1Evaluating the Vulnerability of Agro-Environment in a Cold Region to Climate Change and Developing Adaptation Practices by Snow and Soil Frost Control.

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[Abstract]

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The depths of soil frost are decreasing in the eastern Hokkaido, which is one of the largest agricultural regions in Japan. Due to the recent decrease in soil-frost depths, we have observed weed problems associated with volunteer potatoes. In terms of environmental impacts, the decrease in soil-frost depths may have influenced the transport of soil water and dissolved solutes (mainly NO_3). Moreover, it was previously shown that deep soil frost triggered vigorous N_2O emissions at thawing in the study region. On this basis, the objectives of this study were to assess the vulnerability of the agro-environment in a cold region to climate warming and to develop an adaptation measure for both sustainable agricultural production and environmental protection.

We developed a simultaneous multi-field observation system of atmosphere, soil and greenhouse gases for two experimental sites at Sapporo and Memuro in Hokkaido. This novel system proved to be robust under severe cold weather conditions and contributed to laborsaving and cost-effective observations. Snow management experiments at both sites showed that 1) deep penetration of freezing front was achieved by snow removal, 2) the deep soil frost impeded snowmelt infiltration as well as kept NO_3 in surface soil layer and 3) N_2O emissions at thawing were significantly enhanced by deeper soil frost.

Winter-to-spring N_2O fluxes represented greater than 70% of the annual fluxes. Increases in N_2O concentration coincided with decreases in O_2 levels at the upper half of the frozen soil layer. This coincidence was concomitant with melting of snow cover.

To achieve sustainable agricultural production and environmental protection, we developed a method to control soil-frost depths by artificially manipulating snowcover thickness, guided by a numerical prediction model. The method allowed predicting the maximum soil frost depth within a few cm of accuracy. To prevent the occurrence of volunteer potatoes, contamination of groundwater with NO_3, and over-development of soil frost, which would delay the sowing of spring crops and triggered vigorous N_2O emissions, the optimal frost depth was leading to be 0.3

m.

The application of charcoal as an agricultural snowmelt agent resulted in approximately 1.5 Mg C ha^{-1} of input to the soil, which was nearly equivalent to the annual CO_2 emissions in our study site, suggesting a potential mitigation option for global warming. The use of charcoal can serve as an agronomic practice for both extending the growing period of crops and mitigating greenhouse gas emissions in farmlands of northern Japan.