# Proceedings of
# The 9th U.S.-Japan Workshop
# on Global Change

## *CARBON CYCLE MANAGEMENT*
## *IN TERRESTRIAL ECOSYSTEMS*

**October 9-11, 2001**
**Mita Conference Hall, Tokyo**

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# Joint Report

# 9th Japan-U.S. Workshop on Global Change

## Foreword

This workshop was the 9th in a series of Japan-U.S. workshops on global change research held under the aegis of the U.S.-Japan Liaison Group for Geosciences and Environment under the *U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology*. These workshops contribute to the implementation of global change research activities, fostered by the scientists of Japan and the United States, through information exchanges and discussions which promote long-term collaborations that benefit society.

The 9th Japan-U.S. Workshop focused on the issue of Carbon Cycle Management in Terrestrial Ecosystems. The workshop was held in Tokyo, Japan at the Mita Kaigisho conference center on October 9-11, 2001. Dr. Steven Shafer, the U.S. co-convenor, noted that the events of September 11th affected even this apparently remote scientific effort and shared with the group his personal thoughts, which we believe represent those of all of the participating scientists.

> It is my personal belief that a fitting tribute to those who lost their lives is to work so that their children and successive generations have a world that can provide for their wants and needs and happiness. I believe that in having this meeting, we do our small part in moving the world in that direction in two ways: first, by defying those who would make U.S.fraid to see that such a world can be realized, and second, by dedicating our education and talents toward securing a sustainable environment for future generations.

The theme for the workshop was inspired by research advances following the 6th Workshop on Land Use/Cover Change and Global Environmental Conservation. In the five years since that meeting, much understanding has been gained concerning how the management of land resources, within individual uses such as forestry or crop production, can affect whether a given part of the landscape is a carbon source or sink relative to the atmosphere, the rate of carbon flux, the amount of carbon that might be sequestered in the land, and how long it might remain out of the atmosphere. Managing the carbon cycle in terrestrial ecosystems offers one important way in which the world's societies might temper the steady increase in atmospheric $CO_2$ concentration and slow the rate of climate change.

The 64 workshop participants included scientists, science managers from universities, and representatives of government agencies and ministries. Participants were asked to articulate the current state of our knowledge and to develop recommendations for future collaboration in areas in which Japanese and American scientists are uniquely qualified to address gaps in our knowledge. As the following report shows, they were largely successful in this endeavor.

The workshop was sponsored by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan and the Global Change Research Program (USGCRP) of the United States. Special recognition is given to the exceptional efforts of the two co-convenors, Prof. Yoshifumi Yasuoka of the Institute of Industrial Science at the University of Tokyo and Dr. Steven Shafer of the Agricultural Research Service of the U.S. Department of Agriculture, whose dedicated efforts made this workshop a significant event in the promotion of bilateral cooperation in the global change field.

Mr. Daisuke Yoshida
Director
Ocean and Earth Division
Research and Development Bureau
Ministry of Education, Culture, Sports,
Science and Technology

Dr. Margaret Leinen
Chair
Subcommittee on Global
Change Research

# Japan-U.S. Workshop on Global Change
## Report of the Co-Convenors

**Prof. Yoshifumi Yasuoka**
Institute of Industrial Science
University of Tokyo

**Dr. Steven Shafer**
Agricultural Research Service
U.S. Department of Agriculture

The 9th Japan-U.S. Workshop on Global Change was designed to maximize the exchange of information between Japanese and American scientists engaged in research related to carbon cycle management in terrestrial ecosystems. To that end, two sessions were held, the first dealing with land-cover categories and management methodologies and the second dealing with observation and modeling with scale aspects.

The first session was highlighted by keynote addresses by Dr. Katsuyuki Minami, Director General, National Institute of Agro-Environmental Science, and Dr. Robert Luxmoore, President of the Soil Science Society of America. The second session was begun with keynote addresses by Dr. Syukuro Manabe, Program Director, Global Warming Research Program of the Frontier Research System for Global Change, and Prof. Steven Running, Director of the Numerical Terradymanic Simulation Group, University of Montana.

Following these keynote presentations, the participants broke into concurrent working groups for more detailed presentations and discussion designed to promote the exchange of information and to develop possible cooperative activities. Session I participants were involved in one of four working groups dealing with forests, cropland, pasture and grassland, and wetland and paddies. Participants in Session II divided into working groups on in-situ measurement, flux-net, process modeling, and remote sensing. Each working group developed a set of recommendations to promote cooperative research in their field. Reports of the working groups follow.

The last day of the workshop was devoted to a plenary session designed to highlight cross-cutting issues and areas of common interest. The following themes emerged from the plenary session.

**Recommendations**

- Develop CO2 exposure technology.
    - Widely accessible (inexpensive) for numerous investigators in numerous locations;
    - Adaptable for use in different kinds of systems (forests, croplands, grasslands).

- Conduct long-term, system-wide experiments (have a workshop first, involving modelers and experimenters).

  - Determine the impact of management systems on productivity and other characteristics in managed and non-managed systems.
  - Life-cycle assessment approaches to determine the impact of management practices on the net global warming potential arising from the system.

- Identify and develop methods for using measurements of carbon obtained by different methods (point measurements, flux measurements, remote sensing, model estimates) and at different scales to obtain accurate estimates of carbon in different pools (vegetation, soil, atmosphere) at scales from field to global.

- Convene an international workshop to exchange models and data sets to develop, improve, and validate models to estimate pools and fluxes of carbon in terrestrial ecosystems, and the impacts of management practices on terrestrial carbon.

# Section II

# Working Group 1: Carbon Cycle Management in Forests

**Co-chairs:** Robert. Teskey, Takayoshi Koike
**Participants:** Y. Luo, R. Luxmoore, S. McNulty, R. Oren, S. Palmroth, R. Funada, Y. Morikawa and E. Kdani

## Introduction

The members of WG1 from Japan were T. Kioke (co-chair), R. Funada, Y. Morikawa, and E. Kodani. The members from the U.S. were R. Teskey (co-chair), Y. Luo, B. Luxmoore, S. McNulty, R. Oren and S. Palmroth. An additional five Japanese scientists attended the session. The background and state of the art in U.S.nd Japan as well as the major research issues of this topic were discussed in 10 presentations from the participants. These presentations focused on two main themes, 1) land use effects on carbon sequestration (such as conversion of agricultural land to forest, fertilization of forests, and the sequestration potential of managed and unmanaged forests) and 2) effects of elevated $CO_2$ on forest productivity and carbon sequestration.

The second session of WG1 consisted mainly of discussions of possible research topics that could form the basis of a collaborative program between U.S.nd Japanese scientists. We also discussed funding opportunities, existing international programs, and steps needed to develop the joint collaboration. In this session the group considered both intensive and extensive research approaches. Studies of the effects of forest fertilization on soil and aboveground carbon sequestration pools were considered, but ultimately the group decided that more intensive studies of the effects of elevated $CO_2$ on forest productivity was the most needed research issue. It was decided that we should explore ways of developing elevated $CO_2$ forest ecosystem experiments in a cost effective way, so that many different sites, climatic regions and treatments such as fertilization could be studied.

The rationale for choosing this approach was that there is not enough information at the present time to understand how different forest ecosystems will respond to elevated $CO_2$ or to predict how forest ecosystems will be affected by the increasing atmospheric $CO_2$ concentration. In particular, there is a critical need to understand the interactions between $CO_2$, soil fertility, climate and the forest ecosystem. There is also a critical need to develop an inexpensive $CO_2$ fumigation approach for forest experiments that this group will address. If successful, this effort may lead to a worldwide network of elevated $CO_2$-soil fertility studies.

## Recommendations

Five steps to joint collaboration were developed:

1. First, we identified a contact team for further development of the collaborative effort: T. Koike, S. Yamamoto, Y. Matsuura, S. McNulty, Ram Oren and R. Teskey.

2. It was concluded that the next important step was to expand the dialog and further develop the research ideas of the scientists of the two countries. One of the key efforts in the step will be to hold a Workshop to develop ideas, techniques and objectives for proposals for funding the research.

3. It was also considered important that we begin this research program using similar forest ecosystems in the U.S. and Japan. The group will identify sites and also work to more fully develop the research objectives.

   In Japan, Hokkaido has been identified as having suitable ecosystems and research infrastructure. In the U.S., the Lake States region should be a suitable match

4. An additional activity will be to gather information on techniques and responses from scientists around the world concerning this approach.

5. The contact team will also explore funding options within Japan and the U.S.

## Working Group 2: Carbon Cycle Management in Cropland

**Co-chairs:** Daniel T. Walters, Kazuhiko Kobayashi
**Participants:** R. Dahlman, J. Kimble, H. Koizumi, C. Li, B. McCarl, I. Nouchi, K. Paustian, H. Rogers, K. Suzuki, Y. Shirato and M. Yokozawa

### Introduction

This working group was assigned to identify key areas of bilateral interest regarding carbon management in cropland systems. Our meeting began with short presentations by the working group participants from Japan and the U.S. on their current research in agricultural systems and carbon cycle management followed by a group discussion of scientific issues of common interest.

Studies of cropping system and land-use management impacts on climate change are being conducted in both countries and a general consensus was noted that intensification of agricultural production will be required to achieve the food and fiber needs of a growing world population. Interactions among anthropogenic changes in atmospheric $CO_2$ concentration, agricultural input management, and conservation strategies on primary productivity, carbon biogeochemistry, soil responsiveness and long-term carbon dynamics in arable soils systems were the focus of discussion. Strategies for augmenting soil C-sequestration and assessment of the impact of these strategies on perturbation of non-agricultural systems were also noted as key areas which will influence policy decisions designed to mitigate GHGE from agricultural activity.

### Recommendations

The Cropland Working Group proposes three priority areas of potential collaboration between Japanese and U.S. scientists

1. ***<u>Improvement of regional scale predictions and soil C process models:</u>***
(Paustian, Li, Yokozawa, Shirato, Walters)

Efforts in both Japan and the U.S.re underway to provide regional scale predictions of soil C and GHGE changes with current process models (i.e. CENTURY, DNDC, ROTHAMSTED). Variability in predictions of regional C-sequestration against existing validation sites and databases indicates that significant opportunities exist for effective interdisciplinary collaboration toward the following specific tasks:

- Evaluation and comparison of key parameters controlling C pool fluxes as models are adapted to diverse cropping and soil management systems. These would include estimations of C resulting from yet untested intensification strategies and increasing atmospheric $CO_2$.

- Organization and management of input databases as well as land-use history, cropping system and soil resource inventories and climatic variables especially with regard to extrapolation across spatial and temporal regimes.

- Optimization of protocols for the maintenance of validation sites and datasets. Existing validation sites in both the U.S.nd Japan might be used in comparative simulation studies to improve model performance and also to stimulate research direction.

2. ***Exchange of Conservation Technology Information***
   (Kimble, Koizumi, Kobayashi, Walters)

Agricultural land-use strategies designed to enhance soil C-sequestration may be coupled to off-site effects on nutrient loading, soil erosion, increased emission of other GHG (i.e. $N_2O$ and $CH_4$) and alteration of biogeochemical cycles. Differences in the history of and experience in development and application of conservation technologies (i.e. conservation tillage, nutrient management) exist between our two countries. Assessment of such contingent environmental factors would be useful in directing policy designed to mitigate GHGE from agricultural activity.

3. ***Resolution of measurement as well as temporal and spatial scaling issues for regional scale predictions***
   (Paustian, Shirato)

Coupling of empirical site measurement with model predictions and remote sensing tools to resolve simulation uncertainties is needed. Sharing information on efforts in the development of scaling algorithms would be beneficial given the diversity of approaches taken by various research teams in Japan.

**Other Research Issues**

Several other issues of scientific interest generated considerable discussion during our brief meeting as a working group. Although these are not listed as priority areas, there is significant research activity in these topics that would benefit from joint collaboration.

A. Comparing the success experimental methodologies designed to separate contributions to soil $CO_2$ flux from heterotrophic and root respiration. A number of techniques were discussed for separating these two phenomena and it was suggested that an effort be made to compare these methodologies within existing experimental platforms. Development of an experimental protocol for comparison of direct and indirect measurement techniques would be highly beneficial. Linkage of above ground physiological processes to root respiration would be a valuable contribution to modeling belowground C deposition and metabolism and contribute to our understanding and prediction of inter annual variation in C flux in the soil-plant-atmosphere continuum. (Koizumi, Walters).

B. Brainstorming alternative assessment of GHGE mitigation “scales” in food production systems. Achieving elevated food production per unit land may incur greater GHGE/unit land area with intensification. However, if the result is removal of marginal land from production, scaling mitigation impacts per unit of food production rather than land area may be a more appropriate metric of mitigation strategy. (Paustian, Walters, Kobayashi)

## Possible Implementation Strategies

Year 1: Organization of two different workshops focusing on the exchange of information and detailing achievable experimental objectives for:

- Comparison of soil C process models and methods/approaches to application of these models for regional scale predictions.

- Presentation of predictions, parameterization efforts and scaling strategies and proposed model alterations and improvements. Workshop would end with a planning session for sharing validation data sets and testing scaling strategies.

- Exchange of information on conservation strategies in agricultural systems with emphasis on comparative advantages and disadvantages with respect to GHGE as well as offsite effects. Product would include an assessment of the relative mitigation value with respect to offsite effects and policy implications.

Year 2-3: Establishment of multi-site experiments utilizing existing experimental platforms for testing C process models and initiating methodological comparisons of below ground phenomenon and intensification effects on GHGE.

- Initial visitation by scientists on both shores to review current experimental sites, results and to plant for joint experimentation.

- Products would also include evaluation of comparative mitigation metrics across intensification regimes.

# Working Group 3: Carbon Cycle Management in Pasture/Grassland

**Co-chairs:** Charles Rice, Yoshiaki Honda
**Participants:** T. Boutton, D. Dye, K. Minami, J. Morgan, D. Ojima, S. Sekikawa, K. Takagi and M. Thompson

## Introduction

Grasslands occupy a significant portion of the earth's land area. Grassland ecosystems are diverse and have evolved in response to large seasonal and annual fluctuations in moisture, temperature, and grazing intensity (Knapp et al., 1998; Schuman et al., 2000). One reason for the resiliency of grasslands to climate variations is that a large percentage of total net primary productivity in grassland ecosystems occurs belowground (Elliot et al., 1988; Rice et al., 1998). Thus, the response of grasslands to land management and global change are potentially significant to the global carbon budget. Grasslands contain one of the highest concentrations of soil organic matter of the different ecosystems (Table 1).

