学位論文内容の要旨

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学位論文題名

Modeling soil CO_2 and N_2O emissions and estimating carbon budget in agro-ecosystem at regional scale

(土壌からのCO_2およびN_2O排出モデルの構築と地域レベルでの農業生態系炭素収支の見積もり)

The carbon (C) balance in terrestrial ecosystems has large implications on the variation in atmospheric carbon dioxide (CO_2) emission. Soils are the main source of nitrous oxide (N_2O) emission and nitric oxide (NO) emissions via the microbial processes of nitrification and denitrification. Modeling is an effective supplementary tool to estimate soil CO_2 and N_2O fluxes that allows the extrapolation of the results from the site scale to the large scale. Hierarchical Bayesian (HB) theory is useful tools for modeling multifaceted, nonlinear phenomena such as those encountered in ecology, and potentially used to reduce the uncertainty and to explain the spatial variability of estimated parameters.

The first goal of this study was to modeling CO_2, N_2O and NO flux at Ikushunbetsu River watershed, central Hokkaido, Japan by using HB theory. Secondly, the spatial and temporal patterns of net biome productivity (NBP) impacted by land use change and land management were estimated during the last four decades.

1. Modeling soil CO_2 flux from cropland (CO_2-HB model)

The CO_2-HB model was developed to simulate soil CO_2 flux derived from heterotrophic respiration (RH) based on soil temperature (T), water-filled pore space (WFPS) and soil texture using HB theory. The simulation-observation fit of the CO_2 flux model was R^2= 0.64 ($P < 0.001$). More than 90% of the observed daily data were within the 95% confidence interval. The CO_2-HB model calibration revealed differing sensitivity of CO_2 flux to T and WFPS in different soil texture classes. The CO_2-HB

model provided a method for predicting how the effects of soil temperature and moisture on CO_2 flux change with texture, and soil texture could be regarded as an up-scaling factor for model extrapolation.

2. Modeling soil N_2O and NO flux from cropland (N-HB model)

The N-HB model was developed based on the nitrogen transformation process theory using HB method. Simulation of N_2O and NO fluxes showed appropriate correlation corresponding to observations on a daily time-step, with R^2 value of 0.35 in N_2O simulation and 0.51 in NO simulation. The main advantages of using N-HB model in estimating cropland N_2O and NO fluxes arise as follows: (i) flexibility over the scale range. The N-HB was validated to performance well in predicting N_2O and NO flux at plot scale, and it is easily incorporation into other models as a sub-model, which demonstrate its ability to adequately simulate soil N_2O flux at large scale. (ii) parameter variability. The N-HB model offers a critical guidance for parameterization. Parameters of the NO module could be considered constant for model extrapolation. The calibrated parameters derived from soil-specific calibration could be served as default values for the N_2O module extrapolation for similar soil types. Otherwise, the mean value of the calibration parameters could be served as global-parameter for new sites or soils.

3. Global warming, NBP at regional scale during the last four decades

The complete crop-level yields, the CO_2-HB model and Geographic Information System (GIS) land use data were used to estimate the spatio-temporal changes of net primary productivity (NPP), plant C inputs, and NBP from 1959–2011. For the whole region (2193 ha), overall NBP increased from –1.26 Mg C ha^{-1} yr^{-1} in 1959 to 0.26 Mg C ha^{-1} yr^{-1} in 2011. Overall NPP for all land use was estimated at 5.51 (±1.05) Mg C ha^{-1} yr^{-1}. Overall annual manure inputs were 0.15 (± 0.16) Mg C ha^{-1} yr^{-1}. Overall annual plant C inputs to the soil were estimated at 2.68 (± 0.56) Mg C ha^{-1} yr^{-1}, representing 49% of the whole region NPP. The C sequestration efficiency (CE), defined as the ratio NBP/NPP, equal to –0.07 for cropland (upland crop + paddy rice). This CE value is low compared to the values of 0.22 in grassland. Though upland field and paddy field showed decrease of NBP, in the case of increase of agricultural abandonment (fallow/bush) and grassland from 1988, the regional C pools slowly start to build up.