EXPORT OF DISSOLVED IRON AND THE RELATED SOLUTES FROM TERRESTRIAL TO STREAM ECOSYSTEMS IN NORTHERN PART OF HOKKAIDO, NORTHERN JAPAN

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INTRODUCTION

Iron is an essential nutrient for most biota. Some resent studies suggested that dissolved iron in seawater might be limiting factor for primary production in ocean especially at northern Pacific region (Ducklow *et al.* 2003). While atmospheric deposition and river discharge were possible major sources of the iron for the ocean, qualitative and quantitative understandings of iron dynamics from terrestrial to ocean ecosystem have not been fully clarified yet. In the terrestrial ecosystem, iron is a major element in the rock and parent materials in soil. There are several processes of iron exports from terrestrial to stream ecosystems. Wind and water erosion of surface soil could be possible mechanisms to transfer of solid form of iron especially in agricultural land. Leaching of iron from soil to groundwater and stream water also plays a role to transform of iron from terrestrial to stream ecosystem. Since these processes were closely related to hydrological dynamics and related solute movement (especially dissolved organic matter), human activities (development of agriculture, urban and industry, forest harvesting, fire and so on) in terrestrial watershed have a potential to affect the iron transport from terrestrial ecosystem (Shibata *et al.* 2003). In this paper, we focused on the fate of dissolved iron and the related solute (mainly dissolved organic carbon) from terrestrial to stream ecosystem in northern part of Hokkaido, northern Japan.

TOPOGRAPHIC CONTROL OF DISSOLVED IRON CONCENTRATION IN STREAM WATER IN FORESTED BASIN

In cool temperate and boreal region, topographic characteristics create several gradients of the ecosystem function and processes associated with the difference of the soil moisture regimes in forested basin. For example, riparian wet land was distributed in the large flat area in relatively lower position of the slope. This riparian area tends to have higher groundwater table and anaerobic condition in soil and have some different species of vegetation compared to those at the middle and higher position of the slope. Some soil processes (mineralization and immobilization of organic matters) associated with microbial activities in the soil closely related to the soil moisture condition. In anaerobic condition, decomposition rates of the organic matter decreased than those at the aerobic condition. Topography of the watershed also affects the water flow pass in the ground. Steep and small watershed tend to have relatively shallow water flow and shorter residence time of water, while deep water flow and longer residence time of water tend to distribute at the larger and flatter watershed.

Iron and the related solute concentration in stream water were investigated in Uryu Experimental Forest, Hokkaido University to clarify the relationships between topographic characteristics of watershed and stream chemistry in forest watershed. Annual precipitation in this region is about 1.4 m and about half of the precipitation is supplies as snow. Snowfall occurred generally from end of November to March. Annual mean temperature was about 3.3 ^{o}C. Basin area of the studied watershed was 33 km^2 and dominant vegetation was cool-temperate natural mixed forest. Predominant bedrock is tertiary Andesite, and the predominant soil is Inceptisol (brown forest soil) at the most part of watershed and Histsol (peat soil) at the riparian wetland from middle to lower part of the watershed.

We collected stream water for chemical analysis from several locations in main and sub stream in the experimental watershed. We used the topographic indexes (TI) calculated as "TI = ln (α／tan β) " (α: contribution area, β: slope) to assess the topographic features in each watershed (Ogawa 2003). Soil solution was collected using tension lysimeter (ceramic porous cup) in the riparian wet land and each position (low, middle and high) of slope to understand the source of the solute to stream. Dissolved total iron in stream water was analyzed using ICP spectrometer (IRIS advantage, Japan Jarell-Ash Co Ltd.). DOC (dissolved organic carbon) in stream water and soil solution was analyzed using TOC analyzer (TOC 5000A, Shimadzu Co Ltd.).