Table 1. Soil organic matter content (SOM) of different ecosystem types. (Adapted from Schlesinger, 1997).

| Ecosystem type | SOM (kg C m$^{-2}$) | Area (ha x 10$^{6}$) | Total SOM (MT C x 10$^{9}$) |
|---|---|---|---|
| Tundra and alpine | 21.6 | 8 | 173 |
| Temperate Grassland | 19.2 | 9 | 173 |
| Boreal Forest | 14.9 | 12 | 179 |
| Cultivated | 12.7 | 14 | 178 |
| Temperate Forest | 11.8 | 12 | 142 |
| Desert Shrub | 5.6 | 18 | 101 |
| Tropical Savanna | 3.7 | 15 | 56 |
| Extreme Desert | 0.1 | 24 | 3 |
| Wetland | 68.6 | 2 | 137 |
| Total |  | 147 | 1456 |

Various modeling studies (e.g., Ojima et al., 1990; Hunt et al., 1991) indicate that grasslands could function as either sinks or sources of C, depending on land management regimes. While much of the discussion of carbon sequestration has been directed to forests, global estimates for C sequestration for different ecosystems indicate the grasslands are equivalent to forests (Metting et al., 1999) (Table 2). Biomass crops, some of which are grasses also contribute to C sequestration.

Table 2. Global terrestrial C sequestration potential (adapted from Metting et al., 1999)

| **Ecosystems** | Potential (Gt C/y) |
|---|---|
| Agricultural lands | 0.85 – 0.90 |
| Biomass crops for biofuel | 0.5 – 0.8 |
| Grasslands | 1.7 |
| Forests | 1 – 2 |

Given the inherent variability and heterogeneity in the U.S. grassland climate, large changes in grassland productivity are not expected (Seastedt et al., 1998). However, grasslands are undergoing change due to invasive species, conversion to forest and cropland and restoration of grasslands. Human-controlled management of the grassland will have greater impact on grassland productivity and carbon cycling than modest changes in climate (Seastedt et al., 1998; Rice and Owensby, 2000). These changes in grassland ecosystems alter plant and microbial diversity which then feed back on the C and N cycles. Degraded grassland provide a greater potential for sequester C. The improvement of degraded grasslands also provides economic and sociological benefits as well. Quantifying these benefits is important to enhancing change in grassland management. Detecting change in C stocks can be made with C isotopes and remote sensing.

**International Programs**

SCOPE Emerging Ecosystems
  GCTE Focus 3 Activity: Grazing Lands
  Asian Pacific Network Mongolia
  START (Scientific Training and Research T)
  USDA-ARS Scientific collaboration and Research and Exchange Program
  Conservation International other NGO's
NSF
Network of grasslands
    ILTER (China)
    NSF LTER: KPBS, CPER
  GTOS Global Terrestrial Observation System

**Major Research Issues and Difficulties**

Land use change and grassland management are the greatest challenges facing grasslands. In the context of carbon cycle management, temperate grasslands provide C sequestration and greenhouse gas mitigation. Grasslands also contain large stocks of C but it is unknown how vulnerable that C is to weather variability (drought). Changes in grasslands impact the carbon cycle through changes in plant and microbial diversity. However, there is no systematic way to study temperate grasslands. A network of sites could facilitate development of comparative methodology. The intent would be for methodology that would be translatable not necessarily the same. The methods would span temporal and spatial scales that would provide a database for modeling and remote sensing activities.

## Possibility of Collaboration

### Research Themes

1. What is the carbon sequestration potential of temperate grasslands?

2. What is the greenhouse gas mitigation potential of temperate grasslands?

### Exchange of Information and data

Grassland Website and Email list
Data for modeling use
Site information
Remote sensing data
Climatological data

### Set-up common experimental site

Use existing network of grasslands such as Inner Mongolia Grassland Research Stations, Mandal Gobi, Mongolia, Central Plains Experimental Range, Konza, Prairie Biological Station, and the grassland site at LaCopita, TX. Some of these sites are part of the International Long-term Ecological Research network and the U.S. LTER and USDA-ARS.

## Steps to Collaboration

Other Japanese scientist to collaborate, example GWEX, GLI

## Integration of Issues in each WG

Because some of the changes in grassland ecosystems are due to woody invasion and interaction with cropland, activities may be integrated with those two working groups. Many of the C cycling processes on grasslands translates to other ecosystems. Remote sensing and modeling working groups are components of the grassland working group.

## Recommendations

1. Establish working group to define the carbon sequestration potential of temperate grasslands.

   Dennis Ojima, Y. Honda, Tom Boutton, Zhou Gaungsheng, Chuck Rice, Chuluun Togtohyn

2. Identify potential sites

3. Planning Workshop 12-18 months

   Objective: To develop a framework for comparative site studies

4. Measure $N_2O$ and $CH_4$ flux from selected grassland sites to account for trade off in C sequestration methods among the Japanese andU.S.scientists. (Ojima, Rice, Tsurata).

## Working Group 4: Carbon Cycle Management in Paddy/Wetland

**Co-chairs:** Lewis Ziska, Haruo Tsuruta
**Participants:** L. Brown, K. Inubushi, M. Kimura, G. McCarty, A. Miyata, S.Morita, A. Rosenqvist, S. Shafer, K. Yagi and Yoshifumi Yasuoka

**Summary of presentations in the Working Group**

Kimura; Origin and fate of organic carbon in paddy soils. Field management changes the organic decomposition of paddy soils. No recommendation on farm management to maximize soil carbon. Focus on decomposition of soil organic carbon.

Ziska: Overview of $CO_2$ and $CH_4$ interactions in paddy rice. Elevated $CO_2$ gave an increase in root growth, dissolved soil $CH_4$, and $CH_4$ flux to the atmosphere. The increase appeared independent of air temperature.

Inubishi: Chemical fertilizer is better at enhancing mineralizable N. Mineralizable N can be estimated by anaerobic incubation, and used as an index of soil organic matter accumulation. More algae in the water can add oxygen which can limit the amount of $CH_4$ added by elevated $CO_2$. The elevated $CO_2$ gave more $N_2O$ after drainage.

Yagi: Definite interaction between elevated $CO_2$ and $CH_4$ flux. Bigger difference if straw was less due to soil organic matter already present when straw was added. Amount of $CH_4$ depends on balance between carbon added via rhizodeposition and other sources.

McCarty: Impact of sedimentation on natural wetlands. Set-up of riparian buffers to control nutrients to watersheds. Using Cesium from atmosphere tests to monitor soil movement. Increased sedimentation can stimulate carbon sequestration in setting up riparian "buffer" sites.

Tsuruta: Nitrous oxide and rice management. Inverse relation between cumulative $CH_4$ and $N_2O$ emissions in China and Japan. Crop rotation changed soil carbon (whether fallow or some kinds of vetch or oil rapeseed, for example) was planted after two continuous seasons of rice. Application of Life Cycle Assessment to Agriculture.

**Background and state-of-the-art in U.S.nd Japan**

1) A large number of data bases for soil carbon (more than 10,000) in agricultural soils of Japan from 1970s.
2) IGAC (International Global Atmospheric Chemistry) program from 1990, a core project of IGBP, has a large number of data bases for $CH_4$ emissions in Asian countries.

3) Continuation of field experiments to examine interaction between $CO_2$, and $CH_4$ and $N_2O$.

   FACE program: Phase I (2000)
   Phase II (2002 ): Japan, China to look at
   $CO_2$ / $CH_4$/ $N_2O$ .
4) C and N cycles. Establish best possible management practice to maximize carbon storage and minimize or mitigate GHG emissions
5) Little data on biogeochemical systems in freshwater marshes. Or Agricultural wetlands/watershed or natural wetlands such as floodplains in the Amazon basin. Or a huge area of peat wetlands in southeast Asia.
6) Development of mitigation options
   - Water managements
   - Organic matter managements
   - Different rice cultivars
   - Cultivation practices**Major research issues and difficulties**

There is a need for:

- long-term field experiments to look at carbon sequestration in paddy soils. The soil has a high potential to sequester carbon;
- long-term experiment on $CO_2$ interaction with $CH_4$ and $N_2O$;
- continuation of databases to increase accuracy and to bring databases up to date;
- quantification of carbon source for methanogenesis. (Photosynthesis, straw, SOM);
- determination of fate of different carbon sources; and
- Study on root function and rate of root turnover. C/N (composition) root determination, $CO_2$ influence on root aging and root turnover. Distribution of root system in soil. Clarify the time course of root turnover and carbon distribution.

There is also a need to focus on rice system as a whole, particularly on the life cycle assessment that takes into account fluxes of $CO_2$, $CH_4$ and $N_2O$ with respect to the global warming potential, and how management factors could change this. Life cycles system approach---cultivars, management practices, etc., with and without $CO_2$.Scaling up from point measurements to regional estimate, using modeling, GIS, remote sensing analysis. Interaction with WG8.Cooperate with other countries in Asia in order to accurately reflect environmental conditions in which rice is grown. Look at nutrient inputs on productivity of riparian buffers including soil movement and carbon dynamics. Using a whole ecosystem approach.

- Also look at trace gas emissions from riparian buffer zones. Buffers—source or sink of trace greenhouse gases? Long-term field experiment by elevated CO2 which alters CH4 and N2O emissions to estimate of the impacts of land use/cover change on greenhouse gas emissions.

**Recommendations**

- Development of an integrated, field based approach to modeling the life cycle of carbon and nitrogen in paddy soils and wetlands. One focus of such an approach would be to strengthen links between field scientists and the remote sensing community. (Contacts: Ziska, Yagi)
- Based on a biogeochemical understanding of carbon and nitrogen, to derive management practices which maximize carbon storage while minimizing GHG emissions from agricultural wetlands. This approach should also include the monitoring/modeling of GHG emissions from natural wetlands. (Contacts: Ziska, Tsuruta)
- Development of long-term, field based experiments to overcome spatial variability needed to scale up to regional or global assessment. (Contacts: Ziska, Inubushi)

## Working Group 5: In-Situ Measurements of Terrestrial Carbon

**Co-chairs:** Gregory McCarty, Hiroshi Koizumi
**Participants:** T. Boutton, T. Kibe, R. Dahlman, Y. Matsuura, J. Kimble, S. Palmroth, T. Walters, H. H. Rogers and S. Shafer

### Summary of presentations in the Working Group 5

G. McCarty: Infrared spectroscopy has potential for rapid measurement of soil C (organic and inorganic). Watershed scale studies are needed to assess fate of soil C at sites of erosion and deposition.

K. Kobayashi: The Rice FACE project: Plant biomass growth, photosynthesis and grain yield respond to the $CO_2$ elevation to the extent dependent on N regime.

T. Boutton: Increased woody plants in grassland ecosystems leads to increased carbon storage and changes in turnover rate.

T. Kibe: Availability of Open-top chamber (OTC) technique as a new standard method for measuring soil $CO_2$ efflux.

R. Dahlman: Laser Induced Breakdown Spectroscopy has potential for rapid measurement of soil C.

Y. Matsuura: Depth of soil active layer controls forest structure in permafrost larch ecosystems.

### Gaps and Approaches to fill Gaps

G. McCarty: Addition work is needed to develop spectroscopic methods including tests on a wide range of soils worldwide. Impact of soil movement in ecosystems is poorly understood and can affect ability to measure carbon storage in landscapes. More watershed-scale studies assessing carbon dynamics are needed.

K. Kobayashi: Study belowground processes (root growth and root exudation etc.). Need

$^{14}C$ labeling experiment.

T. Boutton: Important to characterize not only the amount of soil carbon, but also the dynamics and the quality of the soil C. Need to match the temporal scale of the turnover method to the turnover rate of the pool.

T. Kibe: Problems with spatial and temporal variations need to be addressed. Determine cause of variation and unify methodology of soil $CO_2$ efflux.

R. Dahlman: Evaluate effects of soil property on application of LIBS to measure soil organic matter.

Y. Matsuura: Evaluate belowground processes – Fine root production and turnover, root exudates, DOC. Inability to measure NEE (net ecosystem carbon exchange) and cross check with NEP (net ecosystem production). Use both methods to resolve.

J. Kimble: Need to expand analytical methods for soil C. Methods are needed for soil charcoal carbon and for soil carbon pools such as microbial biomass, active, slow etc.

S. Palmroth: Use inventory or remote sensed data for estimating carbon input and pool sizes in terrestrial ecosystems.

D. T. Walters: Understand biophysical controls that influence inter-annual variation in soil respiration. Separation of root respiration from soil respiration by use of $^{13}C$ signatures.

H. H. Rogers: Need better methods for measuring root growth, biomass and turnover. Use stable isotope methods and minirhizotrons.

S. Shafer: Need better techniques to characterize soil biological processes, to measure inorganic carbon pools in soil and to address scaling issues for carbon measurement in terrestrial ecosystems.

**Recommendations**

- Continue to develop techniques useful for studying soil carbon storage and dynamics (e.g. LIBS, $\delta^{13}C$, soil respiration methods, mid IR, black carbon and inorganic carbon) (Contacts: Koizumi, Kibe, McCarty, Boutton, Walters, Breshears)

- Continue to develop techniques useful for studying root dynamics (e.g. $^{13}C$, minirhizotron, etc.) (Contacts: Rogers, Matsuura)
- Develop procedures for scaling up of measurements from point to landscape to ecoregion etc. (Contacts: Boutton, Palmroth)
- Impact of soil erosion, deposition and movement of DOC on carbon storage and dynamics in ecosystems. (Contacts: Lal, McCarty, Inubushi)

- Integrated study on C dynamics in northern ecosystems under global warming. (Contacts: Kimble, Matsuura, Ping)

# Working Group 6: Flux-net of Terrestrial Carbon

**Co-chairs:** Jack Morgan, Susumu Yamamoto
**Participants:** R. Oren, M. Ebinger, J. Smith, A. Miyata, N. SaigU.S., M. Okano and Y. Hayashi

## Introduction

In the past five years, a number of networks for monitoring fluxes of primarily $CO_2$, $H_2O$, and other trace gasses have begun to be established world-wide. Working Group 6, entitled FluxNet of Terrestrial Carbon, met to discuss this work, and to explore how on-going and planned future fluxnet studies might be better coordinated to optimize the efforts of investigators in both countries in their endeavors to understand global change. Implications for managing C in terrestrial ecosystems were also discussed. Herein we report on the discussions and outcomes of three days of meetings of this group.

