Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

ACG37-01 Room:201A Time:May 21 14:15-14:30

Warming experiment, spectral observation and model analysis for predicting global warming effects on forest carbon cycle

Hiroyuki Muraoka[1*], Taku M. Saitoh[1], Shin Nagai[2], Hibiki M. Noda[3], Chika Shoji[1], NamJin Noh[1], Masatoshi Kuribayashi[1]

[1]Gifu University, [2]JAMSTEC, [3]University of Tsukuba

Estimation of global warming effects on photosynthesis and respiration in forest ecosystems based on mechanistic understanding is one of the most crucial research under the current climate change condition. The knowledge and insights gained by such research would be necessary for our further evaluation of ecological, biogeochemical and societal functions of our ecosystems ranging from local, national land to Asian scales. In Takayama site, Gifu University (Japan), efforts have been made for nearly 20 years to clarify the micrometeorological and ecological understandings on the carbon cycle in a deciduous broadleaf forest located on a mountainous landscape in central Japan. Recently we established a multidisciplinary research named ”Satellite Ecology” to link ecophysiology, micrometeorology and remote sensing to encourage cross-scale observation and mechanistic understanding on the forest ecosystems. In this paper we introduce our new project named ”Satellite Ecology II”, in which in-situ artificial warming experiments for forest canopy tree and soil are established. Here we examine the warming effects on foliage photosynthesis and soil respiration, explore the remote sensing techniques to detect any ecophysiological changes in the canopy, and predict the near-future changes in forest carbon cycle.

Increasing air temperature (+5 degreeC) surrounding a branch of canopy tree, Quercus crispula, by installing an ’Open-Top Canopy Chamber (OTCC)’ resulted in earlier leaf expansion (5 days) and delayed leaf senescence (5 days) than the non-warming branch, and about 10% higher photosynthetic rate in summer. Increasing soil temperature (+3 degreeC) by installing heating cables at 3-5cm below the soil surface resulted in stimulation of soil respiration from spring to late growing season. Preliminary prediction of warming effects on leaf phenology, photosynthesis and respiration of the forest revealed that increasing temperature may enhance the growing season of the deciduous trees and hence both photosynthesis and respiration of entire forest.

Keywords: forest ecosystems, photosynthesis, global warming, carbon cycle

Japan Geoscience Union Meeting 2013
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Long-term monitoring of ecosystem by Phenological Eyes Network

Kenlo Nasahara[1*]

[1]University of Tsukuba

Satellite remote sensing (RS) is a strong methodology in the study of terrestrial ecosystems. For example, RS is used in scaling up of the ground measurements of carbon flux, water flux, biomass, etc. from a site scale to a regional or global scale. RS provides numerical regional ecological models with information for initial conditions, boundary conditions, and validation. For the sake of it, various new satellite sensors have been designed and launched. They are now delivering a lot of high-level products regarding to the terrestrial ecology, such as new vegetation indices, LAI, FPAR, phenology, GPP, and NPP.

However, in the ecological standpoint, these RS methodology has not enough checked or validated on the ground level. Because an essential characteristics of ecosystem is its dynamism (especially the seasonal change, or ”phenology”), the accuracy, quality, and interpretation of the RS data should be also studied dynamically. For the sake of it, a stable, continuous, long-term, and multi-ecosystem ground validation network is desired. Of course, the flux observation networks such as AsiaFlux have potential to contribute to it. However, because RS observes vegetation’s optical characteristics rather than carbon or heat flux, we need to include optical (spectral) observation in the validation of ecological RS. We believe that the ecological interpretation of RS data is possible only if it is based on a careful theoretical and experimental study of the relationships between optical characteristics and ecological structure (or function), using the quality-controlled RS data considering the relevant noise factors such as cloud contamination or atmospheric aerosols.

With this background stated above, we started the ”Phenological Eyes Network (PEN) in 2003. PEN is a network of ground observatories for long-term automatic observation of the vegetation dynamics (phenology), vegetation’s optical properties (such as spectral reflectance), and the atmospheric optical properties (such as aerosol optical thickness). Most PEN ground sites have been set up at the AsiaFlux sites. The collaboration of PEN and AsiaFlux is critically important in the interpretation of the optical signals captured by RS in terms of ecology (especially the terrestrial carbon/water cycles).

