Effects of chemical fertilizer and manure application on dissolved carbon leaching and carbon budget in a managed grassland in southern Hokkaido, Japan

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1. Introduction

Grassland ecosystem comprises approximately 40.5% of the earth's terrestrial land area, which plays an important role in carbon (C) balance at the global scale. Export of dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC) from grassland ecosystems can be an important C flux which directly affects ecosystem C balance after leaching from the soil to the groundwater and causes contamination. However, few studies have documented C leaching and the C balance including C leaching loss. Fertilizer and manure, as soil amendments, are widely used nowadays to increase productivity and enhance soil fertility in agriculture. This study aims to investigate the effects of chemical fertilizer and manure application on dissolved C leaching and estimate C budget considering C leaching losses.

2. Materials and Methods

A field experiment was conducted in a managed grassland with Timothy (*Phleum pretense L.*) of Shizunai livestock farm (42°26'N, 142°29'E) in Southern Hokkaido, Japan, from June 2014 to May 2016. Three treatments, a control (CT), chemical fertilizer (F) and manure (4192.9 kg C $ha^{-1}yr^{-1}$) and chemical fertilizer (MF) were established at the begining of June 2014 with four replicates. Tension free lysimeters (0.05 m^2 area, 1 cm height of collars on 3 sides) were installed at 30cm depth below ground to monitor DOC and DIC leaching. Amounts of DOC and DIC leaching were estimated by the DOC and DIC concentrations of the percolated water and the water fluxes calculated by water balance method. Net primary production (NPP) was estimated using harvest method. Heterotrophic respiration (RH) was measured by closed chamber method. Water and gas samples were taken every one or two weeks in growing season and three or four weeks in non-growing season. The net biome production (NBP) was estimated as NPP – RH – Harvest + Manure +Lime – DOC – DIC.

3. Results and discussion

1) Both dissolved C concentration in percolate water and dissolved C leaching loss were significantly higher in MF plot than in CT and F plots (p<0.01), indicating that manure application could increase C leaching loss through increasing organic C source in soil.

2) The amount of SOC in 0-30cm soil depth was 103.2 and 129.8 Mg C $ha^{-1}yr^{-1}$in F and MF plots, respectively. And C from manure was 4.2 Mg C $ha^{-1}yr^{-1}$. Results showed that 98.9 kg C $ha^{-1}yr^{-1}$ C of manure and 69.2 kg C $ha^{-1}yr^{-1}$ C of SOC were leached out from top soil. 1051kg C $ha^{-1}yr^{-1}$ C of manure and 4996.7 kg C $ha^{-1}yr^{-1}$ C of SOC were emitted from the surface soil. The sum of leached and emitted C accounted for 27.4% and 4.9% of manure C and SOC, respectively.

3) The NBP was negative in all treatments. However, MF showed significantly highest (p<0.01) among the treatments (-1.3 ± 1.0 Mg C $ha^{-1}yr^{-1}$), followed by CT (-3.6 ± 1.1 Mg C $ha^{-1}yr^{-1}$) and significantly lowest (p<0.01) in F (-4.2 ± 1.5 Mg C $ha^{-1}yr^{-1}$), indicating that manure application could mitigate C loss in grassland ecosystem. Although chemical fertilizer can increase productivity, it could increase the net C loss.

4) Total dissolved C leaching contributed to 2.2%, 1.6% and 12.9% of NBP in CT, F and MF plots, respectively. This reveals that it is necessary to take C leaching loss into consideration when estimating C budget because of its non-negligible fractions to NBP.

4. Conclusions

1) Manure application significantly increased C leaching losses by increasing organic C source in soil (p<0.01). While chemical fertilizer had no significant effects on C leaching loss.

2) Both chemical fertilizer and manure application led to net C loss in this grassland ecosystem, however, manure addition could significantly mitigate C loss (p<0.01).

3) Due to the non-negligible contribution of C leaching loss to NBP, it is important to take C leaching into consideration to develop reliable estimates of net ecosystem C balances.