The meeting was begun by brief presentations of participants, each discussing the general theme and latest progress of their work; in some cases, presentations outlined a broader view of network activities involving primarily $CO_2$ and $H_2O$ flux monitoring with micrometeorological tower systems. Networks of current C flux monitoring systems in the two countries include AmeriFlux (http://cdiac.esd.ornl.gov/programs/ameriflux/), with approximately 40 eddy covariance sites in the United States; AsiaFlux (http://www-cger.nies.go.jp/~moni/flux/asia_flux/), representing 18 different groups in Asia, including 25 eddy covariance systems monitoring $CO_2$, $H_2O$ and $CH_4$ in Japan; and the USDA-ARS $CO_2$ flux network, with 11 Bowen ratio sites established on rangelands in the western United States. These networks include studies in forests, croplands, marshlands, grasslands, and various rangeland plant communities. Other networks in the international community include EuroFlux (Europe), MediFlux (Mediteranean), and Oznet (Australia), plus more planned sites in Asia and Canada. The reader may want to refer to the list of working group participants and the abstracts found elsewhere in this document for more information on individual projects.

One of the more interesting findings reported was the observation that the vast majority of the projects were indicating a net annual uptake of C. In the United States and in Japan, NEE of 300 ± 100 g C $m^{-2}$ $year^{-1}$ are commonly observed in forest systems. Maximum NEE of almost 800 g C $m^{-2}$ $year^{-1}$ was observed in the southeastern United States in a year in which woody biomass increment was about 400 g C $m^{-2}$ $year^{-1}$, suggesting considerable C storage. Positive annual fluxes were also noted for rice, tallgrass prairie and sagebrush steppe. Further, a recent U.S. DOE report by Dahlman, Jacobs, and Metting, Jr. (What is the Potential for Carbon Sequestration by the Terrestrial Biosphere? available at (http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/5c0.pdf) suggests that through the adoption of advanced science, technology, and management, we should be able to significantly increase the present carbon sequestration potential of the terrestrial biosphere. Current management issues discussed included rice paddy practices, which needed to consider effects on both $CO_2$ and $CH_4$ fluxes; the trade-off in grazinglands, where shrub incursion into former grasslands results in lands with less useful forage for domestic livestock, but greater carbon storage potential; fertilization of forests after cutting as a mechanism to move more quickly from carbon loss to uptake; and bedding practices in forests prior to planting which release carbon dioxide.

A list of critical issues, difficulties and opportunities in the analysis of trace gas fluxes was compiled, and include:

> analysis and estimation methods of $CO_2$ exchange under complex topographical conditions,
>
> scaling up from ecosystem scale to regional scale,
>
> linking flux measurements, biometric carbon budget estimates and modeling to arrive at annual NEP (can use current data sets to evaluate performance),
>
> measuring and modeling respiration (difficult to measure, and more study and modeling needed), and
>
> more isotopic experimentation (e.g., fractionation of C in soil organic pools and possibly differentiating respiration components).

**Primary Recommendations:**

1) Derive NEP products through linkage of measurements & modeling as affected by management. (Teskey, Morgan & SaigU.S.)
2) Develop improved analysis and estimation methods of $CO_2$ exchange under complex topographical conditions (Yamamoto & Katul)
3) Scale up NEP to NBP using remote sensing (Running & Awaya)

**Secondary Recommendations:**

1) Develop collaborative program with China/Japan/U.S. for flux measurement training (Synthesis Center of Chinese Ecosystem Research Network [Dr. Yu Guirui]; National Ins. Of Advanced Industrial Science & Tech; Duke University) (Yamamoto, Oren)
2) Strengthen collaboration between U.S. & Japan through the exchange of data (Dahlman, Yamamoto)

**Summary:** Flux measurements provide unique information on the magnitude of terrestrial carbon sinks. The evolving networks provide a powerful data base for calibrating ecosystem and global carbon models, and constitute a powerful framework for monitoring and managing carbon sinks in both native and agricultural ecosystems. More progress needs to be made in establishing flux towers in unrepresented regions, like Siberia, parts of Asia, and Africa. Major work ahead will be needed to link these networks, and to refine the objectives and experimental protocols to better compare across sites and to scale up.

# Working Group 7: Process Model of Terrestrial Carbon

**Co-chairs:** Dennis Ojima, Gen Inoue
**Participants:** K. Yagi, S. Maksyutov, A Ito, B. Luxmoore, B. McCarl, Y. Shirato, M. Yokozawa, T. Fumoto, J. Shindo, Y. Luo, C. Li, M. Thompson, K. Paustian and C. Rice

**Presentations highlighted issues related to:**

- Focus on Land Use Management and Disturbance on Ecosystems
- Process Characterization
- Techniques of Scaling, Integration, and Linkages to Atmospheric Observations

**Focus on Land Use Management and Disturbance on Ecosystems**

Ojima: Process modeling of the earth system
Paustian: Soil carbon dynamics and GHG mitigation
Ito: Process based model for analyzing ... global terrestrial carbon dynamics
Li: Modeling methane emissions from rice paddies
Luo: Sustainability of carbon storage
McCarl: Economic modeling of carbon sequestration potential
good: NEE, NBP, soil C
fair: GHG emissions, but not included in many models
poor: transport of C not well represented

**Process Characterization**

Rice: Controls on formation and degradation of soil organic carbon
Thompson: Spatial structure of SOM
Shindo: Input-output budget of N in Japanese forest ecosystems
poor: spatial heterogeneity
microbial processes need improvement

**Techniques of Scaling, Integration, and Linkages to Atmospheric Observations**

Inoue: Interface among observations/process studies/models/data
Luxmore: Signal-transfer modeling for regional analysis
Maksyutov: Integrating atmospheric CO2 observations, terrestrial ecosystem models, and flux inventories

**Constraints:**

- need for better interface of field scientists, modelers, remote sensing, etc.
- need for more observation of atmospheric concentrations
- lack of scaling techniques
- ecosystem and land use management systems not well represented in climate analysis

**International and National Activities**

CARBON Joint Project Office
IGBP/GAIM
GCTEGTOS/TCO
CASMGS (U.S.)
CSITE (U.S./DOE)

**Future Directions for Joint Research Collaborations**

BASIC PRINCIPLES:

- Geographic focU.S.cross Asia and North America at hierarchy of scales from field to continental scale
- Stronger linkage between remote sensing, flux tower, inventory research groups with model develop and testing
- Need to facilitate Linkage between field research and process modeling
- Consider Carbon sequestration and GHG emissions
- Promote further model testing and development

**Main Themes**

1) Intercomparison model study and data comparisons of terrestrial carbon and GHG exchanges forced by different land use management and disturbance options (Ojima, Ito, Oikawa, Luo, Li, Maksyutov, Kobayashi)
2) Development of simplified meta-model for carbon and GHG accounting (Luxmoore, Minami, Tsuruta)
3) Evaluation the feasibility of land use management options for enhancing net carbon storage and GHG reduction (McCarl, Paustian, Kobayashi)

**Cross-cutting Interactions with Other Working Groups**

- Development and testing of models need strong interactions with field (grassland, forest, and cropping systems) and laboratory researchers and decision makers

- Remote sensing data useful for input and verification of process models

- Simulation of NEE with process models can identify tower flux estimate uncertainties in NEE

- Development of appropriate land use management options need to be place based

**Recommendations:**

1)Intercomparison model study and data comparisons of terrestrial carbon and GHG exchanges forced by different land use management and disturbance options (Ojima, Ito, Oikawa, Luo, Li, Maksyutov, Kobayashi)

- Develop a working group to identify the appropriate role of field, remote sensing, flux data to verify and constrain process models

- Sensitivity experiment of land-atmospheric feedback to changing land use management options

- Develop a joint project to design experimental protocols for comparison studies and specific experiments High Performance Computing Centers which incorporate the role of land use management on C exchange and GHG emissions

- Develop a collaborative working group of modelers and field experiments (e.g., designing FACE experiments and field studies on C-sequestration and GHG mitigation)

  (Examples: TRANSCOM (atmospheric), VEMAP (ecosystem), Crop models, NPP models, soil organic matter models, PILPS (land process schemes)

2) Development of simplified meta-model for carbon and GHG accounting (Luxmoore, Minami, Tsuruta)

- Joint symposium between science societies, such as American and Japanese Soil Societies

3)Evaluation of the feasibility of land use management options for enhancing net carbon storage and GHG reduction (McCarl, Paustian, Kobayashi)

- Collaborative development of methodology for national inventory of GHG emissions as these changes over time due to land use systems

- Development of a Joint Carbon Management Center which will provide the capability to conduct joint model exercises and maintain key data bases for conducting process model studies

- Develop a data access point for verification/validation data including remote sensing data, fluxnet data, carbon inventory data provide the computing infrastructure for integrated modeling of land-atmosphere, carbon management-economic, land emission analysis of fossil and biospheric exchange

Set of initial studies that this center will conduct:

  - Intercomparison model study of terrestrial carbon exchange forced by different land use management and disturbance options

  - Develop a working group to define the interface requirements for modeling needs and availability of remote sensing information

  - Sensitivity experiment of land-atmospheric feedback to changing land use management options

- Evaluation the feasibility of land use management options for enhancing net carbon storage and GHG reduction

## Working Group 8: Remote Sensing of Terrestrial Carbon

**Co-chairs:** Steven W. Running, Yoshio Awaya
**Participants:** G. Kirkham, L. Brown, C. Li, L. Ziska, Y. Yamagata. K. Okamoto and D.Dye.

### Presentation Highlights

- A simple method of global NPP estimation was presented by Dr. Awaya.
- The role of remote sensing in modeling climate impacts in carbon sequestration was described by Dr. McNulty.
- Estimation of global PAR using TOMS data to support ecological models was presented by Dr. Dye.
- Mapping ARD in the tropics using L-band SAR data was presented according to the Kyoto Protocol agreement by Dr. Oke.
- ARD and roles of remote sensing in the Kyoto Protocol was explained by Dr. Yamagata.
- An estimation of global NPP in agricultural sectors was presented by Dr. Okamaoto.

### Background

The Working Group agreed that there is a necessity of understanding carbon circulation and impacts of global warming. It is also necessary to monitor forests to detect ARD according to the definition in the Kyoto Protocol as well as the need to map forest areas and land covers and biomass.

### Possible Joint Collaborations

Satellite driven models of NPP provide a "top-down" estimate of a key carbon cycle component. Forest and agriculture yield data provide a "bottom-up" carbon cycle estimate. Two useful activities would be:

- A project to transform forest/agriculture yield data to C-cycle estimates; and
- testing of satellite NPP models against other models and against field data.

Collaboration will be undertaken by FRSGC-ECRP (Japan) and the University of Montana (U.S.) to:

- validate and compare the groups' respective radiation (PAR) data sets used in global NPP modeling; and
- perform sensitivity analysis of the U. Montana NPP model driven with the FRSGC

PAR product.

This activity will facilitate development of improved global PAR data, leading to more accurate C cycle model results.

## Forest Inventories for Remote Sensing

Over 100,000 permanent forest biomass plots are remeasured every five years across the U.A. Similarly, Japan has begun a National Forest Biomass and Growth measurement polt system laid out on a 20x20 km grid. Data from these long-term forest plots would be very useful in development and validation of remote sensing equations for predicting forest carbon storage and sequestration, but consistent methods for converting plot based stand volume into carbon stock and growth data are lacking. We propose to assess current permanent plot data and to develop an unified and consistent method for converting forest plot data in carbon values suitable for remote sensing carbon budget and balance predictions.

- Japan needs to estimate accurately $CO_2$ absorption of almost all forests. We need to establish the system by 2007.
- Satellite-based modeling of NPP is a most promising approach, as it is transparent and verifiable.
- In addition to the conventional forest inventory approach, would it be possible to employ such an approach for coming up with reliable estimates of NPP, NEP and NBP at the national level?
- Scientific communities of the U.S.nd Japan together can assess jointly and propose new approaches.

## Satellite Data Acquisition and Data Exchange

Data acquisition:

- Current (high resolution) R.S. data archives are too fragmented to be used in regional/global scale carbon models.
- Acquisition strategies for present/future R.S. missions must be re-assessed to comprise systematic data acquisition strategies with global scale and long-term form.

Exchange of information and data:

- JERS1-SAR GRFM mosaid cata-sets are free of charge for research purposes. (Contact A. Rosenqurish (NASDA).

## Recommendations

1. A project to transform forest/agriculture yield data to C-cycle estimates.
2. Testing of satellite NPP models against other models and against field data

# Section III

# Radial Stem Growth and Wood Properties of Trees Grown at Elevated $CO_2$ Concentrations

Ryo FUNADA
Hokkaido University

Since wood is a major carbon sink, it is expected to play an important role in removing the excess of atmospheric $CO_2$ that is generated by the burning of fossil fuels. In addition, wood is a product of the vascular cambium of living organisms, namely trees. Therefore, wood is an important renewable resource for raw materials and fuels.

There are many studies of the effects of elevated concentration of $CO_2$ on the physiology and development of trees. These observations have revealed that physiological and developmental responses to elevated concentration of $CO_2$ depend on the species and environmental conditions. In contrast, little is known about how elevated concentration of $CO_2$ affects the development of secondary xylem cells and the structure of annual rings. Since photosynthetic substances are accumulated in the stems, changes in the width and structure of annual rings in response to elevated concentration of $CO_2$ influence estimates of capacity of trees to fix carbon. In addition, the structure of annual rings is closely related to the properties of wood. To evaluate the effects of elevated concentration of $CO_2$ on wood properties, we need to investigate changes in dimensions of secondary xylem cells.

Recently we investigated the effects of elevated concentration of $CO_2$ on stem growth (height and radial diameter), anatomical features of annual ring and physiological response, such as photosynthesis, of seedlings. Seedlings of *Larix* and *Betula* were grown in two concentrations of $CO_2$ (ambient and elevated), with two nutrient supplies and three different sizes of pots in phytotron chambers for one-three years. Stem diameter growth tended to increase in response to elevated concentration of $CO_2$ in seedlings of *Larix*. This increase was enhanced by the high nutrient supply. In contrast, enrichment by $CO_2$ had no significant effect on either stem height or diameter growth under low nutrient supply. In addition, in seedling of *Betula*, growth was accelerated when large sizes of pots were used. Therefore, growth might be accelerated at elevated concentration of $CO_2$ only when substantial amounts of nutrients are available or sink strength is not limited. Elevated concentration of $CO_2$ had minor effect on the anatomical features of secondary xylem cells. Therefore, wood properties of trees might not be significantly affected by elevated concentration of $CO_2$.

