Abstract of Dissertation

Development of Spatial 3-PG Model for Net Ecosystem Productivity Estimation in Deciduous Broadleaf Forest

(落葉広葉樹林における純生態系生産量推定のための空間 3-PG モデルの開発)

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According to CO_2 emission increasing, the temperature also increases which affects to the global climate change and global warming. To understand these issues, the carbon cycle processes need to understand. The ecosystem function is one part of carbon cycle processes on the biosphere in terms of the forest properties. The forest plays an important role of a huge natural carbon sink. The amount of carbon sink in the forest is indicated as the ecological variables such as gross primary productivity (GPP), net primary productivity (NPP) and net ecosystem productivity (NEP). The carbon is absorbed by the canopy through the photosynthesis in terms of biomass.

To estimate such ecological variables, the modelling is needed. It is used to estimate and predict the result in the future. There are several ecological models that can estimate that ecological variables such as Biome-BGC, Sim-Cycle, 3-PG and etc. Among ecological models, 3-PG is selected to focus in this study because 3-PG model is commonly used based on the stand level. When the local scale or the national scale are considered in the study site, 3-PG may performs the better result than the other models which are based on the regional scale or the global scale such as Sim-Cycle.

Physiological Principle Predicting Growth, namely 3-PG, is a simple process based model required the meteorological data, site factors and species specific as the main input parameters. It consists of 5 main components as biomass production, biomass partitioning, soil water balance, stem mortality and stand properties. The main outputs are biomass pools, GPP, NPP, LAI and some stand properties.

This study proposed the extension of original 3-PG model in two ways. The first is the method to develop 3-PG model for NEP estimation in deciduous broadleaf forest by doing the parameterizations for deciduous broadleaf forest and adding the respiration part into the model. Since the parameter values in original 3-PG model is initially for *Eucalyptus* and *Pine*. The parameterization is needed for the other vegetation types for more accuracy result.

The second is to extend it from point based model to spatial dimensions by coupling with the remotely sensed data. Then, 3-PG model is namely Spatial 3-PG model. To estimate in larger area, the remotely sensed data has potential to solve the difficulty of original 3-PG model from point based model to spatial dimensions.

Two flux towers at Hitsujigaoka, Northern part of Japan, and Takayama, Central Japan, have been observing the meteorological data and ecological characteristics. The major vegetation type is deciduous broadleaf forest. The input data for Spatial 3-PG model is from the flux tower data such as the meteorological data. Not only for the input data into the model, it is also used for the validation such as GPP and NEP results which are the main outputs of Spatial 3-PG model.

The first step of method is to parameterize the value for deciduous broadleaf forest which is done according to the data from the flux tower sites such as the allometric relationship based on the relationship between foliage mass and stem mass with diameter at breast height. Then, the sensitivity analysis is carried out to analyse the effect of input parameters to GPP which is one of the main outputs. The result showed that the parameters in the environmental factors are most affected to GPP such as minimum temperature, optimum temperature and so on. Since all of these parameters are directly used to calculate GPP. According to the sensitivity analysis, minimum and optimum temperatures are the parameter in the temperature modifier which should be carefully determined the proper value. Then, the temperature was compared to GPP along the year to consider the proper value for minimum, maximum and optimum temperature. It is assigned to be 8.5, 24.5 and 36.0 degree C responding to minimum, optimum and maximum temperature respectively.

Leaf Area Index (LAI) is one principal ecological variable which can indicate the forest characteristics. It is main parameter in the model to estimate GPP. It can be measured from several methods in the field surveys. To extend to spatial dimension, the measured LAI data is compared to the remotely sensed data to find the relationship in terms of vegetation index (VI). Six vegetation indices which are commonly used to estimate LAI are NDVI, NDVIc, SAVI, SAVI2, SR and EVI. Based on LAI-VI relationship, SR and NDVIc showed the strong correlation to LAI with $r^2 = 0.839$ and 0.835 respectively. However, LAI-NDVIc relationship is selected to add into the model because it gave better result than SR when it is applied in both Hitsujigaoka and Takayama.

Before the remotely sensed data applied, the deciduous broadleaf forest area is firstly extracted otherwise the other vegetation types will be affected from the calculation. Then, GPP is calculated from LAI based remotely sensed data and the environmental factors.

To extend the biomass production module for NEP estimation, the respiration part is added into Spatial-3PG model. It is calculated as the function of temperature. The respiration is the ecosystem respiration including the soil respiration and the above ground respiration. To cover in the larger scale, the temperature data is substituted by land surface temperature image because the temperature cannot be applied the same value in the different area. Then, NEP is calculated from GPP and the respiration.

The results showed that GPP estimation in average 4 years from 2002 to 2005 were 986 and 915 gC m^{-2} $year^{-1}$ at Hitsujigaoka and Takayama respectively. The highest value was 1143 gC m^{-2} $year^{-1}$ in 2003 at Hitsujigaoka and 1011 gC m^{-2} $year^{-1}$ in 2002 at Takayama. Estimated GPP was validated with the observed GPP from the flux tower. The root mean square showed 0.94 and 0.96 at Hitsujigaoka and Takayama respectively. The error percentage when comparing with the observed GPP at Hitsujigaoka and Takayama was 15% and 10% respectively.

Average NEP estimation from 2002 to 2005 was 459 and 359 gC m^{-2} $year^{-1}$ at Hitsujigaoka and Takayama respectively. NEP in 2003 had the highest value around 395 gC m^{-2} $year^{-1}$ at Hitsujigaoka and 459 gC m^{-2} $year^{-1}$ at Takayama in 2002. The validation of estimated NEP was to compare with the observed NEP from the flux tower. The root mean square showed 0.94 and 0.96 at Hitsujigaoka and Takayama respectively. The error percentage when comparing with the observed GPP was 10% at the both sites.

Additional, the effect of NEP is investigated according to the variation of temperature and precipitation. The value is varied by increasing and decreasing in 1 to 3 degree Celsius in temperature and 10 to 20% in precipitation. NEP increased when the temperature increased until the increasing temperature is over the optimum temperature, as the limitation, then NEP started to reduce. For precipitation, even though it increased or decreased in 10 or 20 percent, NEP did not vary.