Integrated Evaluation of Soil Carbon Budget by Manure Application on Forage Production

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Introduction

Grasslands and forage crop fields produce forages and also have many services and functions such as repositories of biodiversity, climate regulation and soil conservation (Sala and Paruelo, 1997). Carbon budget is one of these important ecosystem services by high levels of carbon sequestration below ground (Hungate*et al.*, 1997). Manure application increases carbon budget and also affects forage production, NO_3^- leaching to underground water and N_2O emission to atmosphere. Integrated evaluation of these various environmental impacts is important to find optimum condition for forage production and environmental impacts. LIME2 (Life-cycle Impact assessment Method based on Endpoint modeling 2, Itsubo and Inaba, 2010) is one of the methods to evaluate environmental impacts and to integrate them into a single index of environmental damages with the unit of Japanese yen. By comparing this index to economic benefit of forage production, integrated evaluation of environmental damages and profit of farmers is achieved. In this study, the effects of manure application to forage production, carbon budget, NO_3^- leaching and N_2O emission were evaluated and optimum level of manure application level was estimated with LIME2 integration factors.

Materials and Methods

The evaluation flow of manure and chemical fertilizer application and environmental impacts was shown in Fig. 1. The relationships between the amount of nitrogen application (chemical fertilizer: F_N, manure: M_N, kgN ha^{-1} y^{-1}) and dry matter yield on artificial grassland (GY_{DM}, kgDM ha^{-1} y^{-1}) and forage corn (CY_{DM}, kgDM ha^{-1} y^{-1}) were estimated by following equations.

$$GY_{DM} = (1896.3 \ln(F_N + 0.3417 M_N) + 180.80) * (0.02721 T + 0.7234) \quad (1)$$

$$CY_{DM} = 1330.1 \ln(F_N + 0.3417 M_N) + 8471.4 \quad (2)$$

T was mean annual air temperature. A part of M_N (34.17 %) was assumed to be released as inorganic nitrogen. The relationships between the amount of nitrogen application and nitrogen yield on artificial grassland (GY_N, kgN ha^{-1} y^{-1}) and forage corn (CY_N, kgN ha^{-1} y^{-1}) were estimated by following equations.

$$GY_N = (63.653 \ln(F_N + 0.3417 M_N) - 88.704) * (0.02721 T + 0.7234) \quad (3)$$

$$CY_N = 29.874 \ln(F_N + 0.3417 M_N) + 15.262 \quad (4)$$

N_2O emission factors (%) of chemical fertilizer nitrogen application on artificial grasslands (GEF_F,Shimizu *et al.*, unpublished) and forage corn fields (CEF_F, Shimizu *et al.*, 2013) were estimated by following equations.

$$GEF_F = 0.0022 P - 1.3 \quad (5)$$

$$CEF_F = - 0.23 S_{TC} + 18 \quad (6)$$

P was annual precipitation (mm) and S_{TC} was the amount of total carbon in soil (gC kg^{-1}). N_2O emission factors of manure nitrogen application on artificial grasslands (GEF_M, Shimizu *et al.*, unpublished) and forage corn fields (CEF_M, Shimizu *et al.*, 2013) were 0.36 % and 0.53%, respectively. The amount of leaching NO_3^- was estimated by nitrogen balance. Integration factors of LIME2 (yen kg^{-1}) of CO_2, N_2O and NO_3^- were 2.3, 737.7 and 18.6, respectively (Itsubo and Inaba, 2010). The prices of grass and corn whole crop were defined as 44 and 26 yen kg^{-1} DM, respectively.

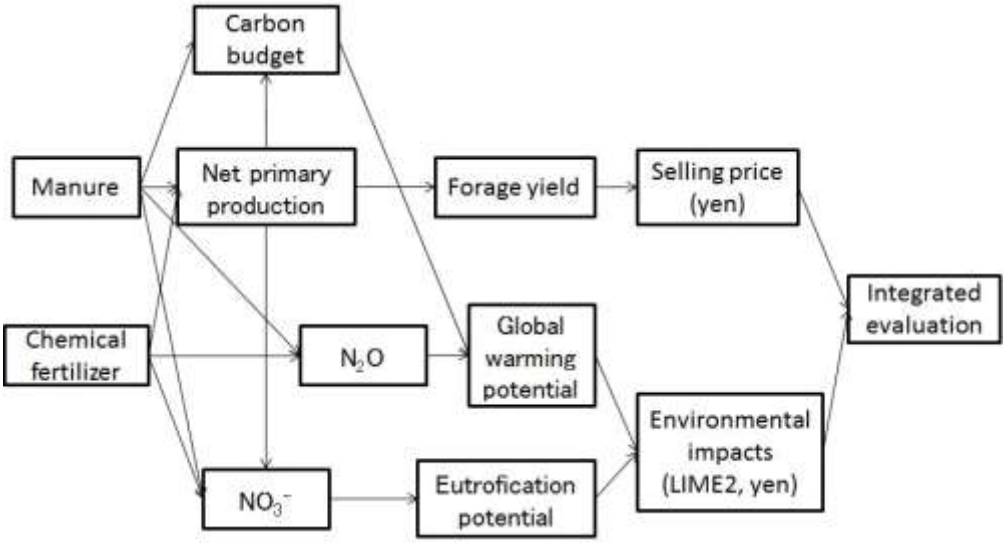

Fig. 1: The evaluation flow of manure and chemical fertilizer application and environmental impacts

