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The effect of gross primary production, net primary production and net ecosystem exchange on the carbon fixation by chemical weathering of basalt in northeastern Iceland

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Abstract

The overall objective of this study is to define and interpret the annual dissolved inorganic carbon (DIC) flux in selected river catchments in North Eastern Iceland. The flux stems primarily from chemical weathering of basalt. The DIC flux out of the catchments is compared with the spatial distribution of the various vegetation communities and their gross primary production (GPP), net primary production (NPP) and net ecosystem exchange (NEE). There is no correlation between the DIC flux and the GPP, but one between DIC and NPP. The DIC flux is highly dependent on the NEE, which in turn is governed by the area extent of wetlands in these catchments. A variation by a factor 5 of the NEE results in a variation by a factor 2.8 in the river dissolved inorganic flux.

Keywords: Chemical weathering; Dissolved inorganic carbon (DIC); Wetlands; Net ecosystem exchange (NEE); GIS; Iceland

1. Introduction

Owing to their abundance in the Earth's crust and their relatively high chemical weathering rates, basalt and basaltic glass weathering play a critical role in the global and local cycling of a significant number of chemical elements and of atmospheric CO_2 (Gíslason et al., 1996; Dessert et al., 2003) and some of them are essential for life. Iceland provides an opportunity to study the chemical weathering and denudation of basalt and organic matter under uniform lithology, at a constant average temperature, variable rainfall and rock age, high relief, and variable glacial and vegetation cover. The high chemical weathering rates in Iceland can be attributed to high runoff and mechanical weathering, the abundance of glassy and crystalline basalt, the age of the rocks and high permeability (Gíslason, 2005). At relatively constant runoff and rock age, vegetation has been shown to enhance chemical weathering rates (Gíslason et al., 1996; Moulton et al., 2000). This effect of vegetation on the chemical weathering of Ca, Mg-silicates has been included in models of past atmospheric CO_2, taking account of mantel degassing, weathering, sedimentation, diagenesis, and metamorphism (i.e. Berner and Kothavala, 2001).

This study addresses particularly the role of the vegetation and its effect on carbon fixation by chemical weathering in Iceland. For this purpose, 7 river catchments in northeastern Iceland were selected (Fig. 1),

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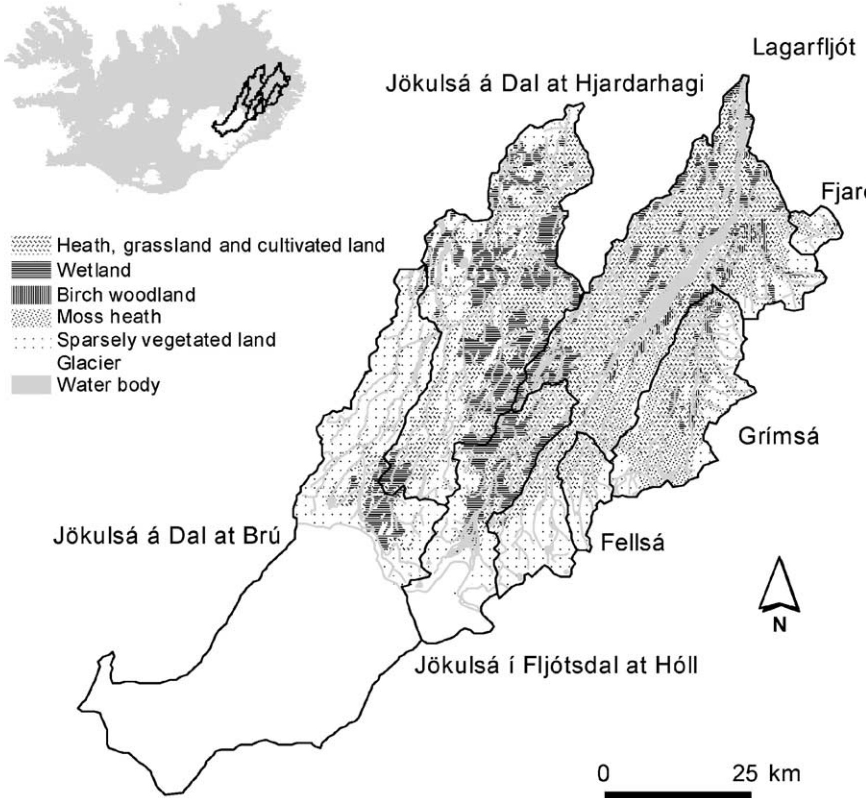

