S-1 Integrated Research on Carbon Budget Management in Terrestrial Ecosystems of Asia in the 21st Century

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1. Introduction

Kyoto Protocol, which accounts for offsetting reduction target of CO_2 emission by carbon sequestration in forests through forest management, became effective on February 2005. Those rules, which were determined at COP6 and COP7, have focused attention on the role of the terrestrial biosphere in global scale carbon cycles. To consider long-term terrestrial carbon management, more accurate information is required for net ecosystem production (NEP) over various terrestrial ecosystems. However, uncertainty remains about the change of carbon stock through ecosystem and land management, and the response of the ecosystem CO_2-exchange to climate variability. In this regards, the elucidation of the carbon budgets at various Asian ecosystems has become an important subject of the global warming issue.

2. Research Objective

The environmental conditions in East Asia under a monsoon climate differ from North America and Europe. The precipitation in East Asia is larger than that in these continents, in particular, the much precipitation in the mid-latitude. Due to the specific features of climate and ecosystem type, the carbon budgets in East Asia should be different from those of North America and Europe. Study sites in this research distribute widely from sub-arctic through tropical zone in East Asia, and cover typical vegetation types in East Asia.

In this project, we have selected 4 research objectives which correspond to sub-theme of the project:

(1) Analysis of carbon balance in terrestrial ecosystems using bottom-up approaches based on micrometeorological and ecological methods
(2) Analysis of meso-scale terrestrial carbon balance using top-down approach based on atmospheric monitoring

(3) Assessment of carbon balance dynamics and evaluation of methodologies for carbon budget management in terrestrial ecosystems of Asia in the 21st century
(4) Promotion of integrated research and information sharing

3. Research results

To investigate the carbon budget and its management in East Asia, we have developed a new Integrated System Approach by combining flux tower measurements, remote sensing, ecosystem and land use modeling. Successful estimates were done for the regional carbon dynamics. In the following we summaries the major results obtained for each sub-theme topic.

3-1. Analysis of carbon balance in terrestrial ecosystems using bottom-up approaches based on micrometeorological and ecological methods

(1) Quantitative analysis for carbon budget in forest ecosystems

1) Carbon budget of boreal forest ecosystems

The CO_2 flux has been measured by the eddy covariance method over three Larch forest sites, Tomakomai (TFS) (Hokkaido, Japan), Laoshan (LS) (Northeastern China) and Tura (Siberia). Forest biomass, soil respiration, and soil organic carbon storage were estimated during 2002 and 2006. Forest biomass was estimated by destructive sampling in two stands. Soil respiration was monitored using Li-Cor LI-6400. Three soil profiles were surveyed for soil organic carbon storage. We also conducted field survey in Tura, Siberia and Laoshan for biomass estimation, soil respiration using LI-820 after air sampling by chamber method, and soil organic carbon storage. Additional survey for tree ring analysis and nitrogen dynamics in soil were conducted.

2) Carbon budget of temperate forest ecosystems

Micrometeorological measurement of carbon dioxide, water vapour and sensible heat fluxes and related ecological observations have been conducted in Japanese temperate forests at Fujiyoshida (FJY; cool-temperate coniferous), Kiryu (KEW; warm-temperateconiferous) and Takayama (TKY; cool-temperate deciduous).

3) Tropical rain-forest ecosystems

The purpose of this study is to estimate net ecosystem production (NEP) of the forest ecosystem in tropics both from CO_2 fluxes above forest using micro-meteorological methods and temporal biomass changes through ecological investigations. The study was conducted in a lowland dipterocarp rainforest in Pasoh Forest Reserve, Peninsular Malaysia, and in a seasonal evergreen forest in the Sakaerat Environmental Research Station, Thailand.

(2) Quantitative analysis for carbon budget in grassland ecosystems

1) Carbon dynamics in a temperate alpine grassland ecosystem in East Asia

To estimate the carbon sink strength and to address its relation with environmental variables, we have conducted a long-term measurement of CO_2, H_2O and energy fluxes for

more than 5 years. From the flux measurement we found (1) this alpine meadow ecosystem absorb about 120 $gCm^{-2}yr^{-1}$, with a large annual variation. This variation is considered to be due to mainly the water availability and plant phenology; (2) a large daily variation in net ecosystem CO_2 exchange with a net carbon release from the ecosystem estimated to be 2 $gCm^{-2}d^{-1}$ during the winter period and a net CO_2 uptake of about 4 $gCm^{-2}d^{-1}$ during summer season from 2001 to 2004; (3) a path analysis indicates that temperature is the major constraint on the short-term variation of CO_2 flux in the alpine meadow.

2) Use of isotopic approach on the analysis of carbon dynamics in a C3/C4 mixed grassland

We use an isotopic approach combined with biomass investigation and flux measurements by eddy covariance technique to estimate the photosynthetic pathway composition (C3:C4 mixture) of carbon dynamics in a C3/C4 mixed grassland and in particularly, seasonal changes in the contribution of C3 and C4 plants to photosynthesis (i.e. gross primary production, GPP), ecosystem respiration (RE), and soil respiration (RS).

3) Carbon budget of agricultural sites

We continued observation at these three study sites and accumulated the data on seasonal and inter-annual variations of carbon exchange. In addition, we partitioned net ecosystem exchange (NEE) observed at HCH and MSE sites (single cropping rice paddy) during the growing season into gross primary production (GPP), plant respiration including root respiration (autotrophic respiration; RA) and decomposition of soil organic matter (heterotrophic respiration; RH), and examined influence of inter-annual variations of meteorological conditions and agricultural practices on respective components of NEE.

(3) Study on carbon dynamics and budgets in different soil ecosystems

1) Quantitative evaluation of ecosystems carbon budget

Ecosystem carbon pools and fluxes were measured with chronosequece in cool-temperate zone, central Japan. Five study sites for secondary succession, ranging from clear-felled site to 100-years mature deciduous forest, were selected in the Takayama and Sugadaira research sites. Four study sites were set on the lower montane zone of Mt. Fuji for primary succession, young pine forest, mature pine forest, conifer forest and climax deciduous forest, which had different age after vegetation establishment (12 - 2850 y).

2) Quantitative evaluation of temporal variability of soil carbon flux in secondary succession

All the studies of the rhizosphere research group were made in the seven research sites, including 22 ecosystems: grasslands, forests, and croplands. Soil carbon fluxes were measured by 6 chamber methods (open-flow chamber, open-top chamber, automated open/closed chamber, closed static chamber, LI6400, LI6200) between 2002 and 2005.

3) Spatial and temporal modeling of soil carbon dynamics and its scaling up

For describing temporal changes in soil carbon dynamics, we developed a process-based model, which includes some compartments of carbon pool with different

residence time of organic matters. The model describes soil carbon dynamics in terms of turnover processes of soil organic matters among carbon pools (compartments), i.e. input organic matter from above ground and roots, microbial biomass humus, and inactive organic carbon. The CO_2 gases also release during these decomposition processes. The basic structure of our model is based on the Rothamsted Carbon model (RothC) consisting of five compartments. The model could simulate long-term changes in soil organic carbon (SOC) as well as seasonal changes in heterotrophic respiration in upland, grassland, and forests.

(4) Construction of the AsiaFlux database of carbon budget and synthetic analysis of carbon budget data in East Asia

1) AsiaFlux database of carbon budget

Eddy covariance flux data obtained at 15 tower observation sites of the present project are combined into a project database, which is expected to be a fundamental dataset of "the AsiaFlux database" after the project is over. The database is utilized for inter-site comparison of carbon and water vapor exchange in terrestrial ecosystem in monsoon Asia. The database will also provide model investigators with basic data to make and validate numerical models of carbon cycle in terrestrial ecosystem in monsoon Asia. The eddy covariance flux measurement technique is commonly employed in the present project, but actually neither instrumentation nor data processing method is unified. It is therefore important to make clear how the differences in the instrumentation and the data processing methods between the observation sites participating in the project affect obtained flux values. In addition, non-laborious and standardized methods for quality control and gap filling of flux data are desired for analyzing multiple-site and multiple-year datasets accumulated in the database.

