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Ministry of Agriculture, Forestry and Fisheries FY2014 Commissioned Research Project

Establishment of a Recycling-Orientated Food Production System in Response to Global Climate

Utilizing Forests under Climate Change

Forestry and Forest Products Research Institute, Japan.

FFPRI - 3rd Period Mid-term Plan Results 28 (Enhancement of Forest Fumnction-19)

Utilizing Forests under Climate Change

Forestry and Forest Products Research Institute (Independent Government Agency)

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Introduction

Climate change is already occurring, and it cannot be avoided. The 5th IPCC Assessment Report, the latest one, puts this very strongly.

“There is no doubt that climate systems are getting warmer. The atmosphere and the seas are warming, snow and ice volumes are declining, sea levels are rising, and greenhouse gas concentrations are increasing.”

You and I have to come to terms with the fact that we are living in an age of climate change and that we need to put in place measures to mitigate this.

Bearing this in mind, therefore, under the theme of “Utilizing Forests in the Midst of Climate change,” this conference is being held with the aim of reporting the latest research findings concerning the challenges confronting forests and looking at the future. This was researched as part of a project commissioned by the Agriculture, Forestry and Fisheries Research Council (AFFRC) entitled “Project for Establishment of a Recycling-Orientated Food Production System in Response to Global Climate Change.”

Countermeasures for climate change include mitigation measures to reduce the greenhouse gas (GHG) concentrations that are responsible for the effect as well as adaption measures to avoid the harmful effects of climate change. At this conference, in terms of mitigation measures, reports focused on the consideration of countermeasures on the basis of future projections. In terms of adaptation measures, reports focused on observations regarding the impacts of climate change and research findings detailing the damage caused by disease, insects, and the weather.

As stated in the latest IPCC report, 10% of global carbon dioxide emissions are caused by deforestation and the degradation of forests in developing countries. Reducing Emissions from Deforestation and Forest Degradation (REDD+) is an international framework that is being looked at as an important means of reducing emissions to prevent this and is an important mitigation measure. To facilitate the promotion of REDD+, effective technology for monitoring carbon changes in forests is being developed, and we will report the progress in this conference.

To date, FFPRI has continued to contribute to our government and society by conducting research and development on matters pertaining to climate change. Examples include the writing of IPCC reports and the development of methods of accounting for carbon removals by forests using the Kyoto Protocol. We are currently participating in committees related to adaptation plans for Japan, which are scheduled to be formulated in 2015. In addition, in 2010, we set up the REDD Research and Development Center, which contributes to early-stage REDD+ implementation both within and outside Japan.

It is hoped that the new findings contained in “Utilizing Forests in the Midst of Climate change,” which will be presented in this conference, will make a positive contribution to the society and policy by facilitating the development of science and technology in the field of forestry.

Dr. Kazuo Suzuki
President
Forestry and Forest Products Research Institute

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Project Outline

This AFFRC-commissioned project, “Establishment of a Recycling-Orientated Food Production System in Response to Global Climate Change,” is a 16-part project studying the impacts of climate change on agriculture, forestry, and fisheries as well as related mitigation and adaptation measures. The Forestry and Forest Products Research Institute (FFPRI) is responsible for seven of these projects. Findings from the four projects that will end at the end of this ficial year will be presented in this conference.

1. Development of climate change mitigation techniques in forestry and the forestry sector (FY2010–2014)

   Aim: In addition to developing climate change mitigation measures, the aim is to develop models for projecting changes in carbon stocks in forests, forestry, and wood use production, together with techniques for proposing optimum climate change policies.

2. Assessment of the impact on forestry and the forestry sector and the development of adaptation technology (FY2010–2014)

   Aim: Developing technology for monitoring GHGs, predicting the impact on carbon removal and water resources, and evaluating the impact of damage from living organisms as part of climate change adaptation measures.
   *Some information will also be presented regarding challenges faced by our on-going project on extreme weather events.

3. Advanced carbon monitoring in Asian tropical forest by high precision remote sensing technologies (FY2012–2014)

   Aim: To develop technology for accurately and precisely estimating ground carbon stocks collating satellite images and aerial data.

4. Estimation and simulation of carbon stock change of tropical forest in Asia (FY2012–2014)

   Aim: To develop the simulation model to predict changes in carbon stock in response to some scenarios of different speed of forest decrease and degradation.

Oral Presentations

Future Projections and Mitigation Methods regarding CO_2 Emissions and Removals in the Forestry Sector

Mitsuo Matsumoto
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Forestry and Forest Products Research Institute

1. Introduction

There are two different approaches to mitigating the impacts of climate change in the forestry sector: increasing carbon removals in forests and reducing emissions through wood use. These two approaches are intricately related, and neither can be implemented in isolation. If a medium-to-long-term view of mitigation is considered, what contribution can the forestry sector actually make? In this report, after considering climate change mitigation measures in the forestry sector, we will discuss the development of a forest carbon integration model that incorporates forests, forestry, and the wood industry as well as mitigation measures that the forestry sector can implement on the basis of future projections from this model.

2. Contributions to climate change mitigation by the forestry sector

Forests remove carbon dioxide (CO_2) from the atmosphere and store this over a period ranging from decades to centuries. Most of this carbon is returned to the atmosphere when the trees dies and decay or we burned; however, it is removed again by the next generation of forests. Carbon circulates between the forest and the atmosphere; however, the total amount remains the same. The forests, including the soil they are situated on, provide a stable reservoir for carbon and ensure that the CO_2 concentration in the atmosphere is kept down. Forests therefore play a role in regulating CO_2 in the atmosphere, which is the main cause influencing climate change.

If good use is made of woods from forests that are part of this carbon recycling process, this can also contribute to a reduction in CO_2 emissions. The forest industry can mitigate climate change in several manners. Firstly, wooden buildings or furniture are a means of storing carbon (the carbon storage effect). Secondly, at the time of manufacture, wooden construction can substitute for metal materials that require a great deal of energy to produce (the energy saving effect). Thirdly, wood used as fuel can also substitute for fossil fuels and can reduce fossil fuel-derived emissions (the fossil fuel substitution effect). Therefore, removal by forests and emission reduction through wood use are part of the cycle that flows from forests and forestry to wood production, and mitigation measures that take advantage of this feature are required.

3. The role of forests in the Kyoto Protocol report

The Kyoto Protocol set binding targets for developed countries to reduce GHG emissions. For Japan, the binding target for the first commitment period (2008–2012) was a 6% reduction in emissions compared with the base year (1990). During this first commitment period, there were many unforeseen events such as the economic decline due to the Lehman Shock and the increase in thermal power generation due to the halts of nuclear power stations. However, because of the integrated efforts of industry, academia, and the government, this target was achieved.

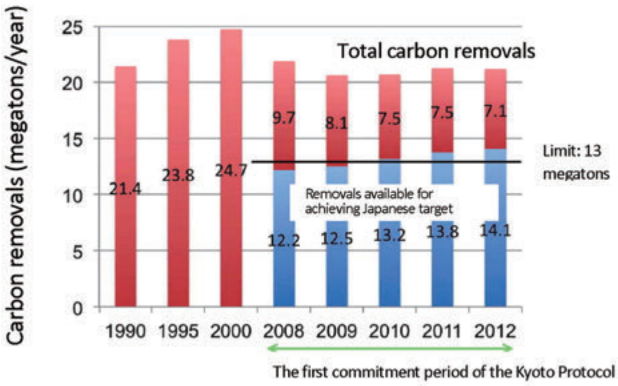

Figure 1. Trends in carbon removals by forests according to the Kyoto Protocol report
Figure compiled from the National Greenhouse Gas Inventory Report[1].

Removals by forests made a major contribution to achieving this target. The rules on calculation allow removals by forests where operations such as forest thinning have been performed after the base year to be included, up to a limit of 3.8% of the base year emissions. The Forestry Agency is promoting thinning; therefore, the mitigation target was finally achieved.

These rules have not changed significantly for the second commitment period; therefore, measures concentrating on thinning are being promoted. However, in the mid-to-long term, many planted forests will be subjected to harvesting; therefore, policies need to be changed to reflect this. Under the present rules, a decline in carbon stocks due to harvesting is accounted as emissions of carbon dioxide. What measures can be put in place under these circumstances?

4. Mitigation measures from the forestry sector

1) Mitigation measures suggested by IPCC

According to the 3rd Working Group Report of the IPCC 5th Assessment Report, the forestry sector provides the most cost-effective means of mitigation. The report cites forestation, sustainable forest management, and reducing deforestation as means of achieving this. The importance of these activities greatly varies according to region. The report also stresses mitigation through the use of wood products as substitutes for fossil fuels and energy-intensive materials such as metals. Of all these mitigation measures, reducing deforestation was the largest contribution that the forestry sector could make; however, this need was concentrated in developing countries. In Japan, sustainable forest management and the use of wood products, including biomass, were considered important.

2) Forest and forestry sector mitigation measures in Japan

This report provides an overview of realistic mitigation measures in Japan and reports on project results.

(1) Harvesting and regeneration

From a carbon cycle point of view, harvesting can be seen as a removal of carbon from the forest and into wood products. Therefore, the amount of harvesting has a major impact on carbon stocks in the forest and emission reduction through wood use. In the case of planted forests, planting after harvesting provides the potential for future carbon stocks. Increasing planting is an effective mitigation measure.

(2) Thinning

If thinning in planted forests is delayed, the height to diameter ratio (form ratio) of the trees increases, a lot of stands contain elongated trees, and the danger of increased CO_2 emissions through wind and other damage increases. In addition, the forest floor is darker, there is less ground vegetation, and the risk of soil erosion therefore increases. Appropriate thinning in planted forests increases the diameter of the trees, prevents damage such as wind damage by reducing the form ratio, and reduces soil erosion by encouraging plant growth on the forest floor. In summary, preserving the integrity of the forest is a mitigation measure to reduce CO_2 emissions.

(3) Use of new and improved varieties

It is thought that climate change will make suitable sites for planted forests with existing species and varieties of trees shift. Therefore, the use of varieties that are resistant to warming and that have positive growth characteristics is not only an important mitigation measure but also an adaptation measure. From that perspective, we will report the results of a research project using an improved cedar variety and the “clean larch” research project in Hokkaido.

Selection of improved cedar varieties [K-05]

FFPRI has developed a “high carbon fixing cedar” variety as a means of combating climate change. This cedar has superior growth qualities and high wood density, and it was selected from a survey of 3,760 elite cedars from throughout the country. From these high carbon fixing cedars, 49 varieties were developed around Japan. Seventeen of these were developed in the Kanto and Chubu districts. This project investigated the use of one of these varieties, Kamitsuga 7.

The Kamitsuga 7 variety showed superior growth in all sites tested. In addition, the wood density was high, indicating a high carbon-fixation ability (Fig. 2). In simulations based on changing existing plantings to Kamitsuga 7, the most significant replanting effect was found in the scenario where there was a gradual increase logging (see 5-3). Therefore, the carbon fixing capacity could be increased as a whole by promoting forestry and the use of these high fixating varieties.

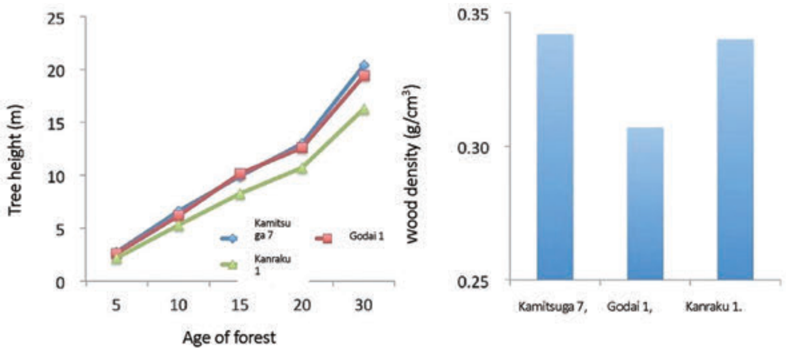

Figure 2. Tree height growth (left) and wood density for each clone at test site 1

The clean larch [K-06]

The clean larch is a hybrid cross between a female Kuril larch (*Larix gmelinii*) clone (Nakashibetsu 5) and a male Japanese larch (*L. kaempferi*) (Fig. 3). It was selected in Hokkaido for its high carbon sequestration. It shows superior qualities of strong wood and a straight trunk. In this project, the practicality of using this variety was evaluated and technological development pertaining to its popularization was initiated.

The mother trees are northern species; however, the clean larch has a higher rate of carbon removals than other larches (Fig. 4). When a growth model derived from the test planting site data is examined, it becomes apparent that even with future warming, carbon removal will be even greater than that currently held in coal seams in most regions of Hokkaido; therefore, the clean larch could be a very effective means of reducing CO_2.

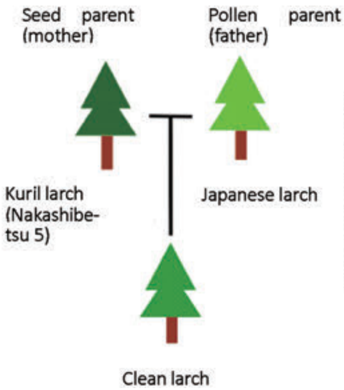

Figure 3. Pedigree diagram of the clean larch

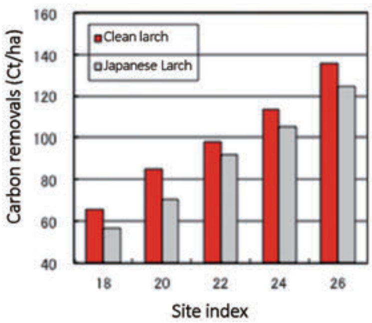

Figure 4. Comparisons between Clean larch and Japanese larch

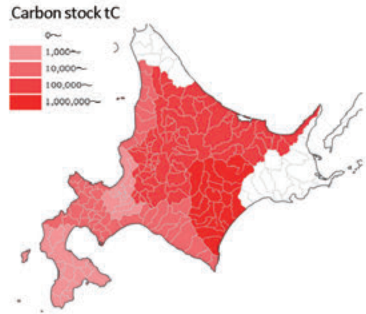

Figure 5. Carbon removals in 2050

Production of seedling of the clean larch has already commenced, and a new seed orchard construction plan was formulated after the clean larch was designated as a specified mother tree in accordance with the Law regarding promotion of thinning. Increased production is already underway. During this project, we plan to mechanize the process of planting and replanting cuttings as a way of increasing production through the use of cuttings. In addition, to promote early carbon sequestration, we built a growth model of the relationship between the photosynthesis rate and light environment to model the optimal band for replanting. Based on the seed orchard construction plan and this project as well as on the future reforested area forecast by the Hokkaido Government, the estimated carbon removals from clean larch in 2050 will be 2,864,000 tons of carbon (Fig. 5).

3) Mitigation through wood use

(1) Increasing the volume and proportion of wood used in construction and furniture

Increasing the volume and proportion of wood used in construction and furniture means an increase in the volume of carbon stocks in wood, which assists with mitigation measures. Approximately 60 years ago, around 90% of construction floor area in Japan was wood. Wood was also used for non-residential buildings such as multi-storey offices, shops, and factories. High economic growth and the Ban on Wooden Building Construction proposed by the Japan Architecture Association have led to a reduction in wood construction. However, the amount of wood construction has not dropped below 30%, and it now stands at around 35% for the past 30 years. The construction of wooden furniture shows the same trend. More recently, with the "Act for the Promotion of the Use of Wood in Public Buildings" and the "Architectural Vision 2050" espoused by the Japan Architecture Association, the use of wooden construction even in non-residential buildings is gaining momentum. Three-story wooden buildings account for 70% of the floor area made from wood; therefore, with a relaxation of the regulations, an increase in wooden construction is possible. The same is the case with furniture. If wood use increases, this could reduce CO_2 emissions through carbon stock, energy savings, and fossil fuel substitution.

The development and promotion of the new wood building material cross-laminated timber (CLT) is one example of technology that is expected to increase the absolute volume and proportion of wood being used. CLT is made up of large panels constructed from layers of dimensional lumber oriented at right angles to each other and bonded together. They can be used even in large-scale building construction; therefore, they are expected to play a part in encouraging the use of wood. CLT is featured in a research project under the auspices of the AFFRC Research Council-commissioned research entitled "The Development of Advanced Utilization Technology for Harvested Wood." This project explores the practical application and popularization of this technology.

(2) Increasing amount and rate of the use of wood in civil engineering

If the wood usage rate is also increased in the field of civil engineering, it will lead to more general usage of wood, more carbon sequestration, and the mitigation of climate change. Traditionally, wood was the main material used in civil engineering. However, after the depletion of forest resources following World War II, the cabinet put in place wood rationalization measures, leading to its substitution with concrete and steel.

Recently, the "Act for the Promotion of the Use of Wood in Public Buildings" has described wooden structures to be used as guardrails and noise dampening barriers. The Timber Engineering Committee of the Japan Society of Civil Engineers, the Japanese Forest Society, and the Japan Wood Research Society have proposed a plan to surpass the presently estimated 1 million m^3 of wood used to 4 million m^3 by 2020, and this plan for the recovery of the wood used is in process. Civil engineering structures that can be made out of wood are diverse, including bridges and erosion control dams. However, there is a major potential for wood to be used in road structures such as guardrails and for ground stabilization in soft swampy areas where logs can be driven into the ground. Research on how all these uses can reduce CO_2 emissions through energy saving is underway; however, if logs used in ground stabilization are driven below the water table, they do not rot, and this also could contribute to emission reductions through the carbon storage effect. The Forestry Agency is setting up demonstration projects in each prefecture.

(3) Biomass use

The use of biomass results in a reduction in CO_2 emissions through its use as a substitute for fossil fuels. Even now, the Feed in Tariff (FIT) system for electrical power means that the use of woody biomass from forestry and construction waste is being strongly encouraged. Such wood industrial wastes are used at 95% efficiency. The Construction Recycling Act is concentrating on recycling waste from the wood industry, with an emphasis on its use in energy production. It can be burned in stoves and boilers in the form of pellets, chips, and firewood for heating and electricity generation and can be mixed with coal in thermal power plants. Further use of woody biomass would require an increase in the flow of woody waste materials, which would mean fundamentally increasing the use of wood products.

5. Future projection of CO_2 emission [K-07]

1) Why is future projection required

Climate change gradually progresses over several decades, and forests are managed in units of at least several decades. Therefore, the impacts of climate change and measures to counter it in the forest sector are forced to be thought on a medium-to-long-term basis from several decades to hundred years. In addition, the effects of mitigation measures also show up after a medium-to-long period of time; thus, future projections are also required to assess the effects of mitigation measures. Moreover, if future projection with models becomes possible, it will allow back-casting to set future goals that we want and examine what mitigation measures we should take to achieve these goals. Therefore, to examine the mitigation measures in the forest sector, it is necessary to compare their effects on the basis of medium-to-long-term projections.

2) A carbon integrated model for forests, forestry, and wood use

As discussed above, any mitigation measures in the forestry sector have to address both carbon removal in the forest and carbon emission reduction through wood use. These two factors are closely intertwined, and the forests and wood industry cannot be considered separately when making projections. The role of forestry is to connect forests and wood use. To reflect this close association, we have developed a carbon integrated model for forests, forestry, and wood use (hereinafter referred to as the integrated model).

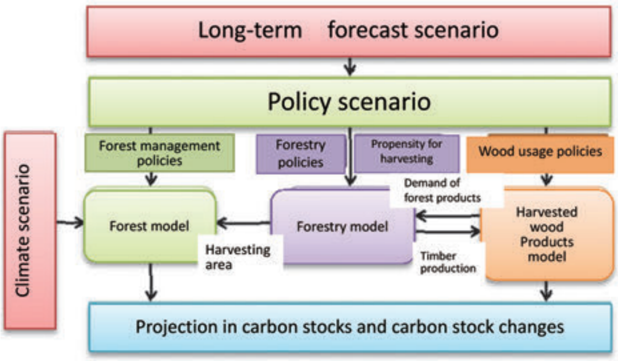

Figure 6. A carbon integrated model for forests, forestry, and wood use

The integrated model consists of the forest model component that uses environmental and geographical factors to estimate the productivity of the forest, the forestry model component to predict the area felled and the volume of felled timber, and the harvested wood products model component that predicts the log volume used for each product (Fig. 6). The forestry model component predicts the log production using various policy scenarios. The value for estimated log volume is passed to the forest and harvested wood products models, and forecasts are performed by each component of the model.

(1) Forest model

To obtain the initial value for forestry resources used for the projection, a forest database was created from the National Forestry Resources Database on the basis of forestry registers and the Forestry Resource Monitoring Survey Database using 3rd Mesh of National Numerical Information (around one-kilometer grids). The forest model is made up of a vegetation model and a soil model. and it calculates growth and carbon increases in response to resources and climate. At the same time, it calculates felling and carbon reduction on the basis of scenarios and is structured so that it sequentially updates the forestry database (Fig. 7). Forest types used were cedar, cypress, larch, natural forests (mostly broadleaf trees), and others (pine, spruce, fir). The distribution patterns of the natural broadleaf forests were determined through remote sensing and ground-based surveys (Fig. 8). Based on these surveys, natural forests were divided into evergreen and deciduous, and carbon stocks of natural forests were estimated.

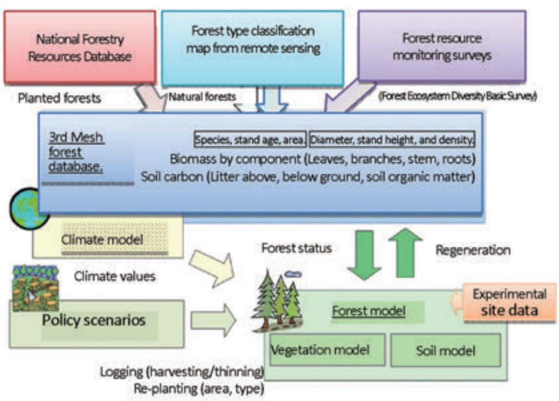

Figure 7. The relationship between the forest model and forest databases

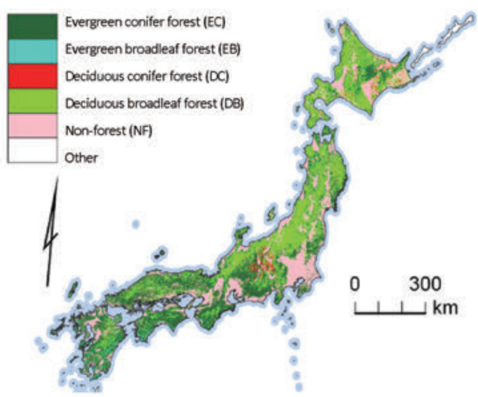

Figure 8. Forest distribution map from remote sensing and ground surveys (Landsat TM&ETM+) [K-03]

(2) Harvested wood products model (K-04)

This model was developed to quantitatively measure the carbon stocks, energy saving, and fossil fuel substitution effect for wood used in construction, furniture, paper, and civil engineering. If pulp is excluded, it is estimated that Japan uses 60%–70% of wood in construction, followed by furniture, packing material, and civil engineering. Paper is another wood product that is extensively used in the society. These products are divided into four usage types. Long-lasting construction and furniture products, short lasting but highly used paper, and civil engineering products, which are predicted to increase. The input volumes for these products are easy to measure; however, estimating the volume of waste is harder. Therefore, because it is difficult to measure the total amount of current stock, this model uses the input volumes to estimate it (Fig. 9). At present, this model does not distinguish between domestic and imported wood material; however, in future, this will be able to be estimated from the forestry model output.

An overview of the estimates is presented below. For the carbon storage effect, the stocks of wood material used in construction were calculated each year and converted to carbon stocks. From this value, carbon emissions and removals from products derived from felled timber within Japan were calculated. To estimate the energy saving effect, the unit emission values for each wooden product were estimated, as shown on Table 1. The fossil fuel substitution effect was estimated by calculating the calorific values produced by the wooden material and converting them equivalent oil volumes.

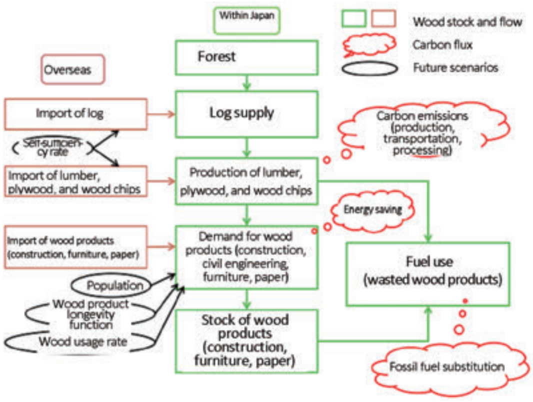

Figure 9. The structure of the harvested wood products model

Table 1. The substitution effect for housing and non-housing

Unit: Kilotons of carbon	Increase	Decrease	Total change	Total change by floor area (kg-C/m2)
Housing	883	-1,070	-187	-31.6
Non-housing	793	-1,033	-240	-34.9
				32.8 *Area-weighted average

3) Policy scenarios

Because predictions greatly vary depending on future policies, five policy scenarios were created (Table 2). The "conservation scenario" assumed a reduction in felling and an emphasis on the preservation of resources. The "status quo" scenario assumed that current policies would be continued. The "gradual increase logging" scenario assumed that the promotion of forestry and wood use would gradually increase. The "owner-driven" scenario reflected the intent of forest owners. Lastly, the "basic plan" scenario was based on ambitious forestry expansion in line with the new Forest and Forestry Basic Plan. However, these scenarios cannot be entirely controlled through policies, and in reality, they can all change through the development of technologies regarding forestry and competing materials, world economic and political conditions, and the changing attitudes of forest owners. Therefore, it needs to be understood that the scenarios are interrelated with policies and used for the purpose of making predictions.
The scenarios are described in more detail below.

(1) Forestry indicators

Under the "status quo" scenario, the age distribution of forest stands becomes older; however, because the area for harvesting remains the same, the productivity only shows a slight rise. The assumption is that the area of planted forests does not increase.