Results and Discussion

The amount of yield, N_2O emission, carbon budget, NO_3^- reaching, environmental impacts and integrated evaluation on artificial grasslands and forage corn fields under various levels of chemical fertilizer and manure application was shown in Fig. 2. Chemical fertilizer and manure application raised yield. Chemical fertilizer application strongly affected N_2O emission compared with manure application. Manure application raised carbon budget in soil. On artificial grasslands, low levels of chemical fertilizer application raised root growth and carbon budget. Manure application strongly affected NO_3^- reaching compared with chemical fertilizer application. As the increase of carbon budget reduced environmental impact and the effect of carbon budget to environmental impact was more than N_2O emission and NO_3^- reaching, environmental impact was in inverse proportion to carbon budget. The result of integrated evaluation (= income - environmental impact) showed that manure application was better for integrated evaluation than chemical fertilizer application.

These results indicated that manure application raises carbon budget, environmental impact and integrated evaluation. It will be important to replace chemical fertilizer with manure for mitigation of global warming.

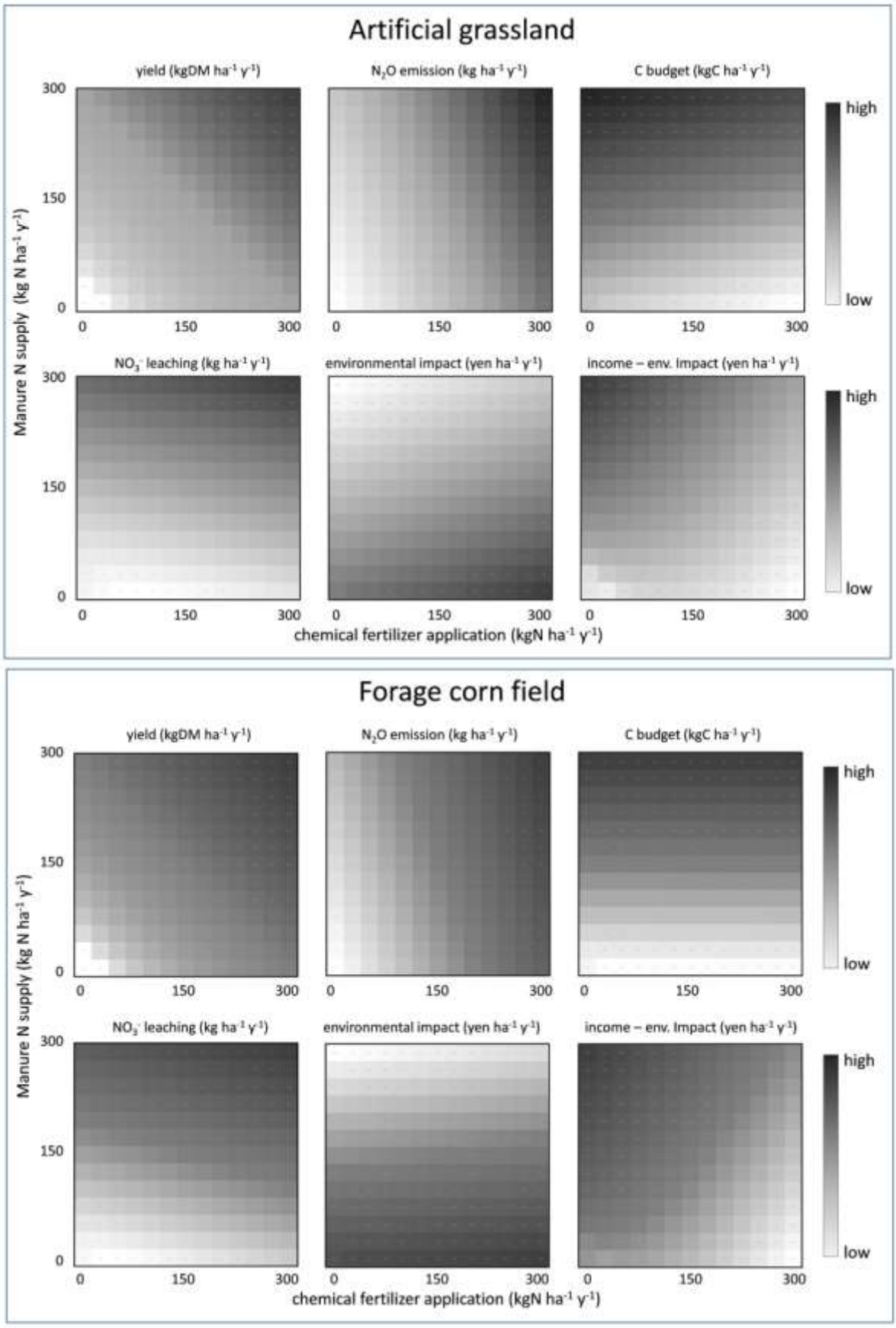

Fig. 2: Environmental impacts, yield and integrated evaluation on forage production

Conclusion

The effects of manure application to forage production, carbon budget, NO_3^- leaching and N_2O emission were evaluated and optimum level of manure application level was estimated with LIME2 integration factors. Application of chemical fertilizer and manure raised yield, N_2O emission and NO_3^- leaching. Manure application raised carbon budget and lowered environmental impact. The result of integrated evaluation showed that manure application was better than chemical fertilizer application. These results indicated that manure application raises carbon budget, environmental impact and integrated evaluation. It will be important to replace chemical fertilizer with manure for mitigation of global warming.

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