2) Synthetic analysis of carbon budget data in East Asia

The dataset, which was obtained at a wide variety of ecosystems in East Asia with multiple years, is quite essential for the understanding on the distribution of the terrestrial carbon budget in East Asia. Inter-site comparisons were conducted for the net ecosystem production (NEP) over forest stands in sub-arctic, temperate, and tropical regions in the East Asia from 2000 to 2005. The sites are distributed over a wide latitude ranging from 3 to 64 ^{o}N, and include sub-arctic and temperate needle-leaf deciduous forests (larch), temperate mixed, broadleaf deciduous, and needle-leaf evergreen forests, and tropical rain forest and seasonal forests.

The annual NEP is compared with that obtained from the biometric method, in order to investigate the source and magnitude of uncertainties in both methods. It is found that large uncertainties are associated with both methods. There are several issues for the quantitative estimation of CO_2 flux by the eddy covariance method, and also a large uncertainty in the biometric method is related to the estimation of carbon flow in the soil. Further studies are necessary to improve the estimation of carbon budget components and to reduce the uncertainties in both methods.

3-2. Analysis of meso-scale terrestrial carbon balance using top-down approach based on atmospheric monitoring

(1) CO_2 observation in West Siberia

The CO_2 observation sites were selected under the guideline of optimizing for error reduction as well as the infrastructure, logistics and manpower. Five tower stations are located in West Siberia and one tower is in East Siberia.

The daytime concentrations which are representative of planetary boundary layer were selected to see the regional characteristics. Daytime data show almost similar values in neighbor sites in winter whereas clear differences are observed in summer. Lower CO_2 concentrations in southern sites indicate that CO_2 intake is larger by southern vegetation.

(2) CO_2 fluxes by Inverse Analysis

Seasonal variations in CO_2 flux in 2005 in southern part of West Siberia are estimated by using an inverse model based on NIES global transport model. CO_2 flux is almost zero or weak positive value in winter season and is turned to absorption in May, showing maximum in June by 0.75[tC/ha/month]. These variations are compared with the CO_2 fluxes estimated by Sim-CYCLE model in Figure 3. Similarity in seasonal variation of CO_2 fluxes by both model indicate high feasibility of phenology in Sim-CYCLE model. Both model show land vegetation in this region act as a sink for CO_2 in 2005. But the absolute values of CO_2 absorption remain substantial differences, inverse model indicating 1.17[tC/ha] whereas Sim-CYCLE showing 0.32[tC/ha].

3-3. Assessment of carbon balance dynamics and evaluation of methodologies for carbon budget management in terrestrial ecosystems of Asia in the 21st century

(1) Comparison of terrestrial ecosystem models

By comparing three models (BAIM, Sim-CYCLE and TsuBiMo), it was found that the density of observation networks determines the accuracy of model simulations. Regional carbon budget in East Asia was investigated using high-resolution terrestrial ecosystem models, as part of an integrated project concerning Asian carbon management. A process-based carbon cycle model was developed from Sim-CYCLE, a global terrestrial carbon model, and validated with observational data at flux measurement sites.

(2) International comparison of terrestrial carbon cycle models

This project is designed to compare preexisting terrestrial carbon models aiming at the further development of modeling carbon budget. This also serves as the basis of coupled carbon cycle modeling under the global carbon project (GCP). Due to the GCP model development, we have shown that there has been a rapid growth in CO_2 emissions and atmospheric CO_2 since 2000: comparing the 1990s with 2000-2005, and the weakening of the effectiveness of natural CO_2 sinks on land in absorbing anthropogenic

emissions. We estimate that the increase in atmospheric CO_2 growth rate since 2000 was caused by the decrease in effectiveness of natural sinks (8%)

(3) Information basis for carbon budget modeling

1) Vegetation-parameter derivation with remote sensing data

To analyze the terrestrial carbon balance in East Asia with higher spatial resolution and more accurately, satellite derived input data were highly qualified by developing several validation systems. For those validations, by collaborating with Flux observation team, ground observation system for validating satellite remote sensing data (hereby PEN: Phenological eyes network) has been developed and operational.

2) Data archive of forest permanent plots

The census data of 44 plots from 10 regions from SE Asia, Southern Japan, and Northern Japan have been gathered for database. The fast-track meta-analysis results of PlotNet. By analysing 44 forest plots ranging in latitude and altitude from tropical lowland rain forests to cool-temperate subalpine forests, change in ecosystem and tree community attributes were related to the Warmth Index (WI).

(4) Development of an integrated carbon management model

By developing a Land use model, we predicted fluctuations in the carbon balance caused by human activities (i.e. terrestrial carbon management) in the near future. And we also conducted the assessment of carbon management potential to do with the Asian terrestrial carbon budget. We were able to discover that for the next several decades, our potential for managing carbon is limited to the 10% of the total emission from the industry section in the region. However, this projection is heavily influenced by agricultural productivity, economic development in the future scenarios.

3-4. Promotion of integrated research and information sharing

By effectively sharing information between the researchers who are involved with each of these topics, we are able to develop new knowledge about the carbon cycle in East Asia. Topic 4 focused on developing (1) a system approach to understanding carbon dynamics and (2) databases.

(1) A System Approach to Understanding Carbon Dynamics

1) Clarification of Carbon Dynamics through Terrestrial Observation

Inter-site comparison was conducted for the net ecosystem production (NEP) over forest stands in sub-arctic, temperate, and tropical regions in the East Asia from 2000 to 2005. The sites are distributed over a wide latitude ranging from 3 to 64 ^{o}N and include sub-arctic and temperate needle-leaf deciduous forests (larch) (central Siberia, Mongolia, China, and northern Japan), temperate mixed, broadleaf deciduous, and needle-leaf evergreen forests (northern and central Japan), and tropical rain forest and seasonal forests (Malaysia and Thailand).

2) Feeding Data from Remote Sensing by Satellite into Models

With obtaining high frequency/high resolution photosynthetically active radiation (PAR) data using observational data from sensors on board two satellites (Terra/MODIS and Aqua/MODIS), it is possible to give quantitative estimates of photosynthetically active radiation (PAR) that reaches the earth's surface at higher frequencies (daily) and higher resolutions (500m) than in the past.

A new approach was developed to integrate the three best land cover maps currently in existence. Highly-precise land cover map that was created and used in terrestrial ecosystem models.

3) Validating Terrestrial Ecosystem Models

Relationship between NPP estimated by an ecosystem model and measurements from ecological research was analysed. The results of the model at 0.5º (resolution of approximately 50km) show a great deal of dispersion. However, the overall trend of the NPP values in the 1km resolution ecosystem model matches the observed values fairly well.

A comparison was made between the seasonal changes in CO_2 by inverse model and Sim-CYCLE. There is a good match between the inverse model data and the Sim-CYCLE data for the absorption period during the summer to autumn months. However, there is a discrepancy between the two in January and February, where the inverse model shows absorption occuring. It is thought that this effect is caused by the suppression of vertical mixing in the Siberian winter, which results in observations of points that do not necessarily represent the CO_2 concentrations of the entire space.

4) Using Ecosystem Models to Understand Carbon Dynamics in East Asia

Ecosystem models were used to map carbon exchange at a high spatial resolution (1km mesh) in the Asian region. As a result, it is suggested that the average NPP is 1.91 Gt C per year and the net annual absorption is 0.057 Gt C per year. During the six years of analysis, distinct interannual variability was observed in the carbon balance.

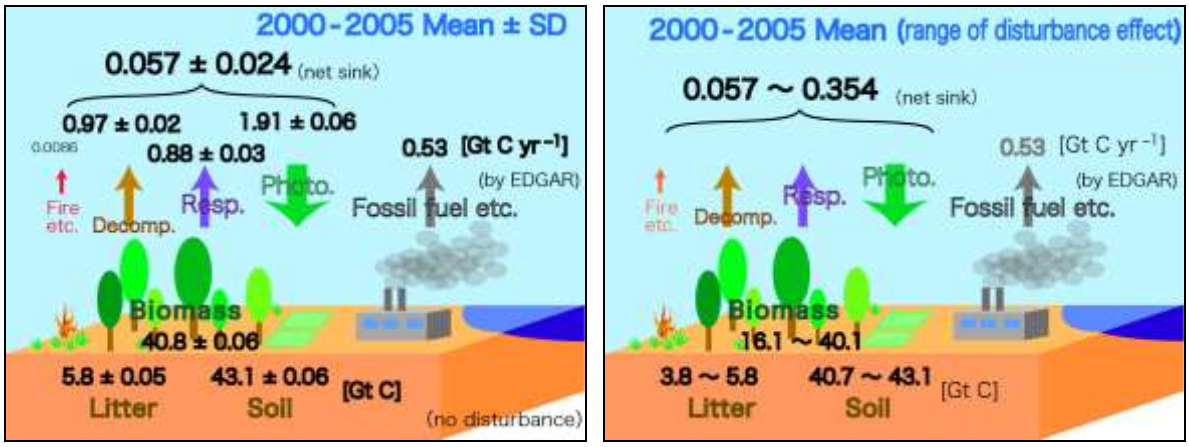

Figure 5. Estimated carbon dynamics (NEP, carbon flux and stock during 2000-2005).