Under the "gradual increase logging" scenario, the forest will contain a diverse range of forest stand ages. Forest stands will be fully utilized at 200 years of age, 20% utilized at 80 years, and up to one-third will be utilized at 100 years. Under this logging plan, the production volume would double from the initial volume by 2050. In contrast, under the "conservation" scenario, assuming that the level of self-sufficiency stays constant, the demand for timber will decline, leading to a concomitant decline in domestic timber demand. Out of the five scenarios presented, this one will lead to the lowest felling volume and the greatest preservation of forests. Under the "owner-driven" scenario, the exact conditions will depend on the region and type of tree; however, based on an opinion survey of forest owners who are part of a forestry cooperative, 15%–30% of planted forests will be harvested between 2011 and 2030 and 25%–30% will be harvested between 2011 and 2050. In total, 0.75%–1.5% of the total area would be harvested each year. Of all five scenarios, this is the one leading to the most harvesting.

Table 2. Indicators for the five scenarios

Scenario	Forestry indicators			Wood use indicators	
	Harvesting area	Re-planting ratio	New varieties used	Building construction, furniture	Civil engineering
Conservation	Less than at present	More than at present	None	Present ratios (35%)	Civil engineering
Status quo	No change	Present rate	None	Present ratios (35%)	Present volume (1 million m³)
Gradual increase logging	More than double the present area by 2050. (20% of planted forests by 80 years of age, one-third by 100 years).	Present rate	None	Increasing to 50% by 2050	Present volume (1 million m³)
Owner-driven	15%–30% increase between 2011–2030. 25%–30% increase between 2031–2050. according to questionnaire results	Increasing to 70% for larch and 50% for cedar and cypress, according to questionnaire findings.	None	Increasing to 70% by 2050	Increasing to 6 million m³ by 2050
Basic plan (aggressive forestry and wood use)	Log production: 39 million m³ by 2020, 50 million m³ by 2050. Major increase in harvesting area, use of thinned logs.	Increase	Increasing to 70% by 2050.	70% production by 2050	6 million m³ by 2050

The scenario for the "basic plan" assumes that the plan will be consistent with the Forest and Forestry Basic Plan formulated in July 2011 and the National Forest Plan for the period between April 2014 and March 2029. The scenario also assumes that the shift from thinning being discarded to being used, together with an increase in harvesting, will contribute to a production volume of 39 million m³ by 2020 and an increase to 50 million m³ by 2030, with an average annual increase of 63,000 ha of forest over the 15-year period. Of the five scenarios, this one shows the second greatest increase in logging after the "owner-driven" scenario and predicts that the increase in logging activity will continue until 2050.

All the scenarios predict an increase in the usage ratio of thinned timber as the forest stands aging; however, the greatest increase is for the "basic plan" scenario, in which 80% of thinning timber is to be used. When the scenarios were examined from the point of view of feasibility, we evaluated the conditions when the re-planting ratio becomes 50% or more; prices per cubic meter for cedar (70-year cutting period), cypress (70-year cutting period), and larch (50-year cutting period) should be equal to or more than 10,000 yen, 17,000, yen and 9,000 yen, respectively, at the present state of productivity. These conditions will change if productivity improves or costs decrease.

(2) Wood use indicators

For these indicators, we used three indicators while concentrating on the use of wood products in building construction, furniture, and civil engineering. In this past 30-year period, approximately 35% of building floor area and articles of furniture has been made from wood. During the same period, the amount of wood used for civil engineering has been around 1 million m3. These values were assumed to be comparable with the current values and used for the "status quo" and "conservation" scenarios.

It is expected that the Act for the Promotion of Wood Use in Public Buildings will prompt a revival in the use of wood in the construction of non-residential buildings and in civil engineering. In total, 70% of the construction floor area is for ≤three-storey buildings that can be built out of wood; therefore, an increase in wooden construction in medium-to-large-scale production projects is likely. For furniture, there is essentially nothing limiting the use of timber. The Wood Construction Committee of the Japan Society of Civil Engineers, the Japanese Forest Society, and the Japan Wood Research Society have proposed a scheme to increase the use of wood in civil engineering to 4 million m³ by 2020.

In consideration of these expectations, the “owner-driven” and “basic plan” scenarios assume that 70% of construction and furniture will be of wood by 2050, and wooden construction in civil engineering will amount to 6 million m³. The “gradual increase” scenario assumes an intermediate level of 50% wood and wooden construction and 3 million m³ for civil engineering.

4) Projected results

Based on the five scenarios shown above, projections were made till 2050 using the integrated forestry carbon model, and the results are shown in Fig. 10. To evaluate the mitigation effects discussed earlier regarding forests, forestry, and wood utilization, we used the sum total of the changes in carbon stocks in forests, changes in carbon stocks due to the carbon storage effect of wood use, and emission reductions due to the energy saving effect and the fossil fuel substitution effect. Changes in carbon stocks are expressed in tons per year of carbon. To convert this to CO_2, the molecular weight ratio “44/12” is multiplied.

Carbon stock changes in forests are large in the “conservation” and “status quo” scenarios and comparatively lower in the other three scenarios. This difference is due to increases in logging and reflects the carbon removed by felling. However, although there were minor fluctuations in the carbon stock change under each scenario, there were no major fluctuations during the period until 2050. Each scenario shows similar peaks and troughs in the carbon volume; therefore, these are likely to be because annual changes in temperature and precipitation of the climate scenario have effects on forest growth.

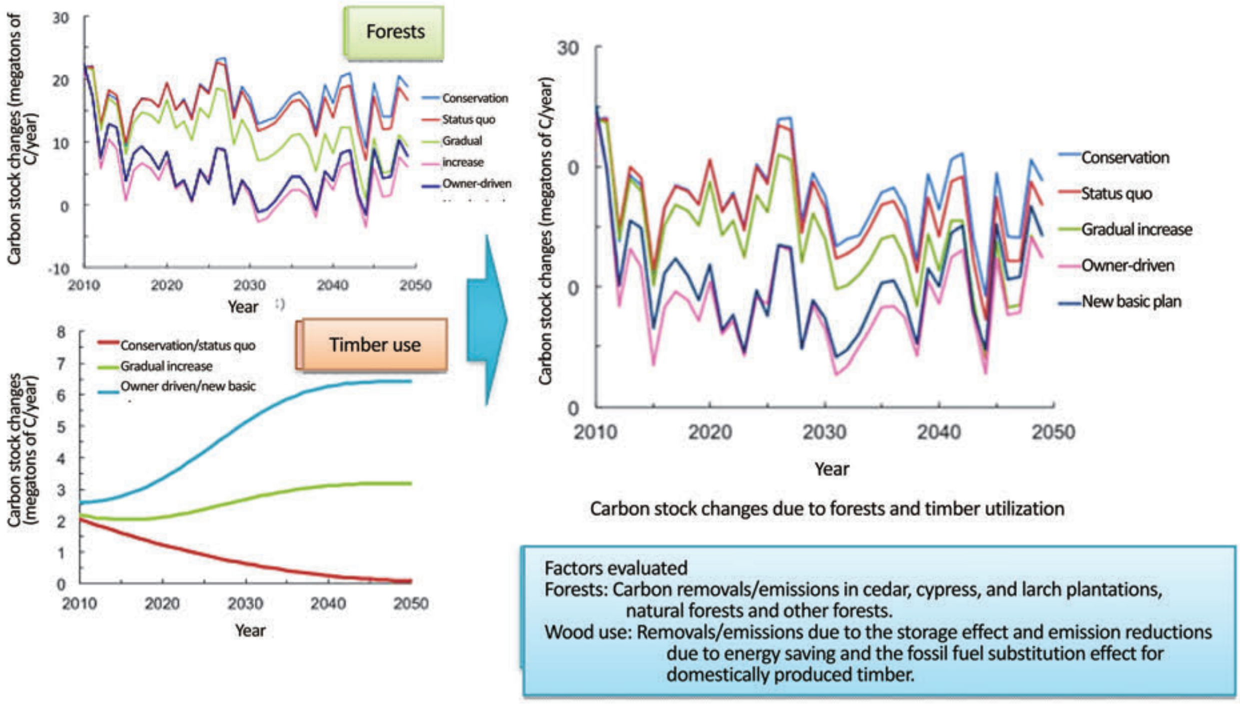

Figure 10. Carbon stock changes due to forests and timber utilization

The top left shows carbon stock changes in forests.

The bottom left shows the sum total of carbon stock changes due to wood use (carbon sequestration) and emission reductions from the energy-saving effect and fossil fuel substitution effect.

The right shows carbon stock changes in forests and timber use.

In contrast, the scenarios for the three timber use indicators show major differences in predictions in terms of the carbon stocks depending on the scenario. Under the “conservation” and “status quo” scenarios, the carbon volume reduces each year as the clear felling volume is small. In addition, carbon accumulation is reduced, leading to a concomitant decline in emission reductions associated with the energy saving and fossil fuel substitution effects. This can be contrasted with the "owner driven" and "new basic plan" scenarios promoting the production of timber products, in which emission reduction is particularly prevalent. The change in the total carbon volume includes the contribution from timber use; therefore, the differences among the scenarios in terms of removal by the forests are comparatively minor, particularly after 2040. By 2050, the "conservation" scenario is top in terms of the change in the total carbon volume, followed by the "status quo" scenario, and the major differences between the "gradual increase" scenario and the "new basic plan" scenario have almost disappeared.

Fig. 11 shows a breakdown of changes in carbon volumes in 2030 and 2050 under the five scenarios, revealing the major differences between each scenario. Under the "conservation" and "status quo" scenarios, the removal of carbon in the forests is high, particularly for natural forests. Under the "gradual increase" and "new basic plan" scenarios, the carbon removal rates are 55% and 47%, respectively, of those under the "status quo" scenario. Under the "status quo" and "conservation" scenarios, carbon in timber is a source of emissions because of population decline as the demand for timber is reduced. Under the "owner-driven" scenario, clear felling increases to such an extent that the forests are predicted to become an emission source. On the other hand, under the "basic plan" and "gradual increase" scenarios, the reduction in emissions due to the energy saving and fossil fuel substitution effects will be extremely large. Consequently, in 2050, total carbon stock changes (made up of both the carbon removals in the forests and the emission reductions through timber use) under the "gradual increase" scenario will be 75% of those under the "status quo" scenario and 88% of those under the "basic plan" scenario, revealing no major difference.

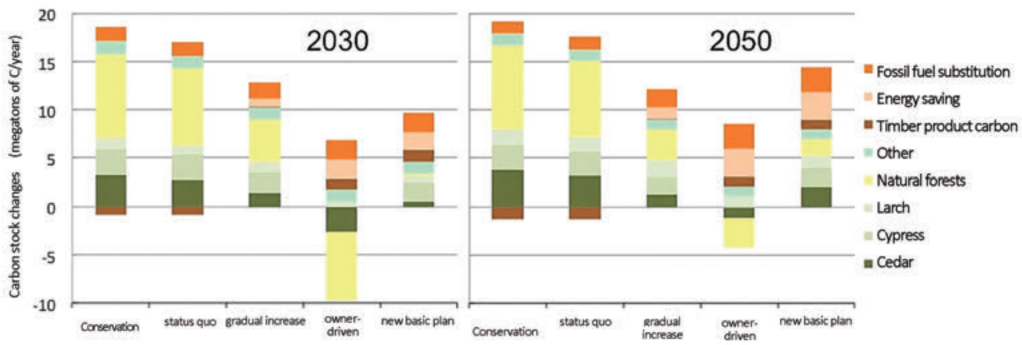

Figure 11. A breakdown of future predicted carbon stock changes

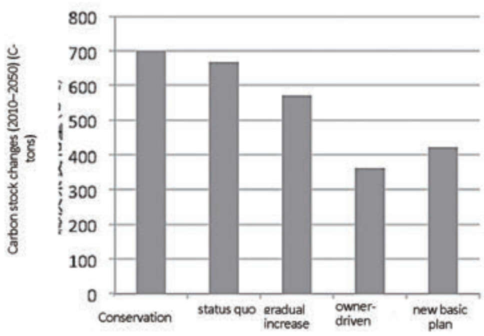

Figure 12. Total sum of carbon stock changes (2010–2050)

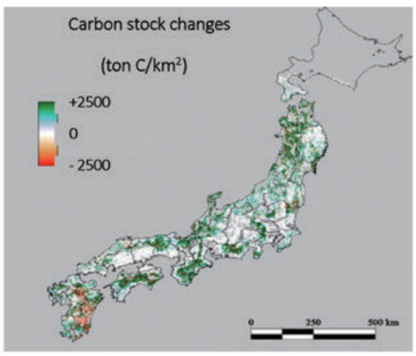

Figure 13. Carbon stock changes for cedar forests under the "basic plan" scenario

Fig. 12 shows the changes in accumulated carbon stock changes for each scenario for 2010–2050. The graph shows the superior effectiveness of the "conservation" and "status quo" scenarios, with the "gradual increase" scenario close behind, at 85% of the "status quo" scenario. The "basic plan" scenario accumulates 63% of the "status quo" scenario, probably because of the size at harvesting and the re-planted forests still being young. The "basic plan" scenario mitigates this by increasing re-planting and using improved varieties, and this effect would be strong once most of the replanted forests have reached their vigorous growth phase. Although this research only projects what should happen up to 2050, it is expected that the characteristics and benefits of the "basic plan" scenario will become evident after that time. When making medium- or long-term projections or comparisons, it is important to be aware that the results will differ depending on the duration of the period under consideration.

The integrated forestry carbon model has features that geographical distribution is also taken into account and the nationwide distribution can be easily illustrated. Fig. 13 shows the carbon stock changes for cedar forests under the "basic plan" scenario. This shows that carbon stocks will be increasing nationwide; however, in the Kyushu and Honshu forestry regions where harvesting is being promoted, carbon stocks will be declining. Carbon stocks are estimated to increase along the Japan Sea side of the Tohoku region, the Kii Peninsula, and Shikoku. Based on current logging activity there, harvesting will not increase; therefore, it represents a potential for promoting forestry in these regions.

5) Discussion

These projections can be summarized as shown below:

- Carbon removals by forests will remain stable in the medium term under all scenarios, and forests will not become a source of emissions.
- The emission reduction effect from wood use is approximately the same as the removal effect by forests, as far as mitigation is concerned.
- The carbon removals by forests and the emission reductions by wood use greatly vary among scenarios.
- Although carbon removal by forests declines with an increase in harvesting, increase in emission reduction due to higher wood use mostly compensates for this.
- Results vary depending on the time period, method used, and duration of the projection period.

Determination of which scenario would be the most effective requires consideration of not only climate change mitigation but also factors such as industrial and regional development as well as the other functions of forests. For example, if climate change mitigation measures were considered together with regional and industrial development, the "gradual increase" and "basic plan" scenarios are almost as effective as the "status quo" scenario at mitigating climate change but are better at growing the regions and the wood industry and would therefore be more realistic.

6. Related research

In this project, while considering the mitigation measures detailed above, we conducted other related investigation. The results of such investigations are reported below.

1) GHG removals and emissions from forest soils [K-02]

Results from observations of the emissions and removals of three types of GHGs from forest soils [CO_2, methane (CH_4) and nitrous oxide (N_2O)] in more than 30 locations over a period of several years were combined with climate data to provide a wide area predictive model. This model was combined with sub-models estimating the soil temperature and water content; therefore, it could also be used to estimate climatic changes. The model was applied to forests within Japan to produce a wide area map showing the emissions and removals of the three GHGs (Fig. 14). In addition, when using this model to estimate the emissions under climatic conditions experienced in the past, it became clear that gas emissions of these three gas species were showing a tendency to increase (Fig. 15).

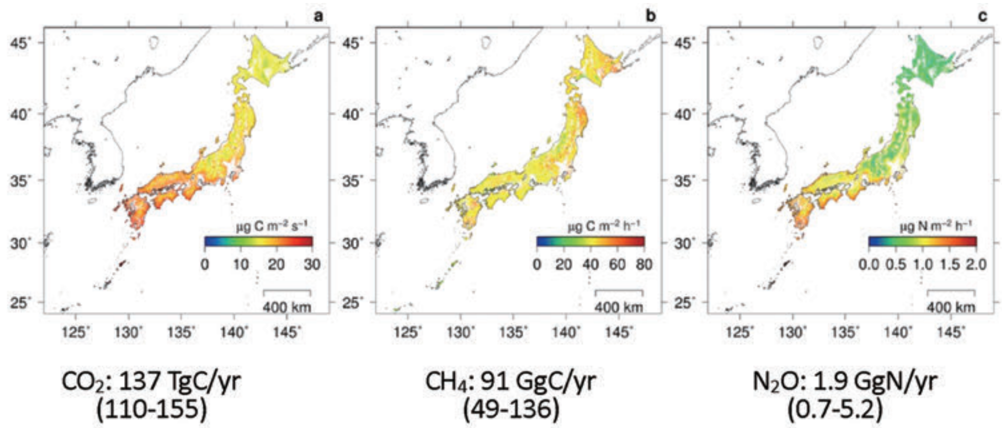

Figure 14. Wide area estimates for GHG emissions and removals from forest soil.

Graphs for CO_2 and N_2O show emissions, while that for CH_4 shows removals. Values in parentheses are 95% confidence intervals. The right shows changes in the total carbon in forests and timber use.

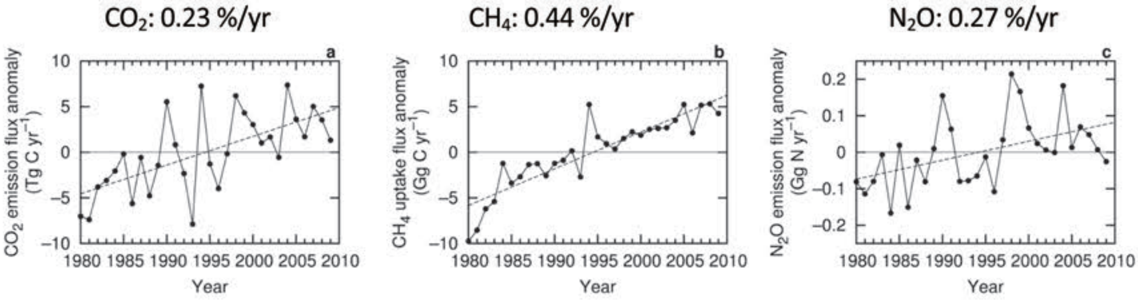

Figure 15. Estimates of past GHG emissions and removals using a wide area estimation model

We have not only modeled trends in GHG increases but also used the MIROC scenario, atmospheric change predictions, and the IPCC atmospheric concentration predictions to forecast future GHG emissions and removals. These results show a simple increase in CO_2 and N_2O emissions. CH_4 removals are expected to decline from around 2050 (Fig. 16).

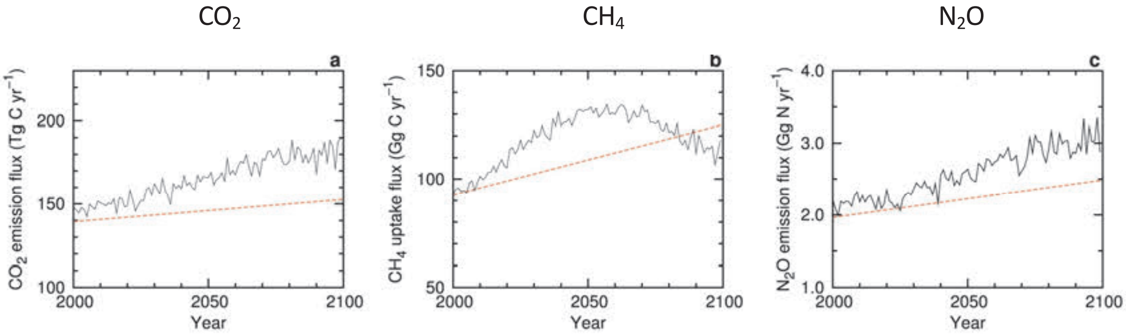

Figure 16. Future GHG emission forecasts using a wide area estimation model

Scenario data: Inputs from the MIROC A1B scenario, (CMIP3), atmospheric methane concentration scenario (IPCC, 2000).
Modeling: Hashimoto et al. 2011 gas model scenario. 1-km grid, 1-month units.
Orange dashed line = linear trend 1980–2009.
During this time period, the atmospheric methane concentration is forecast to decline in response to the trends shown.

This model can produce a wide area prediction in response to climate change, including responses to CH_4 and N_2O that do not have to be reported under conventions such as the present Framework Convention on Climate Change or the Kyoto Protocol.

2) Impact of CO_2 and ozone concentration increases [K-01]

Both CO_2 and ozone concentrations in the air have been increasing every year as a result of burning fossil fuels such as petroleum and coal. How will trees grow in a future with high levels of these two gases? To answer this question, we set up an outside trial to provide set levels of CO_2 and ozone (Fig. 16) and monitored the growth of the trees. Contrary to what was expected, ozone did not reduce the growth rate. When ozone and CO_2 were both increased, the growth of the oak species *Quercus mongolica* and *Q. serrata* was stimulated (Fig. 17). It is thought that the higher growth rate caused by high CO_2 concentrations improves the carbon sequestration function of trees. Ozone was thought to inhibit this function; however, in some species, high ozone concentrations in a high CO_2 level can actually dramatically improve it.

Trial equipment providing CO_2 and ozone outside.
CO_2 concentration
Control: Approximately 380 ppm (present concentration)
High CO_2 treatment: Approximately 550 ppm (predicted 2050 levels)
Ozone levels in the experimental group were set at roughly twice the control level.

Figure 16. Photograph of the experimental equipment and concentrations used.

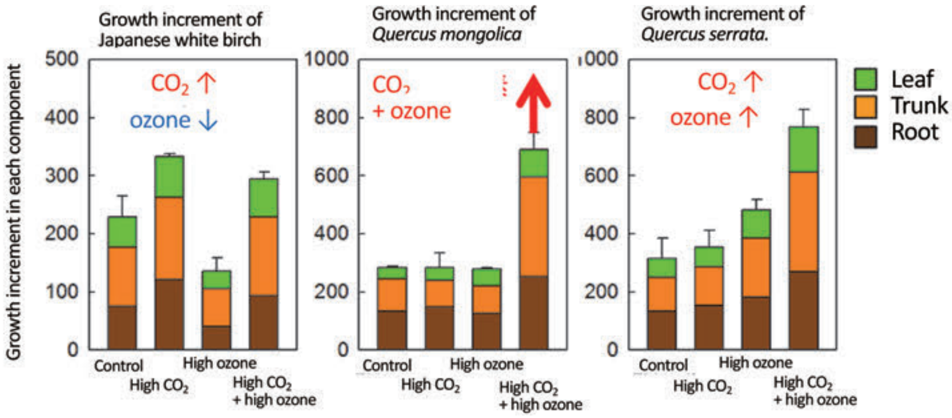

Figure 17. The effect of high CO_2 and high ozone treatments on the growth increment of three broadleaf trees. *The growth increment for the Japanese white birch is for after one growth cycle, while the growth increment for *Quercus crispula* and *Quercus serrata* is for after two growth cycles.

Ozone depletes photosynthesis in the leaves, which are the driving force for growth. It is known that one of the defense mechanisms that plants have in response to ozone is an enhanced carbon allocation into leaves and branches to compensate for the reduction in photosynthesis while suppressing root growth. The two *Quercus* species can synthesize isoprene, which mitigates the effect of ozone and makes them less susceptible to its advense effect on photosynthesis. The enhanced allocation into leaves and branches as a defense mechanism against ozone, in combination with an increase in CO_2, is thought to contribute to the dramatic increase in growth.

3) The thermal barrier effect of green shade [K-08]

One of the proposals put forward as an adaptation measure to climate change is research regarding how to make use of the green shade provided by local suburban forests as a way of raising the awareness of heat-related health threats such as heat stroke and ways of avoiding these.

Here we propose to use the Wet Bulb Globe Temperature (WBGT) as an indicator for determining the cooling influence of green shade. To properly ascertain the thermal environment, in addition to air temperature, humidity, wind speed, and radiation heat must be taken into account and comprehensively evaluated. The WBGT uses a black bulb thermometer (globe thermometer) and a wet bulb hygrometer to calculate a value on the basis of the equations below. The WBGT is also referred to as a heat index 2.

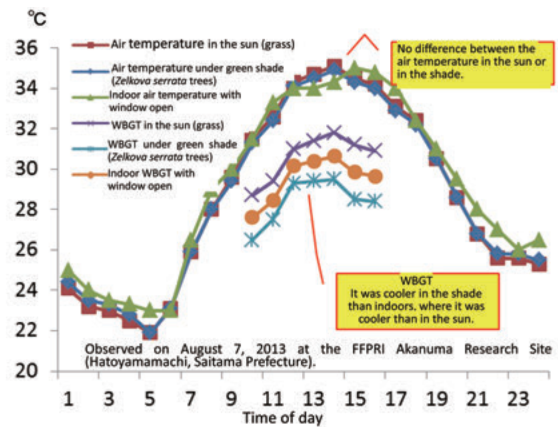

Fig. 18 shows the air temperature and WBGT value in the sun, indoors, and under green shade in midsummer.

WBGT = 0.7 NWB + 0.2 GT + 0.1 NDB: Outdoors exposed to solar radiation

WBGT = 0.7 NWB + 0.3 GT: Indoors, or outdoors, exposed to no solar radiation.

Natural Wet Bulb (NWB): Wet bulb temperature exposed to natural airflow and sheltered from radiation.
Globe Temperature (GT): Black globe temperature.
Natural Dry Bulb (NDB): Dry bulb temperature exposed to natural airflow

There is no difference in the air temperature; however, for WBGT, it was cooler in the shade than indoors, where it was cooler than in the sun. This shows not only that WBGT is a useful indicator for determining that green shade is an effective heat barrier but also that green shade could be a shelter during extreme heat waves that could protect the health of infants and the elderly.

6. Conclusion

To date, Carbon sequestration by forests has been highlighted as a mitigation measure in the forestry sector. The regulations changed after the first commitment period of the Kyoto Protocol, and now, the carbon storage effect of harvested wood products can be evaluated. There has been some general discussion on the emission reduction effect of wood use, and some evaluation has been conducted on considering this effect in isolation; however, there have been no investigations considering the connections between forests and wood use.