# Seasonal Patterns of Canopy Structure, Biochemistry and Spectral Reflectance in a Broad-Leaved Deciduous *Fagus Crenata* Canopy

Eiji KODANI, Yoshio AWAYA, Kunihiro TANAKA
Forestry and Forest Products Research Institute (FFPRI),

The reflectance of a deciduous forest varies from spring to autumn owing to phenological or seasonal changes in the biophysical or biochemical attributes of the canopy. During the growing season in a broad-leaved deciduous stand of Japanese beech (*Fagus crenata*), we measured the continuous reflectance factor in the visible to near infra-red spectrum (380-900 nm) from a tower, measured biomass of stem and canopy, and measured biophysical and biochemical attributes of the canopy (Leaf Area Index [LAI], fraction of Absorbed Photosynthetically Active Radiation [fAPAR], and chlorophyll content). We analyzed the seasonal variations in the reflectance factor with respect to the seasonal variations in the biophysical or biochemical attributes of the canopy.

Canopy attributes (LAI, fAPAR and chlorophyll content) increased rapidly in spring, were stable in summer, and decreased in autumn. In other words seasonal patterns of canopy attributes were trapezoidal. The patterns of the reflectance factor between 380 and 900 nm changed clearly during the growing season. Before flushing, the reflectance factor from the stems and ground covered with fallen leaves increased slowly from visible to NIR bands. This pattern was similar to that typical of soil reflectance. When flushing was complete, the reflectance factor shifted to a pattern typical of vegetation -the green reflectance factor was higher than the red or blue, and NIR reflectance was very high. The reflectance factor returned to the soil pattern at the end of defoliation.

We analyzed the correlations between narrow bands (380-900 nm, 5-nm band width) and the canopy attributes and found that, during the growing season, LAI had the highest linear correlation with the wavelengths between 750-900 nm (NIR), canopy chlorophyll content had the highest linear correlation with the wavelengths between 600-640 nm (red), and fAPAR had the highest linear correlation with the wavelengths between 660-680 nm.
The canopy attributes changed quickly in the seasons of flushing and yellow coloring. To detect the processes and the turning points of the canopy phenology in a deciduous forest, it was necessary to measure reflectance at least once a week, especially in the flushing season.

# Maintenance of High Biomass Productivity of Mixed Conifer-Broadleaved Forests Under Changing Environment: An Ecophysiological Perspective

Takayoshi KOIKE
Hokkaido University

## 1. Background

Atmospheric $CO_2$ concentration is increasing yearly by worldwide intensive use of fossil fuel and destruction of forests, which is considered to cause global warming and environmental changes. The issue of global climate change is an urgent subject concerning the effect of elevated $CO_2$ on forest productivity and capacity of plants to sequester carbon. $CO_2$ is the basic substrate for photosynthetic activities of all green plants including woody plants. Therefore, we should understand the $CO_2$ fixation capacity of woody plants and estimate the capacity for moderating atmospheric $CO_2$. In forest ecosystem, C and N cycles are intimately linked each other and elevated $CO_2$ may affect nutrient cycling. In order to understand these issues at ecosystem level, we need to set up the candidate study sites for monitoring forest growth and nutrient dynamics in relation to soil fertility because $CO_2$ may also act as fertilizer by increasing nitrogen transformation.

## 2. Characteristics

Why shall we monitor the Mixed Conifer-Broadleaved Forests exists temperate forests and Taiga surrounding around North? These Mixed Forests have similarity between the tree species at genus levels. The main difference is found for soil conditions, such as immature volcanic ash in East Asia, infertile soil of Canadian Slide in northern America and fertile soil in southern Scandinavian region and Estonia. Increasing atmospheric $CO_2$ therefore accelerated the growth of tree species and surely will suffer by different nutritional imbalance, such as phosphate deficiency for volcanic ash soil in Hokkaido.

## 3. Forest management

Number of tree species in eastern part of Asia is 3-5 times larger than that in Europe because severe Glacial period eliminated plant species. With increasing the number of species, net primary productivity (NPP) will also increase, which is contributed to moderating changing $CO_2$ level. The role of vines in forests is also important for increasing the leaf area index (LAI) to increasing photosynthetic production of forest ecosystems as $CO_2$ sink. Increasing atmospheric $CO_2$ as time progress, nutrient imbalance will be more apparent forests. We must consider the following methods to increase the activities of $CO_2$ sink. Studies have shown that activities of symbiotic microorganisms are accelerated when host trees are grown under elevated $CO_2$. ThU.S.rrangement of alders and woody legumes in a forest will be an important strategy to maintain the plant productivity. Furthermore, density control in a forest stand will bring further improvement of light or $CO_2$ conditions at canopy level. We also need know what kinds of tree species would be more suitable for moderating $CO_2$. We can list up the characteristics of candidate species as; 1. High density of woody parts, 2. Smaller number of branches or twigs, 3. High growth rate, 4. Long life-span and 5. Shade tolerant capacity.

For evaluating the capacity of $CO_2$ sink in forests, we should study both soil fertility and species characteristics under elevated $CO_2$. We should further understand the potential capacity of forest as $CO_2$ sink.

# Carbon Sequestration of Man-made Forests in Relation to CDM

Yasushi Morikawa
Waseda University

### *Incomes, expenses, and savings*

Tree/forest growth can be interpreted as a budget and be itemized as incomes, expenses, and savings. Photosynthetic production can be signified as income and respiratory loss as expenses; growth as savings. Low savings can therefore be the result of "low income and high expenditure", "high income and high expenditure" or "low income and low income".

In the younger stage of tree growth, the income generated from its crown or canopy is high, and the surplus (photosynthetic production - respiration in the crown or canopy) sufficiently provides organic matters with energy for new growth in foliages, stems, branches, and roots.

In the mature stage or climax stage, the maintenance costs of the stems, branches, and roots increase owing to their enlarged quantity, signifying the increased expenditure. To further the condition, incomes decrease due to the structural factor of the masses being spatial i.e., the photosynthetic production is hindered by chronic water stresses owing to the long distance that lies between the tree crown and the root system.

Low income means low distribution of organic matters to non-photosynthetic parts. If the fine root growth is disturbed, absorption of water and mineral nutrients declines, which in turn accelerates the water stresses in the crown.

### *Role of forests in carbon sequestration*

For easy understanding, I would like to illustrate the process, using the baggage (carbon dioxides) and warehouse (forests) relations. Forest growth means the increasing storage of baggage and the size of warehouse. The warehouse, nonetheless, has limitation in size and it will be occupied to the fullest extent by baggage eventually. That is the stage of the climax forest, and in terms of baggage and warehouse relation, there is no more baggage coming into at this stage. This signifies no room for the role of forest to play in carbon sequestration.

If a forest fire occurs, carbon dioxides gets released into the atmosphere just in the same manner as the baggage gets released from the warehouse when it catches on a fire. In the long term perspective such as 200 to 500 years, the carbon dioxide or baggage is only temporarily in the atmosphere or in the warehouse or tree/forests because of the life cycle of trees/forests and because the naturally caused damages on forests such as natural fire, cyclone, etc., occurs frequently. Therefore, there is no room for the forest to play its role in carbon sequestration when considering such a long time span. For this reason, when we evaluate the role of forests in carbon sequestration, time span should always be kept in our mind. Debates, therefore, on carbon sequestration of forests in relation to CDM of the Kyoto Protocol should take the time span into account.

Another serious problem that we have to keep in our mind is the decreasing warehouses, in another word, deforestation, which is the major problem concerning the global environment. We are strongly reminded that the warehouses be conserved and maintained in regional, national and global levels.

As a measure of increasing the sizes warehouses, utilization of forest products is strongly recommended. Utilization of wood in building houses and in other constructions increases warehouses outside the forest area. Nevertheless, here as well, the time span, that we have to be reminded of, shall always be taken into account of when we evaluate the role of these forest products such as houses because of they have a limited life span as a warehouse. The baggage goes out of the warehouse after their life span is up.

An important role that the forests products (trees in particular) plays in the affairs of global environment is the fact that the forest products can reduce the dependency on limited fossil resources. It is reassuring to know the fact that they are renewable by making best use of solar energy that abounds on earth.

### *Carbon accumulation in planted forests in the tropics*

The amount of carbon in natural vegetation shall be subtracted from the amount of carbon in planted trees in CDM project site for evaluating its carbon sequestration as an CDM activity. Because, obviously, carbon sink in natural vegetation can not be accounted for as the CDM efforts.

Our recent field research (Table 1) indicates that CDM activities are increasing carbon sequestration in planted forests in the tropics even after applying the Rule of the Subtraction of Baseline and give attractive policy material to policy makers concerned.

Table 1. Carbon sink in man-made forests and baselines

| site | species | age | C sink (tC/ha/yr) | |
|---|---|---|---|---|
| | | | man-made forest | baseline |
| Madang, PNG | *Acacia mangium* | 4 , 7 | 6.3-7.8 | |
| Song Be, Viet Nam | *A.mangium* | | | |
| | *A.auriculiformis* | 6 | 10.1, 8.0 | |
| Manjimup, Australia | *Eucalyptus globules* | 2, 5, 8 | 8.1-18.7 | |
| Albany, Australia | *E.globulus* | 3, 6 ,8 | 7.5-12.4 | |
| Lombok, Indonesia | *Cassia siamea* | | | |
| | *Azadiracta indica* | | | |
| | *Dalbergia latifolia* | 3 | 5.9-8.6 | 2.6-3.2 |
| East Kalimantan, Indonesia | (pioneer tree) | 2.5 | | 2.9-5.7 |
| | *Imperata cylindrica* | 2.5 | | 0.6-1.3 |

sources; projects in JIFPRO, JOPP, PPHT-UNMUL(Indonesia), and Waseda Univ.

# Testing the Rothamsted Carbon Model Against Long-Term Experiments on Japanese Arable Soils

Yasuhito SHIRATO and Kevin Coleman
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Rothamsted Carbon Model (RothC) is a model for the turnover of organic carbon in non-waterlogged top soils that allows for the effects of soil type, temperature, moisture content and plant cover on the turnover process. RothC is quite popular as one of models that show good performance. It needs a few inputs that are easily obtainable. So, the model has an advantage to evaluate C turnover of wide area. RothC was originally developed in arable topsoils from the Rothamsted long-term experiments. Later, it was extended to grassland and woodland and to operate in different soils and under different climates. But it had not yet tested against Japanese soils.

Japan has 508 million ha of arable soils, 57 % of which is paddy field. On the other hand, Andisols shares 50% of upland crop field. So, paddy soils and Andisols are characteristic and important soils in Japanese arable land. There are more than 220 long-term experiments (over 5 years) in Japanese arable land, half of which is in paddy field. But a few experiments continued over 50 yrs. The maximum continuous period was 73 yrs in paddy field and 63yrs in upland crop field in 1998.

To test the model against long-term experimental data, it is first necessary to run the model for 10,000 yrs to be reached equilibrium assuming that the soil have been reached equilibrium with the certain condition when the experiments started. Annual input C from plant residue in temperate forest: 2.6t/ha/yr was used for the condition before the experiments started. Then, the model was run with inputting the required parameters. The amount of input C was calculated from the yield data etc.

RothC model fitted well to the measured data in non-volcanic upland soils (Brown lowland soil in Saitama pref. and Yellow soil in Aichi pref.). But it did not fit well to long-term experimental data in Andisols (Aomori pref. and Nagano Pref.). By adjusting the rate constant for the humic fraction of RothC and setting the IOM to zero, we were able to obtain much improved fits between model and measured data for the carbon contents for a set of 32 Andisols from Japan. These adjustments were made using standard chemical measurements for Andisols (Alp, Alo, Fep, Feo and Sio).

RothC did not fit well to paddy soils (Gray lowland soils in Siga pref.). This model has not originally done the waterlogged soil with the object. It was confirmed that it cannot apply in the paddy field. In next stage, the development of the model for the paddy field is required.

# Woody Plant Encroachment in Grasslands and Savannas: Significance for Ecosystem and Global Carbon Storage

T.W. Boutton and S.R. Archer
Texas A&M University

Grass-dominated ecosystems cover 40% of the terrestrial surface, conduct 40% of terrestrial net primary production, and store 30% of global soil organic carbon and 20% of biomass carbon. Hence, land use activities and land cover changes that alter the productivity, decomposition, and/or carbon storage of grass-dominated ecosystems have the potential to impact the global carbon cycle and climate. One of the most prevalent land cover changes in grasslands and savannas around the world is increased woody plant abundance. This phenomenon is geographically widespread in North and South America, Africa, Asia, and Australia, and appears to be driven primarily by livestock grazing and fire suppression [1]. Despite the geographic dimensions of this vegetation change, we know little regarding its impact on the carbon cycle.

Our work in the Rio Grande Plains of southern Texas has shown that, over the past 100 years, open grasslands have undergone succession towards subtropical thorn woodlands dominated by $N_2$-fixing tree legumes such as *Prosopis glandulosa* (mesquite) and *Acacia* species [1, 2]. We used a chronosequence approach to quantify changes in the rate and magnitude of ecosystem carbon storage resulting from this dramatic vegetation lifeform change. Carbon storage in soils and above- and belowground biomass was quantified in remnant grasslands, and in wooded landscape elements differing in topoedaphic characteristics and vegetation structure.

Whole-ecosystem carbon storage (aboveground biomass + roots to 1.5 m + soil organic carbon to 1.5 m) was 12.2 kg C $m^{-2}$ in remnant grasslands, and 19.9 -35.3 kg C $m^{-2}$ in wooded landscape elements. Thus, C-storage has increased 64 -191% where woody plants have replaced grasslands. When these changes are expressed relative to ages of wooded landscape elements in various topoedaphic settings, rates of whole-ecosystem C-sequestration ranged from 80-230 g C $m^{-2}$ $yr^{-1}$ over the past 100 years. These rates are similar to those associated with woodland development occurring over comparable time periods in temperate savanna in Minnesota (180 g C $m^{-2}$ $yr^{-1}$) [3], and during woodland encroachment in tropical savanna in Venezuela (140-280 g C $m^{-2}$ $yr^{-1}$) [4].