Successful estimates were done for the annual carbon dynamics with our newly developed Integrating System Approach. The carbon sink in the East Asian region (in our

analysis) was around 10% of the total carbon emission from the industry sector. However, the carbon budget is estimated without considering the disturbance effect such as fire and harvesting. Geographical distribution of ecosystem disturbances is not well known at the moment. To better understand these, additional researches are needed to study more about natural and human disturbance factors including human land use activities.

(2) Synthetic promotion of project and database establishment for information sharing

The object of S1 project database (S1-DB) is to share the data and to promote synthetic analysis, such as comparison of data among each theme or measuring site. We made data format and dataset concerned to compatibility with other database such as carbon database at Europe or America. As S1 study has been progressed, soil study group, ecological study group, model study group and remotesensing group have submitted each data to S1-DB. Consequently, we have collected various data regarding to carbon balance in terrestrial ecosystem in Asia. This is one of the special characteristics of S1-DB.

Major Publications

1) N. Saigusa, S. Yamamoto, S. Murayama, H. Kondo, and N. Nishimura, Gross primary production and net ecosystem production of a cool-temperate deciduous forest estimated by the eddy covariance method, Agricultural and Forest Meteorology, 112, 203-215 (2002).
2) S. Yamamoto, N. Saigusa, M. Gamo, Y. Fujinuma, G. Inoue and T. Hirano, Findings through AsiaFlux network and view toward the future, Journal of Geographical Sciences, 15, 142-148 (2005).
3) Patra, P. K., S. Maksyutov, and T. Nakazawa, Analysis of atmospheric CO_2 growth rates at Mauna Loa using inverse model derived CO_2 fluxes, Tellus, 57B, 357-365 (2005).
4) Ishizawa M., D. Chan, K. Higuchi, S. Maksyutov, C.-W. Yuen, J. Chen and D. Worthy, Rectifier effect in an atmospheric model with daily biospheric fluxes: impact on inversion calculation, Tellus, 58B, 447–462, doi:10.1111/j.1600-0889.2006.00219. (2006).
5) Ito, A., N. Saigusa, S. Murayama, and S. Yamamoto, Modeling of gross and net carbon dioxide exchange over a cool-temperate deciduous broad-leaved forest in Japan: Analysis of seasonal and interannual change, Agricultural and Forest Meteorology, 134, 122-134 (2005).
6) Canadell, J. G., M. U. E. Kirschbaum, W. A. Kurz, B. Schlamadinger, and Y. Yamagata, Factoring out natural, indirect and direct human effects on terrestrial greenhouse gas sources and sinks, Environmental Science and Policy, in press (2007).
7) Iwao, K., K. Nishida, T. Kinoshita, and Y. Yamagata, Validating land cover maps

with Degree Confluence Project information, Geophys. Res. Lett., 33, L23404, doi:10.1029/2006GL027768. (2006).

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9) Benítez, P., I. McCallum, M. Obersteiner, and Y. Yamagata, Global potential for carbon sequestration: Geographical distribution, country risk and policy implications, Ecological Economics, 60, 572-583 (2007).
10) Ito, A., Inatomi, M., Mo, W., Lee, M., Koizumi, H., Saigusa, N., Murayama, S. and Yamamoto, S., Examination of model-estimated ecosystem respiration by use of flux measurement data from a cool-temperate deciduous broad-leaved forest in central Japan, Tellus (2007).

S-1 Theme I Terrestrial ecosystem carbon budget analysis by bottom-up (micrometeorological and ecological) approach (Abstract of the Final Report)

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Key Words Forest, Grassland, Soil ecosystem, Carbon budget, Cross check

1. Introduction

Kyoto Protocol, which accounts for offsetting reduction target of CO_2 emission by carbon sequestration in forests through forest management, became effective on February 2005. Those rules, which were determined at COP6 and COP7, have focused attention on the role of the terrestrial biosphere in global scale carbon cycles. Therefore, accurate data are required for net ecosystem production (NEP) over various terrestrial ecosystems. However, uncertainty remains about the change of carbon stock through ecosystems and land managements, and the response of the ecosystem CO_2-exchange to climate change. Therefore, the elucidation of the carbon budgets at various ecosystems has become an important subject of the global warming issue.

The environmental conditions in East Asia under a monsoon climate differ from North America and Europe. The precipitation in East Asia is larger than that in these continents, in particular, the much precipitation in the mid-latitude. Due to the specific features of climate and ecosystem type, the carbon budgets in East Asia should be different from those of North America and Europe. Study sites in this research distribute widely from sub-arctic through tropical zone in East Asia, and cover typical vegetation types in East Asia.

2. Research objectives

(1) A flux measurement above land-ecosystems using a micro-meteorological method permits a direct computation of the net ecosystem exchange (NEE). The NEE can be also estimated as a net ecosystem production (NEP=-NEE) from a temporal change of biomass through ecological investigations. Our study aims to focus the micro-meteorological observations not only on a continuous monitoring of CO_2 flux, but also on the model evaluations of CO_2 dynamics such as the leaf photosynthesis, the leaf and stem respiration and soil respiration. The ecological investigation in our study also

aims at quantifying the biomass change paying attention to the heterogeneous properties such as the distributions of fallen trees and decomposition process. The results obtained from the current studies should be used in precise comparisons with ecological direct surveys of photosynthesis, respiration, growth rates, and litter fall in forest ecosystems. Crosschecking analyses are expected to understand the carbon sequestration in various land-ecosystems in Asia.

(2) Recently, several studies have been made on the inter-comparison of CO_2 fluxes in regional and global scales because continuous data of CO_2 fluxes from eddy covariance technique have been accumulated. Valentini et al. (2000) showed the relationship between carbon accumulation and geography in Europe. Law et al. (2002) investigated the response of vegetation to environmental variables using the North America Continent and the Europe flux data corrected by FLUXNET.

The objectives of this paper are to clarify environmental control factors to regulate NEP, gross primary production (GPP), ecosystem respiration (RE) in various forest ecosystems across East Asia and compare with those in the North America Continent and the Europe.

(3) Climate may exhibit change at a larger magnitude in higher elevation areas. It is noted that the extent of temperature elevation on the Qinghai-Tibetan plateau has been much larger than that in the surrounding area. The IPCC (2001) report predicts that annual averaged temperatures in 2071–2100 on the Qinghai-Tibetan Plateau will increase by 3.3 to 8.4 °C during the summer months (June, July, and August) and by 3.2 to 10.9 °C during the winter months (December, January, and February) compared with those in 1961–1990, if the atmospheric CO_2 concentration rises at a rate of 1.0% yr^{-1}. With the high elevation of temperature, the ecosystems at high elevation may be more frangible and sensitive to the climate changes than low-elevation ecosystems. This raises our concerns regarding the fate of possible large carbon stock in the high-elevation ecosystems. From 2001, we have started the research arming to clarifying the carbon storage and carbon dynamics of grassland ecosystems on the Qinghai-Tibetan plateau by focusing on the alpine meadow ecosystem.

(4) Soil organic matter is the largest pool of terrestrial ecosystem carbon. There is a continuum in disturbance characteristics between primary and secondary succession. Therefore, the relationships between the carbon pools and flux in primary and secondary succession are very important things to evaluate the carbon sequestration in the temperate forest. Soil respiration, CO_2 efflux from the soil surface, is one of the most important processes of carbon cycle in terrestrial ecosystems. Soil respiration consists of many processes and biotic factors, such as respiration from root and microorganisms, and abiotic factors and variables in space and time. In addition, it is very important to understand the interaction between annual carbon fluxes and comparison between chamber methods for

soil respiration measurement. This study aims to evaluate quantitatively ecosystems carbon budget, temporal variability of soil carbon flux in secondary succession and spatial and temporal modeling of soil carbon dynamics and its scaling up.