The integrated forest carbon model that combines forests, forestry, and wood use provides a consistent means of evaluating the mitigation effects of all these effects together and can clarify differences under various scenarios.
In parallel with our integrated forest carbon model, we have conducted related research evaluating the impact of ozone, estimating emission and removals of GHGs from forest soil, constructing forest distribution maps on the basis of remote sensing and ground surveys, developing superior tree varieties, and evaluating the effectiveness of green shade as a heat barrier. We would like to see these technologies adopted by the society.

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2) Ministry of the Environment, Environmental Health Department, Environmental Safety Division (2014). The WBGT heat index: An indicator for heat stroke prevention. Heat Stroke Environmental Health Manual, 60-61.

The Impact of Vegetation, Natural Disasters, and Pests on Forests and Related Adaptation Measures

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1. Evident of trends of Global warming from weather reports

The massive increase in torrential rain and large-scale typhoons, which often resulted in natural disasters such as flooding and landslides, reported almost weekly in the world news. We recognized global warming and climate change has come to our daily life. Although we recognized the effects of global warming by changes in seasonal phenomenon, for example, sudden unseasonable blizzard and flowering, there has been little scientific study regarding the impact of climate changes on forest ecosystems and natural disasters.

According to the Japan Meteorological Agency, temperatures have risen at a rate of 1.15°C in the 100 years since 1898 and extreme hot days and nights have increased in number[1]. However, this increase widely fluctuates. From the 1940s to the 1960s, the increase was relatively small; however, from the 1960s to the late 1980s, the increase has continuously been high (Fig. 1). Warming-induced evapotranspiration has led to higher amounts of atmospheric water vapor, which would contribute to a higher rate of rainfall overall. Such a trend is hard to find actually in Japan where the total number of rainy days has declined. However, the number of days of heavy rain, where daily rainfall reached 100 mm or even 200 mm and above, has increased (Fig. 2). In addition, high temperature and high rainfall years seem to follow each other, as do cool summers and drought years. The fluctuations between the maxima and minima temperature are also more pronounced. Climate change can be clearly seen through meteorological data reported by the Meteorological Agency of Japan.

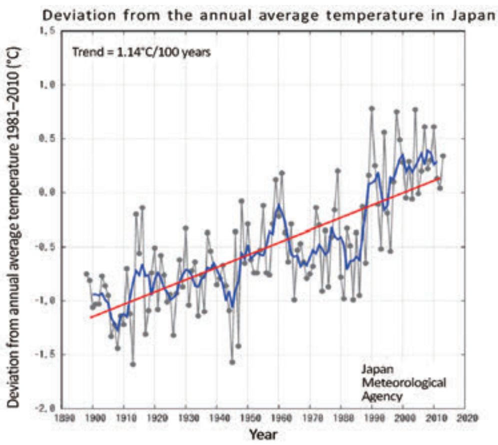


Figure 1. Change in average yearly temperature in Japan[1].

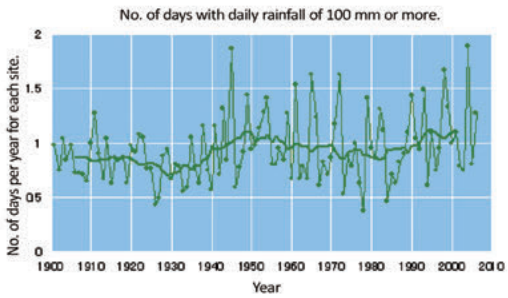


Figure 2. Change in the number of days with daily rainfall of 100 mm or more[1].

The increases in temperature correspond with increases in the concentration of CO_2 and other greenhouse gases (GHGs) that are said to be responsible for global warming; however, the relationship between the two is complex and some skepticism remains. Because different scientific teams produce quantitative models, these results, together with weather data, provide majority support for the link between GHGs and increases in temperature. CO_2 emissions from human activities through consumption of fossil fuels, land-use change, and others are significant, which are influenced by economic conditions and energy sources.

Various predictions regarding temperature fluctuation patterns in future can be made on the basis of economic development and different mitigation countermeasures. Although these predictions involve large uncertainties, under various scenarios, it has been concluded that by the end of 21st century, it will be too late to wait the facts. What this means is that countermeasures to mitigate global warming are not sufficient and that measures to adapt to global warming should be prepared as soon as possible. Such plans are already in place at the government level in countries such as the

UK and Netherlands. In Japan, similar plans are being prepared, aiming for Cabinet approval in the summer of 2015.
This report is based on research conducted by FFPRI as part of the MAFF-funded climate change project. It presents case studies regarding the evaluation of the effects of climate change on forests and measures that can be taken to avoid or adapt to new climate regime. However, we decided to expand on the initial project plan by including the impact of global warming on landslide in mountainous areas and deficit of water resources. Although there are only a few case studies available, we will discuss possible adaptation measures to climate change in light of the findings of those studies.

2. Changes in forest vegetation due to global warming (Poster T-01)

Weather reports and modeling data predict that the effects of global warming will be particularly noticeable at high altitudes and higher latitudes. It is predicted that the area of cool habitat suitable for beech growth will decline under global warming in future[2]. Other effects of climate change in cool ad cold area, such as the reduction in the polar ice caps and the retreat of mountain glaciers, have already been reported in IPCC reports. Similarly, the effect of the 1°C or more increase in air temperature over the last 100 years must be reflected somewhere in the Japanese forests.

This project concentrates on the growth rate in the evergreen broad-leaved forests of Japanese oak (*Q. acuta*)[3]. Because forest vegetation is affected by anthropogenic disturbances such as logging and fire wood collections, old-growth natural forests owned by shrines and temples were suitable for our research as they were less likely to have been disturbed.
A 20-ha research site on the southern slopes of Mt. Tsukuba was studied. The upper regions of the slope were covered by deciduous forests and the middle regions were covered by evergreen forests. The canopy area of the evergreen broadleaved trees was investigated using a combination of ground-based fieldwork and aerial photographs of the area taken between 1961 and 2005 (Fig. 3). The results showed that the area of broadleaved evergreen canopy, of which *Q. acuta* was a main part, gradually increased by 44% over a period of 33 years (Fig. 4). The altitude limit for *Q. acuta* habitat has shifted upward by approximately 150 m over the past 100 years, to such an extent that it could become established on the summit of the mountain. We concluded that this expansion of the canopy area of *Q. acuta* is likely to be a result of global warming.

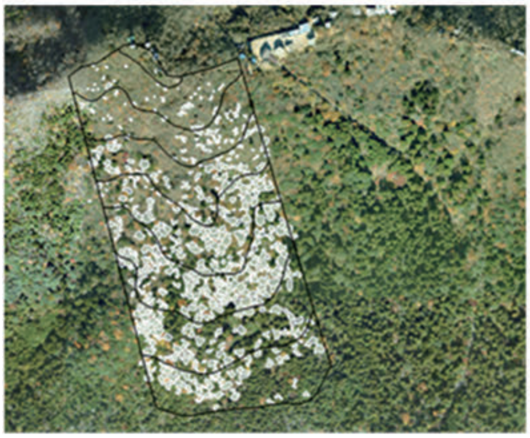


Figure 3. An aerial photograph of Mt. Tsukuba showing the 20-ha survey site marked with 50-m contour lines. The white circle shows evergreen broadleaved canopy.

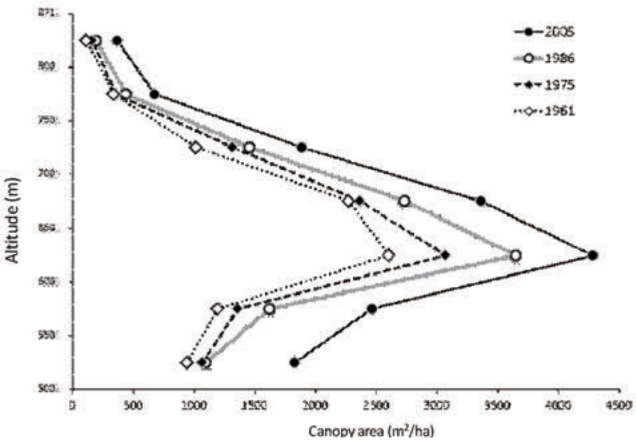


Figure 4. Changes in broadleaf evergreen canopy area at different altitudes.

3. Future forests images in 22th century in Japan

What is going to happen to our forests in Japan if climate change continues? The 4th IPCC report considered a number of background scenarios regarding economic growth and energy consumption and their influence on CO_2 emissions (Fig. 5). According to climate predictions by the scenario A1B, “high growth-orientated society with an emphasis on energy source balance,” which is close to the Japan government’s current policy, GHGs would have reached double their present concentration by the end of the 21st century; Hokkaido would be more than 3°C warmer, the area from Tohoku to western Japan would be 2°C–3°C warmer, and Okinawa and Amami islands would be 1.5°C warmer[1]. Precipitation forecasts have also been prepared for all over Japan.

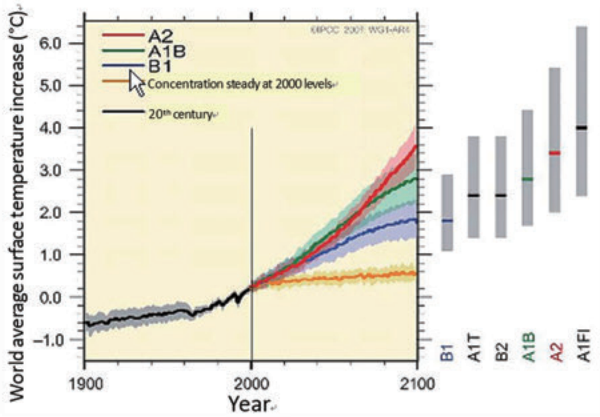


Figure 5. Climate change forecasts in the 4th IPCC report.
The warming effect varies depending on different economic growth and energy source scenarios (B1, A1T, B2, A1B, and others), and the predicted values are also rather variable. However, regardless of the scenario, a rise in temperature is unavoidable.

(1) Spring leafing period (Poster T-02)

As the annual variation in the date of the first cherry blossom attests, plants are sensitive to changes in climate. If warmer temperatures occur earlier during spring, this could also result in earlier leafing in deciduous broad leaved trees. The climatic factors that influence leafing in the mountainous regions of Gifu Prefecture were analyzed using changes in temperature recors, field observation of leafing, and image analysis by remote sensing. It was found that the leafing period was closely associated with an integrated temperature value of over 5°C[3]. If this relationship is used in 50 years, under the A1B climate change prediction scenario, the leafing period will be up to 2 weeks earlier, and in 100 years, it will be up to 4 weeks earlier (Fig. 6). The advancement in the leafing period will be much greater at lower altitudes than at higher altitudes. By the 2090s, leafing in deciduous broad-leaved trees in Gifu Prefecture will occur at the start of March. This will have an effect not only on the tourist season but also on tree growth because the silvicultural season will change and the photosynthetic periods will be extended.

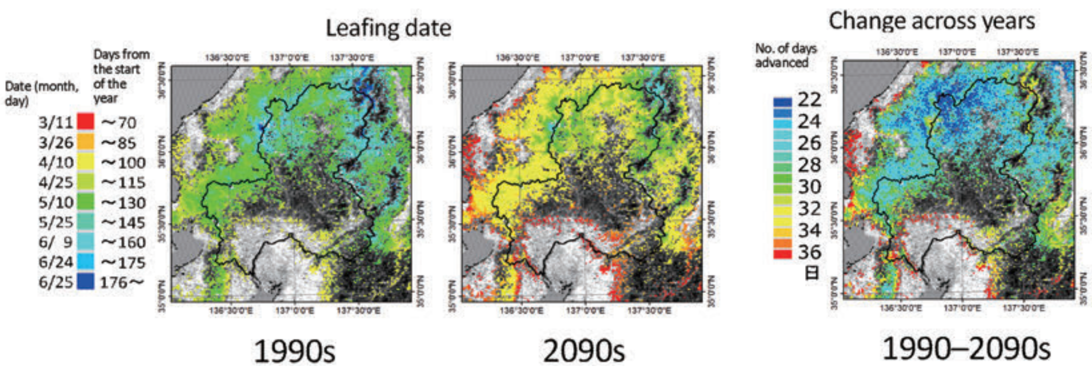


Figure 6. Leafing dates for broadleaf deciduous trees in the Gifu Prefecture area in the 1990s (left) and the predicted dates for the 2090s (middle) .
Right: The number of days that the leafing date will be advanced by in the 2090s.

(2) Proliferation of disease and insect damage (Poster T-10)

Climate change has an effect on insect activity, which means that the growth of insects in forests is affected by changes in the temperature. For example, in Hokkaido, the eight spined , which feeds on damaged Yezo spruce, normally appears twice a year. However, by the end of the 21st century, with the warmer temperatures, this pest will appear three times a year throughout almost half of the region (Fig. 7)[4].

Other examples where insect damage could increase include the geometrid moth *Milionia basalis* that damages *Podocarpus macrophyllus* and other trees, which will be able to overwinter in a number of regions in East and West Japan, and the moth *Diomea cremata* that damages shiitake mushroom beds, will be able to appear more frequently throughout the year.

Scale insects (*Comstockaspis macroporana*) that damage oak trees in Fukushima are predicted to spread to the entire prefecture. A chemical treatment manual has been published to promote protection countermeasure against this proliferation of damage by scale insects[5)]. Because scale insects can also infect edible chestnuts, we expect that the countermeasures for these scale insects set out in the manual can be implemented as quickly as possible.

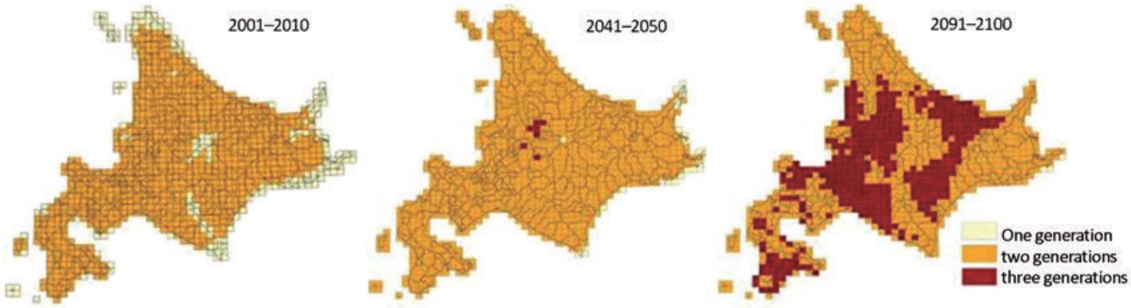


Figure 7. Increase in number of generations per year of the eight-spined ip in Hokkaido as a result of warming.

(3) Effect on shiitake mushroom production (Poster T-11)

The mushroom market in Japan is worth 250 billion yen annually, the scale is comparable to that of timber production of the Japanese forestry. Fresh shiitake production by bed logs has become an important source of income for people in "satoyama" villages. Fungal pests on shiitake such as *Trichoderma* and *Hypocrea* are forecast to proliferate as a result of global warming. Damage from mushroom flies (*sciaridae*) is also forecast to increase with global warming. Kyushu has become the main region for shiitake production, and countermeasures to address global warming are urgently required. One simple prevention measure is to cooler the temperature in the bed-log site under the forest by shading using cheesecloth; however, in terms of long-term management, breeding for warm-resistant strains will be necessary (Figs. 8, 9).

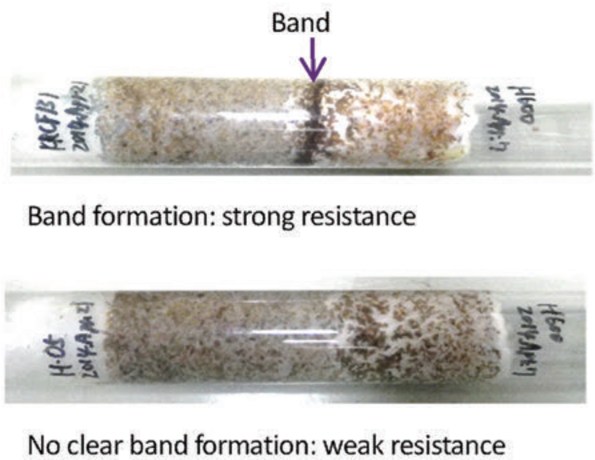


Figure 8. Development of pathogen-resistant shiitake strains using dual cultures. Pathogen and shiitake are cultured from both sides. If a band is created, the culture is resistant to the pathogen.

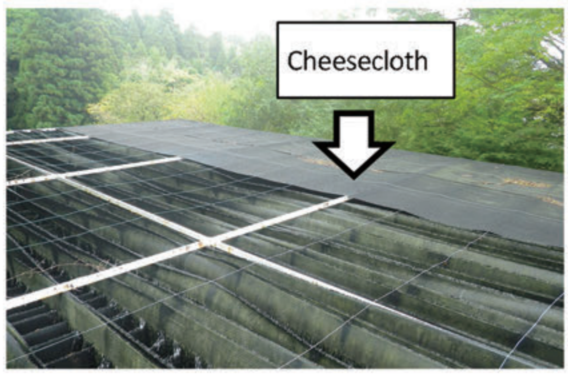


Figure 9. Improving the fresh wood shiitake culture environment using cheesecloth.

(4) Climate change effect on forests as a carbon sink (Poster T-03)

Does climate change affect CO_2 absorption in trees? To answer this question, we built carbon flux observation towers at six sites throughout Japan, from Hokkaido to Kyushu, which were higher than the height of different trees, and evaluated absorption in the forests from the movement of CO_2 in the air above the canopy (Fig. 10)[6)]. The volume of CO_2 absorbed in the forest ecosystem as an entire ecosystem is calculated by subtracting the amount CO_2 respired by the trees and the soil from the amount fixed CO_2 through photosynthesis. Our results showed that the forests sequestrate approximately 2–5 tons of carbon/ha/year (Fig. 9).

To make future projections, we used a Biome-BCG model that incorporated the various reactions involved in the absorption and emission of CO_2 in the ecosystem. When the carbon absorption volumes by the forest were estimated up to year 2100 in Sapporo using this method, photosynthesis together with respiration was predicted to increase as a result of global warming. The estimated amount of CO_2 absorbed thus resulted only slightly higher than current values.

However, these predictions did not take into account the disturbance from large-scale typhoons or insect damage. These estimates were obtained using only predicted temperature and precipitation values. In the course of our monitoring to date, we have observed large disturbances of the study forests; beech leaves being largely eaten by the beech caterpillar (*Quadricalcarifera punctatella*) at Appi mountain (Iwate Prefecture), and trees and observation towers being damaged and falling down due to a strong typhoon that hit Sapporo city (Fig. 11)[7]. While the associated damages would mean a vast reduction in CO_2 absorption, decomposition of felt trees and soil organic matter after the typhoon damage would actually cause an increase in the release of CO_2. Within a few years, the forests became a source of CO_2 emissions, and such a state has been continued over few years. These factors for forest damage and degradation have a critical influence on CO_2 absorption by forests. In Canada, damage from the mountain pine beetle has proliferated to such an extent that forests can no longer be accounted as carbon sinks under the Kyoto Protocol[8].

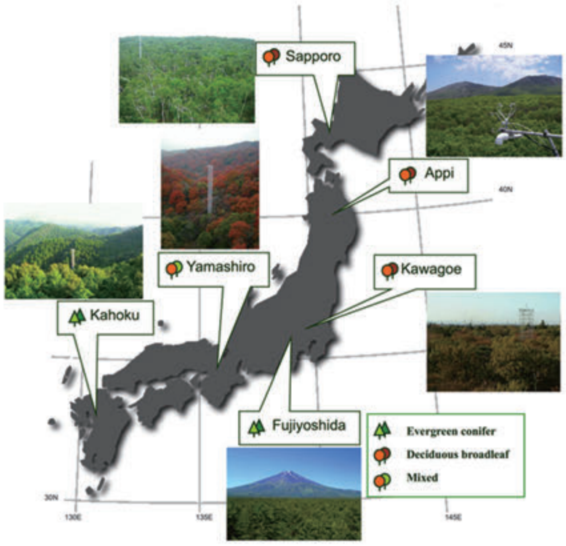


Figure 10. The locations of FFPRI CO_2 flux observation towers.

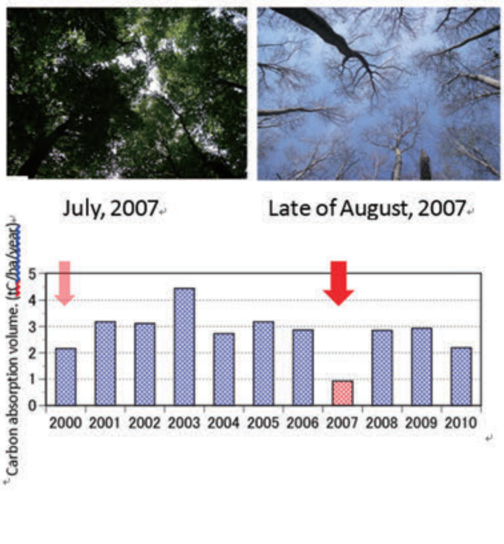


Figure 11. Photographs showing beech caterpillar damage and a graph showing the reduction in CO_2 absorption in infestation years (Appi tower site, Iwate Prefecture).

4. Preparing for natural disasters by extreme events (Posters T-04, T-05)

Natural disasters such as wind damage and landslide intensive increase during times of heavy rain and large-scale typhoons. These extreme climatic conditions that occur with climate change are referred to as extreme events. These extreme events occur more frequently as global warming increases, often accompanied by man-induced disasters. Measures to counter these are urgently required. On the other hand, large-scale soil conservation projects are hugely expensive and take a great deal of time. The costs of such projects can be justified and the priorities should be weighted when it comes to need to be understood by the taxpayers.

In the meantime, we would like to see low-cost measures that utilize the natural protective functions of forests. For example, the stability of the soil on hillsides depends on a number of physical properties, including the steepness of the slope, rainfall, infiltration of rainwater into the soil, and friction of soil layers against slip surface. The network of tree root system in forested soil is also considered to be an important factor in soil retention for preventing landslide.

(1) The function of forests in preventing landslide (Posters T-04 and T-05)

One standard means of investigating this effect is a comparison of hillsides where forests are present and that have been clearly felled. We conducted one such study on slope underlain granite which is susceptible to landslides. The area around

Ichifusayama on the boundary of Kumamoto and Miyazaki prefectures in Kyushu was subject to large-scale clear felling in the 1970s. We used a series of aerial photographs shot at different times up to 2005 to investigate the relationship between the positions and occurrences of landslides and the vegetation types (Fig. 12). Results showed that in forested hillsides, the area of landslides was one-fifth of that of regions that were not replanted after clear felling or where there were dense saplings growing (Fig. 13). In addition, the amount of rainfall required for landslides to occur on clear-felled hillsides was one-third of that required for hillsides that were still forested. This provides a quantitative means of indicating the function of the forest root system for holding the soil layer after heavy rainfall. Recently, although large-scale clear felling has not occurred, it has been suggested that in areas that are geologically weak, the risk of landslides can be decreased by reducing the area of clear felling and promoting thinning instead of clear felling in forest management activities.

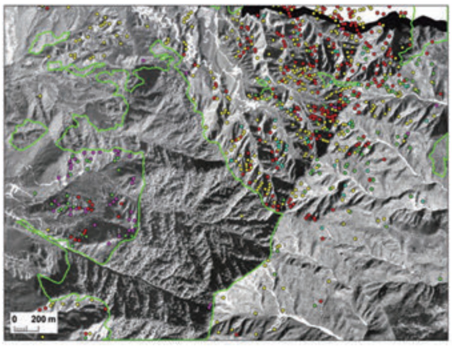


Figure 12. The occurrence of small scale landslides (white circles) from 1985–1990.
The central area has not been clearly felled.

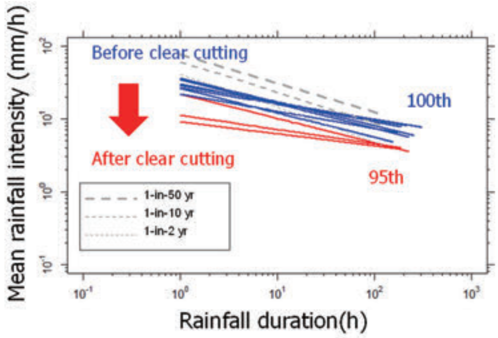


Figure 13. The relationship between landslide occurrence, rainfall intensity, and duration of continuous rainfall at Ichifusayama.
Blue and red lines are before and after clear felling, respectively.

(2) The effect of Chisan dams on preventing landslide (Poster T-06)

In recent years, as rainfall patterns have been changing, there is a possibility that unprecedented heavy rain may fall in places where landslides have not previously occurred. Chisan dams and other erosion control structures are being constructed to prepare against landslides in places where residential areas could be at risk. The effectiveness of these structures is being investigated using three-dimensional terrain modeling and large-scale laboratory equipment (Figs. 14, 15). The results show that constructing Chisan dams improves the stability of the slope and that the duration time to occur landslides take longer. Raising the height of existing Chisan dams is also effective and could be a low-cost method that can be used as an emergency measure.

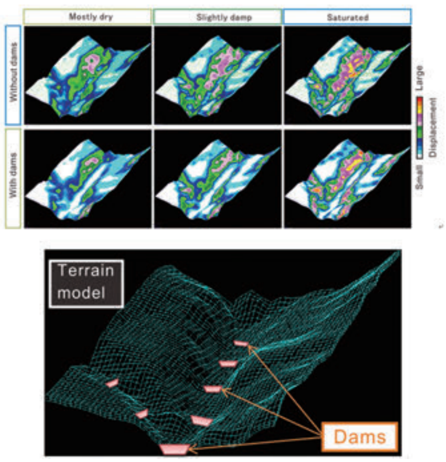


Figure 14. Three-dimensional terrain models of hillsides in places with Chisan dams, the displacement with high rainfall is lower and the slope is more stable.