Fig. 1. The catchment areas of the present study in North Eastern Iceland and the area extent of the vegetation categories.

namely: Jökulsá á Dal at Brú, Jökulsá á Dal at Hjardarhagi, Jökulsá í Fljótsdal at Hóll, Fellsá, Grímsá, Lagarfljót and Fjardará. The total area covers approximately 5% of Iceland, the annual runoff ranged from 1060 mm to 1648 mm in 1998, and the average area weighted age of the rocks ranges from 1.3 to 11.2 million years.

2. Methods

Data from the geochemical database of the Science Institute, University of Iceland and the National Energy Authority (Gíslason et al., 2004) were used to calculate the DIC flux for the selected river catchments. The data include 10 samples per year from the rivers for the period 1998 to 2003. The samples were always collected at the same cross section of the rivers which were continuously monitored for river discharge. The DIC concentrations, which were measured by alkalinity titrations, were plotted versus the discharge and power functions constructed (Knighton, 1998). The power functions have the form of

$$\mathrm{DIC} = aQ^{b} \tag{1}$$

where a and b are coefficients and Q is the discharge at the time of sampling. The square of the correlation coefficients ranged from 0.42 to 0.96. The annual DIC flux in gram carbon per square metre per year units (g C m^{-2} $year^{-1}$), for 1998 was calculated using the measured average daily discharge (Orkustofnun, 2005) to calculate average daily fluxes for each day of the year which were then integrated for the whole year of 1998.

The present vegetation in Iceland is characterized by a nearly total absence of trees, widespread mires, low-density grasses, forbs, willows and abundance of low-growing shrubs sedges and rushes (Gísladóttir, 1998). The aerial extent of the catchments (Orkustofnun, 2005) was used in conjunction with digital vegetation maps (Gudjónsson and Gíslason, 1998) to calculate the carbon flux through the vegetation in the study area. The digital map and the catchment limit layers were intersected and combined to define the aerial extent of the various vegetation communities. Five vegetation categories were used: (1) heath, grassland and cultivated land, (2) wetland, (3) birch woodland, (4) moss heath and (5) sparsely vegetated land. These categories exchange carbon with the atmosphere and soil solutions via net primary production (NPP) and respiration. In this study, NPP is defined as the sum of the carbon fixed by photosynthesis, or gross primary production (GPP) subtracted by plant respiration, or autotrophic respiration. Net Ecosystem Exchange (NEE) is defined as NPP subtracted by the decomposition of organic material, or heterotrophic (non-plant) respiration.

The average annual GPP, NPP and NEE values (g C m^{-2} $year^{-1}$) for each of the 5 vegetation categories were estimated from previous studies (Óskarsson and Gudmundsson, 2004; Sigurdsson, 2004; Sigurdardóttir, 2000; Yarie and Billings, 2002; Snorrason et al., 2002). The area extent of each category (Fig. 1) and the average annual GPP, NPP and NEE for each vegetation category were used to calculate the total annual GPP, NPP and NEE carbon fluxes within each catchment normalized to the total area extent of the river catchments (g C m^{-2} $year^{-1}$).