(5) This project has 15 flux observation sites, which are established and managed by different teams. When we integrate the data obtained at these sites as a single database for common use within the project, standardization of flux observation methodology and assurance of data quality are important. From this point of view, we examined each step of eddy covariance flux measurement including selection and installation of instruments, data processing, correction and quality assurance of data.

For extrapolating of results based tower flux data in spatial and temporal scale, more studies will be required to develop satellite remote sensing and numerical ecosystem models that are really useful for ecosystem monitoring and carbon budget in regional and global scales.

For advances in the synthetic analysis of the carbon budget, it is crucial that the flux research network in Asia be expanded through cooperation among AsiaFlux, KoFlux, and ChinaFLUX. An effective system should be established for the exchange of data obtained from these individual networks and FLUXNET according as the progress in each network.

3. Research method, results and discussion

(1) Quantitative analysis for carbon budget in forest ecosystems

1) Carbon budget of boreal forest ecosystems

The CO_2 flux has been measured by the eddy covariance method over three Larch forest sites, Tomakomai (TFS) (Hokkaido, Japan), Laoshan (LS) (Northeastern China) and Tura (Siberia). Forest biomass, soil respiration, and soil organic carbon storage were estimated during 2002 and 2006. Forest biomass was estimated by destructive sampling in two stands. Soil respiration was monitored using Li-Cor LI-6400. Three soil profiles were surveyed for soil organic carbon storage. We also conducted field survey in Tura, Siberia and Laoshan for biomass estimation, soil respiration using LI-820 after air sampling by chamber method, and soil organic carbon storage. Additional survey for tree ring analysis and nitrogen dynamics in soil were conducted.

2) Carbon budget of temperate forest ecosystems

Micrometeorological measurement of carbon dioxide, water vapour and sensible heat fluxes and related ecological observations have been conducted in Japanese temperate forests at Fujiyoshida (FJY; cool-temperate coniferous), Kiryu (KEW; warm-temperateconiferous) and Takayama (TKY; cool-temperate deciduous).

The observed net ecosystem production (NEP) ranged from 300 to 600 $gCm^{-2}year^{-1}$ in FJY, from 400 to 700 $gCm^{-2}year^{-1}$ in KEW, and from 200 to 400 $gCm^{-2}year^{-1}$ in TKY, respectively. The forest response to the inter-annual climatic variations has been examined through three apparent climatic anomalies happened during the observation period from

2000 to 2005. One was a positive anomaly in air temperature which occurred from January to April 2002 in broader area in East-Asia. It promoted the leaf expansion of the deciduous forest for about 10 days and it brought large annual NEP and gross primary production (GPP) in TKY site. Another was a negative anomaly in solar radiation associated with the longer-term stagnation of stationary front which occurred from July to August in 2003 in Japanese broader area from Kyushu to Kanto districts. During the period, the photosynthetically active radiation and the air temperature were decreased both in FJY and TKY sites. The climatic degradation reduced GPP and ecosystem respiration (RE) at the same time, but the decrease of GPP exceeded the decrease of Re. As a consequence, the apparent reduction of GPP caused the minimum annual NEP in the observation period in FJY, and it strongly affected the reduction of NEP in TKY sites. The third was a positive anomaly in air temperature almost throughout the year in 2004 in Japan. With the observed NEP was larger from summer to autumn in FJY, and from winter to summer and autumn to winter in KEW sites, the annual NEP showed the maximum in the observation period in both sites.

3) Tropical rain-forest ecosystems

The purpose of this study is to estimate net ecosystem production (NEP) of the forest ecosystem in tropics both from CO_2 fluxes above forest using micro-meteorological methods and temporal biomass changes through ecological investigations. The study was conducted in a lowland dipterocarp rainforest in Pasoh Forest Reserve, Peninsular Malaysia, and in a seasonal evergreen forest in the Sakaerat Environmental Research Station, Thailand.

For our micro-meteorological estimations of NEP at Pasoh forest, we focused on detailed measurements on various processes involved in carbon dynamics in order to examine influences of observation errors, and temporal and spatial heterogeneities. Seasonal variations of GPP, RE, Rsoil and NEP at Pasoh are shown in Fig.2. Monthly average diurnal changes in CO_2 exchange over the canopy were fairly constant from 2003 to 2005 despite fluctuations in soil moisture, solar radiation, temperature and vapor pressure deficit between dry and wet periods. An obvious inhibition of canopy CO_2 exchange in the afternoon coupling with increases in VPD and air temperature was observed year-round. Application of a process-based multi-layer model suggested that this inhibition was caused by patchy stomatal closure. Because the CO_2 emission by soil respiration decreased with soil-water decreasing, NEP was estimated to increase in dry seasons. These field observations and analyses suggested a slight uptake for the annual CO_2 balance in this forest.

(2) Quantitative analysis for carbon budget in grassland ecosystems

1) Carbon dynamics in a temperate alpine grassland ecosystem in East Asia

To estimate the carbon sink strength and to address its relation with environmental variables, we have conducted a long-term measurement of CO_2, H_2O and energy fluxes for more than 5 years. From the flux measurement we found (1) this alpine meadow ecosystem

absorb about 120 $gCm^{-2}yr^{-1}$, with a large annual variation. This variation is considered to be due to mainly the water availability and plant phenology; (2) a large daily variation in net ecosystem CO_2 exchange with a net carbon release from the ecosystem estimated to be 2 $gCm^{-2}d^{-1}$ during the winter period and a net CO_2 uptake of about 4 $gCm^{-2}d^{-1}$ during summer season from 2001 to 2004; (3) a path analysis indicates that temperature is the major constraint on the short-term variation of CO_2 flux in the alpine meadow.

2) Use of isotopic approach on the analysis of carbon dynamics in a C3/C4 mixed grassland

We use an isotopic approach combined with biomass investigation and flux measurements by eddy covariance technique to estimate the photosynthetic pathway composition (C3:C4 mixture) of carbon dynamics in a C3/C4 mixed grassland and in particularly, seasonal changes in the contribution of C3 and C4 plants to photosynthesis (i.e. gross primary production, GPP), ecosystem respiration (RE), and soil respiration (RS).

The studied C3/C4 mixed grassland was under significant influence of the Asian monsoon that provided abundant water during the growing season, and showed a high annual GPP (2491-2698 gC m^{-2}), 2-3 times as of the grasslands in semi-arid and arid regions. However, the RE was also great due to the hot and humid summer. During the 3 surveyed years (2001-2003), the inter-annual variation in net ecosystem exchange (NEE) was small and suggested that this grassland ecosystem may act as a small net sink for atmospheric CO_2 (11, 66, and 37 gC m^{-2} for 2001, 2002, and 2003, respectively).

3) Carbon budget of agricultural sites

We continued observation at these three study sites and accumulated the data on seasonal and inter-annual variations of carbon exchange. In addition, we partitioned net ecosystem exchange (NEE) observed at HCH and MSE sites (single cropping rice paddy) during the growing season into gross primary production (GPP), plant respiration including root respiration (autotrophic respiration; RA) and decomposition of soil organic matter (heterotrophic respiration; RH), and examined influence of inter-annual variations of meteorological conditions and agricultural practices on respective components of NEE.

(3) Study on carbon dynamics and budgets in different soil ecosystems

1) Quantitative evaluation of ecosystems carbon budget

Ecosystem carbon pools and fluxes were measured with chronosequece in cool-temperate zone, central Japan. Five study sites for secondary succession, ranging from clear-felled site to 100-years mature deciduous forest, were selected in the Takayama and Sugadaira research sites. Four study sites were set on the lower montane zone of Mt. Fuji for primary succession, young pine forest, mature pine forest, conifer forest and climax deciduous forest, which had different age after vegetation establishment (12 - 2850 y).