Figure 15. Large-scale experimental equipment to mimic the effect of landslides caused by intensive high rainfall on hillsides.
Slide occurs in 2,891 s with heavy rainfall of 100 mm/h.

(3) The effect on water resources in forests (Posters T-07 and T-08)

Rainfall volumes are predicted to change with climate change. According to the A1B scenario of the Meteorological Agency's MRI model, droughts are expected to increase in frequency in Western Japan. At the FFPRI Tatsunokuchiyama forest-watershed experimental site located in southern Okayama Prefecture, detailed monitoring of water flow from the mountains, rainfall, and other parameters such as tree growth has been conducted for more than 75 years. If the next 50 years are forecast using the numerical model HYCYMODEL, an increase in drought frequency is predicted because of factors such as low rainfall, lower evapotranspiration from forests, and reduced interception of rain by the forest canopy (Fig. 16). On the other hand, there are suggestions that there is a difference in the scale of water flow from forests that have been recently planted and water flow from mature forests, suggesting that effective forest management can be a useful countermeasure against droughts and for flood control as well.

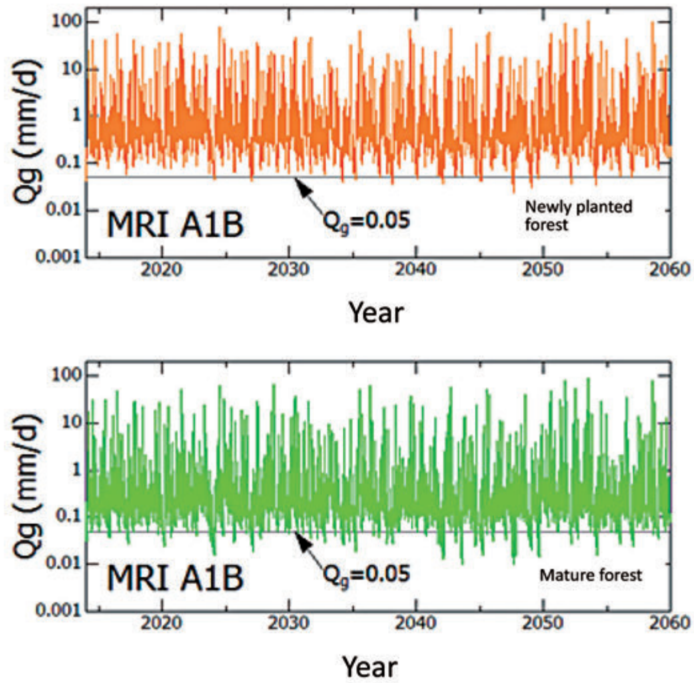
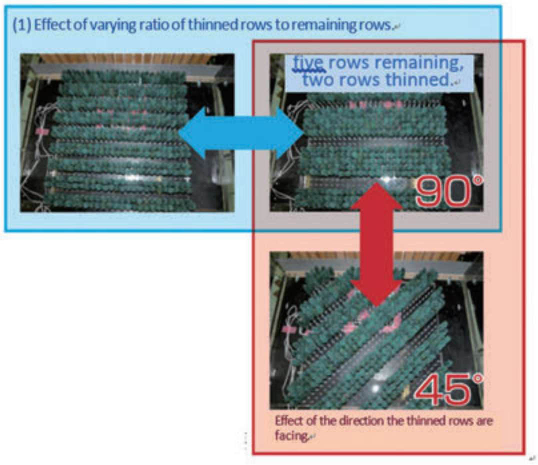


Figure 16. Model for forecasting water flow at the Tatsunokuchiyama forest-watershed experimental site. Top: Recently replanted forest. Bottom: Established forest. A Qg (flow volume in mm/day) value of 0.05 or less corresponds to drought conditions.

(4) Effects of global warming on coastal forests (Poster T-09)

If climate change progresses, coastal forests suffer from high waves, high tides, flying sand, and salt damage due to low-pressure troughs and large-scale typhoons. Recently, coastal forests have been widely established so that damage from flying sand can be reduced. However, in the face of ever strengthening typhoons, continuous maintenance of coastal forests is a must. Coastal forest management usually involves dense planting of black pine and then just letting the forest grow without any maintenance. Consequently, the forests become dense and dark (Fig. 17). Although thinning or the introduction of broadleaved trees is desirable, no standard thinning method for coastal forests has been established; therefore, they are usually left unmanaged. If there is intense thinning, this can create a channel for the wind, which will lead to more widespread windfall and undermine the function of coastal forests. We therefore investigated thinning techniques for coastal forests using wind tunnel experiments and field measurements of wind speed and salt distribution. We found that if three rows were allowed to remain lined up perpendicular to the sea breeze with one row being thinned, this continues to protect against wind-blown sand and salt damage. This maintains growth and preserves the role of the coastal forest in protecting against natural disasters (Fig. 18). A pamphlet on this method has been prepared for dissemination to forest managers[9].

Figure 17. Overcrowded coastal forests.



Wind Pressure. The wind pressure before thinning is used as a baseline.

	None logged	2 R1L	3R1L	4R1L	3R2L	4R2L	5R2L
90°	1.0	1.4	1.4	1.4	1.8	1.8	1.8
45°	1.1	2.0	2.0	2.0	2.7	2.7	2.7

Figure 18. Wind tunnel trials measuring wind pressure against thinning rows oriented in different directions.

5. Discussion

Because the response to climate change in forests is comparatively slow, it takes time to verify the effect. However, this project was able to use past changes to demonstrate the effect that climate change is progressing on the proliferation of broad-leaved tree canopies on the southern slopes of Mt. Tsukuba. Changes in forest vegetation are slow; however, there has been a steady change in a certain direction. Although the effect of global warming on forests takes time to become apparent, by the same token, so do the effects of adaptive measures. If early measures against global warming are not taken, the cost of such measures will build up, damage will become more widespread, and in a worst-case scenario, this could become irreparable.

If measures are to be taken to prevent widespread disease and insect damage, it is essential to understand the factors and etiology of the damaging agents. However, in cases where trees cannot physiologically adapt to global warming, weak trees will be susceptible to disease or insect damage, and this is hard to deal with. For plantation forests, appropriate felling and timber production regimes are called for, together with step-by-step replacement with improved tree varieties that can adapt to a warmer climate. Normally, the cycle for forest harvesting is 40–50 years. With a longer clear felling cycle, forest managers will need to think in terms of 100-year management cycles, meaning that for them, the end of the 21st century is not in the too far distant future.

Forestry managers will need to understand the geography of their region, learn how to harvest on hillsides while avoiding landslides, and put in place measures to avoid damage downstream. They will need to build landslide conservation structures such as Chisan dams and establish observation systems for the early warning of unusual events.
The multi-functional benefits that we receive from forests are known as ecosystem services. These include air purification, protection from natural disasters, securing of watersheds, wildlife refuges, and other functions that are not immediately apparent in our everyday lives. The Science Council of Japan in 2001 calculated these invisible benefits to be worth approximately 70 trillion yen per year[10]. This was an old estimation more than 20 years ago, and it may be necessary to revise this value to the present; however, it does show that the public good component of forests is huge.

Quantifying the benefits from forests that would be lost as a result of global warming, the severity of the impact, and the costs of countermeasures is just as important as finding adaptive measures to counter these effects. Quantifiable data can be used by policymakers and by the general public as a basis for considering suitable policies. On the other hand, because people tend to not think much about anything that does not affect their own immediate surroundings, it should be the role of scientists to remind importance of the forest for our future.

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Monitoring and Estimating Carbon Stock Changes in Tropical Forests for REDD-plus

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1. Introduction

Forests in developing countries, particularly in the tropical region, are disappearing rapidly. Greenhouse gas (GHG) emissions from deforestation and forest degradation are said to have reached 20% of the total global GHG emissions, which include those from industry sectors. To help developing countries reduce the forest-origin GHG emission, a scheme called "Reducing Emissions from Deforestation and Forest Degradation in Developing Countries; and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries," or REDD-plus for short, has been developed under the United Nations Framework Convention on Climate Change (UNFCCC), in which developed countries would provide technical and financial resources, while developing countries would undertake to reduce GHG emission from/enhance GHG absorption to forest and receive financial incentives on a result base.

REDD-plus involves political, economic, sociological and scientific aspects, e.g., consistencies between the existing institutions and/or governance mechanisms and the new REDD-plus frameworks, legitimate carbon pricing and fair distribution of income, harmonization of land tenure and/or customary use of forest by the local people and REDD-plus activities, and accurate and objective evaluation of carbon stocks, among others. Among the factors considered, developing techniques to measure the forest carbon stock volume and its changes by means that are achievable under the REDD+ scheme is one of the most important ones for any country. It is because reliable estimation of the carbon emission from forest is a fundamental variable to evaluate a REDD-plus activity as a mitigation means against the climate change.

Under the REDD-plus scheme, the emission reduction is evaluated as a relative reduction of emission and/or increment of absorption against what the emission would have been without emission reduction and/or forest carbon stock enhancement efforts at the national level (or temporarily at the sub-national level). Economic incentives will be provided for the emission reduction on the result base.

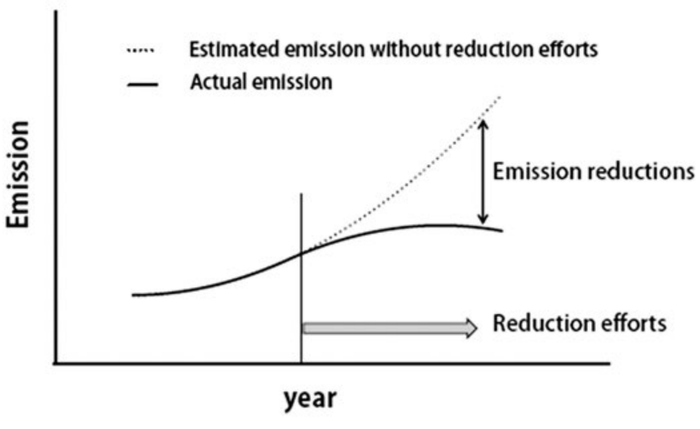

Figure I02-2 The concept of emission reductions

Figure 1. The concept of emissions reduction (from FFPRI[1])

Thus, carbon emissions from forest should be estimated in a transparent and verifiable manner (Fig. 1 solid line). The emissions in the absence of any effort are called emissions due to "business as usual" (BAU) and represent a reference for calculation of emission reduction by REDD+, which is referred to as "forest reference level" (RL) or "forest reference emission level" (REL) (Fig. 1 dotted line).

However, if countries implement measures under REDD+, emissions from BAU should not actually occur. Future RL or REL values must therefore be calculated by analyzing past emission trends representing pre-REDD+ BAU emissions. If the deforestation and degradation drivers have been identified, the influence that removing these factors through REDD+ activity would have on emission reductions can be predicted. In other words, accurate and efficient measurement of forest carbon stocks and past trend-based estimation of emissions and absorption to and from the forests under both the BAU scenario and the amount expected under REDD+ are essential to accurately estimate forest carbon emissions from the interannual changes in forest carbon stocks and thus accurately evaluate emission reduction volumes.

To address these issues, FFPRI has conducted two projects as a port of the AFFRC comissioned project over the 4 years since 2011, namely the D-1 project “Advanced carbon monitoring in Asian tropical forest by high precision remote sensing technologies” and the D-2 project “Development of simulation models and quantitative measurement of changes in Asian tropical forests.” We present our main findings below. For more detailed information, please refer to our poster presentations and original papers.

2. Measuring forest carbon stocks

2.1. Summary

In the project “Advanced carbon monitoring in Asian tropical forest by high precision remote sensing technologies” we set out to develop new, more accurate and sensitive remote sensing technology for measuring carbons stocks in tropical rain forests and tropical deciduous forests, the two main forest types in southeast Asia.

Carbon emissions or absorption to or from forests to the atmosphere is determined by changes in the forest carbon stock over a given time period (Equation 1). Of all the carbon that is stored in the forest, we measure biomass carbon volumes that are large in quantity and change. The carbon stock of every single tree across the forest cannot be measured. Therefore, the total area of each forest type, determined using remote sensing, and the carbon stock per unit area, estimated for each forest type by measuring the carbon stock from a number of sample plots, are multiplied together to give the total carbon storage volume (Equation 2). However, for some developing countries, it is difficult to produce sufficient numbers of sample plots.

$$\text{Carbon emissions and absorption}_{t_1,t_2} = \text{Carbon stock}_{t_2} - \text{Carbon stock}_{t_1} \quad (1)$$

$$\text{Carbon stock} = \sum_i (\text{Area}_i \times \text{Carbon stock per unit area}_i) \quad (2)$$

where t_1 and t_2 are the starting and finishing times, respectively, and i is the forest type.

In this project, by combining the ground surveys and the airborne and satellite remote sensing, we developed a suit of technologies to distinguish the forest conditions such as forest degradation, which has previously been difficult to detect, and to accurately estimate the forest carbon stocks using aerial laser survey, which would complement the sample plot surveys on the ground (Fig. 2).

The high-resolution satellite images have a resolution ranging from 60 cm to 1 m on the ground. At this resolution, individual trees crown in the forest canopy can be distinguished.

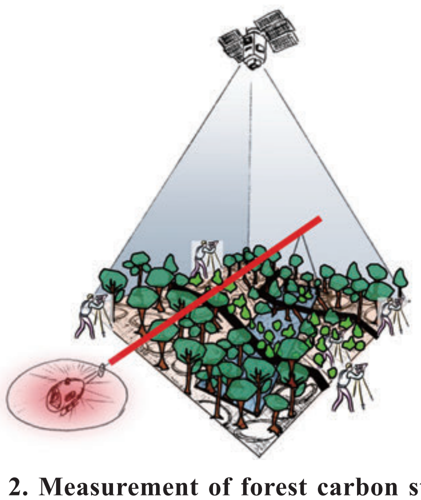

Figure 2. Measurement of forest carbon stock using a combination of field surveys and remote sensing technology using aircraft and satellites.

The aerial laser survey is a method to accurately map the surface altitude using a combination of a laser rangefinder (Light Detection and Ranging: LiDAR) and GPS-IMU (both mounted on an aircraft), which precisely measures the aircraft position and orientation. The distribution of canopy height could be estimated as the difference between the distribution of heights reflected from the canopy area and the distribution of heights reflected from the forest floor.

The research sites were tropical rain forests in Sabah State, Malaysia, and tropical seasonal forests in Kampong Thom Province, Cambodia. These sites differ from each other in landscapes, reflecting differences in vegetation and patterns of disturbance. Research results for each of these sites are reported below.

2.2. Tropical Rainforest in Sabah State, Malaysia

The research site was located at the southern tip of Sabah. It consisted of selectively logged forests and the secondary forests after clear-cut managed by Sabah Forest Industries Sdn Bhd (SFI) as well as state-owned forests used by local people for shifting cultivation (Fig. 3). The terrain was steep, and the altitude roughly ranged from 1,000 to 2,000 m. LiDAR measurements were made in October 2012. IKONOS-2 high-resolution satellite images taken on February 28, 2010 were used. In addition, ground measurements at 50 sample plots of 30 m × 30 m were performed.

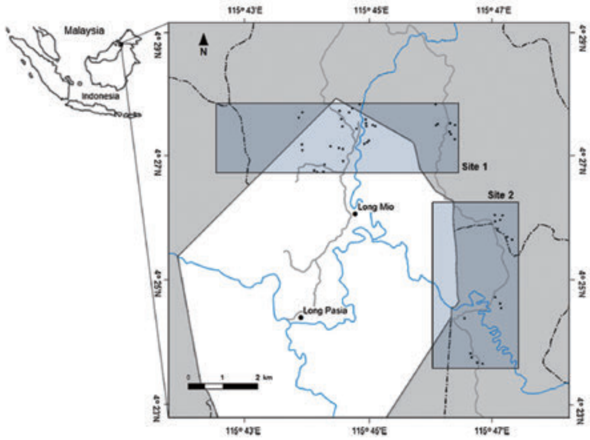

Figure 3. Research site in Sabah, Malaysia
Partially modified from Ioki et al.[2)]

Fig. 4 shows part of the three-dimensional point cloud from LiDAR measurements revealing the dense and non-homogenous nature of the forest canopy. Previous studies have shown that the canopy height distribution patterns derived from the three-dimensional point cloud accurately estimate the carbon stocks in forest stands. In addition to these parameters, we factored the transmittance of laser pulses (the proportion of laser pulses emitted in a square meter that reach a certain height from the forest floor) into the model to provide an even more accurate estimate of carbon stocks[2)] (Fig. 5). This model can be commonly used for different types of forest structures: old growth, moderately or severely degraded forest, and others. The transmittance itself is suggested to reflect the differences among the different structures. In summary, with LiDAR, the carbon stock can be estimated regardless of the stand structure, and high levels of accuracy and efficiency can be accomplished in distribution estimation.

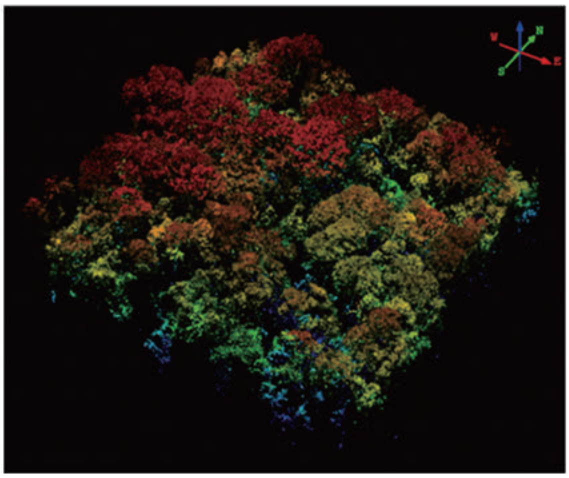

Figure 4. Part of the three-dimensional point cloud using laser pulses at Sabah, Malaysia.
The forest canopy heights are higher as the color progresses from blue to red.

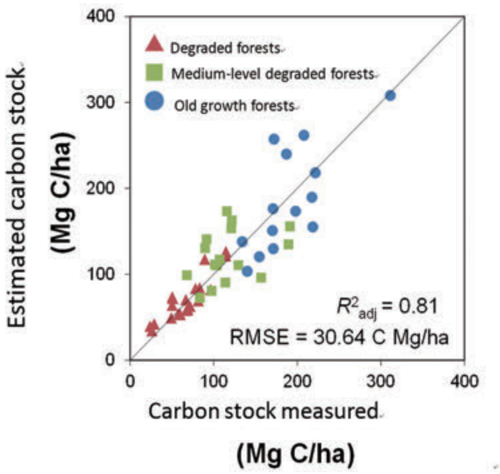

Figure 5. Carbon stock estimation model based on canopy height and canopy transmittance obtained by LiDAR. **(See p.56)**

When observing forest canopies from the air using high-resolution images, the density and size of individual crown differ according to the structure of each stand, resulting in different canopy textures on the image. This suggests that it is possible to distinguish individual tree crowns from the image texture (Fig. 6). Unlike LiDAR, high-resolution satellite images do not provide any information on canopy height. They also do not provide information on the diameter at breast height under the canopy. However, large trees are expected to have large canopies and vice versa. We therefore analyzed the relationship between the extracted crown area of individual trees and the diameter at breast height measured on the ground and found a strong correlation between the two values (Fig. 7)[3)]. In addition, it was also shown that the forest could be accurately classified as undisturbed or degraded depending on the differences in the spectral reflectance on satellite images. By combining those results, we could successfully estimate the diameter and the biomass of individual trees for both undisturbed and degraded forests.

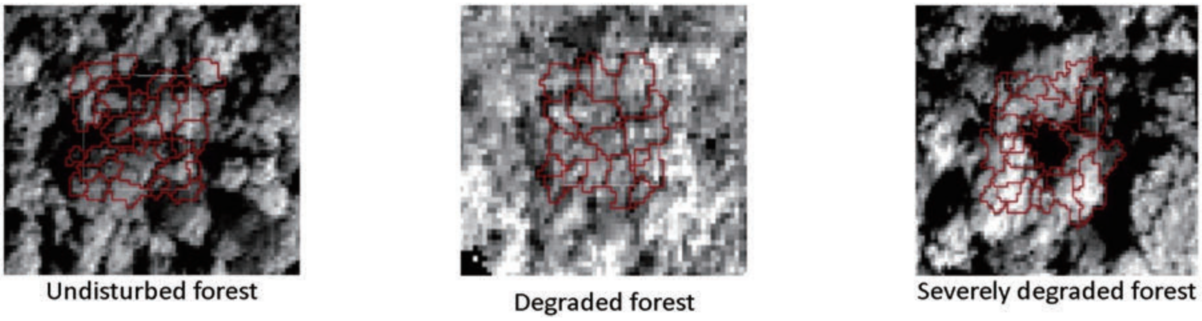

Figure 6. Examples of different textures found in satellite images that reveal different forest structures
Red lines indicate boundaries of delineated individual tree crown. (See p.57)

Estimates of carbon stocks from LiDAR are more accurate but more costly for large-scale measurement. Because high-resolution satellite images are less accurate but can be used over a wider range, it is expected that by combining these two methods, it will be possible to make accurate estimates of the carbon stock over a wide area.

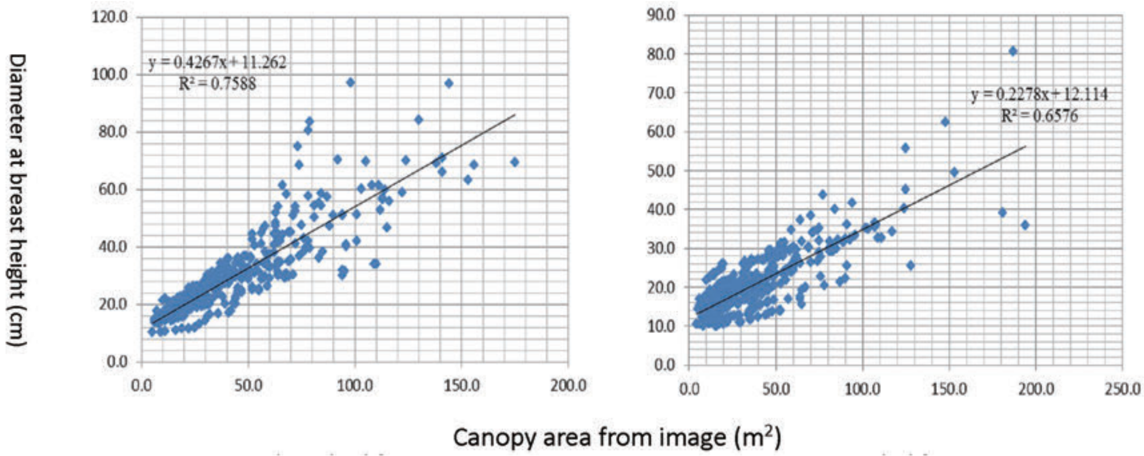

Figure 7. The relationship between the individual crown area as seen from images and the diameter at breast height.(See p.57)

2.3. Tropical seasonal forests in Kampong Thom Province, Cambodia

The research site was located in the center of Kampong Thom Province. It mainly consists of the tropical seasonal forests (deciduous forest), with a mixture of the secondary forests after shifting cultivation and evergreen forests (Fig. 8). Deforestation and forest degradation have rapidly progressed because of conversion to farmland and illegal logging (see next chapter). Two LiDAR measurements were made, one in January 2012 and the other in January 2014.

Many high-resolution satellite images were also taken. In 2011, Quickbird images were taken on November 30 and December 19. In 2013, Quickbird images were taken on November 28, and WorldView2 images were taken on December 22. In addition, 65 permanent sample plots of 0.12–0.25 ha were surveyed twice in 2011–2012 and in 2013.

Fig. 9 shows part of the three dimensional point cloud from LiDAR measurements. In contrast to Fig. 4, it shows how sparse the forest canopy was in the tropical seasonal forest. Biomass has been estimated from mean canopy height, as measured by LiDAR (Fig. 10). The results show that it is possible to use the single model to accurately estimate the forest despite the huge varieties in biomass and structure among the

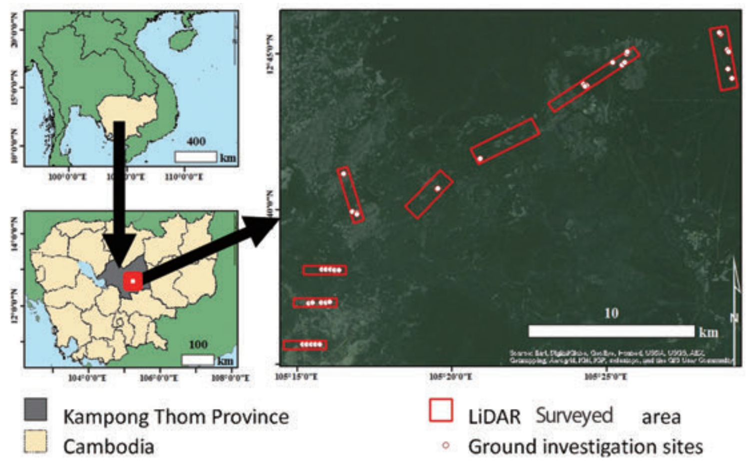

Figure 8. The research site in Kampong Thom Province, Cambodia
Partially modified from Ota et al.[4]

different forest types. In addition, it was clear that the second series of measurements in 2014 line up with the earlier ones, demonstrating the reproducibility.

Forest degradation by removing small number of trees from stand, e.g. by illegal logging, have been difficult to detect using satellite images, because the forest stands still exist even after the carbon stock reduction. Recognizing an ability of high-resolution satellite images to delineate individual tree canopy, we successfully developed a method that detects individual crown losses in a forest canopy. This method utilizes a technique known as pattern matching to accurately determine the position and size of individual crowns from two images at two different times. If a tree canopy was found at the start period but had disappeared by the end period, this meant that the tree corresponding to the crown had been presumed logged (Fig. 11). By quantitatively determining forest degradation caused by the extraction of individual tree in forests where only local people have access, this method can contribute to the elucidation of the current state of forest degradation due to illegal logging and the related underlying reasons.