Figure 1 shows spatial pattern of concentration of DOC in soil solution at each slope position and riparian wet land (Suzuki 2003). DOC concentration in soil solution tends to higher in lower position and riparian area, suggested that the source of DOC in the ground distributed in the anaerobic zone accumulating organic matters. Iron concentration in stream water significantly correlated with watershed slope and topographic indexes (Fig. 2). There was also significant positive relationship between iron and DOC concentration in stream water (Fig. 3). These suggested that topographic feature of the watershed was very important to assess the iron export from terrestrial to stream ecosystem. It was suggested that the difference of the topography created the moisture gradient from upper to lower watershed, resulting the different magnitude of the dissolution of iron through the conjugation between DOC and dissolved iron. Our results indicated that the riparian wet land has a significant source of dissolved iron and conjugated DOC to stream ecosystem in this watershed. Elder *et al.* (2000) and Mulholland (1981) also revealed the significant importance of riparian wetland as a source of DOC to stream water. Ogawa (2003) indicated that the concentration of dissolved nitrogen in stream water was controlled by the similar topographic feature in this studied watershed. She discussed that nitrate retention of the riparian wet land was very important the formation of the spatial differences of nitrate concentration in stream water. Shibata *et al.* (2004) indicated that the hyporheic exchange flow affects the dissolved nitrogen dynamics and the mechanisms of nitrogen sinks in riparian zone in northern Japan. These results suggested that the topographic features and the related soil moisture regime might me primary driver as a dissolve iron source in forest catchments in this region.

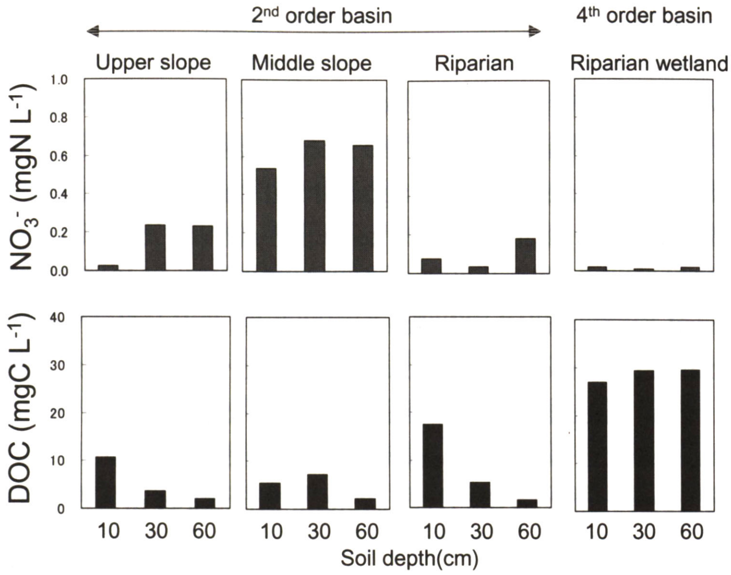

Fig. 1 Mean concentration of nitrate (NO_3^-) and dissolved organic carbon (DOC) in forest soil solution in each slope position and riparian wetland of 2nd and 4th order basin in Uryu Experimental Forest, Hokkaido University (modified from Suzuki 2003).

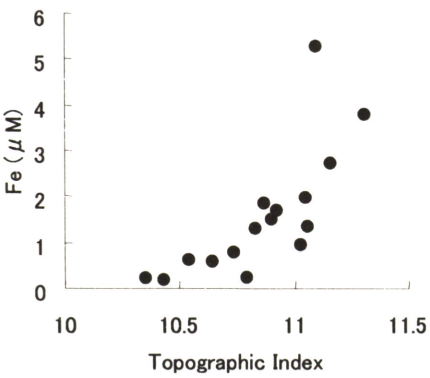

Fig. 2 Relationship between dissolved total iron concentration in stream water and mean topographic indexes in each forested basin.

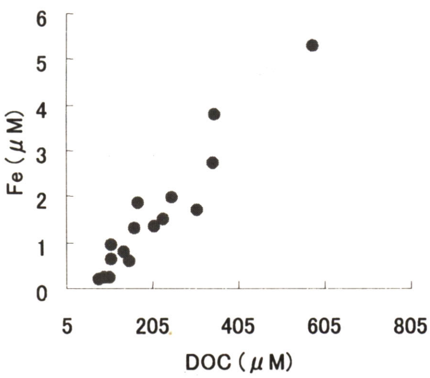

Fig.3 Relationship between total dissolved organic carbon (DOC) and iron concentrations in stream water of forested basin.