Keywords: phenology, remote sensing

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ACG37-03 Room:201A Time:May 21 14:45-15:00

A model-data integration framework to a terrestrial ecosystem model using multiple satellite-based constraints.

Kazuhito Ichii[1*], Masayuki Kondo[1], Masahito Ueyama[2], Takahiro Sasai[3], Hideki Kobayashi[4]

[1]Fukushima University, [2]Osaka Prefecture University, [3]Nagoya University, [4]JAMSTEC

Various satellite-based spatial products, such as evapotranspiration (ET) and gross primary productivity (GPP), are now available by integration of ground observation and satellite observation. Therefore, effective use of these multiple spatial products to terrestrial biosphere models is an important step toward better simulation of terrestrial carbon and water cycles. However, due to the complexity of terrestrial biosphere models with a large number of model parameters, the application of these spatial data sets to terrestrial biosphere models is difficult.

In this study, we show an effective but simple framework to refine a terrestrial biosphere model, Biome-BGC, using multiple satellite-based products as constraints, and tested it in the monsoon Asia region (60E-180E and 80N-10S) covered by eddy-covariance observations. The framework is based on the hierarchical analysis (Wang et al. 2009) with model parameter optimization constrained by satellite-based spatial data . The Biome-BGC model is separated into several tiers to minimize the freedom of model parameter selections and maximize the independency from the whole model. For example, the snow sub-model is first optimized using satellite-based snow cover product, followed by soil water sub-model optimized by satellite-based ET (estimated by an empirical upscaling method), photosynthesis model optimized by satellite-based GPP, and respiration and residual carbon cycle models optimized by biomass data.

As a result of initial assessment, we found that the most of default sub-models (e.g. snow, water cycle and carbon cycle) showed large deviations from satellite-based products; however, these biases were removed by applying the method. For example, gross primary productivities were overall underestimated in boreal and temperate forest and overestimated in tropical forests. However, the parameter optimization scheme successfully reduced these biases. Our analysis shows that terrestrial carbon and water cycle simulations in monsoon Asia were greatly improved, and the use of multiple satellite observations with this framework is an effective way for improving terrestrial biosphere models. We also found that respiration fluxes, biomass, and soil carbon data, which are currently unavailable, are also important to constrain simulated terrestrial carbon cycles and generation of these products are urgent.

Keywords: terrestrial biosphere model, remote sensing, optimization, carbon cycle, water cycle

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ACG37-04 Room:201A Time:May 21 15:00-15:15

How much complexity of plant canopy structure is good enough for the light environment simulation?

Hideki Kobayashi[1]*

[1]Japan Agency for Marine-Earth Science and Technology

Most land surface models assume that a plant canopy can be abstracted as a turbid medium to compute mass, energy, and carbon exchange. The canopy is horizontally homogeneous as leaves are randomly distributed in space. Consequently, radiation only changes in a vertical direction. Lambert-Beer type light penetration scheme is widely adapted for transmission and absorption simulation of a plant canopy. In this scheme, the incoming light exponentially decreases with an increase in leaf area. Leaf inclination angle and light incident angle is considered in the model. This model is only valid when the leaves are randomly distributed in space. To consider the spatial anisotropy of leaf distribution, Nilson (1971) introduced clumping modeling. By putting the clumping index into the Lambert-Beer equation, this scheme extends the light environmental computation for non-random distribution of leaves within a plant canopy. The clumping modeling is simple. Yet, there are some issues. For example, the clumping index is not a constant value. The clumping index changes with the light incidence angle and vertical levels. Also, we cannot directly measure the clumping index. The 3-dimensional modeling of forest light environment needs a lot of ecosystem structural data sets along with a vast computation time. The recent progress of measurement techniques (e.g. LiDAR) enables to run and evaluate the realistic light environment. In this presentation, I show some of the comparison results to see how the different complexities of light penetration modeling affect the light environment.