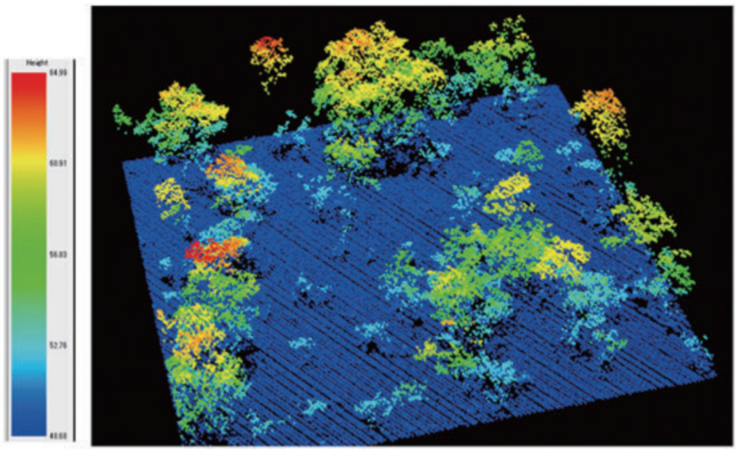

Figure 9. Part of the three-dimensional point cloud created using laser pulses (Kampong Thom Province).

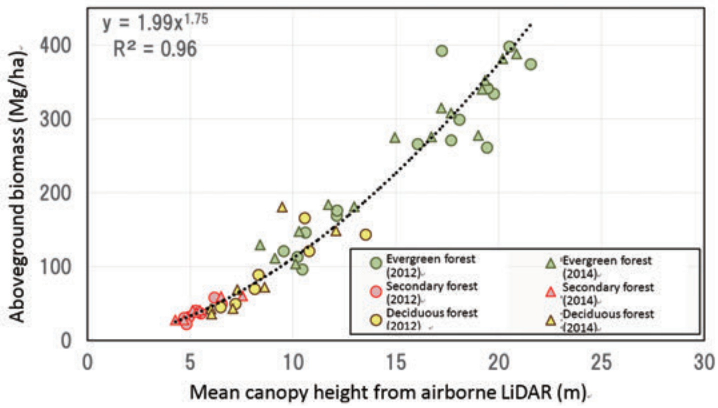

Figure 10. Estimation of the aboveground biomass using LiDAR.(See p.55)

The abovementioned results show that remote sensing in two time periods provides consistent estimates of biomass and is a novel means of detecting change that has successfully overcome the difficult challenge of pinpointing forest degradation. This is expected to make a contribution to the clarification of the present state and causes of forest degradation.

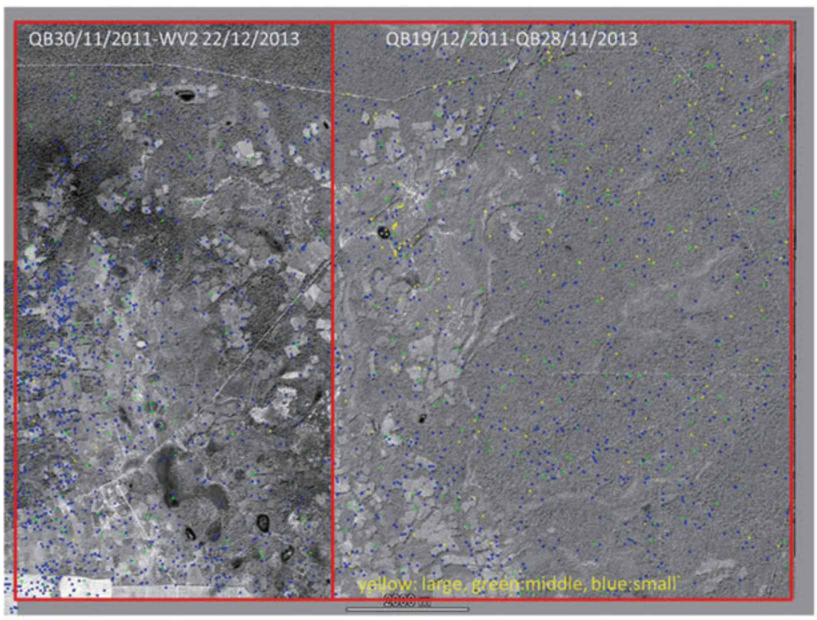

Figure 11. Individual tree canopy disappearance detected by comparison of high-resolution satellite images in two different time periods (from Furuya et al., unpablished).

3. Estimating changes in forest carbon stock

3.1. Purpose and significance of the simulation model

In the D2 project "Development of simulation models and quantitative measurement of changes in Asian tropical forests," we developed a simulation model that could forecast the changes in carbon emissions under various land use policies. Fig. 12 shows a conceptual diagram of the model. The left diagram (Fig. 12a), titled as "status quo," shows a supposed area with a particular land use pattern. The right diagrams (Fig. 12b–12d) represent three patterns estimating how the land use of supposed area will changed on the basis of "scenarios." The top right (Fig. 12b) represents the forecasted land use pattern under the scenario of "stopped deforestation" by the REDD+ implementation. In this scenario, the status quo pattern shown in Fig. 12a is upheld. In contrast, Fig. 12d shows the predicted pattern in the case that REDD+ activities are not implemented at all (i.e., reference scenario), Where two places, of forest could be converted to cassava fields. Fig. 12c represents the forecast pattern on the basis of the scenario "reduced deforestation in half" of reference scenario by the REDD+ implementation. The area of two places with change from forest to cassava fields in Fig. 12d could reduce to half in Fig. 12c. The characteristic of our simulation model is to estimate the carbon stocks under the different situation expected in various scenarios. We consider that our simulation model has multiple utilizations. First, the model contributes to improve the quality of the reference scenario.

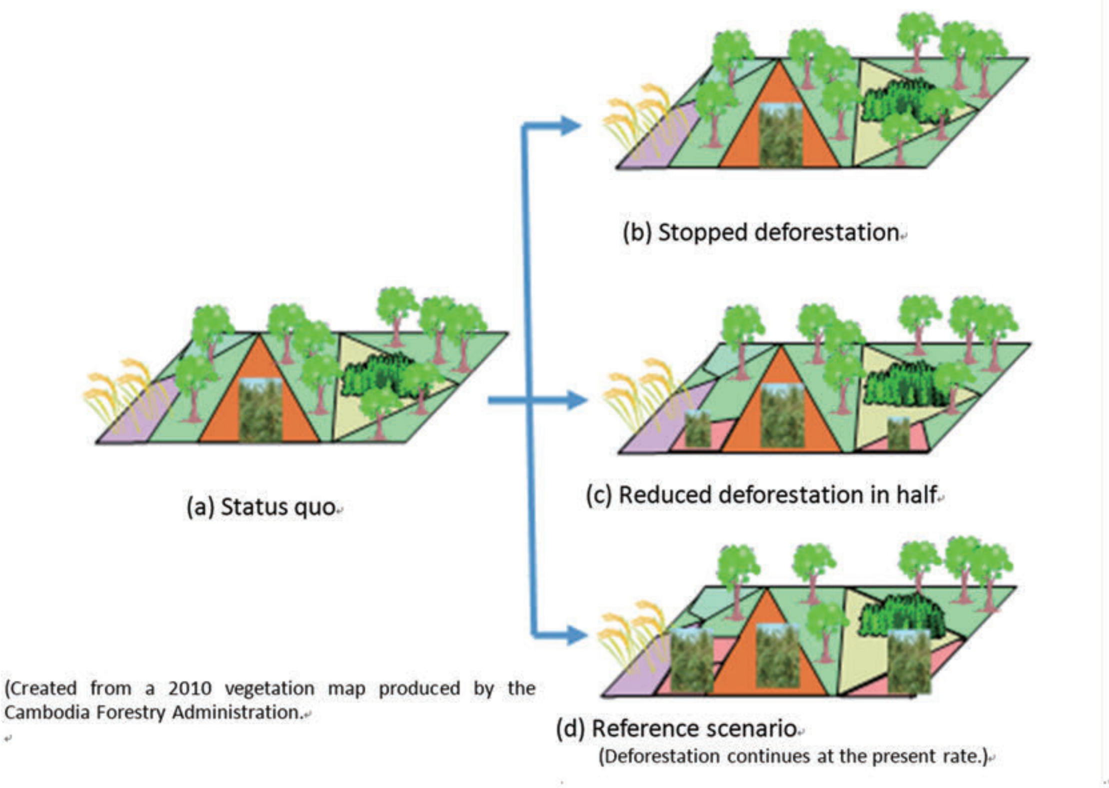

Figure 12. Conceptual structure of our simulation model to forecast the changes in carbon emissions.

Fig. 12d, which is the reference scenario, provides a scientific basis for forecasting the changes in carbon emissions when REDD+ actives could not be implemented. In addition, it leads to enhance the accuracy of reference scenario. In addition, it can use as a tool to support the governmental policy making. For instance, the government is likely to have to decide what extent of setting could maximize the effect of REDD+ implementation, and conversely, what level of forest degradation could be tolerated. These simulations, which predict carbon stock levels under different scenarios, can provide objective information that governments can use in policymaking. The scenarios would also allow governments to understand the effects of zoning different areas for conservation or development. More deforestation is likely to occur nearby roads and settlements at the local scale[5]. Such geospatial characteristics can be helpful in deciding the appropriate location of roads and settlements for reducing carbon emissions.

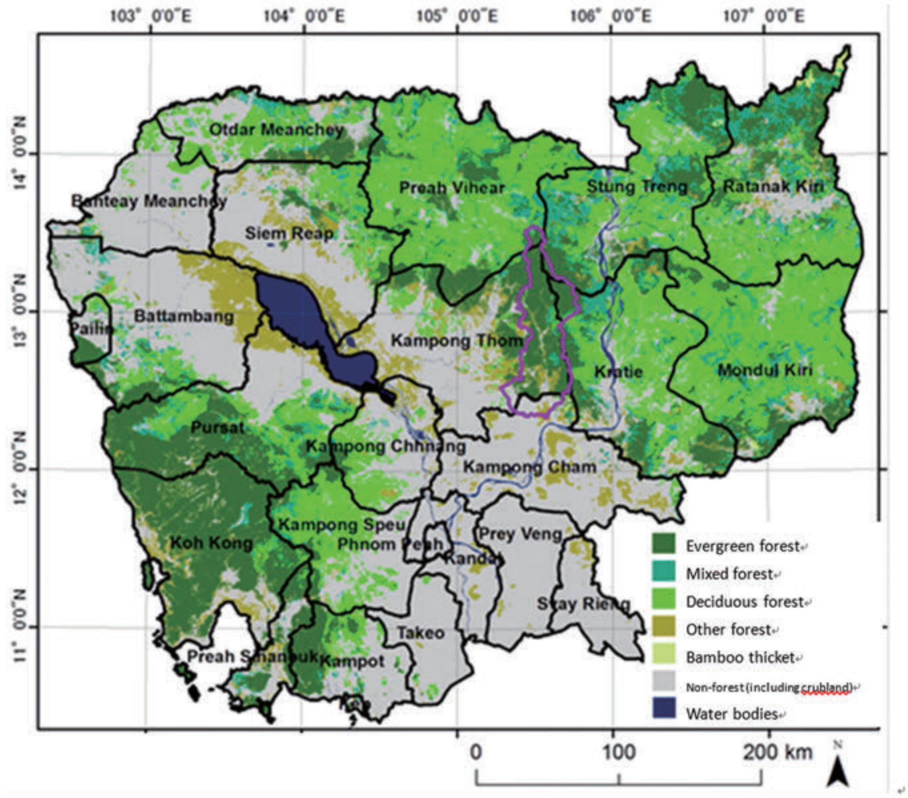

Figure 13. Cambodia vegetation map showing the location of the study site created from a 2010 vegetation map produced by the Cambodia Forestry Administration.

3.2. Study site

The Chinit River basin located in Kampong Thom Province was chosen as the site to develop the simulation model (Fig. 13, area 3,659 km$^{2)}$ because of the following reasons:

1) A large area has been still covered by forest (mainly dry evergreen forest).
2) Several community forestry has been designated, while forest conservation zoning such as research forest and the REDD+ project site have been under consideration by the national government.
3) In contrast, both large-scale plantations (mainly rubber plantation) and local farming developments (cash crops, e.g., cassava) have drastically increased.
4) These mean that it is suitable to analyze the effect of zoning countermeasures for both development and conservation.

The general framework of the simulation model developed here can be used in other areas in Southeast Asia as long as local data are available.

3.3 An overview of the structure of the simulation model

Carbon stocks in the study site were estimated by multiplying the average carbon stocks by the area of each forest type using the predicted future land use map (Fig. 14). Future land use changes were predicted on the basis of the deforestation potential map under different scenarios. The average carbon stocks for each forest type were estimated from field observations and remote sensing techniques used in the D-1 project. In the D-2 project, we also estimated carbon dioxide (CO_2) emission and absorption for each forest type, as shown in 2) below.

1) Map showing predicted changes in land use

① Map showing potential deforestation

Deforestation potential map

We generated a deforestation potential map, which shows the susceptibility of deforestation (Fig. 15). The red- or yellow-colored areas show the places with a higher probability of deforestation. The map was derived from statistical analysis of the geospatial characteristics of deforested areas using various geographic factors such as distance from the forest edge, roads, settlements, rivers or water bodies; terrain features; and zoning. We only analyzed small-scale deforestation for local farming activities, which is strongly dependent on local geographical factors. Because the scale and location of large-scale developments are dependent on permission granted by government agencies, they are incorporated in the scenarios described later.

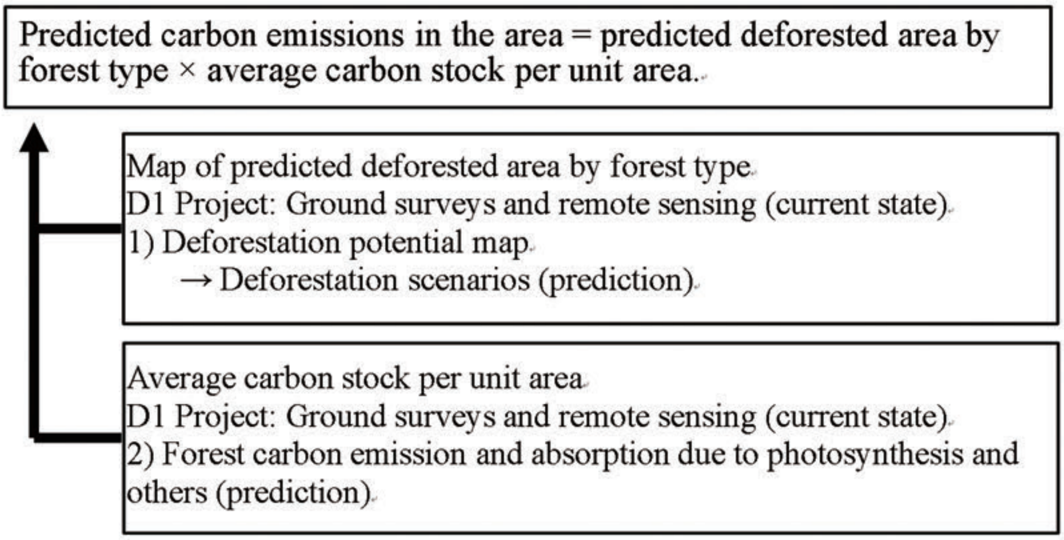

Figure 14. An overview of the structure of the simulation model for predicting changes in carbon emissions

② Scenarios

Several scenarios were used in this study, e.g., business as usual (BAU), accelerated deforestation, and forest conservation scenarios. In addition, we used several zoning scenarios such as additional designation of community forestry, REDD+ project, or economic land concession (ELC) by the national government. Using these scenarios, it is possible to estimate the effect of land use policies by the government. Because most small-scale developments have been conversion to cassava cultivation by locals, we created scenarios with different deforestation rate depending on both the price of cassava and the REDD+ payout.

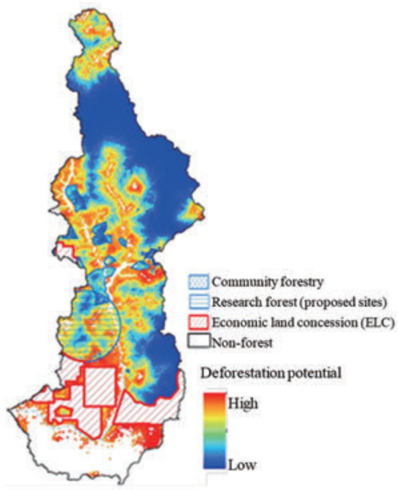

Figure 15. An example of a deforestation potential map

2) Developing techniques for evaluating carbon emission and absorption

Although forests release CO_2 through respiration, they grow by absorbing it through photosynthesis. The growth rate of rubber trees directly after planting is particularly significant. Several years after planting, they form a closed canopy, and this is when the rubber is ready for harvest. Although carbon stocks in rubber plantations are small compared with those in dry evergreen forests, the absorption rate of CO_2 is higher[6)]. To predict carbon storage and emissions in watersheds where significant areas of dry evergreen forests have been converted to rubber plantations, it is necessary to be able to evaluate absorption and emission volumes from photosynthesis for all forests, including rubber plantations. The development of methods for carrying out such measurements is one of the challenges of this project.

CO_2 used for photosynthesis passes into leaves through their stomata. However, when there is insufficient moisture available because of dry soil conditions and other reasons, the stomata close to prevent loss of water to the atmosphere through evaporation and photosynthesis ceases. In the Southeast Asian countries of Cambodia and Thailand, there is a dry season lasting from November to April during which there is hardly any rain. During this time, the effect of the hydrological environment on photosynthesis is particularly pronounced. Most forests in the watershed in which the study site was located are dry evergreen, dry deciduous, or rubber forests, and the way in which the hydrological environment affects photosynthesis for these three types of forest is clearly known.

Dry evergreen forests show comparable transpiration in the dry and rainy seasons, and suppression of photosynthesis under dry soil conditions has not been observed[7)]. This is thought to be because of water stored in a deposition layer at a depth of up to 10 m that is used during the dry season. Rubber trees release a lot more water through transpiration than dry evergreen trees. This means that they have a shortage of water in the dry season, and suppression of photosynthesis has been clearly observed[6)]. This knowledge can be used to determine carbon storage volumes and thus to develop a means of forecasting forest carbon emission and absorption. Using this method, it is possible to reproduce the actual situation with rubber forests, which is that growth shows a plateau after approximately 30 years. The reliability of the method is thus confirmed.

4. Conclusion

In these projects, we have developed new methods for measuring and predicting the forest carbon storage that will be vital for the REDD-plus implementation from our case studies conducted in Sabah State, Malaysia, and in Kampong Thom Province, Cambodia. We assume that the development process of these methods can be applied in other regions. Embedding these methods to the national accounting system will be the next step to the implementation of the REDD-plus scheme.

We have actively engaged in the dissemination of our achievement through presentations at various academic forums, targeting interested parties not only witin Japan but also in countries where we had conducted the researches. An international seminar was held in May 2014 at Universiti Malaysia Sabah, one of the research consortium members. Many officials and personals from the Sabah State Government, non-governmental organizations, forestry companies and the university attended the seminar and exchanged professional knowledge and ideas. Particularly, the method to accurately observe the forests in remote areas using remote sensing had drawn attention from many participants, which consequently resulted in a request of a more detailed training from the forest company to the university.

In Cambodia, we had a technical workshop at the capital city of Phnom Penh to deliver our achievements to the Forestry Administration, which had provided us necessary permissions and cooperation for our project. In the workshop, we reported to the executives the summary of the research and its implication, and provided an on-the-job training to the forest officers followed by a discussion with them on the feasibility of applying the data and analysis methods to the actual forest management. To enhance the applicability of our research outcomes to REDD-plus, we would continue the dissemination activities to both Japan and overseas and reflect the feedbacks to improve our technologies.

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Poster Presentations

Promotion of the Growth of *Quercus mongolica* and *Q. serrata* in a Future High CO_2, High Ozone Environment

Mitsutoshi Kitao (FFPRI) and Hiroyuki Tobita (FFPRI)

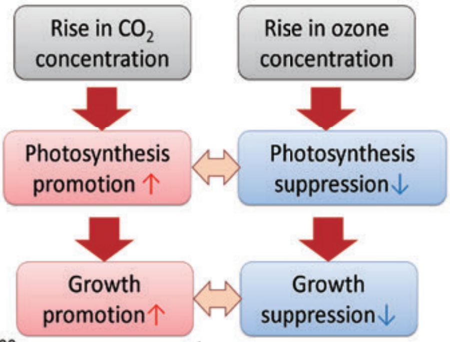
The atmospheric concentration of CO_2 and ozone is rising year by year as a result of burning fossil fuels such as coal and petroleum, leading to the question of what effect a future environment high in CO_2 and ozone will have on tree growth. Our studies on tree growth in *Quercus mongolica* and *Q. serrata* showed that high CO_2 and high ozone promoted growth in these species.

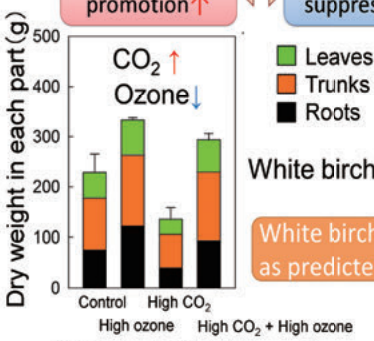
1 Providing ozone and carbon dioxide to trees

The outdoor equipment for providing ozone and carbon dioxide to trees.
CO_2 concentration: Control = 380ppm (present atmospheric concentration)
Elevated CO_2 = 550ppm (predicted value for 2050)
The elevated ozone concentration was twice that of the control.

Outdoor CO_2 and ozone exposure

2 What are the expected effects on growth?



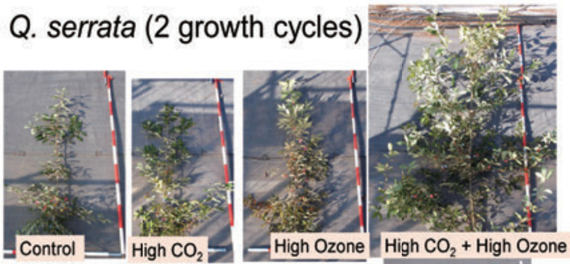


White birch (1 growth cycle)

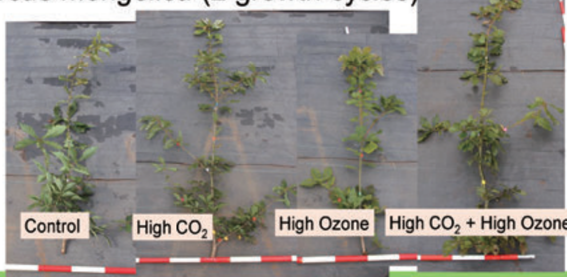
White birch results were as predicted

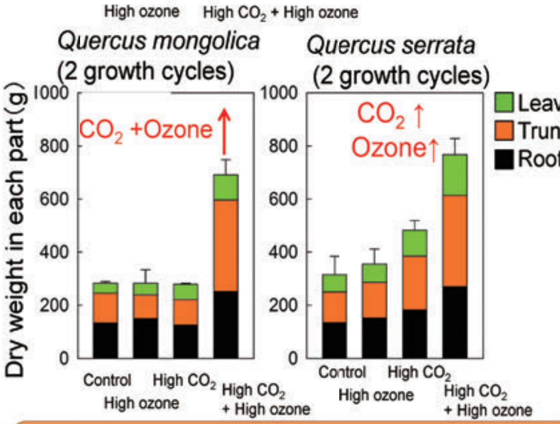
3 The results for *Quercus mongolica* and *Q. serrata* growth differed greatly from predictions

Q. serrata (2 growth cycles)



Quercus mongolica (2 growth cycles)





Increases in both CO_2 and ozone resulted in a far stronger growth promotion effect than high CO_2 alone in *Quercus mongolica* and *Q. serrata*. The reason for this is currently under investigation.

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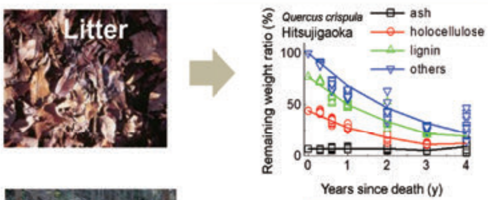
Obtaining the required parameters for the construction of a new soil carbon model

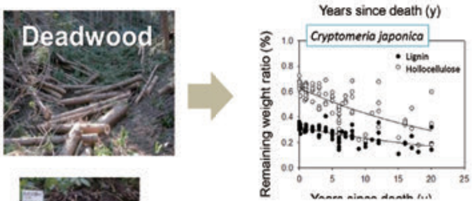
Shigehiro Ishizuka, Satoru Miura, Shoji Hashimoto, Keizo Hirai, Tadashi Sakata, Junko Nagakura, Kyotaro Noguchi, Toru Hashimoto, Kenji Ono, Toko Tanikawa, Hisao Sakai, Tomoaki Morishita, Hidetoshi Shigenaga and Yoshimi Sakai (FFPRI)

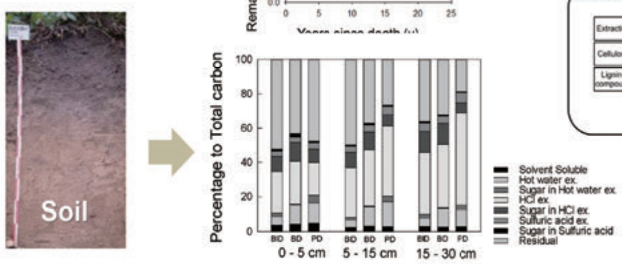
Soil carbon was separated into quantifiable and verifiable fractions in order to construct a soil carbon model for predicting carbon stock changes in Japanese forest soils over a nation-wide area. An important carbon sink in tree stumps, etc., has been firstly measured.