The geographic extent of woody plant encroachment into grasslands and savannas remains unknown, so the global significance of these rates of C-storage is difficult to quantify. However, if this land cover change affects 20% of tropical savanna area worldwide ($2.5 \times 10^9$ ha), and all savanna area in North America ($0.5 \times 10^8$ ha), then woody plant proliferation in grasslands and savannas would represent a sink of 0.8 Pg C $yr^{-1}$ [3]. If these approximations are reasonable, then woody encroachment in drylands is a significant phenomenon in the global C-cycle and climate system.

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[2] Boutton TW, Archer SR, Midwood AJ, Zitzer SF, Bol R. 1998. ***Geoderma*** 82: 5-41.

[3] Tilman D, Reich P, Phillips H, Menton M, Patel A, et al. 2000. ***Ecology*** 81: 2680-2685.

[4] San Jose J, Montes R, Farinas M. 1998. ***Forest Ecology & Management*** 105: 251-262.

# Soil $CO_2$ Flux in a Japanese Cool-Temperate Grassland

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There have been very few studies on soil $CO_2$ flux, i.e. soil respiration, in Japanese grasslands, because abundant precipitation (more than 1000 mm) limits establishment of natural grasslands. Semi-natural (managed) grasslands, however, can be maintained by mowing and burning in Japan. Since 1998, carbon cycle in a cool-temperate *Miscanthus sinensis* grassland managed as a hay meadow, has been studied in Sugadaira Heights, Nagano Prefecture, the central region of the main island of Japan. Here, based on the result obtained in its study and the only previous report (a Japanese warm-temperate pasture; Kirita *et al*., 1984), general carbon dynamics of Japanese grasslands be discussed. The soil $CO_2$ flux (soil respiration) was measured using a dynamic system with open top chambers which were designed by Fang and Moncrieff (1998). Temporal variation in the soil $CO_2$ flux was mainly related to soil temperature at 5 cm of a soil depth. Annual NPP and soil $CO_2$ flux in the cool-temperate *Miscanthus* grassland were estimated to be 430 g C m$^{-2}$ yr$^{-1}$ and 670 g C m$^{-2}$ yr$^{-1}$, respectively. These values are less than those in the warm-temperate pasture, but greater than the average values in the world temperate grasslands (Raich and Schlesinger, 1992). Thus, carbon cycle in Japanese temperate grasslands is characterized by high rates of production and decomposition of organic matter, which arises from abundant precipitation due to monsoon climate. Spatial variation in soil $CO_2$ flux seemed to be governed by combinations or interactions of various factors: abiotic factors such as soil temperature and moisture, and biotic ones such as rhizosphere distribution, vegetation (biomass) variation and animal distribution in soil.

## Roles of *Sasa* (dwarf bamboo) in Carbon and Water Cycles of Several Ecosystems

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### Abstract

*Sasa* species (dwarf bamboo) are widely spreading in Asian regions and in several types of ecosystems (e.g. forest, wetland, grassland,..). In Japan, the coverage is > 7 Mha, and more than half of the area (4.25 Mha) exists in, northern island in Japan, Hokkaido (Toyooka, et al., 1983; Shimizu and Harada, 2000). The above ground dry weight in Hokkaido is assumed to be 7.5 Mt (Toyooka, et al., 1983), and this value equals 28% of the dry wood resources in Hokkaido. Two aspects of this plant in carbon and water cycles are presented in this report. One is the role in water balance in a cool-temperate mire, and the other is the role in the carbon balance in a cool-temperate hardwood-conifer mixed forest. Both sites are located at 45°N in Hokkaido.

In Sarobetsu mire, a bog exists in the center, and a transition peatland extends around the bog. The original vegetation of the transition peatland has been invaded by *Sasa* and this plant is now invading the sphagnum-dominated bog. In order to assess the effect of the invasion of *Sasa* on the water balance, evapotranspiration rate in the *Sasa*-invaded transition peatland was compared with that in the sphagnum-dominated bog throughout a growing season. Cumulative evapotranspiration over 152 days was 372 mm in the transition peatland and 285 mm in the bog. Therefore, the invasion of *Sasa* into the sphagnum-dominated bog would accelerate water consumption of the mire (Takagi, et al., 1999).

A watershed scale carbon cycle in a cool-temperate mixed forest is now monitored in Teshio Experimental Forest, FSC-Hokkaido Univ. After the monitoring on the mixed forest, the trees in 13.7 ha will be clear-cut and larch saplings will be planted. Then the change in the carbon dynamics according to the larch growth will be evaluated. The heavy snow and the high density of *Sasa* in the forest floor characterize this study site. The biomass and production rate were assumed for each organ of *Sasa* and trees in this forest. The carbon in leaf, stem, root of *Sasa* were 1.1-1.7, 5.2-9.7, 7.7-9.2 tC ha$^{-1}$ respectively and the amount of the carbon accumulated in the stem was ca. 13-24% of that of trees. Yearly production rates of the leaf and stem are 0.54-0.85 and 1.4-2.8 tC ha$^{-1}$, respectively, and the value for leaf was almost the same order of the tree leaf production rate. Accordingly, much carbon is allocated to *Sasa* in the forest ecosystem. However, since *Sasa* disturbs the regeneration process of other native plants in ecosystems, the interaction with other plants should be clarified to develop the ecosystem management.

# Dynamics of Soil Organic Matter in Paddy Fields

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Paddy fields are important for the production of rice, which is a staple food in Asia and other area. Soil organic matter dynamics in paddy field were investigated in two ways. First, organic matter accumulation in paddy soils from long-term experimental fields (28-53 years) was examined by using mineralizable nitrogen (MN) and total nitrogen (TN) contents. MN was estimated by anaerobic incubation for 28 days at 30$^{o}$C as proportional index of accumulated organic N after continuo U.S.pplication of organic manure, and fitted in the figure MN vs. TN to the formula; MN = $k$(TN -$a$), where $k$ is constant for and $a$ varied among various soil types examined. Effect of long-term application of organic manure was demonstrated also in the figure MN vs. TN, as vectors and their lengths were proportional to the cumulative amount of applied manure during experiment until about 600 ton ha$^{-1}$, then leveled off above this amounts. This indicates that accumulation of organic matter in paddy soil became saturated after input and decomposition of organic matter became equiblium. Algae in floodwater were regarded as another source of organic matter input as examined by chlorophyll-type compounds in surface soil.

Second, effects of elevated $CO_2$ in the atmosphere on methane and nitrous oxide emission from paddy fields as well as soil microbial biomass and biological nitrogen fixation were investigated in the rice FACE experiments. Methane flux from FACE treatment was higher than that from ambient treatment except the first year when initial methane flux was reduced possibly by active algal mat in the floodwater. Nitrous oxide flux was negligible during flooded period, but became higher in FACE treatment than in ambient after final drainage. Soil microbial biomass C increased under FACE conditions. Biological $N_2$ fixation (ARA) was also increased by elevated $CO_2$ in surface soil layer during early stage of crop season, and in subsurface during late period of the season.

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# Source and Fate of Organic-C in Paddy Field Ecosystem

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Plant residues are the main source of soil organic carbon, and it is well known to increase soil fertility by applying organic fertilizers (compost and green manure) in comparison with the application of inorganic fertilizers. Paddy soils contain more organic-C than corresponding upland soils. Paddy fields have been generally managed intensively for the better yield of rice, and many of the field management closely relate to the C cycling in the paddy field ecosystem. Harvest of rice plant and land preparation in spring are the main practices amending organic-C to the paddy soil. Plant residues are not only important as the source of organic-C but also important as the main site of organic-C mineralization. Water percolation affects the fate of organic-C as well as inorganic-C ($CO_2$ and $CH_4$). The followings are the summary of the origin and fate of organic-C in paddy field ecosystem.

## Origin of organic-C and the relative contribution

As the origin of organic-C to paddy fields, organic fertilizers (compost and green manure), phydrophytes such as floating plants and algae, weeds, rice litter of dead old leaves, and rhizodeposition from rice roots are pointed out during the cultivation period of rice plant. In addition, during the off-crop season from late October to the next spring stubble and dead roots of rice plant are amended to paddy fields in autumn and weeds grown in winter and early spring and their rhizodeposition are added to the soil after spring plowing. Among these versatile origins of organic-C, stubble and weeds plow-in in spring took the large contributions, amounting to about 20% and 30% of the total organic input, respectively. In contrast, the organic-C from green manure and compost were relatively small accounting for less than 20% of the total input. Rice straw is another important source of organic-C. Production of rice straw is about 6 tons ha$^{-1}$ on average in Japan, and it is left on the paddy field after harvest because of the harvest by a combine machine being common in Japan.

## Field management results in the input and relocation of organic-C

Many field practices result in the input and relocation of organic-C in paddy fields. Harvest of rice plant adds organic-C as stubble and dead roots, and plowing incorporates weeds into soil. Application of herbicides also supplies dead weeds to soil surface. Midseason drainage and the drainage at the time of harvest may supply dead hydrophytes to the soil surface. Thirty five to 55% of carbon in rice straw was decomposed during the off-crop season under drained condition (from October to June). In addition, plowing incorporates plant debris into soil resulting in the change of decomposition process. Drainage and flooding also affect the condition of decomposition (aerobic or anaerobic), resulting in the change of responsible microorganisms.

## Coarse plant residues are the main sites of organic-C decomposition

The seasonal variation in the amount and C/N ratios of coarse plant residues (CPR; more than 1 mm fraction) was analyzed in a Japanese paddy field under a long-term fertilizer trial for three consecutive years. The CPR were collected from four plots in the field; the plot without fertilizer application, the plot with chemical fertilizer, the plot with green manure, and the plot with compost. The main forms of CPR added to the paddy field were stubble of harvested rice and weeds plow-in in spring with a similar contribution to CPR amounting to ca. 2 tons $ha^{-1}$ each. The fraction > 4 mm accounted for the largest part, followed by the 1-2 mm and 2-4 mm fractions throughout the year. The C/N ratio of the > 4 mm fraction exceeded 25, that of the 2-4 mm fraction was in the range of 20-30, and that of the 1-2 mm fraction in the range of 15-20, respectively. Thus, the CPR with similar size showed similar C/N ratios irrespective of the plots or the sampling season. The finding that the C/N ratio of the 1-2 mm fraction ranged from 15 to 20 was generalized from the study of the C/N ratio of the fraction collected in Thai and Philippine paddy fields, in the study of which paddy fields under different water regime (poorly drained and well-drained) , different fertilization (different application levels including no fertilization) and different cropping frequency (from one to four times per year), paddy fields belonging to different soil types (including Histosols and Ultisols) were included. The decrease of the C/N ratio from the original plants to the 1-2 mm fraction suggests that more than 50 % of plant materials plowed-in should be decomposed before their size becomes less than 1 mm.

### Leaching of organic-C and inorganic-C into subsoil by water percolation

Percolation of water in soil is necessary for the sound growth of rice plant, and 10 to 15 mm of percolation per day is recommended in Japan. Percolation of water leaches not only cationic and anionic nutrients but organic-C. In a soil pot experiment, total amount of dissolved organic carbon (DOC) leached during the rice cultivation period accounted for ca. 0.5 % of the total amount of organic-C in soil. Leaching of DOC increased by the application of plant residues, and the total amount leached was 2-3 % of the total amount of organic-C in plow layer soil. Bicarbonate is the main anion in the percolating water in paddy fields, and the total amount of $\Sigma CO_2$ leached amounted to 8.4 % of the total amount of organic-C in plow layer soil during the period of rice cultivation. The fate of $\Sigma CO_2$ leached into subsoil has not been elucidated.

Methane produced in plow layer soil was also leached into subsoil by percolating water, and it amounted to 8.6 % of the sum of the amount of emitted and leached methane under 15 mm d-1 percolation condition.

# Modeling Carbon Sequestration in the U.S. Cropland

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A process-oriented model, Denitrification-Decomposition or DNDC, was developed for predicting carbon (C) and nitrogen (N) dynamics in agroecosystems. Carbon storage in cropland soils is highly dynamics due to the intensive management including crop rotation, tillage, fertilization, manure amendment, irrigation, and weeding. Soil organic carbon (SOC) contents in the U.S. cropland may have never reached equilibrium because the ever changing management (e.g., crop yield, litter production, fertilization rate, tillage system etc.) during the last 100-200 years didn't provide consistent environmental conditions. The assumption that current SOC is in an equilibrium through several hundred years' evolution may be suitable to the natural ecosystems with least disturbance, but inherently improper for cropland C studies. DNDC adopted a different concept by assuming (1) current SOC in most of cropland is in non-equilibrium status with a C change tendency driven by a prospective future equilibrium; (2) the prospective equilibrium is determined by environmental factors such as climate, soil properties, and management; and (3) the prospective equilibrium will change if any of the environmental factors varies in future. DNDC captures SOC dynamics from one day to several centuries by means of six interacting sub-models (Figure 1). The soil climate sub-model calculates soil temperature, moisture and Eh profiles to provide a basic foundation for simulating various biogeochemical processes occurring in the plant-soil systems. The plant growth sub-model tracks crop growth, C assimilation and allocation, and litter production. The decomposition sub-model simulates turnover of litter to humads and humus with $CO_2$ released into the atmosphere. The nitrification and denitrification sub-models calculate N transformation, N availability for plants, and emissions of nitrous oxide, nitric oxide, dinitrogen and ammonia. The fermentation sub-model simulates C loss through methane emission. Validations against observed litter decomposition, $CO_2$ fluxes, and long-term SOC changes indicated that the model's behaviors were in agreement with observed short- and long-term C dynamics (Figure 2 and 3). 200-year sensitivity analyses were conducted to test effects of change in natural conditions or management on long-term SOC dynamics at a typical cropland in Iowa. The results demonstrated (1) under same climate/soil /management conditions, the soils with different initial SOC contents were different in C sequestration capacity: the soils with high initial SOC contents lost C, and the soils with low SOC contents gained C (Figure 4, 5 and 6); (2) under the higher temperature scenarios, SOC decomposition rates were elevated, and the prospective equilibrium shifted to lower C levels (Figure 4); (3) no-till, manure amendment or enhanced fertilization increased C accumulation in the soil, and hence the prospective equilibrium shifted to higher C levels (Figure 5); and (4) with a same current SOC content, the heavy soils would gain more C than the light soils (Figure 6). Estimation for C sequestration in cropland in the U.S. was accomplished by linking DNDC to a GIS database (Figure 7). The database was constructed based on daily meteorological data, soil survey data, land cover, and management in the U.S. in 1990. The modeled results indicated (1) about 7,900 Tg C was currently stored in the soils (0-30 cm depth) of 141.2 million ha of cropland in the U.S. (Figure 8 and 9); (2) the U.S. cropland lost about 30 Tg

C (Figure 11) with emitting 447 Tg $CO_2$-C (Figure 10) and receiving 332 and 94 Tg crop residue-C and manure-C, respectively, per year; and (3) the cropland with relatively high SOC contents in Iowa, Illinois, and North Dakota had lower potential to sequester C in comparison with other states. In the scaling up processes, the major uncertainty came from the data of manure amendment. There was no reliable database to partition livestock waster into cropland at county or state scale.