Keywords: radiative transfer, Land surface model, light environment

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ACG37-05 Room:201A Time:May 21 15:15-15:30

Global model inter-comparison with GOSAT L4A and support vector machine based estimates of biospheric variables

Masayuki Kondo[1*], Kazuhito Ichii[1]

[1]Faculty of Symbiotic Systems Science, Fukushima University

Estimation of carbon exchange in terrestrial ecosystem associates with difficulties due to complex entanglement of physical, chemical, and biological processes: thus, the net ecosystem productivity (NEP) estimated from simulation often differs among process-based terrestrial ecosystem models. In addition to complexity of the system, validation can only be conducted in a point scale since reliable observation is only available from ground observations. With a lack of reliable spatial data, extension of model simulation to the global scale results in significant uncertainty in the future carbon balance and climate change. Greenhouse gases Observing SATellite (GOSAT), launched by the Japanese space agency (JAXA) in January, 2009, is the 1st operational satellite promised to deliver the net land-atmosphere carbon budget to the terrestrial biosphere research community. Using this information, the model reproducibility of carbon budget is expected to improve: hence, gives a better estimation of the future climate change.

Because of the direct association with climate change, improving estimation of global NEP is essential; yet, global gross primary productivity (GPP) and ecosystem respiration (RE) need to improve as well for further sophistication of ecosystem modeling. In the system of carbon cycle, GPP and RE are the true physiological quantities representing photosynthesis and respiration, and NEP is a byproduct of them. Since a major purpose of process-based ecosystem models is to clarify the mechanism of carbon cycle, it is important to invest efforts to refine GPP and RE as well.

Currently, the most reliable estimate of global GPP is provided by observation-based empirical upscaling with machine learning models [Jung et al. 2011]. Machine learning regression is based on a network of eddy covariance flux tower observation, in conjunction with global satellite remote sensing and meteorological data sets. Because of the high correlation with GPP, availability of long-term global observations of vegetation indexes (e.i. EVI, NDVI, and NDWI) from operational satellites makes performance of machine learning model finer in prediction of GPP. Because of limited availability of carbon pool data, however, it is difficult to induce equivalent performance in RE with machine learning models [Jung et al. 2011]. Instead of a direct estimation, combination of global GPP estimated by machine learning regression and NEP from GOSAT L4A would produce a more reliable budget of global RE.

This initial analysis is to compare a set of observation-based global carbon flux products, NEP from GOSAT L4A, GPP from support vector machine regression, and RE from a combination of them, with three types of TEMs and an inversion model: Biome-BGC (prognostic model), CASA (diagnostic model), LPJ (dynamic vegetation model), and Carbon Tracker (inversion model). Comparison was conducted with the standardized format based on GOSAT L4A: 42 sub-continental tiles and monthly temporal coverage from June 2009 to May 2010. Through the comparison, we discuss similarities and dissimilarities in (1) seasonal variations, (2) global and annual averages, (3) variability with climate (air temperature, precipitation, and solar radiation).

Reference

Jung, M., et al. (2011), Global patterns of land-atmosphere fluxes of carbon dioxide, latent heat, and sensible heat derived from eddy covariance, satellite, and meteorological observations, Journal of Geophysical Research, 116.

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Keywords: GOSAT, machine learning regression, terrestrial ecosystem model, carbon cycle

ACG37-06 Room:201A Time:May 21 15:30-15:45

ADMIP: Asian Drylands Model Intercomparison Project

Kaoru Tachiiri[1*], Kazuhito Ichii[2], Masayuki Kondo[2], Akihiko Ito[3], Kazuo Mabuchi[4], Shin Miyazaki[5], Kazuaki Yorozu[6], Jun Asanuma[7]

[1]Japan Agency for Marine-Earth Science and Technology, [2]Fukushima University, [3]National Institute for Environmental Studies, [4]Meteorological Research Institute, [5]Hokkaido University, [6]Kyoto University, [7]Tsukuba University

In this presentation we introduce our ongoing project entitled Asian Drylands Model Intercomparison Project (ADMIP). As the name shows, the project focuses on the Asian drylands which comprise large portion of the Asian land surface. Due to small amount of rainfall and low productivity, the dryland ecosystem is vulnerable, and has large inter-annual variability. Such environment is difficult to simulate, and the model outputs have large variation.