5 carbon pools in forests

1 Clarifying the decomposition characteristics of the fractions of soil carbon

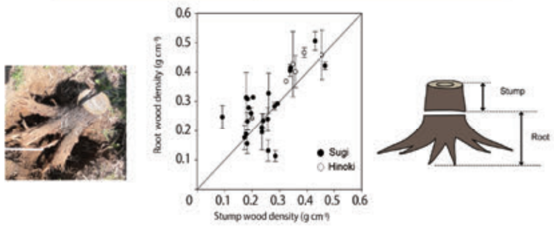






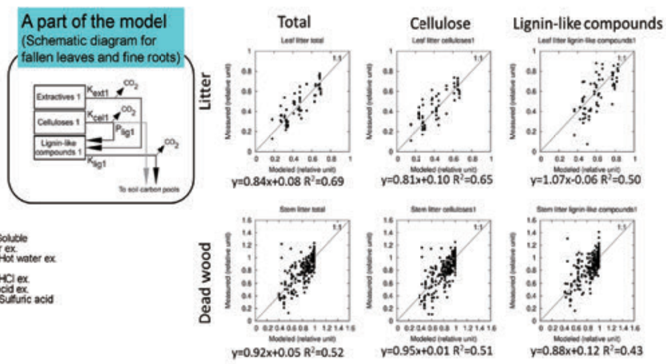
Lignin is reportedly more persistent and this was confirmed in our study, but the difference in degradability was not as great as has been thought.

2 Investigating the decomposition of abandoned stumps



Dead wood was consisted of fallen logs, standing deads and roots. Of these, not much is known about the volume and decomposition of roots. We found there was no major difference in decomposition between the above and below ground portions of stumps.

3 A model for decomposition of different components



We formulated a model for decomposition based on these data. All compounds are quantifiable so it is possible to improve the model by collecting more data in the future.

We constructed a soil carbon model that reflects climate and soil conditions for Japan. By incorporating this in an integrated model it is possible to forecast changes in these carbon stocks over a nation-wide area under various scenarios.

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Mapping Forest Cover Types of Japan to Evaluate the Carbon Stocks Using Landsat Satellite Images

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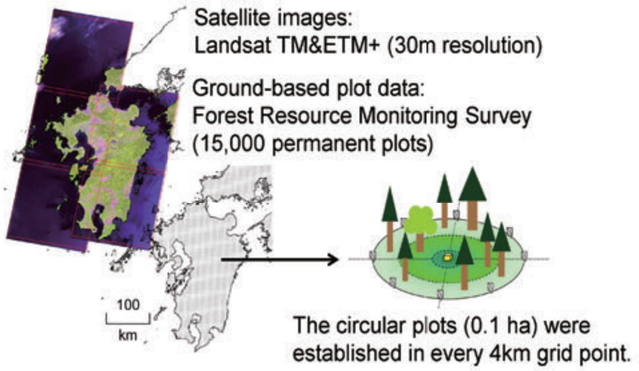
Fumiaki Kitahara (FFPRI Shikoku Research Center),
Tomoaki Takahashi, and Toshiro Iehara (FFPRI Kyushu Research Center)

The evaluation of carbon stocks is one of the major themes in the scientific studies of climate change and global warming. In the present study, we created a forest cover type map of Japan using multi-seasonal Landsat TM and ETM+ satellite images and ground-based plot data. The map can be used to estimate the carbon stocks in Japan.

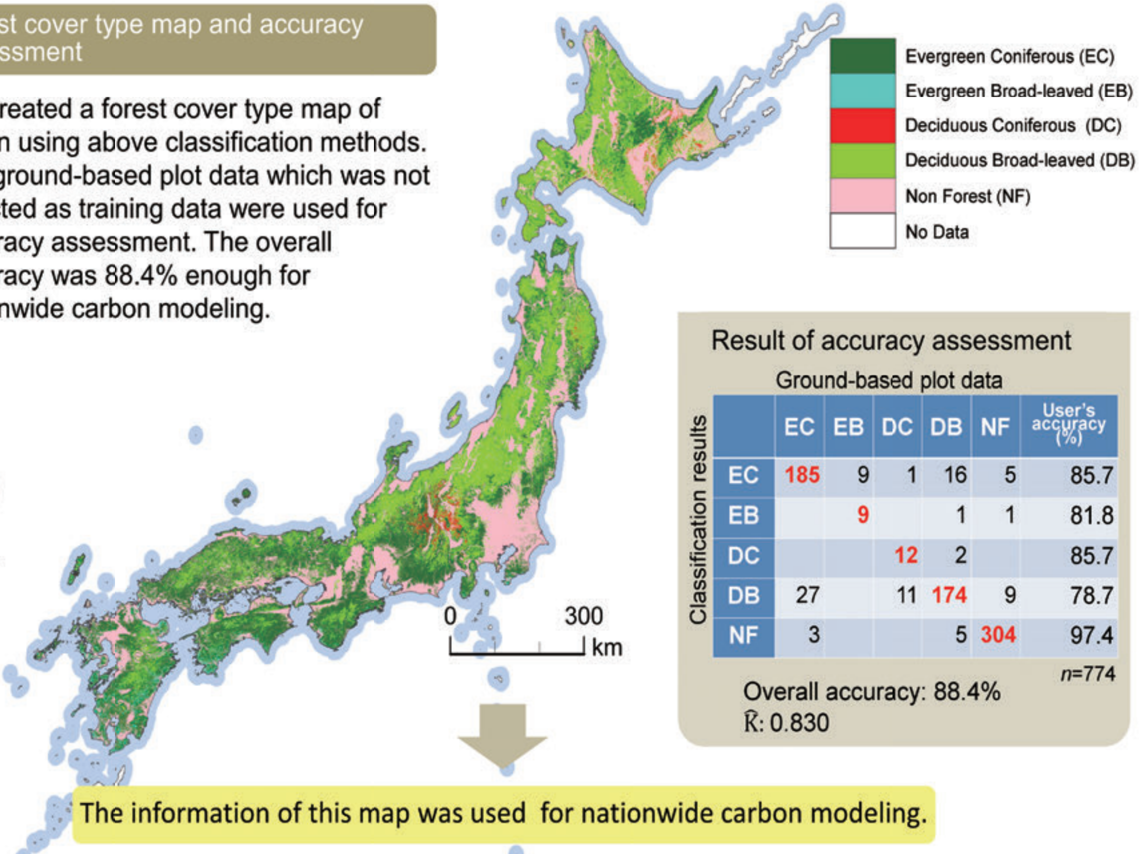
1 Classification of forest cover types

The Support Vector Machines method (supervised classification) was applied where there were sufficient training data for classification of satellite images, while the ISODATA method (unsupervised classification) was applied to other areas in Japan.



2 Forest cover type map and accuracy assessment

We created a forest cover type map of Japan using above classification methods. The ground-based plot data which was not selected as training data were used for accuracy assessment. The overall accuracy was 88.4% enough for nationwide carbon modeling.



Result of accuracy assessment

Ground-based plot data (columns) / Classification results (rows)

	EC	EB	DC	DB	NF	User's accuracy (%)
EC	185	9	1	16	5	85.7
EB		9		1	1	81.8
DC			12	2		85.7
DB	27		11	174	9	78.7
NF	3			5	304	97.4

n=774

Overall accuracy: 88.4%
$\hat{K}$: 0.830

The information of this map was used for nationwide carbon modeling.

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Developing a Simulation Model for Carbon Balance in the Forest and Harvested Wood Products by Forestry and Wood Use Scenarios

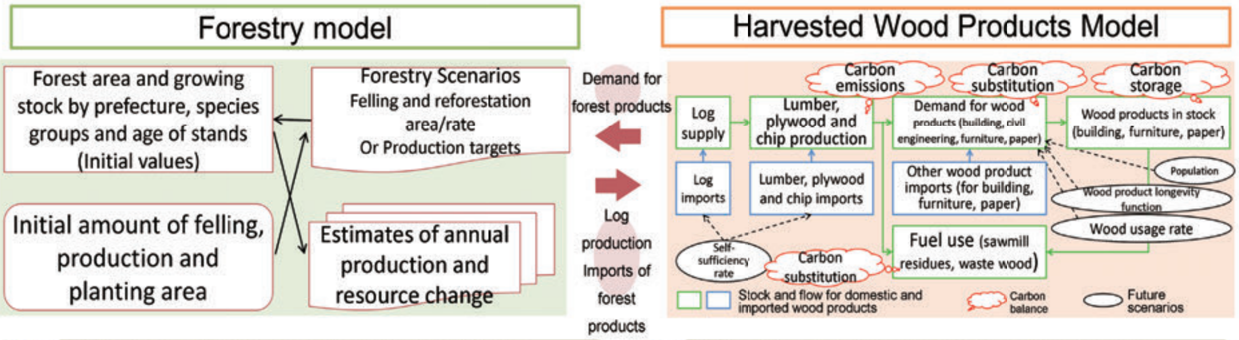
Hiroyasu Oka, Yuko Tsunetsugu, Mario Tonosaki, Hirofumi Kuboyama, Kazuya Tamura, Wataru Tanaka, Masahide Hayashi (FFPRI)
Takuya Hiroshima (University of Tokyo), Yasuhiro Takiguchi (Woodmiles Forum), Yasunari Matsuno (University of Tokyo),
YokoHirano (Dot Corporation), Chihiro Kayo (Tokyo University of Agriculture and Technology)

We developed a simulation model for forestry and harvested wood products.

- Under a "gradual increase scenario" log production doubled and under a "basic plan scenario" it become threefold from initial amount of production.
- Under scenarios with wood use promotions, emissions reduction effects were substantial by the three effects: the carbon storage effect, energy saving effect by material substitution, and fossil fuel substitution effect.

1 Outline of the forestry and harvested wood products model

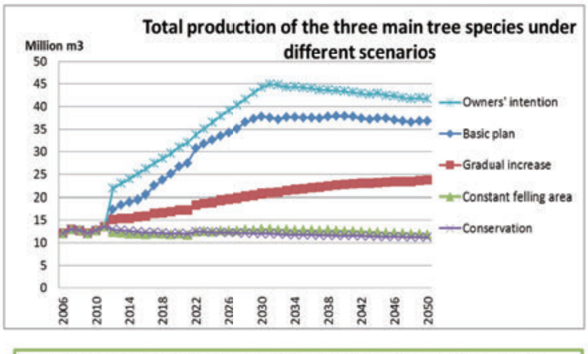
☞ For details regarding forestry and harvested wood products scenarios, see K-07.



2 Estimation of felling and log supply with the forestry model

Felling rates based on questionnaire responses from forest owners

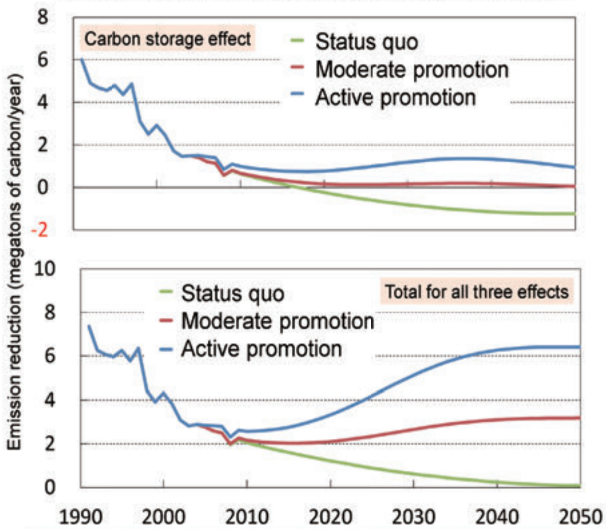
	Within 20 years	21–40 years	After 41 years or later	Never clear cut	Poor growth
Cryptomeria	31%	31%	19%	19%	9%
Chamaecyparis	23%	32%	25%	20%	11%
Larch	50%	29%	13%	9%	7%
Planted forest total	33%	29%	18%	19%	9%



Compared with the constant felling area scenario (10% of the existing planted forests will be felled until they become 80 years old), the production in the gradual increase scenario (20% of existing forests will be felled before reaching 80-years old) become double by 2050. Production for the basic plan (30% by 80-years) was threefold by 2030.

3 Estimating emission reductions effects using harvested wood products model

Effects of emissions reduction with wood use for each scenario



Although the status quo scenario showed only a slight effect on emission reduction, under both promotion scenarios substantial reduction effect was obtained. The active promotion scenario (wood usage rate in building and furniture is expected to reach 70% and wood usage in civil engineering is expected to reach 6 million m3 by 2050) had a particularly strong impact on emission reduction due to the combined impact of all three effects.

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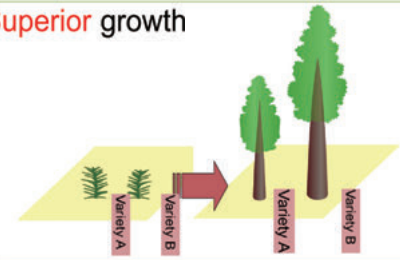
Evaluating a High Carbon-fixing Cedar Variety and the Effectiveness

Taiichi Iki, Yuichiro Hiraoka (Forest Tree Breeding Center, FFPRI)

We evaluated a variety of cedar (Kamitsuga 7) developed at the Forest Tree Breeding Center for its high carbon-fixing ability. This variety showed superior growth and high wood density at all test sites. If conventional seeds and seedlings are replaced by this variety it has a significant effect on carbon sequestration.

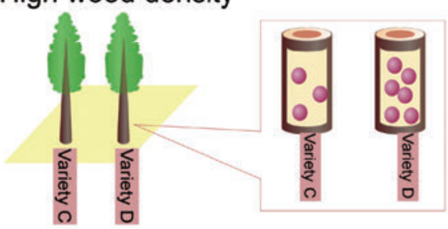
1 What are high carbon fixing trees?

· Superior growth



Superior growth compared with other cedar varieties

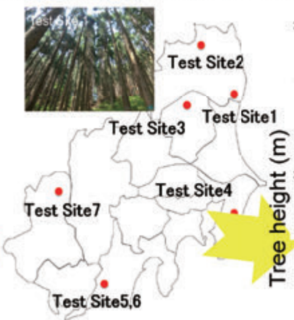
·High wood density

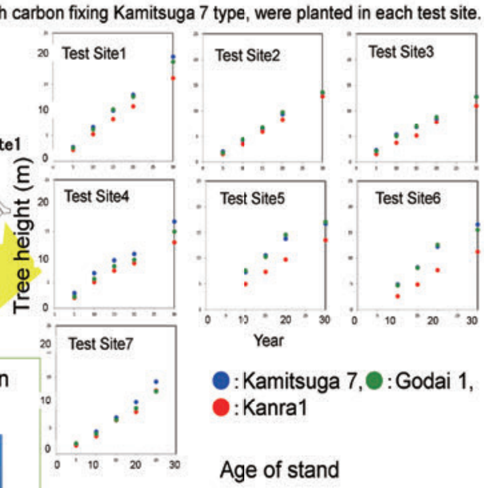


Higher wood density at the same speed of growth

2 Test sites for evaluation of potential

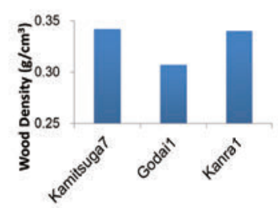
· The same clones, including the high carbon fixing Kamitsuga 7 type, were planted in each test site.





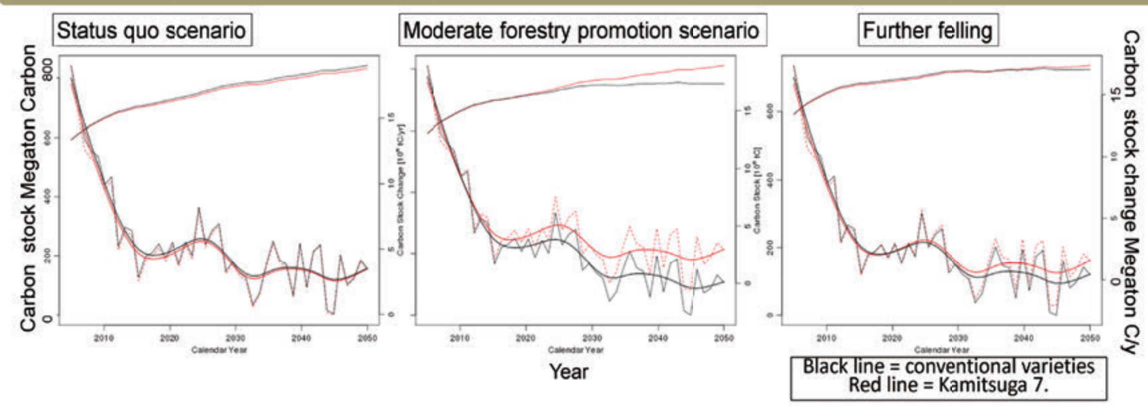
●: Kamitsuga 7, ●: Godai 1, ●: Kanra1

·Wood density comparison



·Kamitsuga 7 showed superior growth at all test sites. The wood density value was also high.

3 Replacing existing trees with high carbon fixing varieties: A simulation



Black line = conventional varieties
Red line = Kamitsuga 7.

If conventional varieties are replaced with Kamitsuga 7, then under the moderate forestry promotion scenario there is a significant increase in carbon fixation.

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Development of Technology for Improving Carbon Absorption utilizing a high carbon fixing Kuril Larch F1 Variety

Kazuhito Kita, Yasuyuki Ohno (Hokkaido Research Organization, Forestry Research Station)
Hisanori Harayama, Akira Uemura, Chinmin Han (FFPRI, Hokkaido Branch)Hajime Utsuki (FFPRI)

The high carbon fixing "clean larch" is a cross between Japanese larch and Kuril larch which is northern larch species, so there are concerns that its carbon fixing capacity may diminish with global warming. However, when characteristics of photosynthesis under warmer conditions were analyzed together with a growth model, it was found that photosynthesis was influenced in the same way as it was in other larch species. Even under global warming conditions, carbon fixation increased with increasing temperature over almost the whole of Hokkaido.

1 The high carbon fixing "clean larch"

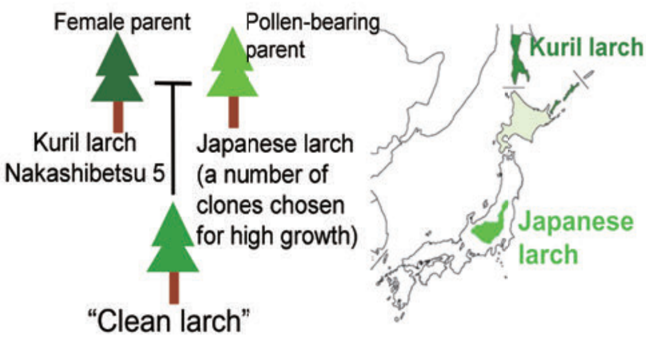


Figure 1. The "Clean larch" is a hybrid cross between Kuril larch (Nakashibetsu 5) distributed in Sakhalin and the Kuril Islands, and Japanese larch distributed in central Honshu.

Table 1. Growth volume and timber quality at each site

Tree variety	Timber volume**	Wood density**	Carbon fixation weight***	Young's Modulus***	Trunk curvature rate***
	m^3/ha	g/cm^3	t-C/ha	GPa	%
Clean larch	361	0.469	84.6	13.1	17.3
Superior variety of Japanese larch*	364	0.450	82.5	11.9	24.4

* Selected for fast growth. ** Results from 31-year old trees from one Eastern Hokkaido site and two central Hokkaido sites. *** Results from 31- and 34-year old trees from two Eastern Hokkaido sites

The "clean larch" was selected for high carbon fixation
⇨ It also showed superior timber characteristics

2 Photosynthesis temperature characteristics

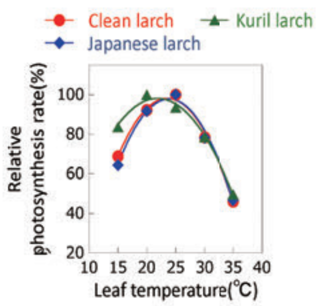
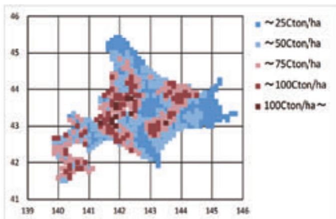


Figure 2. Photosynthesis rates at different leaf temperatures for 3-year old potted trees

The clean larch has the same photosynthesis temperature characteristics as the Japanese larch right up to the high temperature range.

3 The impact of warming in 2050

Carbon fixation if 2001 climate conditions continue



Increase in carbon fixation under climate warming scenario A1B

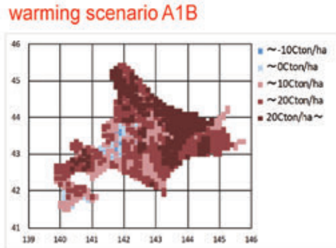


Figure 3. The effect of warmer temperatures on carbon fixation in the clean larch. Calculations for 40-year old stands in 2050.

Growth model constructed from growth data for 5- to 39-year old trees in nine sites, wood bulk density (specific gravity), and climate data from weather monitoring stations.

Global warming progresses
→ Carbon fixation increases at most sites.

For further information: Kazuhito Kita, Hokkaido Research Organization, Forestry Research Institute e-mail: kita-kazuhito@hro.or.jp

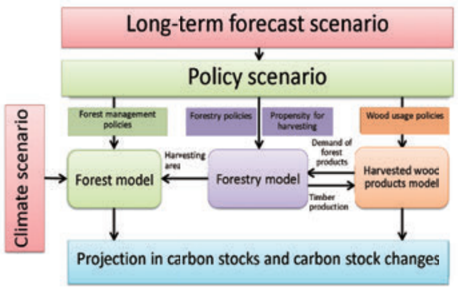
The Best Mix of Mitigation Measures Against Climate Change in the Forestry Sector based on Future Projections

Mitsuo Matsumoto, Hiroyasu Oka, Mario Tonosaki, Yuko Tsuneji, Hideaki Kanomata, Takuya Shimase (FFPRI)
Yasushi Mitsuda (Miyazaki University)
Chihiro Kayou (Tokyo University of Agriculture and Technology)

For mitigation of climate change in the forestry sector, we have to seek for the most effective "best mix" measures considering the relationship among forests, forestry and wood use. Different policy scenarios were set up and an integrated forest carbon model was formulated. Results showed that the scenarios promoting forestry production and wood use were effective for mitigation. It was clear that wood use had an significant role to play in reducing carbon dioxide emissions.

1 An integrated carbon model for forests, forestry and wood use

When considering mitigation of climate change, the role of forests in removal of carbon dioxide and the role of wood use in emission reduction need to be considered together. We developed an integrated forest carbon model that makes it possible to project future outcomes considering relationship among forests, forestry and wood use.



Structure of an integrated forest carbon model.

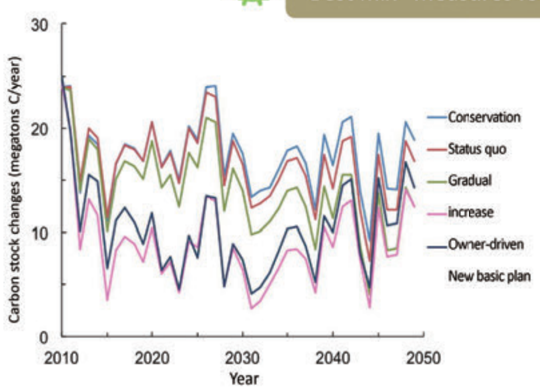
2 Policy scenarios for projecting forestry sector in future

For projecting future conditions in the forestry sector, 5 policy scenarios and indicators were developed. Indicators were selected by promoting forestry production and utilization of harvest wood, which may contribute mitigation of climate change.

Indicators for the five scenarios

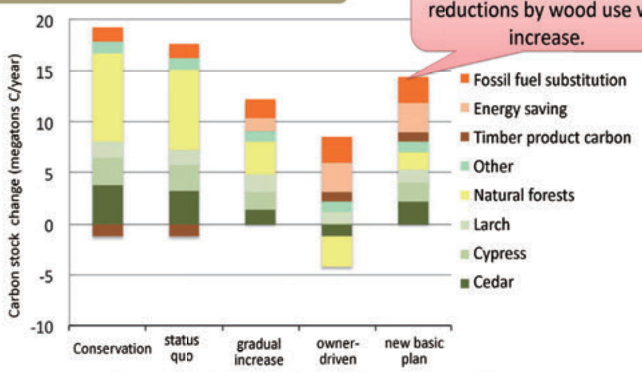
Scenario	Forestry indicators			Wood use indicators	
	Harvesting area	Re-planting ratio	New varieties used	Building construction, furniture	Civil engineering
Conservation	Less than at present	More than at present	None	Present ratios (35%)	Present volume (1 million m^3)
Status quo	No change	Present rate	None	Present ratios (35%)	Present volume (1 million m^3)
Gradual increase logging	More than double the present area by 2050. (20% of planted forests by 80 years of age, one-third by 100 years).	Present rate	None	Increasing to 50% by 2050	Increasing to 3 million m^3 by 2050
Owner-driven	15%–30% increase between 2011–2030. 25%–30% increase between 2031–2050. according to questionnaire results	Increasing to 70% for larch and 50% for cedar and cypress, according to questionnaire findings.	None	Increasing to 70% by 2050	Increasing to 6 million m^3 by 2050
Basic plan (aggressive forestry and wood use)	Log production: 39 million m^3 by 2020, 50 million m^3 by 2050. Major increase in harvesting area, use of thinned logs.	Increase	Increasing to 70% by 2050.	Increasing to 0% by 2050	Increasing to 6 million m^3 by 2050

3 "Best mix" measures for mitigation based on projections



Carbon stock changes due to forests and wood use

Although removals by forests will decrease, emission reductions by wood use will increase.



Breakdown of projected carbon stock changes in 2050

【Experimental parameters】
Forests: Removals and emissions in cedar, cypress, larch, natural forests and others.
Wood use: Removals and emissions due to the carbon sequestration effect associated with domestic wood use and the emission reductions due to the energy saving effect and the fossil fuel substitution effect.

It was clear that the two scenarios where forestry production and wood use are promoted were effective also for the mitigation of climate changes. The scenarios seem like to be the "best mix" measure.