3. Results and discussion

The results and its correlation with the GPP, NPP, NEE and the percent area extent of wetlands are shown in Fig. 2. The DIC flux varies between 3.2 (g C m^{-2} $year^{-1}$) for River Fjardará to 10.2 (g C m^{-2} $year^{-1}$) for River Jökulsá í Fljótsdalur. The Fjardará catchment is the oldest catchment, 11.2 My and of intermediate runoff, 1555 (mm $year^{-1}$), but the catchment of Jökulsá í Fljótsdalur is of intermediate age, 2.1 My and has a slightly higher runoff 1609 (mm $year^{-1}$). The gross primary production of the vegetation (GPP) in the catchments is more than an order of magnitude higher than the river dissolved inorganic carbon flux out of the catchments and there is no correlation between them (Fig. 2A). The net primary production of the vegetation (NPP) is still higher than the river flux of dissolved inorganic carbon (DIC) and there is a correlation between them (Fig. 2B). The net ecosystem exchange of carbon is slightly lower than the DIC flux and there is a strong correlation between the two (Fig. 2C). The NEE was lowest for River Fellsá catchment—1.3 g C m^{-2} $year^{-1}$ but highest for River Jökulsá í Fljótsdalur catchment, 8.3 g C m^{-2} $year^{-1}$ (Figs. 1 and 2C). There is also a good correlation between the percent area extent of the wetland and the river DIC flux (Fig. 2D). The catchment of Jökulsá í Fljótsdalur has the highest wetlands area extent, 18% but wetlands are nearly nonexistent for the catchments of Fjardará and Fellsá (Figs. 1 and 2D). Birch woodland has the highest average annual NEE, 66 g C m^{-2} $year^{-1}$ of the vegetation categories and wetlands come next with 50 g C m^{-2} $year^{-1}$. Here, it should be noted that the wetlands do

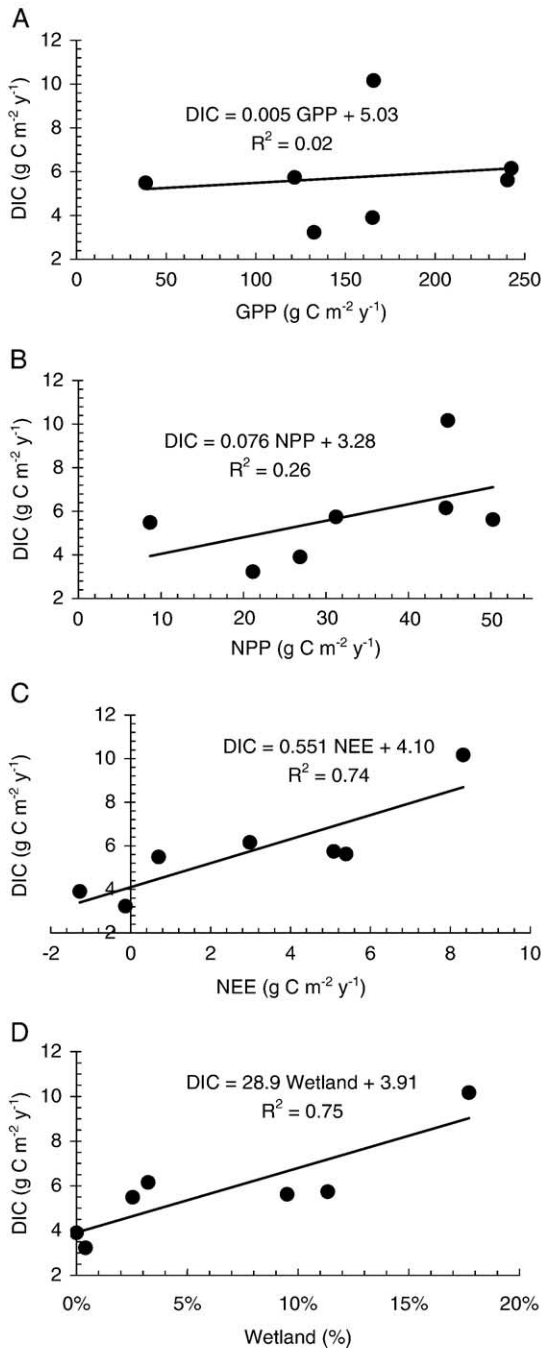

Fig. 2. The river dissolved inorganic carbon flux (DIC) versus carbon fluxes stemming from vegetation and percent area extent of the wetland scaled to the total surface area of the catchments (Fig. 1): (A) DIC versus gross primary production of the vegetation categories (GPP), (B) DIC versus the net primary production of the vegetation categories (NPP), (C) DIC versus the net ecological exchange of the vegetation categories (NEE) and (D) DIC versus the percent area extent of wetland in the catchments.

not have the highest NEE rates, those are the woodlands. Birch woodland however, covers relatively small areas of the studied catchments (Fig. 1).

This study shows that net ecological exchange of vegetation affects the rate of carbon fixation by chemical weathering of basalt. The correspondence is about one half as shown by the slope of the regression line in Fig. 2C. Factor 5 variations in NEE results in factor 2.8 variations in river dissolved inorganic carbon flux.

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