The goals of the project are to assess the uncertainty in the model prediction, and to improve accuracy of the model prediction for the land surface environment. As the participants, we have 18 models including land surface models and terrestrial ecosystem models. Since these models have different focuses and different input/output variables, we needed study sites which cover a wide range of observation data, and as a result of discussion we selected Kherlenbayan-Ulaan in Mongolia and Tongyu in China. In addition to the ground-based observation data for model validation, in the experiments we also use remote sensing data as a complement to the station data and reanalysis data for spin-up.

The experiments have three stages: an experiment using the default parameter values (Stage 0), an experiment using the parameter values in the existing literature (Stage 1), and an experiment using the parameter values tuned to well-reproduce the observation in the important variables (Stage 2). In the presentation, we will show some results from Stages 0 and 1.

Keywords: Asia, Drylands, Terrestrial ecosystem models, Land surface models, Observation data

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ACG37-07 Room:201A Time:May 21 15:45-16:00

The assessments of climate change impact on global SOC stock by a model intercomparison project

Kazuya Nishina[1*], Akihiko Ito[1], Etsushi Kato[1], Tokuta Yokohata[1], ISI-MIP participants[2]

[1]National Institute for Environmental Studies, [2]ISI-MIP team

Although soils form a thin covering terrestrial earth's surface like a skin, soil organic carbon (SOC) is considered to be the largest carbon pool in terrestrial ecosystems. Global SOC stock reach 2 or 3 times higher than the amount of atmospheric CO2. Therefore, in climate systems, because of the vast carbon pool of SOC, the behavior of SOC is the key to understanding the feedback of terrestrial ecosystems to atmospheric CO2 concentration in a warmer world. SOC dynamics are critically affected by temperature and precipitation. In this study, we examined the SOC dynamics in 7 biome models obtained from the inter-sectoral impact model intercomparison project, which were simulated using 5 global climate models (GCMs) in the newly developed climate scenarios, i.e., representative concentration pathways (RCPs), aiming at specifying the uncertainty in the projection of global SOC stocks from global and regional perspectives. By the assumption that SOC is a one-compartment of earth system, we assessed global SOC turnover rate and the sensivitities to globa mean temperature and precipitation anomalies by steady-state model.

In a higher forcing scenario (HadGEM forced with RCP8.5), inconsistent estimates of impact on the total SOC (2099–2000) were obtained from the different model simulations, ranging from a net sink by 347 Pg C to a net source by 122 Pg C. Cluster tree of the wavelet spectra for the SOC time-series data in all combination of simulations suggeted that the uncertainties derived from the biome models overwhelmed those derived from the climate scenarios. Our simplified dynamic model (state-space model) for global SOC stock revealed that primarily balance by the global SOC stock turnover and Input from VegC are quite different among the biome models and further implies the different sensitivities to global mean temperature anomaly of the global SOC stocks among the biome models. On the other hand, global precipitation anomaly did not influence global SOC stock dynamics. Furthermore, the regional differences among ecosystem models will be discussed in this presentation.

Keywords: Soil organic carbon, RCP, GCM, Model intercomparison, Uncertainty

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ACG37-08 Room:201A Time:May 21 16:15-16:30

Calibrating the parameters of a crop growth model using MCMC algorism with statistical yield data in global scale.