2) Quantitative evaluation of temporal variability of soil carbon flux in secondary succession

All the studies of the rhizosphere research group were made in the seven research

sites, including 22 ecosystems: grasslands, forests, and croplands. Soil carbon fluxes were measured by 6 chamber methods (open-flow chamber, open-top chamber, automated open/closed chamber, closed static chamber, LI6400, LI6200) between 2002 and 2005.

3) Spatial and temporal modeling of soil carbon dynamics and its scaling up

For describing temporal changes in soil carbon dynamics, we developed a process-based model, which includes some compartments of carbon pool with different residence time of organic matters. The model describes soil carbon dynamics in terms of turnover processes of soil organic matters among carbon pools (compartments), i.e. input organic matter from above ground and roots, microbial biomass humus, and inactive organic carbon. The CO_2 gases also release during these decomposition processes. The basic structure of our model is based on the Rothamsted Carbon model (RothC) consisting of five compartments. The model could simulate long-term changes in soil organic carbon (SOC) as well as seasonal changes in heterotrophic respiration in upland, grassland, and forests.

(4) Construction of the AsiaFlux database of carbon budget and synthetic analysis of carbon budget data in East Asia

1) AsiaFlux database of carbon budget

Eddy covariance flux data obtained at 15 tower observation sites of the present project are combined into a project database, which is expected to be a fundamental dataset of “the AsiaFlux database” after the project is over. The database is utilized for inter-site comparison of carbon and water vapor exchange in terrestrial ecosystem in monsoon Asia. The database will also provide model investigators with basic data to make and validate numerical models of carbon cycle in terrestrial ecosystem in monsoon Asia. The eddy covariance flux measurement technique is commonly employed in the present project, but actually neither instrumentation nor data processing method is unified. It is therefore important to make clear how the differences in the instrumentation and the data processing methods between the observation sites participating in the project affect obtained flux values. In addition, non-laborious and standardized methods for quality control and gap filling of flux data are desired for analyzing multiple-site and multiple-year datasets accumulated in the database.

2) Synthetic analysis of carbon budget data in East Asia

The dataset, which was obtained at a wide variety of ecosystems in East Asia with multiple years, is quite essential for the understanding on the distribution of the terrestrial carbon budget in East Asia. Inter-site comparisons were conducted for the net ecosystem production (NEP) over forest stands in sub-arctic, temperate, and tropical regions in the East Asia from 2000 to 2005. The sites are distributed over a wide latitude ranging from 3 to 64 ^{o}N, and include sub-arctic and temperate needle-leaf deciduous forests (larch), temperate mixed, broadleaf deciduous, and needle-leaf evergreen forests, and tropical rain forest and seasonal forests.

The annual NEP is compared with that obtained from the biometric method, in

order to investigate the source and magnitude of uncertainties in both methods. It is found that large uncertainties are associated with both methods. There are several issues for the quantitative estimation of CO_2 flux by the eddy covariance method, and also a large uncertainty in the biometric method is related to the estimation of carbon flow in the soil. Further studies are necessary to improve the estimation of carbon budget components and to reduce the uncertainties in both methods.

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(1) Quantitative analysis for carbon budget in forest ecosystems

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(4) Construction of the AsiaFlux database of carbon budget and synthetic analysis of carbon budget data in East Asia

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S-1 Theme II Terrestrial Carbon-budget study in Meso-scale by Top-down Approach (Abstract of the Final Report)

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Total Budget for FY2002-FY2006 381,725,000 Yen (FY2006; 61,000,000 Yen)

Key Words Carbon Dioxide, Top-down Approach, West Siberia, Inverse model, CO_2 Flux

1. Introduction

The problem of determining the space-time structure of carbon fluxes to the atmosphere has gained considerable prominence along with the rising interest in anthropogenic climate change. The two classes of methods available are distinguished as "bottom-up" or "top-down" methods. In the bottom-up method, local knowledge, often instantiated in process models, is integrated to regions of interest while in the top-down or atmospheric method, integrated signatures of the fluxes are deconvolved to recover the structure of fluxes. Two advantages of the top-down method are that it integrates some of the small-scale heterogeneity that may not be of direct interest (either policy or scientific) and that it does not require knowledge of the processes giving rise to the fluxes.

2. Research Objective

The atmospheric concentration is determined as a result of the surface CO_2 process integrating over the time and space. In order to retrieve the atmospheric concentration to the surface CO_2 exchange process, we need very accurate dataset. The spatial resolution of this retrieval process, so called inverse-model analysis, at the first stage in the scale of 22 parts in globe, and the temporal resolution is too poor to identify the year-to-year variability of sink/source distribution, or it is not reliable even though the calculation is possible. This is mainly due to the lack of atmospheric data: the present observation network is too sparse and the distribution is weight to developed countries in northern hemisphere.

The improvement of the atmospheric observation network will be realized but the enough number of stations will be difficult to realize from many reason. We propose to develop the methodology to identify the sink/source distribution in a limited area, meso-scale, where a dense observation network is established. The inverse model

analysis at this stage should be different from the present one, because the process treated is small in both temporal and spatial scale, and new detail process parameters such as the variation of photosynthetic radiation in daily scale, the change of soil moisture, and the age structure of forests and so on are required. In other words, these fine scale model calculation is validated by this observation. We selected West Siberia as a research area, because it is a plateau and the land cover structure is rather simple.

3. Research Method

In this project, five atmospheric CO_2 concentration continuous measurement towers were installed in West Siberia. These towers provide us with lots of information about the time and space evolution of atmospheric CO_2 concentration over West Siberia. The project was aimed to estimate regional CO_2 fluxes by "top-down" or inverse approach using the information contained in the atmospheric continuous measurements. The inverse method innovates in its ability to optimized daily fluxes for each grid cell over West Siberia.

4. Results and Discussions

(1) CO_2 observation in West Siberia

The CO_2 observation sites were selected under the guideline of optimizing for error reduction as well as the infrastructure, logistics and manpower. Five tower stations are located in West Siberia and one tower is in East Siberia (Figure 1).

Fig.1 Locations of CO_2 observation site

Observed CO_2 concentrations in six sites are shown in Figure 2. The daytime concentrations which are representative of planetary boundary layer were selected to see the regional characteristics. Daytime data show almost similar values in neighbor sites in winter whereas clear differences are observed in summer. Lower CO_2 concentrations in southern sites indicate that CO_2 intake is larger by southern vegetation.

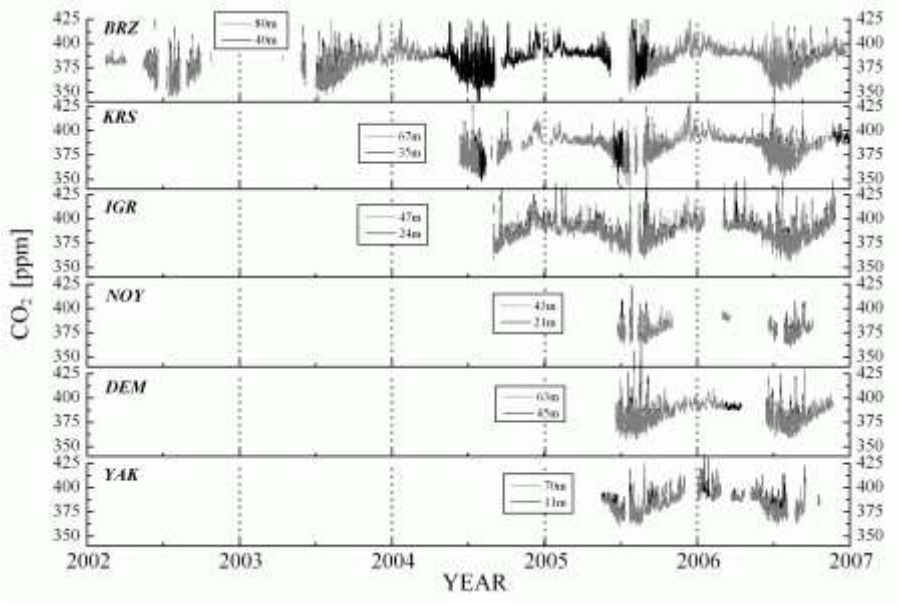

Fig.2 One-hour averaged values of CO_2 at Berezorechka (BRZ), Karasevoe (KRS), Igrim (IGR), Noyabrsk (NOY), Demyanskoe (DEM), Yakutsk (YAK).