# Land Cover Changes and Soil Carbon Dynamics: Insights From Natural Ä$^{13}$c and Long-term Incubations

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Livestock grazing and fire suppression are causing woody plant proliferation in grasslands and savannas worldwide [1], and this land cover change may be responsible for sequestering >0.8 Pg C yr$^{-1}$ [2]. Our recent work has shown that, where subtropical thorn woodlands have replaced grasslands in the Rio Grande Plains of southern Texas, whole-ecosystem C storage has increased by as much as 200% within 50-100 yr of woodland development [1]. As a result of this dramatic change in the quantity and quality of organic matter inputs, we hypothesized that turnover rates of soil organic C (SOC) would be affected by this land cover change.

To test this hypothesis, we measured the mass and isotopic composition (ä$^{13}$C) of SOC in chronosequences consisting of remnant grasslands ($T_0$) and woody plant stands ranging in age from 10 to 120 yrs. Because remnant grasslands are dominated by $C_4$ grasses with high ä$^{13}$C values (-13 ‰) while the more recent woodlands are dominated by $C_3$ trees/shrubs with low ä$^{13}$C values (-27 ‰), it was possible to uniquely specify rates at which C derived from grassland decayed out of the soil and C derived from woodlands accumulated in the soil. To better understand the dynamics of the more labile C fractions not resolved by the isotopic method, we also conducted long-term measurements of soil respiration in soils incubated under controlled conditions for >500 days.

ä$^{13}$C of SOC (0-10 cm) decreased exponentially from -19 ‰ at $T_0$ to approximately -23 ‰ after 100 yr of woodland development [3]. Mass balance indicated that 40-60% of the grassland-derived carbon present at $T_0$ was still present after 100 yr of woodland development. Compartmental analyses revealed that mean residence times (MRT = $k^{-1}$ ) for bulk SOC ranged from 69 yr in coarse-textured upland soils to 130 yr in fine-textured lowland soils. The rate of accretion of SOC derived from $C_3$ woody plants was greater than the rate of loss of SOC derived from the original $C_4$ grassland, so total SOC has increased 30-200% over the past century.

During long-term incubations, larger SOC pools in woodlands sustained rates of soil respiration that were up to 180% greater than those in remnant grasslands. Despite higher soil respiration, soil C turnover rates were slower (longer MRTs) in wooded portions of the landscape. Hence, increased C-sequestration in wooded landscape elements is at least partially a consequence of slower C turnover rates. Pool sizes of slow/resistant C increased from 65% of total SOC in grasslands to 80-90% of total SOC in wooded areas. Conversely, pool sizes of labile C decreased from 35% of total C in grasslands to 10-20% of total C in woodlands.

Grassland-to-woodland conversion during the past 100 yr has been geographically extensive in grasslands and savannas wordwide, suggesting that the changes in SOC storage and dynamics documented here could have significance for the global carbon cycle and climate.

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# Carbon Management Requirements and Technology Potentials

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J. A. Edmonds and colleagues (2001) summarize future CO2 emissions from IPCC scenarios, and they estimate future emissions paths (years 1990 to 2090) based on different technology assumptions for a worldwide energy supply system. They also identify an emissions scenario required to achieve CO2 stabilization at about 550 ppm by the end of the next century. This analysis points out that massive emissions reductions and carbon sequestration offsets will likely be required for stabilization of atmospheric CO2. That is, once next-generation energy supply technology brings global emissions to a level of 20 gigitonnes or less, an additional increment of at least 10 gigatonnes emissions reduction or carbon sequestration offsets will be needed to approach atmospheric CO2 stabilization. Where will this additional increment come from?

In a more detailed analysis of potential carbon management approaches, Edmonds also identifies eight options that could further reduce global CO2 emissions by amounts that could possibly achieve the proposed stabilization level. Among the options, he lists bioenergy and soil sequestration as prominent biological mechanisms for carbon management that could account for as much as 25% of the total – in both global terms and for a U.S. component. Interestingly, because of near-technical feasibility and readiness for implementation, these two options offer immediate carbon management opportunity and significant potential payoff. Fortuitously, these same biologically based options are the topics evaluated by the 9th U.S.-Japan Workshop on Global Climate Change. The U.S. – Japan workshop on "Carbon Cycle Management in Terrestrial Ecosystems" is therefore providing timely and highly relevant information that contributes solutions to the worldwide carbon management problem.

In the U.S., the Department of Energy produced a comprehensive study of "Carbon Sequestration Research and Development" http://www.ornl.gov/carbon_sequestration/ that identifies a number of mechanisms -- including separation and capture of CO2, ocean sequestration, carbon sequestration in terrestrial ecosystems, sequestration in geologic formations, and advanced biological processes and chemical approaches to sequestration. This study confirmed an important role for carbon sequestration by terrestrial ecosystems, and estimated a potential global quantity of 5 to 10 gigatonnes carbon per year for a wide range terrestrial biomes. A key focus of terrestrial ecosystems research is to determine how small changes in the large annual carbon fluxes associated with photosynthesis and respiration might achieve significant gains of net carbon sequestration. In addition, carbon enrichment of terrestrial ecosystems can benefit other qualities such as intrinsic productivity, and hydrologic and soil properties. Additional research is needed on multiple benefit aspects of terrestrial carbon sequestration.

# FACE: A Window Into Future Ecosystems Under $CO_2$-Rich Atmosphere

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FACE (free-air $CO_2$ enrichment) provides us with a unique opportunity to study intact terrestrial ecosystems under elevated $CO_2$ concentration ([$CO_2$]) with little artificial alterations. We conducted Rice FACE project through 2000, and carried out FACE experiment at farmers' rice fields in Shizukuishi, Iwate in northern Japan for 3 years from 1998. Carbon and nitrogen (N) metabolisms in plants, water-layer, and soil under elevated [$CO_2$] were studied. The results showed that the plant biomass growth, photosynthesis, and grain yield responded to the [$CO_2$] elevation to the extent dependent on the amount of N supply with fertilizers. Soil microbial processes also responded to the elevated [$CO_2$] depending on N availability. In the water layer, changes were found in the biomass of floating weeds and $CO_2$ exchange across the water surface. These changes in the ecosystem processes in the FACE experiment need to be incorporated into process-based models of vegetation and ecosystem dynamics under changing atmospheric [$CO_2$]. Temporal scale of ecosystem responses must also be considered: responses of annual plant species tend to be quick while some soil processes could respond to high [$CO_2$] quite slowly. In a long run, however, the soil process changes would alter the plant responses. Ecosystem management could experience substantial changes due to some other drivers, e.g. population pressure, for the 50-100 years to come. In a sense, the future is not fixed yet, but is up to us (to some extent). Future research with FACE would focus on the changes in soil processes as well as soil-plant interactions. Further research is also needed on ecosystem responses to the [$CO_2$] increase under environmental constraints at present and in the future such as climate change: temperature and precipitation changes.

# Carbon Dynamics and Sequestration in Two Different Cropping Systems in Japan

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Carbon dynamics and budgets were investigated in upland agricultural ecosystems in central Japan. The experiments were carried out in upland single-cropping (Upland rice, Corn, Peanut) and double-cropping (Upland rice-Barley, Corn-Barley, Peanut-Wheat) fields in Tsukuba, Japan. Carbon budgets were different between the single- and double-cropping systems. The annual carbon balance was estimated to be -270~-320 gC $m^{-2}$ for the upland single-cropping fields, -160~-270 gC $m^{-2}$ for the upland double-cropping fields. Therefore, great use of upland double-cropping systems can significantly increase soil carbon levels, due to high root and stubble carbon production, and protection from erosion. Changing the cropping system from the upland single-cropping to the upland double-cropping, there are mitigation potentials of 50~110 gC $m^{-2}$ $yr^{-1}$ from the use of the double-cropping system.

These results suggest that effective agronomic measures are needed to maintain the carbon balance in prevailing upland agro-ecosystems in order to sustain soil fertility, and the upland agro-ecosystems may contribute to the increase in the carbon dioxide concentration of the atmosphere as the carbon accumulated in the soil is constantly being released in the atmosphere, and improved management is capable of increasing carbon levels on existing agricultural soils in central Japan.

Key words: Carbon balance, Carbon dioxide, Double-cropping system, Single-cropping system, Soil respiration

# Measuring Total Soil Carbon With Laser-Induced Breakdown Spectroscopy (LIBS): Progress on a New Method

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Improving estimates of carbon inventories in soils is hindered by lack of a rapid analysis method for total soil carbon. A rapid, accurate, and precise method is needed for use in the field and would be a significant benefit to researchers investigating carbon cycling in soils and dynamics of soil carbon in global change processes. With support from DOE's Office of Science and National Energy Technology Laboratory, in conjunction withU.S.Department of Agriculture, we are in the process of testing a new analysis method for predicting total soil carbon using laser-induced breakdown spectroscopy (LIBS). In our preliminary analyses, we determined appropriate spectral signatures and calibrated the method using measurements from dry combustion of a Mollisol from a cultivated plot. From this calibration curve we predicted carbon concentrations in additional samples from the same soil, as well as an Alfisol collected in a semiarid woodland, and compared these predictions with additional dry combustion measurements. These initial tests suggest that the LIBS method rapidly and efficiently measures soil carbon with excellent detection limits (~300 mg / kg), precision (4-5%), and accuracy (3-14%). LIBS measurements and dry combustion analyses from initial testing were highly correlated (adjusted $r^2 = 0.96$) for soils of distinct morphology, and that a sample can be analyzed by LIBS in less than one minute. These initial results are to be published in *Journal of Environmental Quality* 30 (6), 2001. The LIBS method is adaptable to many configurations, including a field-portable instrument, and this attribute—in combination with rapid and accurate sample analysis—suggest that this new method offers promise for improving measurement of total soil carbon. Future efforts will focus on additional testing of LIBS is required to understand the effects of soil properties such as texture, moisture content, and mineralogical composition (i.e., silicon content) on LIBS measurements. We are in the process of testing the LIBS method with a large set of soil samples from USDA. Future advances with LIBS could revolutionize soil carbon measurement.

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# Impacts of Grazing and Fire on Carbon Fluxes in Western Rangelands

J.A. Morgan, W.A. Dugas, A.B. Frank, M.R. Haferkamp, D.A. Johnson, D.R. LeCain, N.Z. Saliendra & G.E. Schuman

The cycling of carbon in rangelands has taken on increased attention in the last decade as scientists have sought to understand how management of these ecosystems interacts with the environment to affect attributes like C storage and rangeland health. Rangelands encompass well over 40% of the terrestrial surface, so collectively these lands represent important C sinks and sources. This presentation discusses carbon dioxide flux experiments conducted at six USDA-ARS rangeland research stations in the western United States encompassing sites in the shortgrass steppe (SGS), northern mixed prairie (NMP), tallgrass prairie (TP), and sagebrush steppe ecosystems (SS). Carbon dioxide flux was determined by chamber (SGS, NMP) and Bowen ratio/energy balance (SS, TP and NMP) techniques. Treatments evaluated were grazing (SGS, NMP and SS) and fire (SS and TP). The effects of grazing and fire depended on the ecosystem evaluated. Fire enhanced C uptake in TP, but decreased it in SS because of the removal of most of the shrubs in the SS. Yet in both systems, net ecosystem exchange (NEE) was positive, indicating C storage. In the TP, an average 1.1 kg $CO_2$ $m^{-2}$ $year^{-1}$ was assimilated over seven years of continuous measurement. In the SS, between 0.4 and 0.8 kg $CO_2$ $m^{-2}$ was assimilated during the growing season over three years of measurement. Intensive sheep grazing (removal of 50-80% of aboveground phytomass) in the SS and NMP reduced C assimilation compared to ungrazed control plots, while moderate cattle grazing (removal of < 50% of aboveground phytomass) exhibited little effect on C exchange in the SGS and NMP. In all of the rangelands evaluated, weather, particularly precipitation, had the greatest impact on C exchange. These results suggest complicated interactions of management strategies and ecosystems on C cycling. Positive NEE rates in most years indicate good potential of these extensive rangelands for sequestering C.

# Carbon Sequestration in Managed Loblolly Pine Forests in the Southeastern United States

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Managed pine forests in the southeastern U.S.re harvested on short rotations, currently averaging 22 years, so the amount of carbon sequestered by them will be determined by two things: 1) the amount of recalcitrant carbon remaining in the soil at the end of the rotation and 2) the amount of carbon sequestered in products created from the wood removed from the forest, including their final disposition. Managed forests will generally have higher productivity than unmanaged forests. Continued high productivity through multiple rotations combined with the potential for substantial storage of carbon in products suggests that managed forests can be substantial sinks for atmospheric carbon.

Southern pine forests typically grow on soils that have been greatly degraded by past land use. It has been estimated that 200 years of native forest clearing, followed by cycles of agriculture, have reduced the total regional carbon pool by 25 Gton. In the 1900's, a substantial portion of this agricultural land was converted to pine forests. Drastic changes in species composition and land management during conversions from native forests to agriculture and then to pine forests have greatly impacted both inputs and outputs of carbon on these sites. The “new” soil C starting values for old field agriculture sites can be very low and restoration of these soils, via plantation pine forestry, should sequester C from the atmosphere. Plantation forests in the region are now in their first, second or third rotation of pines. Our data is providing evidence that that the soil carbon pool continues to increase in managed forests with each successive rotation until a new equilibrium level is reached (Figure 1).