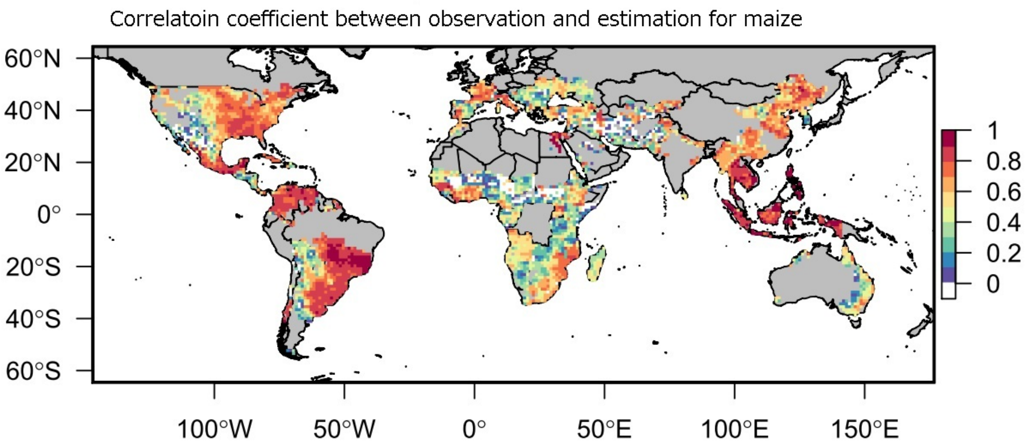
Gen Sakurai[1*], Toshichika Iizumi[1], Masayuki Yokozawa[1]

[1]National Institute for Agro-Environmental Sciences

In the land ecosystem, farmland area accounts for large proportion in land area, and plays an important role in the interaction between land ecosystem and atmosphere. In addition, in accordance with the rapid world population growth to be expected in the future, the rapid expansion of agricultural area would be also predicted. Therefore, to reveal the response of crop growth to climate change has become a critical issue. On the other hand, one of the major problems in evaluating crop production in global scale using process based crop model would be large spatial variations in crop varieties and farming method among regions. This non-uniformity should result in large variation in the responses of crop growth to the changes of temperature, precipitation, and atmospheric CO2 concentration among regions. Therefore, it is important how we determine the model parameters for every region in global scale.

In this study, we have developed a crop growth model (PRYSBI2; Sakurai et al. in prep) to solve these problems, in which the parameter set were statistically calibrated using MCMC method for each region. The crop growth model has a large advantage in calibration of parameters in global scale because there is large number of data base about yield statistics in many countries. Recently, the data base about historical yield data was developed in which yield data was collected from bureaus of statistics of major crop-producing countries in state, county, or prefecture scale, and historical crop yields for each grid point of 1.125 deg x 1.125 deg (latitude by longitude) were estimated by averaging the yield data of the counties, states, or prefectures included in the grid (Iizumi et al. in prep). Using this global historical yield data, we estimated the posterior distribution of the parameter set of the model (PRYSBI2) for each grid point using Markov chain Monte Carlo methods (MCMC). The target crops were four major crops: maize, soybean, wheat, and rice. The selected target parameters were those relevant to crop varieties and regional variabilities, such as water stress, nitrogen stress, temperature dependency, and maturity. As the result, we obtained the model parameter set with large estimation capacity in global scale in which high correlation coefficient between historical yield data and estimated yield data for almost all grid points. In this presentation, we will discuss the past effect of climate change on past crop yields in global scale using this spatially tailored crop growth model.

Keywords: Agro-ecosystem, MCMC, crop yield, crop growth model, statistical yield data, global scale



Japan Geoscience Union Meeting 2013
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ACG37-09 Room:201A Time:May 21 16:30-16:45

Development of a global integrated model for predicting both crop production and water resources

Masashi Okada[1*], Toshichika Iizumi[1], Gen Sakurai[1], Masayuki Yokozawa[1]

[1]National Institute for Agro-Environmental Sciences

Crop growth mainly depends on a climate condition such as temperature, precipitation and solar radiation. Therefore, to assess climate change impacts on crop production, many studies have utilized a large-scale crop model which empirically and/or mechanistically can describe phenological development and crop production under a climate condition and an agricultural management. On the other hand, crop growth and production are largely affected by regional available water resources though an irrigation process. Future climate changes and increasing demand due to population increases and economic developments would intensively affect the availability of water resources for agricultural production. However, there are few large-scale crop models that can describe dynamically account for changes in crop production and water resources.