(2) CO_2 fluxes by Inverse Analysis

Seasonal variations in CO_2 flux in 2005 in southern part of West Siberia are estimated by using an inverse model based on NIES global transport model[1]. CO_2 flux is almost zero or weak positive value in winter season and is turned to absorption in May, showing maximum in June by 0.75[tC/ha/month]. These variations are compared with the CO_2 fluxes estimated by Sim-CYCLE model in Figure 3. Similarity in seasonal variation of CO2 fluxes by both model indicate high feasibility of phenology in Sim-CYCLE model. Both model show land vegetation in this region act as a sink for CO_2 in 2005. But the absolute values of CO_2 absorption remain substantial differences, inverse model indicating 1.17[tC/ha] whereas Sim-CYCLE showing 0.32[tC/ha].

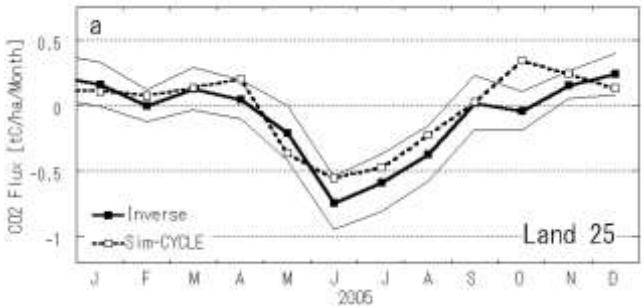

Fig.3 Comparison in CO_2 flux in southern West Siberia estimated by Inverse model and Sim-CYCLE model.

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S-1 Theme III Carbon budget change and its management in the 21st century Asian terrestrial ecosystems

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Total Budget for FY2002-FY2006 495,133,000 Yen (FY2006; 110,000,000 Yen)

Key Words Terrestrial Ecosystems, Modeling, Remote Sensing, Carbon Management
Model/System Acronyms BAIM, BEAMS, Sim-CYCLE, TsuBiMo

1. Introduction

Current uncertainty in estimating carbon budget at global or regional scales is not that profound that one can dispute their validity. Nevertheless, the estimates accuracy is critical for a successful implementation of UNFCC and related international agreements. Of prime importance is the reduction of uncertainties in net terrestrial carbon uptake and the attribution of the so called 'residual terrestrial uptake' to well-established biophysical mechanisms.

Asia has complicated geographical feature, land cover, various vegetation and agricultural forms, intense land alteration and seasonal change, etc. Therefore, satellite remote sensing is a leading tool. Satellite data is useful when understanding vegetation change of such various terrestrial. However, in a satellite data independent, carbon balance cannot be presumed but presumption by a terrestrial model is needed. When using satellite data as input data, verification of the data is important in presumption of the carbon balance. Moreover, those model estimation results also not well verified especially in Asian regions. They serve as uncertain factors in presumption of the carbon balance of Asia. It is partly because that those varieties of observation data from ground to satellite and model results are not well managed.

2. Research Objective

For any methodology applied to estimate the impact of climatic changes, the anomalies in the sink magnitude should be consistent with the estimates derived by other methods. Therefore, the research was focusing on model calibration and validation using observations of CO_2 fluxes and CO_2 concentrations made by other research groups of the same project.

By comparing and developing several terrestrial ecosystem models, we tried to estimate the carbon balance of highly precise and realistic in Asia using a satellite driven

type model. In order to realize this, ground observation network for verifying satellite data product has been deployed. While improving and guarantee the reliability, it aims at building the research support environment which makes it possible to treat a series of data from ground observation, satellite data product, to model presumption result integrative. In addition, PlotNet project was conducted, which aims to construct database of permanent forest plot censuses covering over Eastern Asia and to carry out meta-analysis of cross-plot biomass-productivity-biodiversity.

Land-use models is developed to assess the economical efficiency of managed and unmanaged forests, agricultural land, and grasslands. Static models of international food and forestry products were used to calculate the profitability of land areas by using the price of future forestry and agricultural products and management costs to predict a change to more lucrative land-use. The model used in this research integrates agricultural productivity data from previous research, forest productivity and carbon flux data from the terrestrial ecosystem model in the current study, and land cover maps from the current study.

3. Research results

(1) Comparison of terrestrial ecosystem models

By comparing three models (BAIM, Sim-CYCLE and TsuBiMo), it was found that the density of observation networks determines the accuracy of model simulations. Regional carbon budget in East Asia was investigated using high-resolution terrestrial ecosystem models, as part of an integrated project concerning Asian carbon management. A process-based carbon cycle model (Ito et al., 2005) was developed from Sim-CYCLE, a global terrestrial carbon model, and validated with observational data at flux measurement sites. At the Takayama temperate forest (a site of the AsiaFlux), the model captured seasonal and interannual variability in net ecosystem CO_2 exchange and carbon pools, but required to additionally include a disturbance effect (i.e. by logging) to account for the observed net carbon sequestration by as high as 200 g C m^{-2} yr^{-1}. The model was applied to the regional scale at a spatial resolution of 1-km by use of satellite-based land cover maps (MOD12 and GLC2000) and interpolated climate and soil datasets (WorldClim and IGBP-DIS Soil Collection).

Such high resolution was effective to capture spatial heterogeneity over the region. Using the model, the project is intended to produce a regional carbon budget map during the period 2000-2005, which would contribute to improve the accuracy of regional carbon budget and be useful for planning carbon management. The model result will be validated with an independent estimation by the inverse-model on the basis of atmospheric data. Finally, we will discuss the potential applications and problems of the model in relation to full carbon accounting for the Kyoto Protocol.

(2) International comparison of terrestrial carbon cycle models

This project is designed to compare preexisting terrestrial carbon models aiming at

the further development of modeling carbon budget. This also serves as the basis of coupled carbon cycle modeling under the global carbon project (GCP). GCP is internationally coordinated project under ISCU, the modeling inter-comparison activity is conducted as a part of GCP project. In the first phase of the project, the objectives and outline of the database was elaborated, and the pre-existing terrestrial carbon models were tentatively compared. In the later phase, we have experimented with coding the models for their treatment framework. The model comparison coding scheme includes characteristics of the model components, modeling approaches, and their utility. Once the models have been coded, their strengths and weaknesses will be summarized for the purpose of "fully" carbon-climate-human dimensions, with a focus on measures of such inclusivity.

Due to the GCP model development, we have shown that there has been a rapid growth in CO_2 emissions and atmospheric CO_2 since 2000: comparing the 1990s with 2000-2005, and the weakening of the effectiveness of natural CO_2 sinks on land in absorbing anthropogenic emissions. We estimate that the increase in atmospheric CO_2 growth rate since 2000 was caused by the decrease in effectiveness of natural sinks (8%)

(3) Information basis for carbon budget modeling

1) Vegetation-parameter derivation with remote sensing data

To analyze the terrestrial carbon balance in East Asia with higher spatial resolution and more accurately, satellite-driven model, BEAMS was used, and was conducted with 1-km spatial resolution and monthly time-step. To achieve this, satellite derived input data were highly qualified by developing several validation systems.

For those validations, by collaborating with Flux observation team, ground observation system for validating satellite remote sensing data (hereby PEN: Phenological eyes network) has been developed and operational. PEN enables us to validate major vegetation parameters (NDVI,FPAR,LAI,GPP,NPPetc.,) derived from satellite data (such as MODIS). For the new land cover map, a method, which enables to validate the accuracies of existing land cover maps, is proposed. Using this method, five kinds of land cover data were evaluated preliminary. Based on this method, it is planned to develop a newly land cover data with well validated.

2) Data archive of forest permanent plots

The census data of 44 plots from 10 regions from SE Asia, Southern Japan, and Northern Japan have been gathered for database. The fast-track meta-analysis results of PlotNet were published by Takyu et al. (2005). By analysing 44 forest plots ranging in latitude and altitude from tropical lowland rain forests to cool-temperate subalpine forests, change in ecosystem and tree community attributes were related to the Warmth Index (WI). The change is explained by WI, while in biome-specific manner. Cool-temperate deciduous forests and evergreen coniferous subalpine forests showed higher tolerance against small WI compared to tropical and warm-temperate evergreen rain forests, suggesting the tolerance against seasonal cold spell in the former forest biomes.