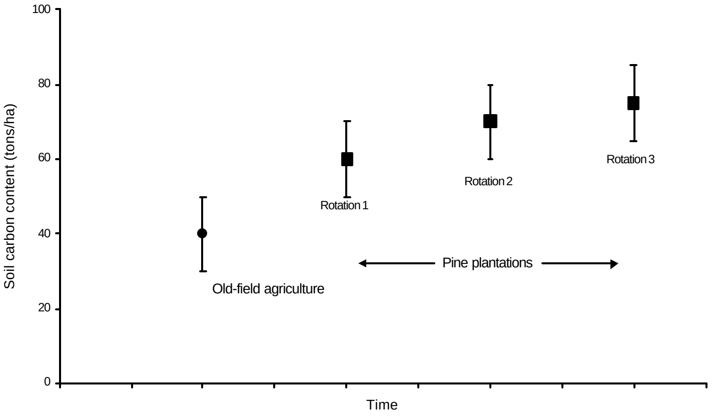

Figure 1. Conceptual diagram of the change in soil carbon content on three successive rotations of pine plantations in comparison to that of old field agriculture.

Different wood and fiber products and uses have very different duration-of-use and final dispositions, which will affect carbon sequestration. For instance, conventional lumber is often incorporated into a building structure and its lifespan will range from decades to centuries. Based on U.S. Census of Housing data, the median half-life for single family houses built in the United States after 1950 is estimated to be 100 years. Fibers incorporated into paper products provide a shorter sequestration period, the exact length dependent on considerations such as the amount recycled. However, the deposition of paper products in landfills provides a substantial long-term carbon sequestration pool.

An example of the potential importance of carbon sequestered in wood products is shown in simulations based on the HARVCARB model for a generic loblolly pine stand in the southeastern U.S. (Figures 2a, 2b and 2c). This example assumes average rates of stand growth, a 20 or 25 year rotation length, and products of lumber, and pulp for paper production with waste burned for fuel. In this scenario, 25 years after the first harvest, 30% of the carbon from the first rotation remained stored in products in use. Over successive rotations this C pool increases. An additional accumulation occurs in waste that enters landfills. Over time the C accumulation in these two pools, along with buildup of soil carbon (Figures 1 and 2a) indicates that successively harvested pine plantations have the potential to sequester significantly more carbon than uncultivated, unharvested forests (Figure 2b). When pine plantations are intensively managed for increased productivity using fertilization and weed control, the rotation length is reduced to 20 years and the impact on C sequestration is substantially magnified (Figure 2c).

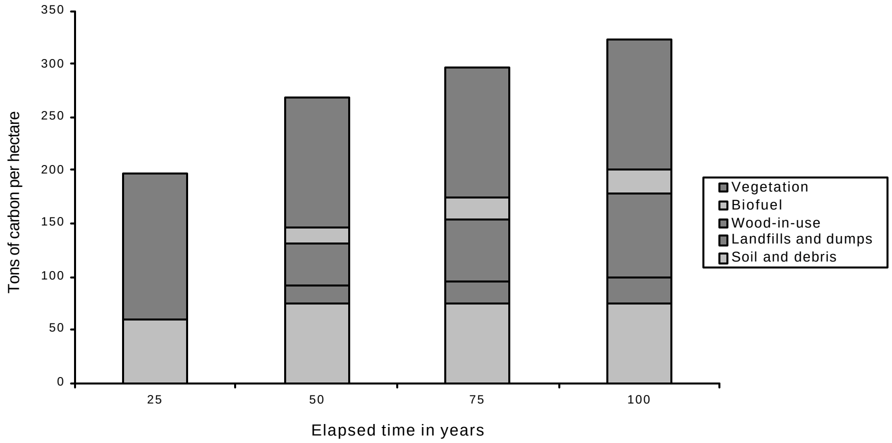

Figure 2a. Simulations of the carbon sequestration potential in four 25-year rotations of loblolly pine using the HARVCARB model and gerneric loblolly pine parameters (Row and Phelps 1996).

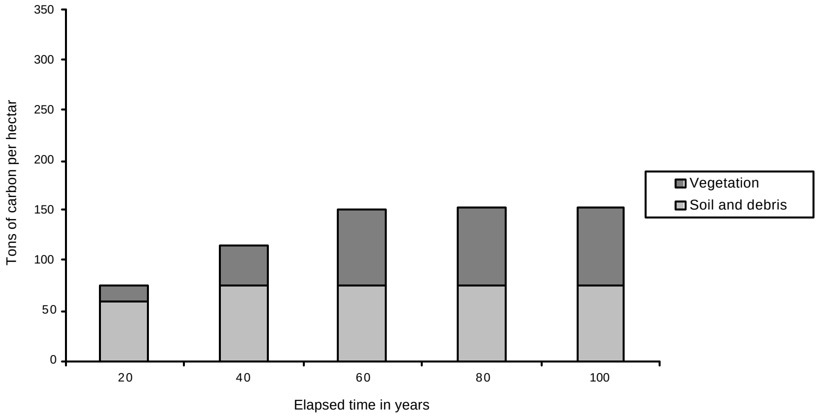

Figure 2b. HARVCARB simulation of the carbon sequestration potential in soil and vegetation in an uncultivated, unharvested forest over a 100 year period.

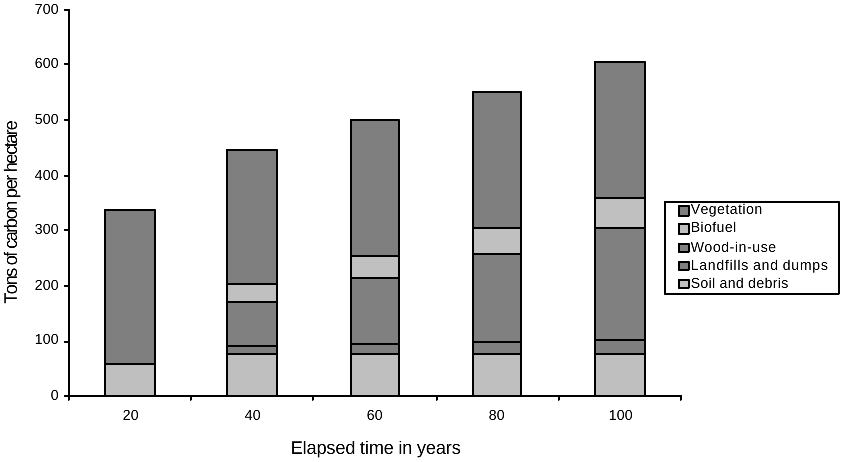

Figure 2c. Simulation of the carbon sequestration potential in soil, vegetation and products in an intensively managed loblolly pine plantation having five 20-year rotations because of high growth rates.

While we anticipate that the scenarios described in Figure 2 provide a reasonable generic approximation of the sequestration potential of managed loblolly pine forests, there is still a great deal to understand about carbon dynamics in plantations including the role of coarse woody root debris, the effects of different soil types and climate on soil carbon content, and the effects of management activities on both above-ground productivity and soil carbon. These efforts are currently underway as part of a regional, collaborative research project examining carbon sequestration in managed forests in the southeastern US.

# Long-term Measurements of Net $Co_2$ Exchanges Over Contrastive Forest Ecosystems in Japan

N. SaigU.S., S. Yamamoto, S. Murayama, H. Kondo, Y. Fujinuma, and T. Hirano
National Institute of Advanced Industrial Science and Technology

Net $CO_2$ exchanges have been measured by the eddy covariance method over two different forest ecosystems: a cool-temperate broadleaf deciduous forest in a mountainous region of Takayama (central Japan) and a larch forest in a flat region of Tomakomai (northern Japan). The maximum level of daily $CO_2$ uptake was slightly higher in the larch forest (0.8-1.0 mol $m^{-2}$ $day^{-1}$) than in the broadleaf forest (0.7-0.8 mol $m^{-2}$ $day^{-1}$). However, the $CO_2$ uptake rate in the larch forest decreased with photon flux density (PPFD) at PPFD > 1000ìmol $m^{-2}$ $s^{-1}$ during the daytime in midsummer. This result suggests that high temperature coincident with high PPFD caused an increase in the respiration rate and/or a decrease in the photosynthesis rate, which resulted in a decline in the $CO_2$ uptake in the larch forest.

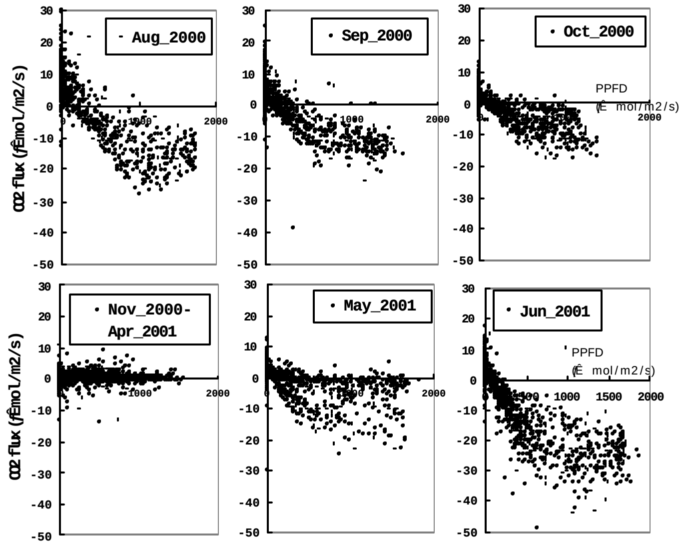

Figure 1. A monthly relationship between $CO_2$ flux (30-minute average) and PPFD measured from August 2000 to June 2001 at Tomakomai.

# Integrating Atmospheric CO2 Observations, Terrestrial Ecosystem Models and Flux Inventories

S. Maksyutov
Frontier Research System for Global Change, Japan

Inverse models of global carbon dynamics use models of atmospheric transport to link models and inventories of the terrestrial and oceanic carbon fluxes to the observations of spatial and temporal distributions of the atmospheric carbon dioxide. The Bayesian inversion framework (Tarantola, 1987) is convenient in a sense that it can accommodate various kinds of input information in a logically consistent manner.

The estimates of the annual average flux of carbon usually indicate that the northern hemispheric land is a carbon sink (e.g. Tans et al., 1990). However, the attempts to use spatial structure of the observed concentrations to deduce the annual average fluxes for large terrestrial and oceanic regions resulted in large spread in the estimations for regions such as North America and Eurasia (Fan et al., 1998; Rayner et al., 1999). The reasons for the differences between inverse model results are believed to originate in model transport and inverse modeling approaches. Another factor limiting the application of the inverse modeling to discrimination of the carbon fluxes between land regions is the lack of the observations close to the target areas. In one of the recent inverse model studies (IGBP/GAIM Transcom project, Gurney et al, 2001), we used $CO_2$ observations and inverse model to improve estimates of the regional $CO_2$ sources and sinks. The global $CO_2$ flux distribution is evaluated using several atmospheric transport models, atmospheric $CO_2$ observations and recent estimates of the oceanic and terrestrial carbon fluxes and their seasonality. In an accompanying analysis (Maksyutov et al., 2001) we included recent observations over Asia, and the inclusion of the data reduced uncertainty of the estimated regional $CO_2$ fluxes for Boreal Asia (Siberia), Temperate Asia, and South-East Asia.

Several newer approaches are being proposed recently that can be considered for collaboration between atmospheric observation, transport modeling and ecosystem carbon flux modeling groups.

Approach 1: Use monthly average atmospheric CO2 observations to solve for parameters of the terrestrial biosphere model and produce observation-adjusted spatial patterns of the net ecosystem exchange. Examples of the model optimization studies are few now: 1) SDBM by Rayner et al. AGU Fall 2000 2) BETHY by Rayner et al. CO2 conf. 2001, 3) CASA by Randerson et al 2001.

Approach 2: Apply “time-dependent” inversion that uses daily atmospheric CO2 concentrations to derive surface flux distributions at higher resolution. Observations: tall towers, background stations with continuous observation (e.g. Cape Grim, Pt Barrow, Hateruma), Fluxnet CO2 concentrations observations. For example Law et al. CO2 conf (2001) use continuous CO2 observations around Australia to quantify the Australian carbon source–sink distribution at 2-3 degrees resolution.

The success of the inverse model studies depends on quality of a number of model ingredients: ecosystem fluxes and flux inventories, atmospheric transport model, oceanic fluxes, and atmospheric CO2 observations. In order to achieve further improvements in the optimally constrained estimations of the regional CO2 emissions and sinks, all the components should be enhanced: transport modeling requires more support from forecast centers, we also need more accurate and higher resolution ecosystem fluxes, the atmospheric CO2 observations need to be supported and extended.

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Maksyutov et al. 2001, *Extended Abstracts 6th Int. CO2 conf*. 723-726.
Randerson et al. 2001, *Global Biogeochemical Cycles, submitted*
Tarantola A., 1987, *Inverse problem theory, p 605, Elsevier Sci. Publ.*

# NPP Estimation of Forest Area Using Satellite Data

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The global mean air temperature is going to increasing, and the global warming becomes realistic rather than simulation scenario of general circulation models. Increasing amount of greenhouse gasses in the atmosphere is believed to be the cause of global warming, and carbon dioxide ($CO_2$) is one of major greenhouse gasses. Therefore, reduction of $CO_2$ and understanding of the carbon storage and balance in the terrestrial ecosystems are strongly required world widely. Amount of carbon balance in the terrestrial ecosystem is called the net ecosystem productivity (NEP), and the amount, which subtracts the soil respiration from NEP, is called the net primary productivity (NPP). NPP is amount of carbon fixation by vegetation and an important parameter to estimate carbon balance. Due to such background, I aim to estimate the global NPP, which has a parameter to understand the global carbon balance, using NOAA satellite data and world climate data.

Production efficiency approach using the normalized difference vegetation index (NDVI) is one of popular method to estimate the net primary productivity (NPP). The approach needs light use efficiency (LUE) of vegetation and a relationship function between fraction of absorbed photosynthetically active radiation (fAPAR) and NDVI. However, there are uncertainties in estimating LUE and the function, if they are estimated from a few samples. Instead of estimating LUE, a relationship between NPP, which was estimated by a climatic NPP model (potential NPP) called Chikugo model, and sum of NDVI multiplied by solar radiation (SR) during growing seasons was estimated to reduce the uncertainties. There was a clear liner relationship between them (Potential NPP = 0.494* sum(NDVI*SR), $R^2$=0.845). Average light use efficiency (LUE) of global plants, which was calculated based on the relationship, was the same level with moderate LUE of tree and grass species in the literature. The NPP estimation model included growth multipliers for air temperature and soil water with LUE. NDVI anomalies were reduced by a correction of path radiance of channel 1. Seasonal NDVI patterns were clearly retrieved by the atmospheric correction, although the correction might be an over correction a little. Global NPP between 1988 and 1993 was estimated using the model, NDVI, air temperature and soil water content data. The global NPP during the 6 years was almost same level with the estimate by IPCC.