Therefore, we developed an integrated model for predicting both crop production and water resources. We coupled a large-scale crop model, PRYSBI2 (Sakurai *et al.* in prep), with a global water resources model, H08 (Hanasaki *et al.* 2008). The newly designed integrated model was consisting of five sub-models for the following processes: land surface, crop growth, river routing, reservoir operation, and anthropogenic water withdrawal. The land surface sub-model was based on a watershed hydrology model, SWAT (Neitsch *et al.* 2009). Surface runoff and percolation to aquifer simulated by the land surface sub-model were input to the river routing sub-model of the H08 model. A part of regional water resources available for agriculture, simulated by the H08 model, was input as irrigation water to the land surface sub-model. All processes in the integrated model were calculated on the daily time-step. The integrated model was applied to Northeast China, which has extensive crop land in China including present semi-arid climatic areas, and the region will be strongly affected by future climate change. This study verified the reproducibility of modeled elements in water balance over Songhua river watershed, which is main river watershed in Northeast China.

As the result, it was confirmed that biases between observations and estimations of soil water content and evapotranspiration were comparatively small, thus the integrated model can relatively reproduce the water balance over the watershed. Additionally, the large-scale crop model with estimated parameters at regional scale can faithfully reproduce the long-term trend and annual fluctuations in yield, especially in Northeast China Plain.

It is essential to estimate the regional water resources available in the contiguous watershed for evaluating actual crop productivity especially in drier region. Therefore, integrated model of crop productivity and water resources circulation in watershed is powerful tool for projecting climate change impacts on crop production.

Keywords: crop production, water resources, integrated model, large-scale

ACG37-10 Room:201A Time:May 21 16:45-17:00

Terrestrial carbon cycle feedbacks in the Earth system models

Tomohiro Hajima[1*]

[1]Japan Agency for Marine-Earth Science and Technology

Anthropogenically emitted CO2, which is partly absorbed by land and ocean ecosystems, produces energy imbalance on the Earth due to its greenhouse effect and leads to global climate change. Changes in atmospheric environment such as global warming and CO2 increase can alter the various processes in the land ecosystems (e.g. photosynthesis, evapo-transpiration, ecosystem respiration, plant growth, and mortality). So far, two processes have been considered to be the major processes of the impact from environmental changes on terrestrial carbon cycle. The first is the climate impact on land ecosystems that is often called ”climate-carbon feedback”. One of the examples of this process is the enhanced ecosystem respiration due to warming, which can accelerate CO2 increase in the atmosphere. The second is the impact of CO2 increase on the land ecosystems. As CO2 has a ”fertilization effect” on plants because elevated CO2 stimulates photosynthesis, plant growth can be promoted and resultant carbon accumulation occurs. This process is sometimes called ”concentration-carbon feedback” and works as a negative feedback against CO2 increase in the atmosphere. The balance of these two processes determines the magnitude of net carbon uptake in terrestrial ecosystems and thus could affect the degree of global warming. In this study, the strength of the carbon cycle feedbacks were evaluated by the Earth system models, which are advanced from climate models by incorporating biogeochemical processes and have been commonly used for long-term climate projections. First, we applied several scenarios to an ESM and found that the response of carbon cycle feedback evaluated by cumulative airborne fraction showed large variation among scenarios, likely due to the different response of concentration-carbon feedback across scenarios. Second, we applied a common scenario to multi-ESMs (this analysis was conducted as a joint research) and found that the strength of concentration-carbon feedback in terrestrial ecosystems showed the largest inter-model variation, largely affecting global carbon budget. This inter-model variation produces uncertain estimates of compatible fossil fuel emission that is the amount of emitted carbon to achieve a given atmospheric CO2 pathway and calculated from the carbon budget estimated by ESMs. From these results, it was suggest that the strength of concentration-carbon feedback in terrestrial ecosystem is a key to reduce the uncertainty of projected climate by ESMs.