For further information, Mitsuo Matsumoto (FFPRI), email: machan@ffpri.affrc.go.jp

Using Forests and Green Shade as Shelter
— Simple Climate Change Adaptation Measures to Prevent Heat Stroke —

Michiaki Okano (FFPRI)

Lining avenues and other places with trees to provide shade on hot days is a practice that has been going on since ancient times. We have investigated the effectiveness of shade from stands of trees ("green shade") using Wet Bulb Globe Temperature (WBGT) measurements, which are suitable for this type of investigation. Using this WBGT method we found that stands of trees in suburban areas can provide shade that can protect against the ill effects such as heat stroke.

1 What are the indicators of green shade/tree shade coolness?

The Wet Bulb Globe Temperature (WBGT) index is calculated from the wet and dry temperatures recorded using a black globe thermometer and hygrometer. When measuring the heat environment it is necessary to consider not only the air temperature but to also humidity, wind speed and solar radiation (radiant) heat. The WBGT is also known as the hotness index.

WBGT = 0.7 NWB + 0.2 GT + 0.1 NDB   Outdoors in the sun
WBGT = 0.7 NWB + 0.3 GT   Indoors, or outdoors out of the sun.

NWB (Natural Wet Bulb Temperature) is the bulb temperature when exposed to natural air without solar radiation. GT (Globe Temperature) is the black bulb temperature and NDB (Natural Dry Bulb Temperature) is the dry bulb temperature when exposed to natural air.

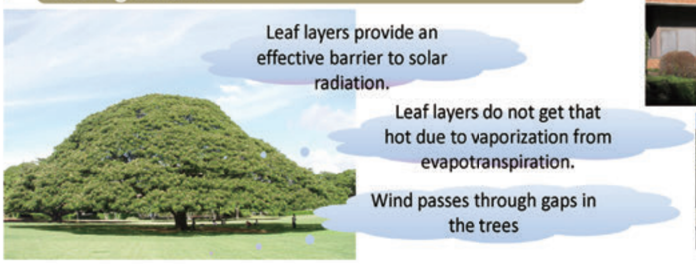
2 How effective is green shade at cooling?

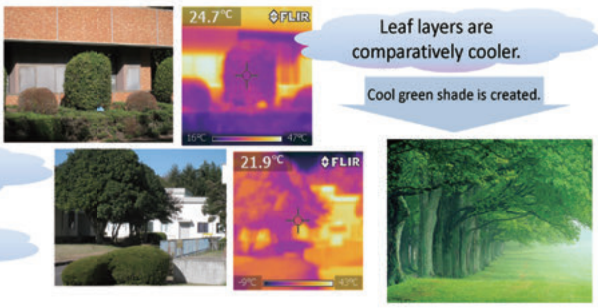
We took measurements in a variety of different stands, including single trees. Even bright shade was 2 to 4 ° C cooler than direct sunlight when measured using WBGT. Some shady areas were up to 5 to 6 ° C cooler. This cooling is sufficient to reduce heat stroke risk by 1 to 2 ranks.

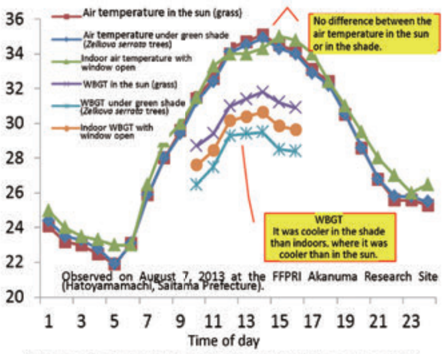
Examples of air temperature and WBGT average deviation (control site = grassland).
(Sunny days in August (2011–2014, 10:00-16:00))

	Temperature	WBGT
Grassland control	—	—
Shade from single tree (loblolly pine)	-0.4℃	-2.4℃
Green shade (Zelkova stand)	-0.8℃	- 3.4℃

3 Why do green shade and tree shade have a cooling effect?







Outdoor, indoor and green shade temperatures on a sunny day in mid-summer.

- WBGT (heat index) measurements can appropriately evaluate green shade.
- The WGBT in green shade is lower than in a non-air conditioned room with the window open in the middle of summer. There have been case studies showing that this reduces the heat load on the body.
- Green shade has a cooling effect so can be a useful shelter during heat waves.
- Green shade can provide cooling to those with less efficient heat regulation, such as infants and older people, as well as to people with disabilities. It can reduce the ill health effects caused by heat.
- Using WBGT (heat index) measurements to evaluate the effectiveness of green shade can help to avoid the ill health effects caused by heat and contribute to measures to adapt to global warming.

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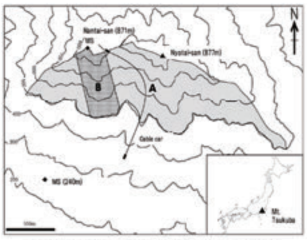
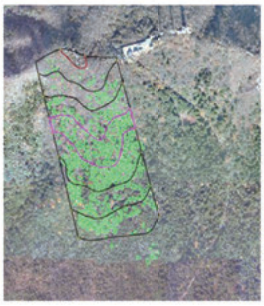
Estimating the Impact of Climate Warming on Changes in Evergreen Broadleaf Tree Distribution on Mt. Tsukuba over Past 44 years using Aerial Photographs

Nobuyuki Tanaka, Masatsugu Yasuda, Etsuko Nakazono, Hiromu Daimaru (FFPRI)

We analyzed changes in tree crown distributions of old-growth natural forests on the southern slope of Mt. Tsukuba from 1961 to 2005 using aerial photographs. Our results showed increases in the area of evergreen broadleaf tree crowns at each elevation. The coldness index (CI) corresponding to the coldness limit of broadleaf evergreen forest distributions is −10, and the average minimum daily temperature for the coldest month corresponding to the coldness limit for Japanese evergreen oak (*Quercus acuta*) distributions is −4.7. Over the last 100 years, the elevations of these temperature limits have risen by 147 m and 146 m, respectively. Since these forests have been protected as a sacred site at least after the eighth century, these changes are more likely due to climate warming than plant succession after disturbances.

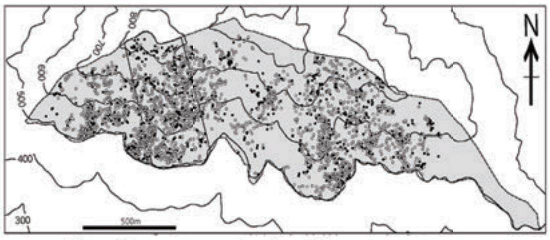


Plots (A and B) and meteorological stations (MSs)
Shaded: plot A (125 ha) ; Dark shaded, plot B (20 ha)

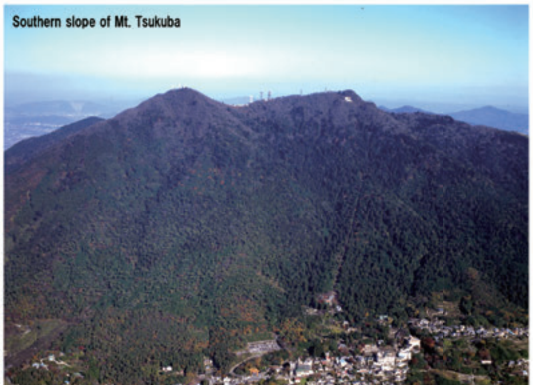


Photograph taken in the winter of 2005.

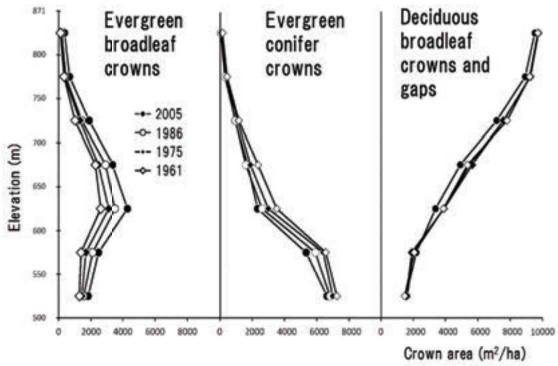
1 Emergence and disappearance of evergreen broadleaf tree crowns



Map of tree crown centers in plot A
○: persisting crown from 1961 to 2005 (1820 crowns)
●: crown emerging between 1961 and 2005 (600 crowns)
▲: crown disappearing between 1961 and 2005 (18 crowns)

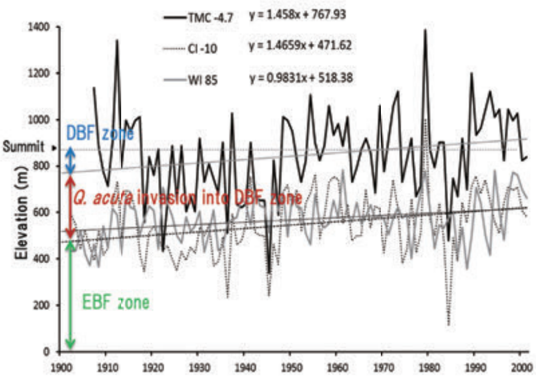


2 Increase in the area of evergreen broadleaf tree crowns



Yearly changes of the crown area along elevation in plot B

3 Historical changes in climate



Yearly changes of elevational distribution limits estimated by climatic indices

CI-10: coldness limit of warm-temperate evergreen broadleaf forests (EBFs)
WI 85: warmth limit of cool-temperate deciduous broadleaf forests (DBFs)
TMC-4.7: coldness limit of *Quercus acuta*

For more information: Nobuyuki Tanaka (FFPRI) ntanaka@affrc.go.jp

Will Leafing Occur Earlier in Deciduous Broadleaf Forests due to Warming? — A Case Study in Gifu Prefecture —

Yoshio Awaya (Gifu University)

We used air temperature forecasts data from a climate model to estimate changes in leafing, concentrating on Gifu Prefecture. Taking 1990s as a base, leafing is predicted to occur 14 days and 28 days earlier in the next 50 and 100 years, respectively. The advance is predicted to be particularly marked at lower rather than higher elevations.

1 Background and objectives

- Plant growth periods are affected by global warming.
- Leafing is closely associated with the cumulative air temperature exceeding 5˚C.

→

1. Developing a model to estimate leafing day based on daily average air temperatures.
2. Determining the effects of global warming by estimating yearly changes in leafing day.

2 Methods for determining leafing day

- Analyzing the leafing day in 2007 using Terra/MODIS data.
- Creating a leafing model based on the relationship between air temperature and the results of the MODIS data analysis (Table 1, Figure 1).
- Determining leafing days using daily average air temperature predicted using the climate model MIROC.

Table 1: Conditions for leafing determination

Diapause ending	2 days with average air temperature of 10ºC
Resetting	average air temperature of 4ºC or less
Pause	Sudden cold snaps -> reopening at 8ºC or more
Integration	Days of 5ºC or more
Cumulative air temperature	120ºC or more

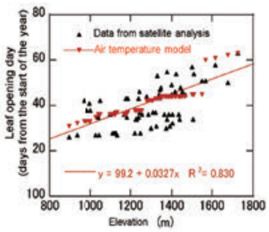
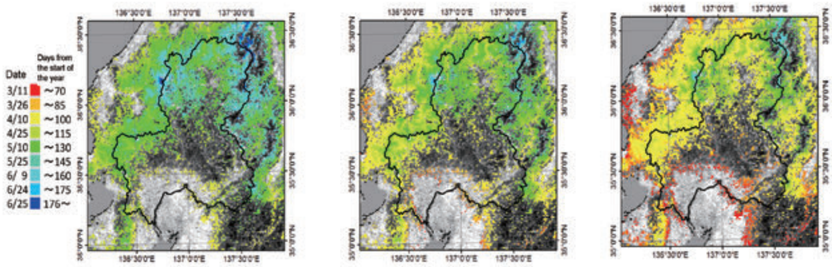


Figure 1. Validation of the leafing day model.

3 Changes in leafing date.

Determination of leafing date (10-year average):
1990s, 2040s, 2090s
Yearly change (difference between 2 points in time):
1990s – 2040s
1990s – 2090s

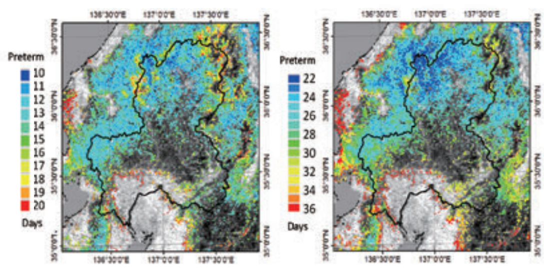


1991–2000 2041～2050 2091～2100

Figure 2. Average leafing dates over a 10-year period.

Results and Discussion

- In the 1990s (present day), leaf opening starts around 100 days from New Year's Day at low altitudes, and around 160 days at high altitudes (Fig. 2).
- In the 2090s, leafing will start around 70 days from New Year's Day at low altitudes and around 140 days at high altitudes (Fig. 2)
- On average, leafing will start approx. 2 weeks earlier after 50 years and approx. 4 weeks earlier after 100 years (Fig. 3)
- The advance in leafing date is more marked at low than high altitudes (Fig. 3).
- The period from first appearance at low altitudes to last appearance at high altitudes will become longer.



1990s – 2040s 1990s –2100s

Figure 3. Yearly changes in leafing day (effect of global warming)

Acknowledgement
We would like to express our thanks to Dr. Izumi Nagatani, who corrected the Terra/MODIS data provided by the of the Ministry of Agriculture, Forestry and Fisheries' Research Information Centre, and Dr. Shinji Sawano of FFPRI who prepared the MIROC data.

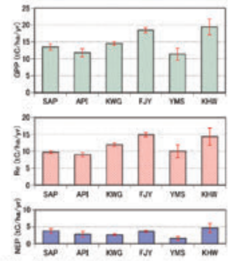
Forecasting changes in carbon budget in forest ecosystems as a result of global warming

Katsumi Yamanoi, Yasuko Mizoguchi, Yukio Yasuda, Gen Utsugi,
Takafumi Miyama, Satoshi Takanashi, Hiroshi Kominami, Kenzo Kitamura (FFPRI)
Takashi Nakano (Mount Fuji Research Institute, Yamanashi Prefectural Government)

We constructed observation towers to monitor carbon budget in a variety of forests throughout Japan. There was some variation due to year and location, but in general, forests in Japan absorb a lot of carbon. We used a model to analyze future carbon budget and found that global warming would result in high tree growth in Hokkaido deciduous broadleaf forests, and therefore an increase in carbon absorption.

1 Carbon absorption in various forests

The FFPRI flux observation network.



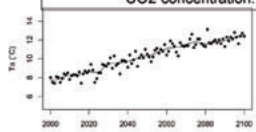
The carbon budgets in different forests
GPP: Gross primary production = Photosynthesis
Re: Total respiration = maintenance respiration + growth respiration + heterotrophic respiration
NEP: Net ecosystem productivity = GPP-Re = ecosystem carbon absorption

- Carbon budget has been obtained for each forest type based on measurements carried out over a period of 10 years.
- Carbon budgets are influenced by weather conditions each year (temperature, solar radiation, snow cover period, etc.).
- The causes of annual variations in carbon budgets are complex, making it difficult to forecast them based on observed values alone.

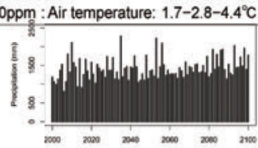
2 Predicted warming and environmental changes

Predicted climate change values for the Sapporo site based on warming scenarios.

MIROC-H A1Bscenario
: High growth society scenario. An emphasis on balancing carious energy sources.
CO2 concentration: 750ppm : Air temperature: 1.7–2.8–4.4℃



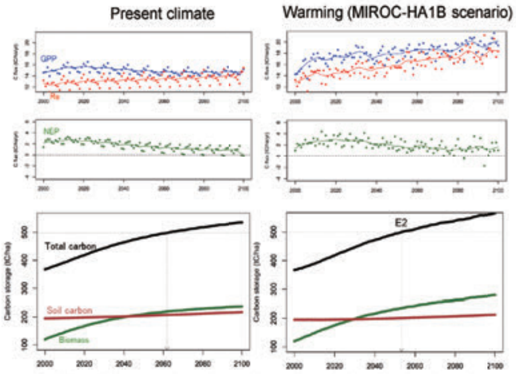
redicted average air temperature



Predicted precipitation

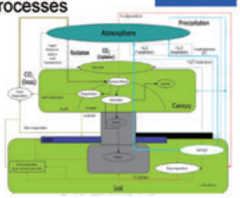
After 100 years, the average air temperature in Sapporo is predicted to rise by 4° C and there is expected to be a slight increase in precipitation.

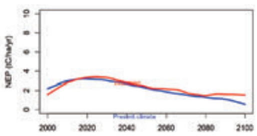
3 Predicted effect of warming on carbon budget



Predicted changes in carbon absorption (carbon budget) and accumulation with warming at the Sapporo site.

Model of ecosystem processes





A comparison of carbon absorptions at the Sapporo site.

GPP: Under the present climate, changes in GPP are minor and these are expected to decrease slightly in the future. If the climate warms, GPP will show an increasing trend, which will continue for 100 years.
Re: Under the present climate Re shows a slight increase, which will continue. If the climate warms, the rate of increase will be higher and that tendency will continue.
NEP: This will reach a peak by 2020 under the present climate or 2030 under a warming scenario. Carbon absorption will show a declining trend.
The differences between the two scenarios are minor, but if the climate warms then the carbon absorption volume will increase.
Carbon accumulation: Total carbon accumulation in the forest ecosystem will be greater if the climate warms. The main cause will be a greater biomass accumulation in trees.

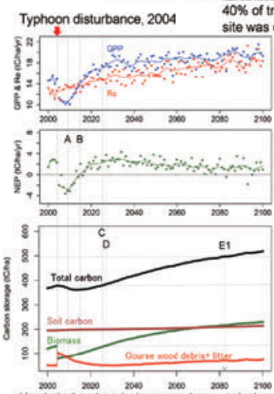
4 Increased disturbances predicted by global warming

What is happening at the Sapporo site? What will happen in the future?)

Forest disturbances: Forest fires, Disease and insect damage, Wind damage, Logging, Snow damage

40% of trees in the Sapporo site was damaged by wind.

Typhoon disturbance, 2004



Carbon balance compensation points
A: Emission peak
B: Emission → absorption (NEP=0)
C: Emitted amount absorbed= total carbon recovery (Accumulated NEP=0)
D: Biomass recovered

Predicted carbon balance and sequestration (including typhoon damage).

- Such disturbance is by no means unusual.
- If windfall trees are remained on site like at the Sapporo site, then the carbon stocks lost will take 20 to 30 years to recover (C and D)
- Carbon lost through disturbance cannot be recovered and the effect will last a long time (E1>E2).

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The Relationship between Landslides and Deforestation on the Northern Slopes of Mt. Ichifusa, Kyushu

Wataru Murakami (FFPRI), Hitoshi Saito (Kanto Gakuin University), Hiromu Daimaru (FFPRI)

There have been concerns about the increasing numbers of landslides that accompany the more frequent bouts of heavy rainfall caused by recent warming. In order to evaluate landslide risk it is necessary to consider vegetation change due to cutting, etc., in addition to climate change. Our research showed that on granite slopes, landslides occurred more frequently after clear cutting, but this could be reduced if reforestation occurred immediately after cutting.

1 Research site, geology and methods

This investigation compared landslide occurrence and forest management records (e.g. deforestation or non-deforestation, and reforestation after the deforestation) over the last 30 years on the northern slopes of mountains in Mt. Ichifusa, on the boundary of Kumamoto and Miyazaki Prefectures in Kyushu. Geologically, the test site was Neogene course grain to medium grain granodiorite. We used aerial photographs to pinpoint the site of landslides, classify the vegetation patterns and investigate the relationship between the two (Fig. 1).

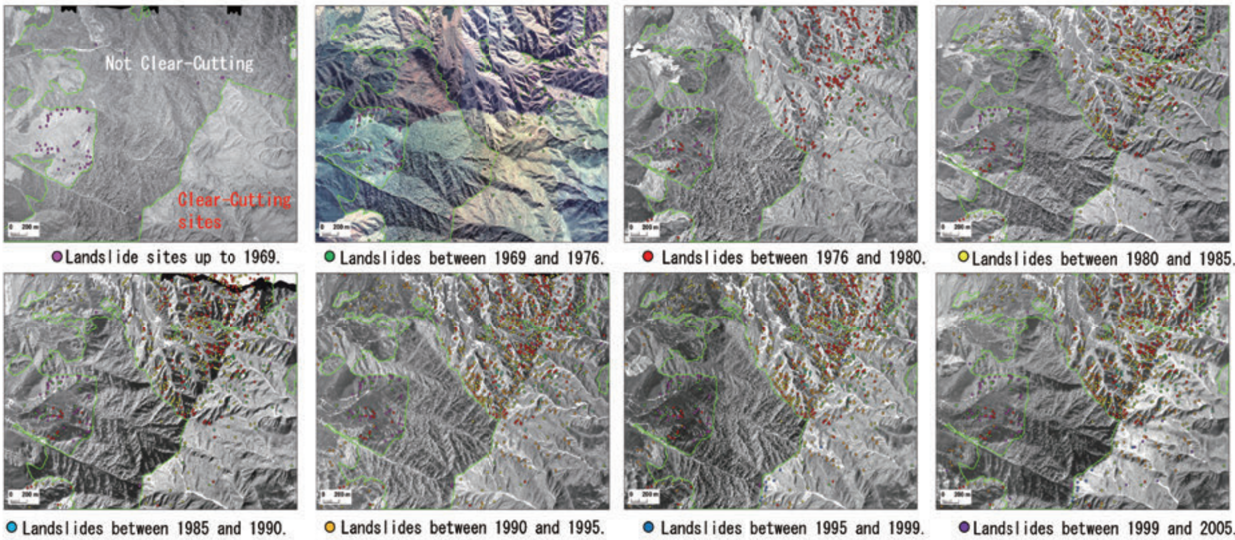

Figure 1. Vegetation changes and changes in landslide sites.

2 Survey results

Survey results During the period between 1969 and 1976 large scale cutting and reforestation was carried out in the survey area (Fig. 2). After that, since 1980, there were a high number of landslides in deforestation zone, but hardly any in the non-deforestation zone (Fig. 3). Furthermore, there were few landslides on slopes where reforestation had been carried out immediately after cutting (Fig. 3). What this means is that on easily subsiding granite slopes, it is important to avoid large-scale cutting and to reforest immediately after logging. The relationship between landslides and rainfall that occurred at the time is shown in T-05.

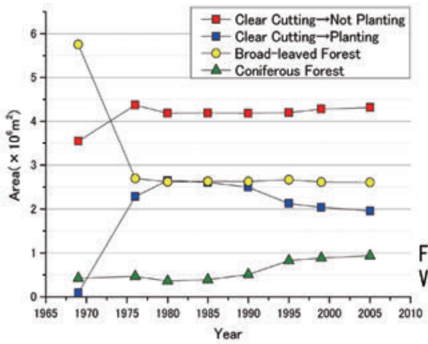

Figure 2. Vegetation changes.

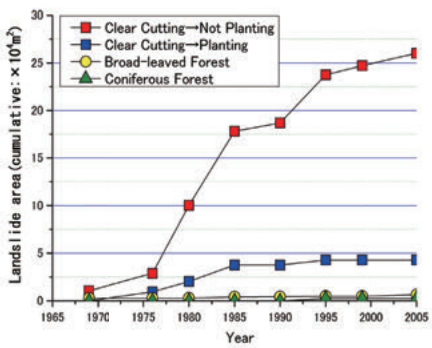

Figure 3. Changes in landslide area according to the state of vegetation.

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Relationship between the Occurrence of Shallow Landslides on Granite Mountains and the Recurrence Intervals of Heavy Rainfall — A Case Study at Mt. Ichifusa and the Abukuma Mountains —

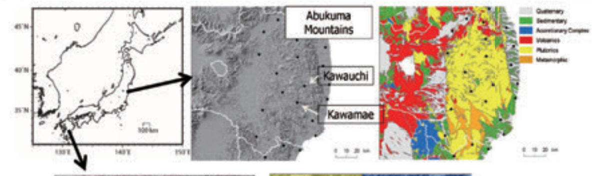
Hitoshi Saito (Kanto Gakuin University), Wataru Murakami, Hiromu Daimaru (FFPRI), Takashi Oguchi (University of Tokyo)

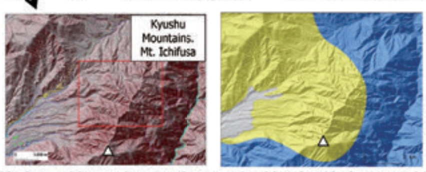
This study examined recurrence intervals of heavy rainfall and rainfall intensity-duration (I-D) thresholds for shallow landslide occurrence in two granitic mountains. In Mt. Ichifusa, results show that few shallow landslides occurred at the beginning of clear-cutting but occurred frequently after clear-cutting. I–D thresholds after the clear-cutting declined to one-third of those at the beginning of the clear-cutting. These thresholds roughly correspond to return periods of >5 yr and <1 yr for before and after clear-cutting, respectively. In the Abukuma Mountains, the I–D thresholds for the extensive shallow landslide occurrences correspond to a return period of >5 yr.

1 Background and Aim

- Dealing with predicted increases in extreme weather conditions due to climate change requires robust knowledge about controls on rainfall-triggered landslides. Numerous studies have attempted to decipher critical rainfall conditions during which hillslopes become unstable.
- This study examined recurrence intervals of heavy rainfall and rainfall intensity-duration (I–D) thresholds for shallow landslide occurrence in two granitic mountains in Japan which have different climatic conditions and topography.

2 Study sites

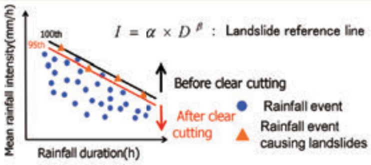




Relief maps and geological conditions of the Abukuma Mountains and Mt. Ichifusa in the Kyushu Mountains

- he Abukuma Mountains are characterized by the Abukuma and Kitakami granite rocks with the mean annual precipitation less than 1,500 mm. The Mt. Ichifusa is consists of thickly weathered granite rocks with mean annual precipitation of more than 3,000.