# Toward Improved Satellite Monitoring of Photosynthetically Active Radiation for Global Carbon Cycle Studies

Dennis Dye
Frontier Research System for Global Change, Japan

A reliable global data source for photosynthetically active radiation (PAR) is required to support efforts in modeling and monitoring terrestrial primary production and related ecosystem processes. This paper describes our research plan to develop an improved global PAR data source by using observations from the Total Ozone Mapping Spectrometer (TOMS) and the future Ozone Monitoring Instrument (OMI). Prior research has shown that TOMS ultraviolet (UV) reflectivity measurements (360 or 380 nm), in combination with a simple atmospheric radiation model, are uniquely effective for estimating PAR irradiance at the Earth's surface. We plan to introduce several refinements to the current TOMS-based PAR estimation method. These refinements include incorporating a more sophisticated radiation model, accounting for geographic and seasonal variation in background surface UV reflectivity, and applying corrections for the effects of UV-absorbing aerosols on the TOMS-observed reflectivity. We will validate and evaluate the satellite PAR product through comparisons *with in situ* PAR measurement and intercomparisons with existing PAR data sets. A global, time-series PAR data set will be produced with the existing TOMS data archive, which begins in 1979 with Nimbus-7 TOMS and continues today with EarthProbe TOMS. The deployment of the OMI in 2003 will provide an ongoing data source to support continued global PAR monitoring. The global PAR data set produced by this project will be useful to research groups concerned with modeling and analysis of terrestrial ecosystem processes and the global carbon cycle.

# Estimation of Global NPP in the Agricultural Sector

Katsuo OKAMOTO and Masayuki YOKOZAWA
National Institute for Agro-Environmental Sciences

There are some problems on global NPP estimation. In the previous studies, researchers have neglected the agricultural sector. They have focused on only natural vegetation. In their studies, there is no agricultural class or at most one class. The area of agricultural sector is 14% of land. However, the ratio of NPP in agricultural sector to that in land would be more than 14%. For example, the NPP in Europe is calculated climatically to be 7-10 t/ha, while the annual yield of wheat and maize is 6-9 t/ha, i.e., it is equivalent to 20-30 t/ha in NPP. The equivalent NPP being larger than the climatic NPP is affected by biological resources, i.e., yielding crops, and technical resources, i.e., chemical fertilizer, agricultural chemicals, agricultural implements and irrigation systems. The agricultural sector would be potentially large sink/source of C.

There are two methods to estimate the NPP, i.e., direct and indirect methods. A direct estimation is to calculate the NPP using satellite remote sensing data. The NPP is defined as NPP=IPAR*å =ÓPAR*fAPAR*å =ÓPAR*f(LAI)*å= ÓPAR*f(NDVI)*å An indirect estimation is to calculate the NPP using process models; for example, a plant growth model and a material distribution model.

As a case study, we calculated the global NPP in agricultural sector in 1998, using NDVIs from global satellite remote sensing data of the 10-day composite Pathfinder Dataset (with 8 km resolution), solar radiation data from the 1998 NCEP-NCAR Climate Dataset, and the Land-use/Land-cover map of USGS-EDC/DAAC. We used a mean å during the growth season and ignored temperature and water stresses. We also assumed that NDVIs had reflected plant conditions. We defined å of rice, wheat, maize, C3 crops and C4 crops and ignored individual difference among species. We considered cropping systems, i.e., double rice, rice and winter-wheat/other crop, and maize and winter-wheat/other crop for double cropping systems, and rice, winter/spring-wheat, maize, other C3 crops and other C4 crops for single cropping systems. We redefined mixels to dominant land-use/land-cover.

We estimated the 1998 NPP in agricultural sector to be 33.9 x$10^{15}$ PgC (33.9 GtC), while the climatic NPP during April 1992-March 1993 17.6 GtC. In our estimation, double cropping areas in South America, India and Central China had large NPP. å used in this study would be too large. There are some remaining problems; verification, improvement of å, and accurate detection of green period.

# Appendix A: Program Agenda

# Agenda for
# 9th Japan-US Workshop on Global Change
# Carbon Cycle Management in Terrestrial Ecosystem

**October 9-11, 2001**
**Mita Kaigisho, Tokyo, Japan**

## October 9, Day 1

**[Auditorium]**

| | |
|---|---|
| 9:30-10:00 | **Registration** |
| 10:00-10:15 | **Opening Address**<br>**Mr. Yoichiro OTSUKA**, Director, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology (MEXT)<br>**Mr. Lou BROWN**, Senior Staff Associate for International Science Affairs, Directorate for Geosciences, National Science Foundation |
| 10:15-10:45 | **Chair-person's address**<br>**Dr. Yoshifumi YASUOKA**, Professor, Institute of Industrial Science, University of Tokyo<br>**Dr. Steven SHAFER**, National Program Leader, Global Change, Natural Resources and Sustainable Agricultural Systems, Agricultural Research Service,U.S.Department of Agriculture |
| 10:45-11:30 | **Keynote speech**<br>**Dr. Katsuyuki MINAMI**, Director General, National Institute for Agro- Environmental Sciences |
| 11:30-12:15 | **Keynote speech**<br>**Dr. Robert LUXMOORE,** President,U.S.Soil Science Society of America |
| 12:15-12:30 | **Introduction of Working Groups** |
| 12:30-14:00 | **Lunch** **[Mita Room]** |

**[Meeting Room A to D]**

14:00-17:00 **Working Group Sessions (Presentations)**

| | |
|---|---|
| WG1: CC at Forest and its management | **[Room D]** |
| WG2: CC at Cropland and its management | **[Room C]** |
| WG3: CC at Pasture/Grassland and its management | **[Room B]** |
| WG4: CC at Paddy/Wetland and its management | **[Room A]** |

18:00-20:00 **Reception** **[Mita Room]**

## October 10, Day 2

**[Auditorium]**

9:30 - 10:15 **Keynote Speech**

**Dr. Syukuro MANABE**, Program Director, Global Warming Research Program, Frontier Research System for Global Change

10:15 -11:00 **Keynote Speech**

**Dr. Steven W RUNNING**, Professor and Director, Numerical Terradynamic Simulation Group, School of Forestry, University of Montana

11:00-11:15 **Coffee Break**

**[Meeting Room A to D]**

11:15-12:45 **Working Group Sessions (Panel Discussions)**

WG1 - WG4

12:45-14:00 **Lunch** **[Mita Room]**

14:00-17:00 **Working Group Sessions (Presentations)**

| | |
|---|---|
| WG5: In-situ measurement of CC | **[Room D]** |
| WG6: Flux-net observation of CC | **[Room C]** |
| WG7: Process model of CC | **[Room B]** |
| WG8: Remote sensing of CC | **[Room A]** |

## October 11, Day 3

**[Meeting Room A to D]**

9:30-11:00 **Working Group Sessions (Panel Discussions)**

WG5 - WG8

11:00-11:15 **Coffee Break**

**[Auditorium]**

11:15-12:35 **Working Group Summary**

WG1 – WG4 (20 min. for each)

12:35-14:00 **Lunch** **[Mita Room]**

14:00-15:20 **Working Group Summary**

WG5 – WG8 (20 min. for each)

15:20-16:00 **Wrap up and closing**

16:00-16:10 **Closing remarks**

**Mr. Lou BROWN**, Senior Staff Associate for International Science Affairs, Directorate for Geosciences, National Science Foundation

**Ms. ChigU.S. HANAOKA**, Director for Earth Science and Technology, Ocean and Earth Division, Ministry of Education, Culture, Sports, Science and Technology (MEXT)

16:10 **Adjourn**

# Appendix B: Welcoming Remark

# Welcoming Remark By Director Of Ocean And Earth Division, MEXT

Yoichiro OTSUKA

On behalf of the Ministry of Education, Culture, Sports, Science and Technology, or MEXT, it is my greatest pleasure that this workshop is held as such a large group of leading researchers both from U.S.nd Japan. Let me express my deepest condolence for the victims in the World Trade Center on Sep. 11, and thank all theU.S.participants for coming to the workshop in this difficult time.

This is the ninth workshop in a series of *US-Japan Workshops on Global Change Research* held under the framework of the *U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology*. Last year a workshop was held at National Institutes of Health in Maryland, U.S. The workshop title was *"Health and the Environment"*. The theme of the workshop this year in Tokyo is *"Carbon Cycle Management in Terrestrial Ecosystem"*.

As a director of Ocean and Earth Division, MEXT, I am responsible for the wide area of research activities on Earth, including global observation of carbon cycle and climate change both on land and ocean. Global carbon cycle is now one of the most important aspects controlling the on-going global warming process. Especially, land area is a hemisphere where the human beings influence significantly. Consequently, this workshop is very important for understanding global carbon cycle and establishing new schemes of management on land.

The 3rd report of IPCC was published this year. The report tells that the annual mean air temperature will rise up to 1.4-5.8 degrees and the sea level will rise up to 9-88 cm at the end of the 21th century. Global warming is also tightly linked with a large number of issues; such as sinking of lowlands, food production, energy problems, biodiversity in the natural environment, and rainfall controlling water resources. The key process is the global carbon cycle and its feed back system. The monitoring of global carbon cycle and climate change, and evaluation of carbon source and sink is the important issues to be addressed in the *U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology.* It is expected that this workshop create bases for the future development of collaborative research activities in *Carbon Cycle Management in Terrestrial Ecosystems.*

I would like to draw your attention to the importance of ocean as well as land in the global carbon cycle. Oceanic carbon cycle is also a significant topic and should be discussed together with land. Ocean covers 70% of the Earth and its carbon flux is comparative to land. Ocean is also important in climate change owing to its large heat capacity. In the ocean, U.S.nd Japan have agreed on various research activities such as global monitoring network known as Advanced Ocean Observation System (ARGO) floats, which map out temperature and salinity from sea surface down to a depth of 2000 m automatically and periodically.

In the global monitoring, the earth observing satellites play an important role as a brige between land and ocean. Japan is now preparing for the launch of Advanced Earth Observing Satellite (ADEOS) II next year. This satellite is equipped with high technology sensors. These are the sensors enable to observe various properties such as atmospheric ozone, water vapor, rain fall, chlorophyll, surface temperature, vegetation, snow, and ice. One of the sensors which observers wind direction and speed on sea surface was developed by NASA. This is also a good example of collaboration between U.S.nd Japan.

Japanese government is now promoting science and technology policy under the leadership of *Council for Science and Technology Policy, Cabinet Office* after the reorganization of the government ministries. The council adopted the global warming as one of five prioritized research topics for 5 years and launched *Global Warming Research Initiative. Global Warming Research Initiative* coordinates activities of five ministries, and forms an integrated Japanese initiative on global warming. In order to meet the requirement of the council, MEXT is now further the research activities on carbon cycle and climate change. The development of monitoring systems and simulations with use of good models are our priority.

Japan is now constructing a sophisticated super computer named ‘Earth Simulator’, which will start operation next year and run at a speed of 40 Terra FLOPS. Global observation of carbon cycle both on land and ocean combined with the appropriate modeling on *Earth Simulator* enables us to develop the research in the global carbon cycle and global warming process. The results will be incorporated into the 4th report of IPCC, to be issues in a few years.

Finally, I do hope that there are good presentation and good communication among U.S.nd Japanese participants in this workshop.

# Appendix C: List of Acronyms

| | |
|---|---|
| ARA | Acetylene Reduction Activity |
| CDM | Clean Development Mechanism |
| CSITE | Carbon Sequestration in Terrestrial Ecosystems |
| DNDC | Denitfification-Decomposition |
| DOC | Dissolved Organic Carbon |
| FACE | Free Air Chamber Experiment |
| FRSGC-ECRP | Frontier Research System for Global Change - Ecosystem Architecture Model Group |
| GCTEGTOS | Global Change and Terrestrial Ecosystems - Global Terrestrial Obeserving System |
| GHG | Greenhouse Gas |
| GHGE | Greenhouse Gas Emissions |
| GLI | Global Imager |
| GRFM | Global Rain Forest Mapping Project |
| GWEX | Global Energy and Water Cycle Experiment |
| HARVCARB | Harvested Carbohydrates |
| IGBP/GAIM | International Geosphere-Biosphere Programme/Global Analysis, Integration, and Modeling |
| IPCC | Intergovernmental Panel on Climate Change |
| LAI | Leaf Area Index |
| LIBS | Laser-Induced Breakdown Spectroscopy |
| LUE | Light Use Efficiency |
| MAI | Mean Annual Increment |
| MEXT | Ministry of Education, Culture, Sports, Science and Technology |
| MN | Mineralizable Nitrogen |
| NBP | Net Biome Productivity |
| NDVI | Normalized Difference Vegetation Index |
| NEE | Net Ecosystem Exchange |
| NEP | Net Ecosystem Production |
| NMP | Northern Mixed Prairie |
| NOAA | National Oceanic and Atmospheric Administration |
| NPP | Net Primary Production |
| OMI | Ozone Monitoring Instrument |
| OTC | Open Top Chamber |
| PAR | Photosynthetically Active Radiation |
| SAR | Synthetic Aperture Radar |
| SGS | Shortgrass Steppe |
| SOC | Soil Organic Carbon |
| SOM | Soil Organic Matter |
| SR | Solar Radiation |
| SS | Stagebrush Steppe |
| TN | Total Nitrogen |
| TOMS | Total Ozone Mapping Spectrometer |
| TP | Tallgrass Prairie |
| USGCRP | US Global Change Research Program |
| VEMAP | Vegetation/Ecosystem Modeling and Analysis Project |

# Apendix D: List of Participants

# 9th U.S.-Japan Workshop on Global Change
# Japanese Keynote Speaker List

October 9-11, 2001
Mita Kaigisyo, Tokyo, Japan

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# 9th U.S.-Japan Workshop on Global Change
# Japanese Participant List

October 9-11, 2001
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