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ACG37-11 Room:201A Time:May 21 17:00-17:15

Effect of land-use and climate changes on carbon budget in Borneo Island using VISIT model

Minaco Adachi[1*], ITO, Akihiko[1], TAKEUCHI, Wataru[2], YAMAGATA, Yoshiki[1]

[1]NIES, [2]University of Tokyo

More reliable estimation of carbon budget in forest ecosystems including the impact of deforestation is an important goal for environmental researchers. Carbon emission from land-use change accounts for about 20% of the total anthropogenic emissions worldwide. Especially, evaluation of carbon emission due to land-use change in tropical region is a very important task for management activities related to the Reducing Emissions from Deforestation and Forest Degradation (REDD+) initiative. In previous regional-scale studies, many models have been applied to the deforestation impacts specifically in Amazonian forests, whereas only a few studies have investigated the impacts of land-use change occurring in Southeast Asia. In the present study, we estimated the carbon budget of Borneo Island in Southeast Asia using remote sensing data and a process-based terrestrial ecosystem model (VISIT), aiming at evaluating the differences of carbon budget between land-use and climate change.

To develop a broad-scale system of forest carbon monitoring, we used time-series data of forest coverage derived from satellite remote-sensing images to track a transition through forest disturbance history. We found that the active radar sensor PALSAR (Phased-Array L-Band Synthetic Aperture Radar) onboard the ALOS satellite is especially advantageous for monitoring tropical forest cover under clouds, and that temporal changes in forest coverage could be also detected using MODIS (MODerate resolution Imaging Spectroradiometer) data during the period from 2002 to 2008. Then, by applying the VISIT model to every grid point, we estimated the atmosphere?ecosystem exchange and internal dynamics of carbon at 1km solution.

When the effect of land-use change was neglected, gross primary production (GPP), aboveground biomass, and soil respiration rate were overestimated by about 10 to 20% for the whole of Borneo Island. The difference of GPP between 1986 (a warm and wet year) and 1999 (a cool and dry year) was 3.01tC ha^{-1} yr^{-1}. On the other hand, when the land-use impact was included, GPP was estimated smaller by 3.33 to 5.15 tC ha^{-1} compared with estimates of the no-deforestation case. These results suggested that the effect of land-use change on carbon budget in the study area would be larger than that of climate variability, and that land management is very important for mitigation of global warming by reducing carbon emission. Additionally, we mention our preliminary estimation of the carbon budget under the future climate scenarios in Borneo Island.

ACG37-12 Room:201A Time:May 21 17:15-17:30

Simulation study of the vegetation structure and function in eastern Siberian larch forests under changing climate

Hisashi Sato[1*], Hideki Kobayashi[2], Go Iwahana[3], Takeshi Ohta[4], Alexander Fedorov[5]

[1]Graduate School of Environmental Studies, Nagoya University, [2]Research Institute for Global Change, JAMSTEC, [3]International Arctic Research Center, University of Alaska Fairbanks, [4]Graduate School of Bioagricultural Sciences, Nagoya University, [5]Melnikov Permafrost Institute

Siberian larch forest covers is the largest coniferous forest region in the world; in this vast region, larch often form pure of nearly stands, regenerated by recurrent fire. This region is characterized by a short and dry growing season. With its huge area and vast potential carbon pool within the biomass and soil, Siberian larch forest likely plays a major role in the global carbon balance.

In this study, we refine the parameterization of the Spatially Explicit Individual-Based DGVM (SEIB-DGVM) (Sato et al., 2007, 2010) to the larch forest at Eastern Siberia. Unlike models thoese are employed by previous studies, SEIB-DGVM is based on individual trees, and thus it can analyze interactions between forest size structure (tree density and mean tree size) and ecosystem material cycles. With this model, we examined the impact of changes in climatic factors and parameters of plant-population dynamics on structures and ecological functions at Eastern Siberia.

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Sato, H., Kobayashi, H., & Delbart, N. (2010) Simulation study of the vegetation structure and function in eastern Siberian larch forests using the individual-based vegetation model SEIB-DGVM, For. Ecol. Manage., 259, 301-311.

Keywords: Larch, Eastern Siberia, Permafrost, SEIB-DGVM, Wild fire, Simulation study