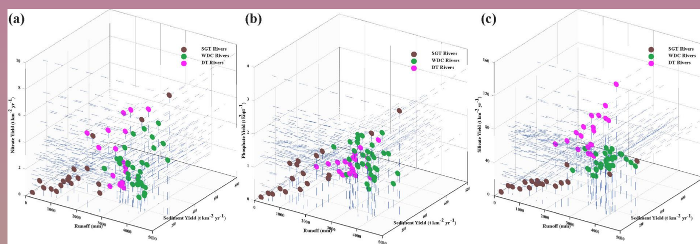

Conclusions

- This study demonstrated that the small mountainous rivers are the potential natural sources of carbon and nutrients to the receiving coastal regions.
- The WG region covers less than 0.1 % of the global landmass yet contributes about 1 % of global fluvial nutrient flux.
- Natural factors dominate over the anthropogenic activities in the nutrients export to the Arabian Sea.
- Among the dissolved inorganic nutrients to the Arabian Sea from these coastal rivers, nitrate limitation and high silicate

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