(4) Development of an integrated carbon management model

By developing a Land use model, we predicted fluctuations in the carbon balance caused by human activities (i.e. terrestrial carbon management) in the near future. And we also conducted the assessment of carbon management potential to do with the Asian terrestrial carbon budget. We were able to discover that for the next several decades, our potential for managing carbon is limited to the 10% of the total emission from the industry section in the region. However, this projection is heavily influenced by agricultural productivity, economic development in the future scenarios.

Using the land use model, we projected the regional geographically explicit land use changes in the next 30 years. Comparing with FAO Forest Resource Assessment 2005, we could verify that the spatial deforestation pattern projected by our model and the FRA report fairly shows an agreement at least during the last 5 years. This land use change projection result was inputted entered into the ecosystem model to estimate the carbon dynamics associated with the land use change. In this estimation amount of biomass above ground and stock change of soil carbon were both accounted, although most of conventional models are not dealing with soil carbon.

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S-1 Theme IV Integrative advancement of the project and information sharing

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Total Budget for FY2002-FY2006 106,775,000 Yen (FY2006; 52,427 Yen)

Key Words System Approach, Policy Contribution, Integration Analysis, Database, Terrestrial Area in East Asia

1. Introduction

The Kyoto Protocol was ratified and signatory countries are preparing for the first commitment period which will start during 2007. Actually, international negotiation already started on post 2012 (beyond Kyoto) framework. From now on, the main agenda is the long-term atmospheric greenhouse gas (GHG) stabilization target setting. Scientific knowledge regarding terrestrial carbon sink function and its variability is also vitally needed to support the decision.

2. Research Objective

To investigated regional carbon dynamics in Asia with a newly developed Integrated System Approach. This approach combines:

- flux tower measurements and ecosystem measurements at test site network
- remote sensing for scaling up meteorological measurements and land cover classification
- ecosystem modeling based on the new understanding of ecosystem processes
- land use change modeling for projecting future carbon dynamics.

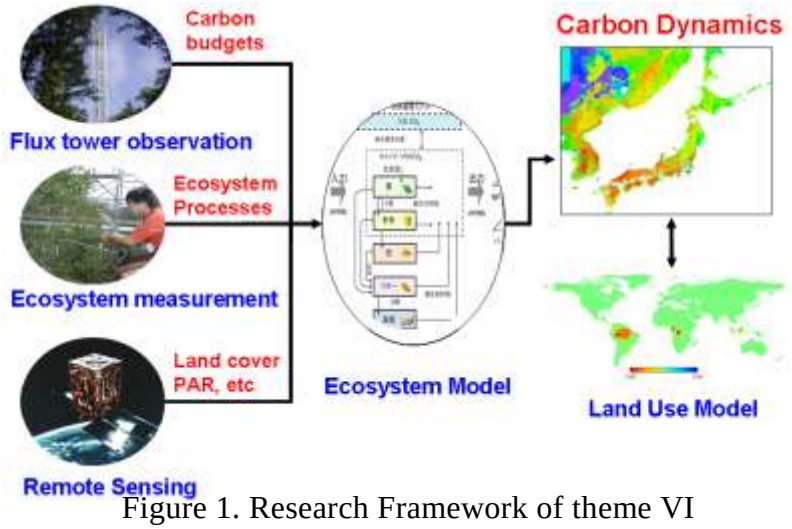

Figure 1. Research Framework of theme VI

3. Research results

(1) A System Approach to Understanding Carbon Dynamics

1) Clarification of Carbon Dynamics through Terrestrial Observation

a. Comparing annual observed carbon balance values from various ecosystems

Inter-site comparison was conducted for the net ecosystem production (NEP) over forest stands in sub-arctic, temperate, and tropical regions in the East Asia from 2000 to 2005. The sites are distributed over a wide latitude ranging from 3 to 64 ^{o}N and include sub-arctic and temperate needle-leaf deciduous forests (larch) (central Siberia, Mongolia, China, and northern Japan), temperate mixed, broadleaf deciduous, and needle-leaf evergreen forests (northern and central Japan), and tropical rain forest and seasonal forests (Malaysia and Thailand).

We collected and summarized annual net ecosystem productivity (NEP) values from various locations in Asia observed during the course of this research project and other projects. We were able to determine that in the sub-arctic zone, the annual absorbed amount is less than 1 tC ha^{-1} year^{-1}, while from the temperate zone to the tropical zone there was a maximum of 5 to 6 tC ha^{-1} year^{-1}. Furthermore, by comparing ecosystems in temperate zones, we were able to find that evergreen forests, with their long growing period, were able to absorb more per year than deciduous forests.

b. Comparison of NEP Values using Micrometeorology and Ecological Science Techniques.

Table 1 shows the net ecosystem productivity (NEPM) as derived by the eddy correlation method (micrometeorology) and the net ecosystem productivity (NEPB) from a biomass survey (ecological science). The table includes data from both the current research and from terrestrial sites in North America. In general, the NEPM values are larger than the NEPB values, and the two values do not match for many of the sites. Problems have been identified with both methods: NEPM values are susceptible to nocturnal measurement error and NEPB values cannot accurately estimate the carbon exchange of underground root systems. It is necessary to clarify the causes of these errors in the future.

2) Feeding Data from Remote Sensing by Satellite into Models

a. Obtaining high frequency/high resolution photosynthetically active radiation (PAR) data

Using observational data from sensors on board two satellites (Terra/MODIS and Aqua/MODIS), it is possible to give quantitative estimates of photosynthetically active radiation (PAR) that reaches the earth's surface at higher frequencies (daily) and higher resolutions (500m) than in the past.

b. Creating highly precise land cover maps

A new approach was developed to integrate the three best land cover maps currently in existence. Figure 10 shows the resulting highly-precise land cover map that was created and used in terrestrial ecosystem models.

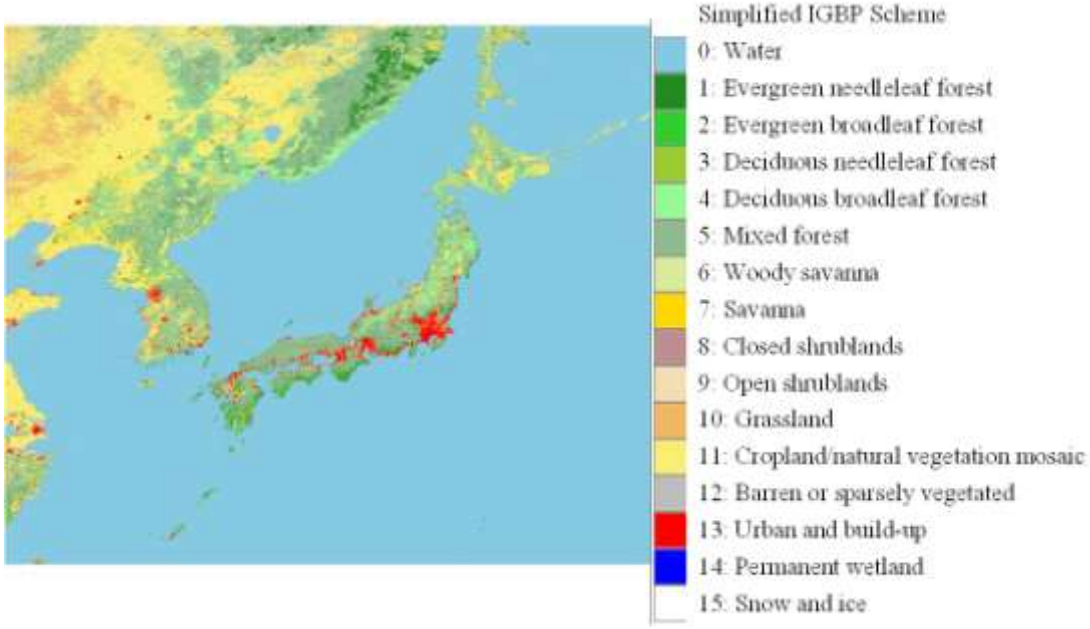

Figure 2. New land cover maps.