Spatial differences of dissolved iron concentration in stream water in regional scale

In more wider and regional scale, some land-use and human's activities are involved in the watershed environment to understand the mechanisms of iron release from terrestrial to aquatic ecosystem. Regional observation of iron concentration in river water was conducted in Tesio River, second longest river in Hokkaido Island, to clarify the regional distribution pattern of iron concentration in a wider cathchment scale. In Teshio River basin, agriculture, industry and urban activities mainly exist in the middle part of the river. We found the large increase of iron concentration in river water at the middle of the basin (Fig. 4). DOC concentration in river water also increased with the increase of the iron concentration. There was significant positive relationship between iron and DOC concentration in river water (Fig. 5). It seemed that two major reasons affected the iron release from terrestrial to river system; anthropogenic and natural sources. Major agricultural lands (including paddy field) are mainly located at the flood plain near the river, especially in the middle of the basin. And the peat soil was also distributed in this riparian flood plain as well. Therefore, iron release associated with dissolved organic materials from terrestrial ecosystem to the river seemed to be released from combined source of the peat soil and/or agricultural treatment (drainage, fertilizer and so on). The integrated analysis of hydro-biogeochemical processes in soil solution and groundwater would be necessary to clarify the quantitative contribution of each land-use pattern on the iron release to the river system. Shibata *et al.* (2001) indicated that the hydrological processes in the ground played an important role for the fate of DOC in soil-groundwater-stream continuum in the basin.

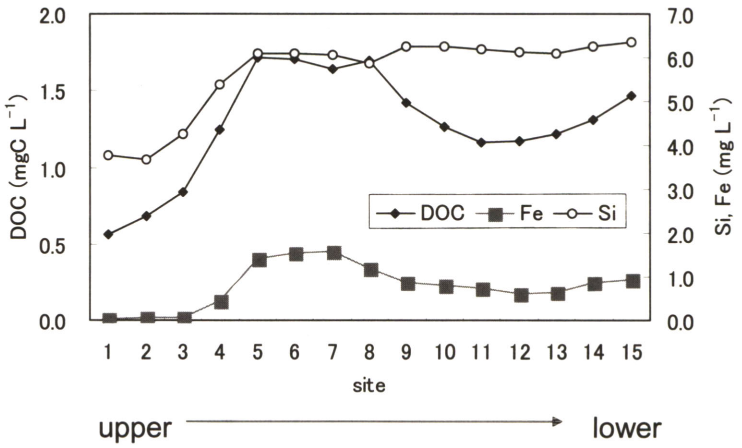

Fig. 4 Spatial distribution of dissolved organic concentration (DOC), dissolved total iron (Fe) and dissolved total silicon (Si) concentrations in river water from upper to lower part of Teshio River. (May 2001)

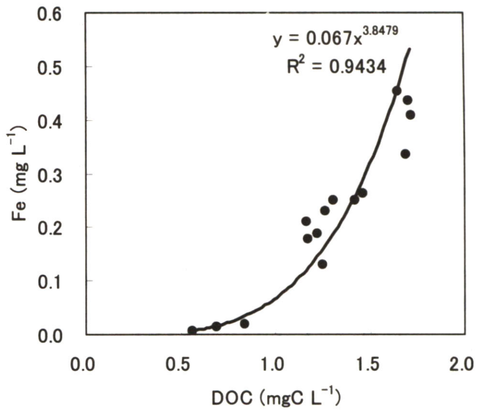

Fig. 5 Relationship between dissolved organic carbon (DOC) and dissolved total iron (Fe) concentrations in Teshio River from upper river to the river mouth (May 2001)

Conclusions

Our results suggested that the soil moisture regime associated with topography would primary influenced on the iron dynamics from terrestrial to aquatic ecosystem. Soil moisture regime closely related to the vegetation composition and soil physico-chamical characteristics as well. DOC dynamics would play a important role on the dissolved iron movement in the ground to water, especially in a riparian wetland which is an interface between terrestrial and aquatic ecosystem. It seemed that the land-use change from natural ecosystem to agricultural and/or urban system could affect the soil moisture regimes, dynamics of organic materials, excess inputs of chemicals in each terrestrial ecosystem, resulting to the significant change of iron release from terrestrial to aquatic ecosystem. The reported results are based on the very limited observation temporally and spatially, indicating that the more comprehensive and integrated observation would be necessary to understand the role of the terrestrial ecosystem as a supplier of the iron which is an important nutrient for oceanic biota.

Acknowledgement

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