3) Validating Terrestrial Ecosystem Models

a. Observation and validation of the carbon balance through ecological science

Figure 3 shows the relationship between NPP estimated by an ecosystem model and measurements from ecological research. The results of the model at 0.5º (resolution of approximately 50km) show a great deal of dispersion. However, the overall trend of the NPP values in the 1km resolution ecosystem model matches the observed values fairly well. In order to increase the precision, it may be necessary to consider environmental parameters such as altitude and precipitation and the impact of disturbances.

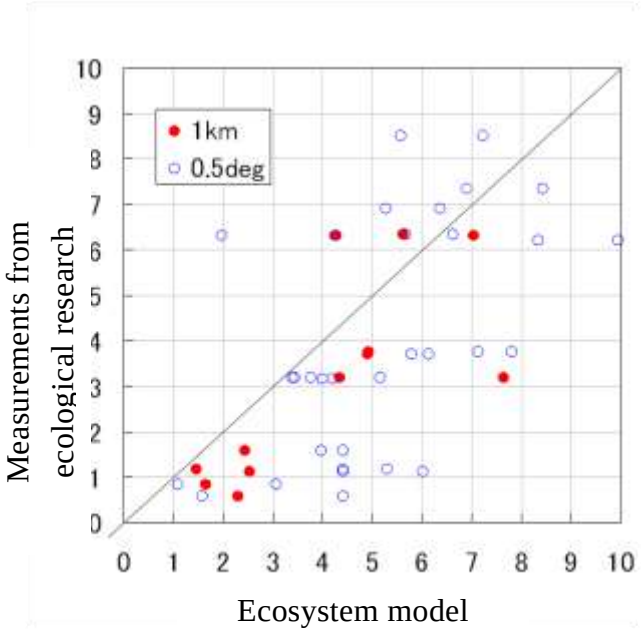

Figure 3. NPP estimated by an ecosystem model and measurements from ecological research.

b. Top-down approach and cross-checking

A comparison was made between the seasonal changes in CO_2 by inverse model and Sim-CYCLE. As can be seen in Figure 4, there is a good match between the inverse model data and the Sim-CYCLE data for the absorption period during the summer to autumn months. However, there is a discrepancy between the two in January and February, where the inverse model shows absorption occuring. It is thought that this

effect is caused by the suppression of vertical mixing in the Siberian winter, which results in observations of points that do not necessarily represent the CO_2 concentrations of the entire space.

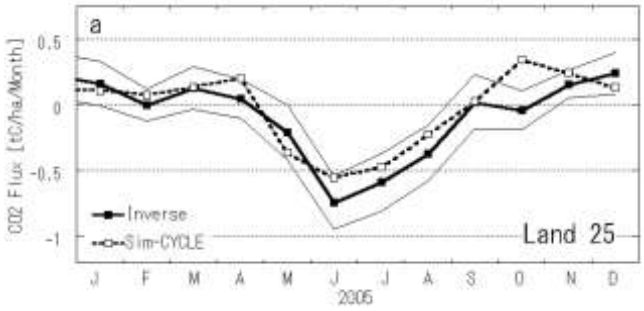

Fig.4 Comparison in CO_2 flux in southern West Siberia estimated by Inverse model and Sim-CYCLE model.

4） Using Ecosystem Models to Understand Carbon Dynamics in East Asia

In the current research, models were created at the city-town-village scale and at the small river basin scale. Those models were used to map carbon exchange at a high spatial resolution (1km mesh) in the Asian region. As a result, it is suggested that the average NPP is 1.91 Gt C per year and the net annual absorption is 0.057 Gt C per year. During the six years of analysis, distinct interannual variability was observed in the carbon balance.

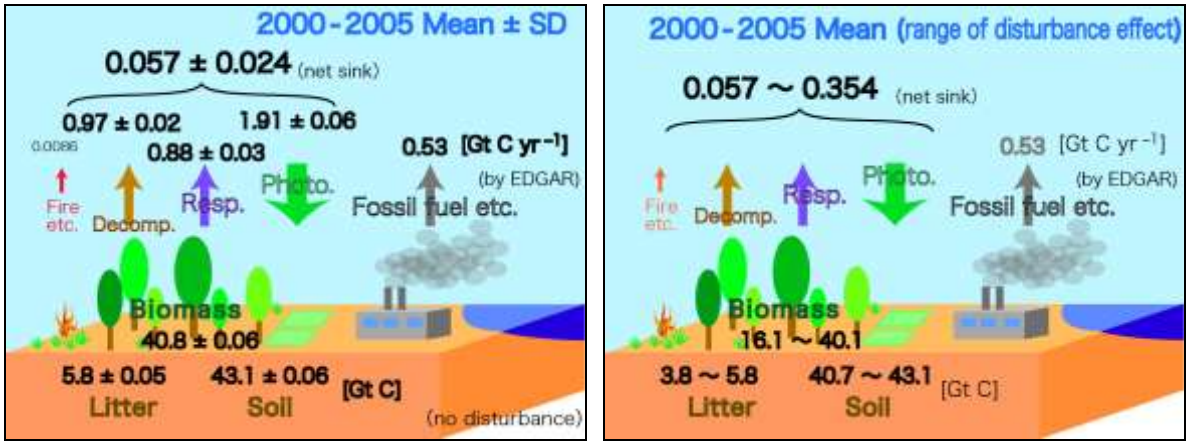

Figure 5. Estimated carbon dynamics (NEP, carbon flux and stock during 2000-2005).

5） Conclusion and future work

Successful estimates were done for the annual carbon dynamics with our newly developed Integrating System Approach. The carbon sink in the East Asian region (in our analysis) was around 10% of the total carbon emission from the industry sector. However, the carbon budget is estimated without considering the disturbance effect such as fire and harvesting. Geographical distribution of ecosystem disturbances is not well known at the moment. To better understand these, additional researches are needed to study more about natural and human disturbance factors including human land use activities.

(2) Synthetic promotion of project and database establishment for information sharing

1） Significance of database

The object of S1 project database (S1-DB) is to share the data and to promote synthetic analysis, such as comparison of data among each theme or measuring site. We made data format and dataset concerned to compatibility with other database such as carbon database at Europe or America. As S1 study has been progressed, soil study group, ecological study group, model study group and remotesensing group have submitted each data to S1-DB. Consequently, we have collected various data regarding to carbon balance in terrestrial ecosystem in Asia. This is one of the special characteristics of S1-DB.

2） S1-DB system

Web application is consisted of JSP/ servlet. We use “Tom cat” for JSP/servlet container, ‘Apache’ for Web server, “MySQL” for database server. Data users are to input ID and password, which are provided by database manager, and login to database.

3） Data collected at S1-DB system

S1-DB is consisted of “Terrestrial ecosystem monitoring database”, “Remotesensing monitoring database” and “Model database”, which include data from various study regions regarding to carbon balance in terrestrial ecosystem.

“Terrestrial ecosystem monitoring database” is consisted of “Flux/micrometeorological database”, “Soil respiration database”, “Ecological database”, “Flux gapfilling database” and “Site information database” in addition. Data user can download 15-site-dataset including data with csv file and document file, which includes site information and method and so on. were written. Data user can confirm QC/QA and data traceability by the document files. At “Remotesensig monitoring database”, GPP/NPP map created by terrestrial model based on remotesensing monitoring data and incoming PAR map. Carbon balance map from process-based carbon cycle model (Sim-CYCLE) and the results of inverse model from theme 2 were submitted to “Model database”. Currently, about 70-data files were submitted to “S1-DB”.

4） S1-DB used condition

Number of enrolled users in S1-DB are 37 at the end of March in the 19th year of Heisei era. About 1000-data files have been downloaded in total. The number of downloaded data increased rapidly and used for comparative or synthesis analysis in the 17th and 18th year of Heisei era, when synthesis analysis has been progressed in second phase of S1 project.

Major Publications

1) N. Saigusa, S. Yamamoto, T. Ohtsuka, S. Murayama, H. Kondo, and H. Koizumi, Inter-annual variability of carbon budget components in a cool-temperate deciduous forest in Japan (Takayama, AsiaFlux), Phyton, Vol.45, No.4, pp.81-88 (2005).
2) Ito, A., Inatomi, M., Mo, W., Lee, M., Koizumi, H., Saigusa, N., Murayama, S. and Yamamoto, S., Examination of model-estimated ecosystem respiration by use of flux measurement data from a cool-temperate deciduous broad-leaved forest in central Japan, Tellus (2007)