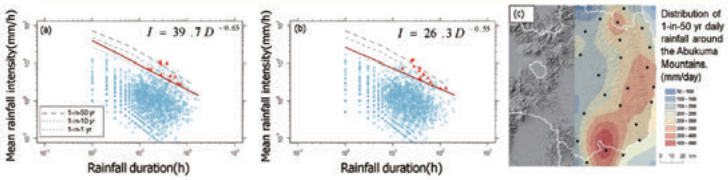
3 Methods of analysis



Overview of the analysis using mean rainfall intensity (mm/hr) – rainfall duration (hr).

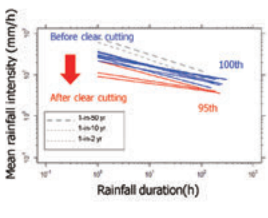
- We collected landslide data from disaster reports and interpretation of aerial photographs.
- In the Mt. Ichifusa, we detected clear-cutting areas and landslides from orthorectified aerial photographs taken in 1969, 1976, 1980, 1985, 1990, 1995, 1999, and 2005. We identified initiation areas of landslides larger than 10 x 10 m (Murakami et al., T-04).
- We analyzed the mean rainfall intensity (I, mm/h) and duration (D, h) of all rainfall events using data for raingauges from 1950s in Mt. Ichifusa, and from 1970s in the Abukuma Mountains operated by JMA and MLIT. We examined rainfall I-D thresholds for landslide occurrences using the quantile-regression method (Saito et al., 2010, Geomorphology). A rainfall I-D threshold is usually obtained by drawing minimum-level lines to the rainfall I-D of landslide events.

4 Results and discussion



Relationships between mean rainfall intensity (mm/hr) and duration (hr) at (a) Kawauchi and (b) Kawamae, and (c) the recurrence interval 1-in-50 yr daily rainfall (c).

- Relationships between mean rainfall intensity (mm/hr) and duration (hr) at (a) Kawauchi and (b) Kawamae, and (c) the recurrence interval 1-in-50 yr daily rainfall (c).
- Rainfall I-D thresholds are I = 39.7 * D -0.65 at Kawauchi, and I = 26.34 * D -0.55 at Kawamae which correspond to the return period of >5 yr. In the Abukuma Mountains, the I-D thresholds for the extensive shallow landslide occurrences correspond to the return period of >50 yr.



A comparison of the rainfall I-D thresholds before and after clear cutting at Mt. Ichifusa with recurrence intervals of rainfalls.

- Results show that few shallow landslides occurred at the beginning of clear-cutting, and that shallow landslides occurred frequently after clear-cutting, such as during periods of 1976–1980, 1980–1985, and 1990–1995. The cumulative shallow landslide area reached c.a. 6 % in the clear-cutting area. I–D thresholds after the clear-cutting declined to one-third of those at the beginning of the clear-cutting. These thresholds roughly correspond to return periods of >5 yr and <1 yr for before and after clear-cutting, respectively. These results are expected to be important for landslide hazard assessments and for future forest management that should be verified in other granitic mountains

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Technological Developments to Protect against Landslide Disasters Occurring as a Result of Global Warming

Yasuhiko Okada, Takashi Miyamae, Ushio Kurokawa (FFPRI)

We evaluated the effectiveness of Chisan dams (erosion-control structures) designed to preserve the stability of slopes after extremely heavy rain through physics experiment using large-scale model and numerical experiment. The physics experiment showed that if the Chisan dams are built, this increases the time before landslides occur. The numerical experiment showed that this reduces the area of deformation of the slopes. These results confirm their effectiveness at preventing landslides.

1 Experiments using a large-scale model of a slope

Large-scale model of a slope

A backfilled Chisan dam on the model slope.

A 9-meter long slope model was packed with soil and subjected to rainfall of 100 mm/hr and 200 mm/hr.

Under 100 mm/hr rainfall conditions, an experiment replicated a backfilled Chisan dam on a gentle model slope

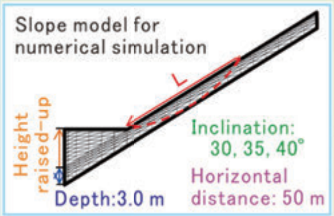
Under 100 mm/hr rainfall conditions, it took 2,891 seconds for the slope to collapse. Under 200mm/hr conditions, the collapse took 1,471 seconds, which was half the time required in the 100 mm/hr scenario. When the backfilled Chisan dam was in place, the time until collapse was much longer (3,586 seconds), confirming the effectiveness of the dams.

We constructed a 3-D geomorphological model to study the stability of mountain slopes. The model simulated a number of Chisan dams in two mountain streams.

We analyzed the way that the Chisan dams improve slope stability under three soil conditions: mostly dry (normal conditions), slightly damp (light rain) and saturated (heavy rain). The Chisan dams reduced the volume displaced and the area of slope deformation, and proved effective at stabilising the slope.

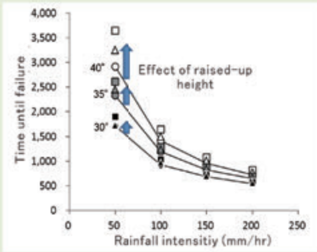
2 The effectiveness of Chisan dams (erosion control structures) in stabilising slopes

We ran numerical simulations using 2-D and 3-D models to determine the effect that raising the height of the Chisan dam or constructing Chisan dams would have on stabilising slopes.



2-D model used in analysis

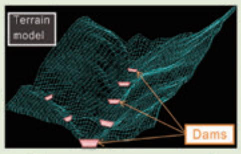
We performed calculation under various condition of the soil accumulation at the lower levels when a Chisan dam was constructed, various rainfall intensities and incline values.

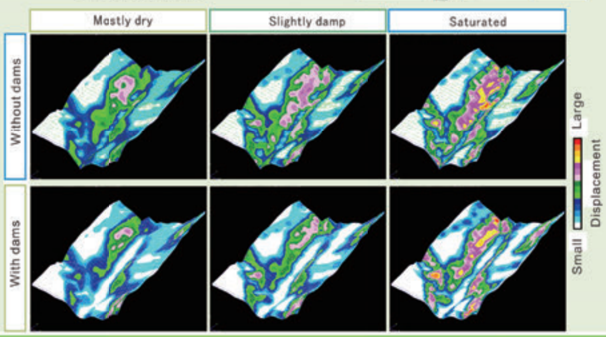


Results from the 2-D analysis

Results showed that at inclines of 30°, 35° and 40°, and at any rainfall intensity, increasing the soil accumulation by raising the height of the Chisan dams delayed the onset of collapse.

The 3-D analysis model and results





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Futural Water Discharge in Mountain Streams: The Effect of Forests

Ikuhiro Hosoda, Shinji Sawano (FFPRI)

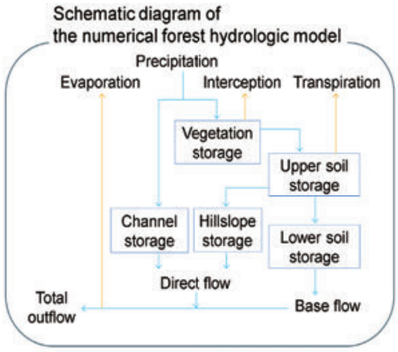
We estimated the water flow rate in headwater catchments in temperate with little rainfall region using climate change data for the next 50 years. We found that grown forest catchment were more prone to droughts than newly planted catchment. On the contrary, floods were mitigated in grown forest catchment. These results suggest importance of forest management to cope with both water resource reservation and natural disaster mitigation.

1 Effect of climate change on water discharge

- We are trying to forecast the influences of global climatic change on water discharge in mountain streams which is indispensable water resource for such as agricultural production.
- We used a numerical forest hydrologic model that the model parameter sets were separately calibrated to a grown forest catchment and a newly planted catchment in temperate with little rainfall region*1. We analyzed difference of changes in estimated water discharge on the basis of climate change data*2 up to 2060.

*1: The Minami-tani catchment in the Tatsunokuchi-yama experimental watershed where data are accumulating since 1937.

*2: Used data are from 2008 to 2060 based on the IPCC AR4 (2007) PCMDI CMIP3.



2 Grown forests are not beneficial in terms of water use

- Base flows*3 and direct flows*4 were higher in newly planted catchment (therefore total outflow*5 was higher).
- Drought frequency was higher, and the flow levels were deeply dropped in grown forest catchment (serious drought will be apprehended).

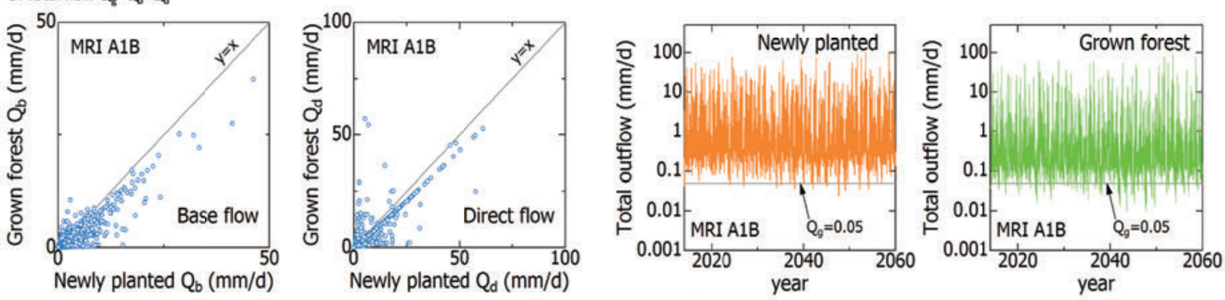
*3: Flow from the lower soil storage (Q_b)

*4: Flow from the channel storage and the hillslope storage (Q_d)

*5: Total flow Q_g=Q_b+Q_d

3 Grown forests are favorable for natural disaster mitigation

- As there is high evapotranspiration in grown forest catchments, the soil is drier than in newly planted catchments, which reduces direct runoff (contributing to flood mitigation).
- Because the soil layers are drier in the grown forest catchments, increasing of the soil pore water pressure will be delay compared with the newly planted catchments (contributing to slope stability).



Graphs show the estimated results based on the MRI A1B data (A1B climate scenario data from the Japan Meteorological Agency Meteorological Research Institute), which cumulative precipitation is the least around the target area in the CMIP3. Q_g = 0.05 mm/d is assumed as a critical value for drought condition of the catchment.

Proper forest management is important to cope with both water resource reservation, and flood mitigation and slope stability.

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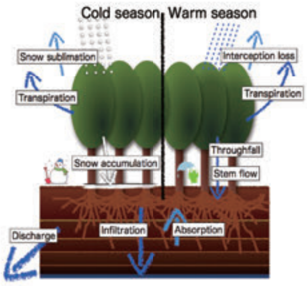
Evaluation of the amount of water resources in Japanese forested areas

Shinji Sawano (FFPRI)

Climate change such as global warming will have significant impacts on water supply from a forested area that represents the most significant land cover type for water resources, and therefore may affect the water use at a downstream region. Distribution of water resources in forested areas provides most essential information for proper water resources management. We have been developing a large-scale forest hydrological model to evaluate the distribution of water resources in forest areas under changing climate.

1 Large-scale forest hydrological model

We have developed a large-scale forest hydrological model to simulate the water cycle in forested areas with taking into account the characteristics of Japanese forest water cycle.

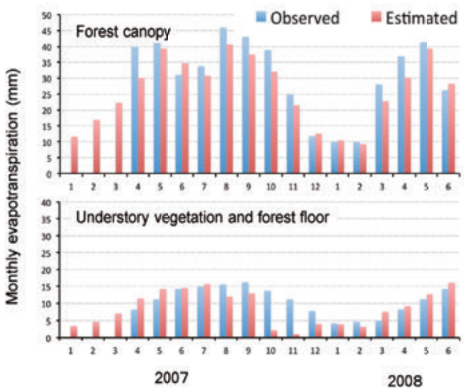


2 Model validation data

■Kahoku forest experimental watershed No.3
- -Kahoku-machi, Yamaga-City, Kumamoto
- -Altitude: 165m
- -Catchment area: 12.7 ha
- -Vegetation: Cedar, cypress

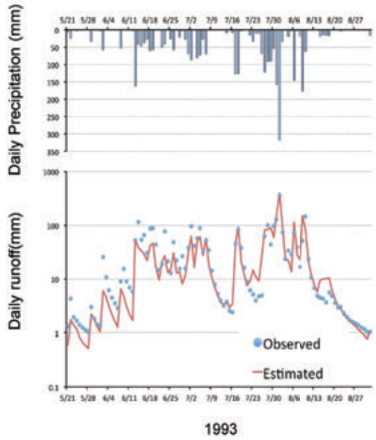
■Sarukawa long-term forest experimental watershed No.3
- -Takaoka-cho, Miyazaki-city, Miyazaki
- -Altitude: 202-288m
- -Catchment area: 8.2ha
- -Vegetation: Cedar, Boehmerica spicata, Neolistsea aciculate

3 Simulation of forest water use



Our model represents the observed seasonal changes in evapotranspiration at Kahoku forest experimental watershed both forest canopy evapotranspiration and evapotranspiration from understory vegetation and forest floor.

4 Simulation of the runoff from a forested area



Our model replicates the observed runoff characteristics of the increase trend during rainfall events and the decrease trend after rainfall ceases at Sarukawa long-term forest experimental watershed.

Now we are constructing a model to simulate snow processes in forested area. After integrating the snow process model to our large-scale forest hydrological model, we will evaluate future water supply from Japanese forested area under changing climate.

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Towards Healthier Coastal Forests

Tomoki Sakamoto, Satoru Suzuki, Hironori Noguchi, Yoshiaki Goto, Takashi Miyamae (FFPRI)

With climate change, typhoons are forecast to get stronger and danger of tidal surges is forecast to increase, which means it will be particularly important that judicious thinning practices are used to regulate tree numbers for the low tree density and improve the health of coastal forest zones. If a single row parallel to the shoreline is logged and several rows left unlogged, then the remaining trees are protected by the seaward rows, and the impact of logging on these is minimal. This is considered to be an effective way of regulating tree numbers.

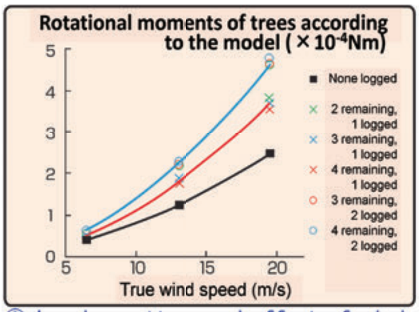
1 Managing density can lead to healthier forests

- In coastal black pine forests, controlling tree numbers is often delayed. This means that the forests become overgrown, the trees are thin, and the branches are spindly in spite of their height (1). The dangers from strong typhoons and high tidal surges will likely increase with climate change, making it important to grow healthy coastal forest zones with trees that have strong trunks and robust branches and leaves. This requires judicious thinning techniques to regulate tree numbers, but it should be noted that this will expose the remaining trees to the sea wind.

① Overgrown forests with thin and spindly trunks and withered branches

2 Effect of single row thinning: wind tunnel experiments

- From the working point of view, thinning by rows is an effective means of regulating tree numbers in densely planted coastal forests. Wind tunnel experiments were set up to determine how the positioning of thinned rows and remaining rows affected the strength of the wind experienced by the remaining rows, and how the direction of the thinned rows against the sea wind affected.
- If the number of logged rows was increased from one to two, the wind strengthened. However the number of remaining rows made no difference to the effect of wind (2 and 3). In addition, the wind effect for the remaining rows was not as strong when the wind direction was perpendicular to the logged rows as it was when it was on a diagonal.



② Logging pattern and effect of wind

③ Comparative wind effect before and after logging(R:remaining,L:logged)

	None logged	2R1L	3R1L	4R1L	3R2L	4R2L	5R2L
90°	1.0	1.4	1.4	1.4	1.8	1.8	1.8
45°	1.1	2.0	2.0	2.0	2.7	2.7	2.7

3 Effect of single row thinning: field observations

- The wind speed, aerial salt concentration, and salt on the leaves were measured when a 1.2-m strip had been felled and when there is a 5-m working road (4).
- The wind speed ratio near the canopy dropped as one progressed inland. The wind was stronger on the road, but even here it was not as high as it was on the seaward side.
- The distribution of aerial salt concentration resembled that of wind speed, except there was no increase observed on the road.
- Logging did have an effect on the salt on the leaves, but where three rows had been left unlogged, the trees in the two landward rows were protected by the seaward row.

④ Field measurements of wind speed and aerial salt concentration

4 Logging every 4th row (1 logged, 3 retained) perpendicular to the direction of the sea wind is an effective means of regulating tree density that will lead to healthier forests.

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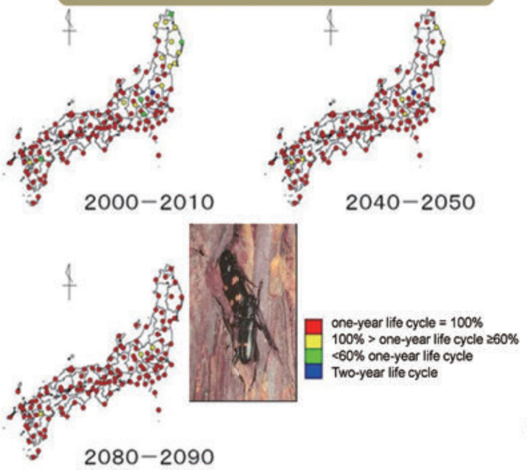
Possible Damage Expansion by Forest Insects under Global Warming

Kenichi Ozaki, Kazuma Matsumoto, Tadahisa Urano, Hiroshi Kitajima, Akira Ueda, Shigeho Sato (FFPRI)
Asaji Kyuna (Okinawa Forest Resources Research Center),Shinya Kubo (Kagoshima Forest Technology Center),Yoshinori Shintani (Minami Kyushu University),Ai Takeda (Chiba Agriculture and Forestry Research Center),Shoichi Saito (Yamagata Forest Research and Training Center),Mitsuhiro Okada (Nagano,Prefectural Forestry Research Center),Toshihide Hiruta (Fukushima Prefectural Forestry Research Center),Hironori Yasuda (Yamagata University)

We have predicted increases in the number of generations and occurrences, expansions of infested area and distribution of harmful forest insects. We used climate scenario data of the MIROC-H A1B scenario up to 2100 for the prediction. For the following insects, we predicted more widespread damage due to the global warming, which suggests a need for countermeasures.

1 Increasing number of generations in cryptomeria bark borer

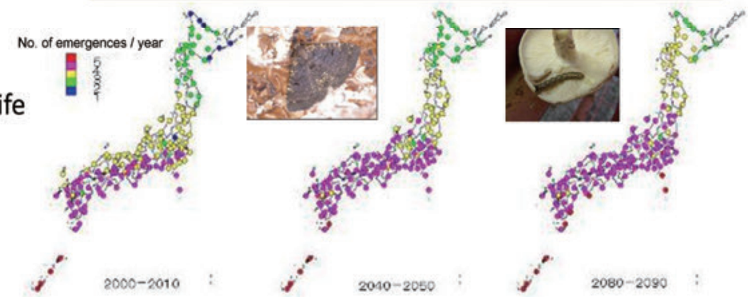


Two-year life cycle will change to one-year life cycle in the northern Tohoku region.

2 Range expansion in orange-banded pine moth

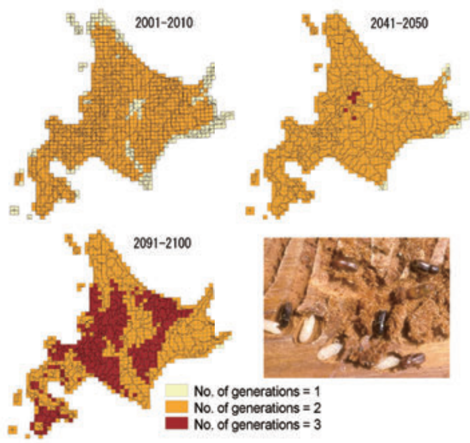
Possible overwintering sites will expand.

3 Increasing number of occurrences in *Diomea cremata*



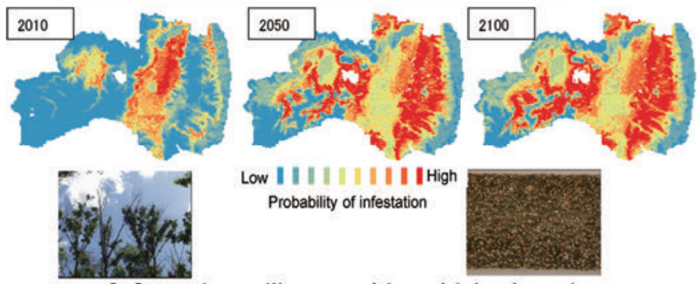
Areas with 3−4 occurrences per year will expand to north.

4 Increasing number of generations in spruce bark beetle



Number of generations will increase to 3 in some parts of Hokkaido island

5 Expansion of infested area by scale insects, *Comstockaspis macroporana*



Infestation will expand into high elevation areas in Fukushima prefecture

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Global Warming and Infestation during Shiitake Mushroom Bed-log Cultivation: Effects and Countermeasures

Kazuhiro Miyazaki, Masahiro Sueyoshi (FFPRI, Kyushu)

There are concerns that infestation in shiitake mushroom beds from insect and fungal pests will become more widespread with global warming. Our research aims for a better understanding of actual damage, and particularly seeks to determine whether the application of shade cloth would be an effective means of countering the effects of global warming. Our results confirm that this is effective in lowering the temperature in the beds and in the surrounding air.

1 Effect of global warming on increases in fungal damage

Recently, there have been increasing numbers of reports on damage from the fungi *Hypocrea peltata* and *H. lactea* on shiitake mushroom bed-logs. This is thought to be influenced by increases in summer temperatures and rainfall.

Log infested with *H. peltata* (Saga City, Saga Prefecture)

Log infested with *H. lactea* (Morotsuka, Miyazaki Prefecture)

Note: *H. peltata* and *H. lactea* are parasitic fungi, parasitizing on shiitake hyphae.

2000 AD 2010 AD 2014 AD

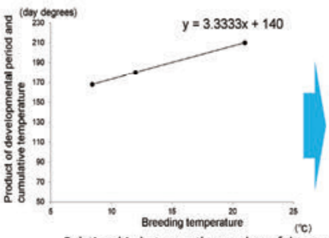
Confirmed reports of damage from *Hypocrea peltata* and *H. lactea* in Kyushu (red dots) have been increasing in number.

2 Effects of fungus gnat infestation

Fungus gnats damage shiitake mushrooms by their larvae eating the fruiting bodies and contaminating the crop. The period of infestation is predicted to increase in response to global warming.

Mycetophia ruficollis (adult)

Mycetophila ruficollis (larva)



With global warming, fungus grats can fly 2-8 weeks earlier.

Relationship between the number of days required before eclosion and cumulative temperature.

3 The effectiveness of shade cloth application on mushroom beds as a countermeasure

We confirmed the effectiveness of shade cloth application on top of artificial mushroom beds as a mitigation measure for warming.

Top view of the log mushroom bed showing the experimental application of shade cloth.

Bottom view of the log mushroom bed showing the experimental application of shade cloth.
Left= With shade cloth
Right= Without shade cloth

We confirmed the effectiveness of shade cloth by taking humidity and temperature measurements on the sites with and without shade cloth, and by measuring the temperature inside the logs, using a temperature probe.

↓

Application of shade cloth on the artificial beds reduced the number of days over 30° C and suppressed the temperature increase inside the logs.

↓

The use of shade cloth should be effective in reducing insect and fungal infestation.

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Monitoring Changes in Tropical Forests from Space

Yasumasa Hirata, Naoyuki Furuya, Hideki Saito, Gen Takao (FFPRI)
Nobuya Mizoue, Tetsuji Ota (Kyushu University)
Tsuyoshi Kajisa (Kagoshima University)
LENG Chivin, PAK Chealy (Forestry Administration, Cambodia)

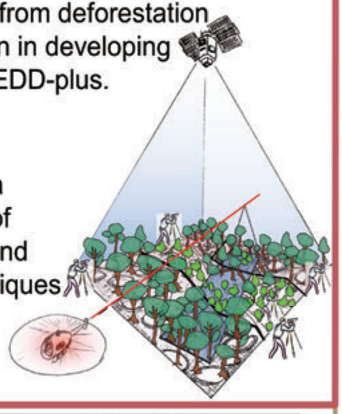
We have developed ways of effectively measuring carbon stocks and their changes in tropical forests using a combination of varied remote sensing techniques (See Posters D-01 to D-06). Here we present one of these new methods to quantitatively measure deforestation and forest degradation, a vitally important variable to estimate carbon sequestration and emissions from forests.

0 The multi-level forest observations

Accurate, efficient and verifiable measurements of carbon sequestration and carbon balance in forests is required for

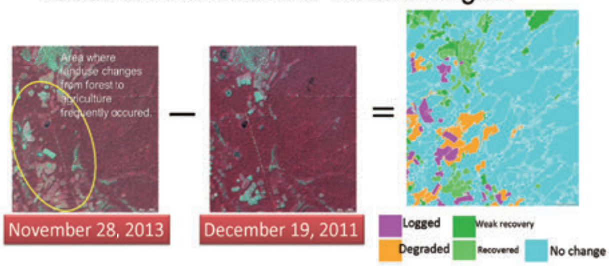
"Reducing emissions from deforestation and forest degradation in developing countries, etc.", or REDD-plus.

We have developed means of monitoring forests in remote area using a combination of field measurements and remote sensing techniques (see D-01 to D-06).



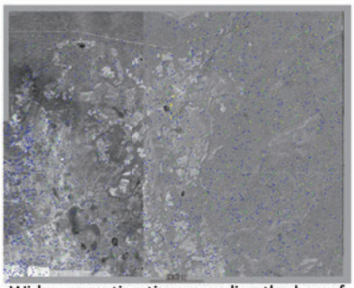
1 Monitoring deforestation

Deforestation is obvious when seen from the air. Forest changes were detected from a pair of images taken at different time points. Changes were determined not through pixel-by-pixel comparisons but by larger "objects" treated collectively where change has occurred. Changes are detected not only in the reflection spectrum but also in the size and shape. Interpretations can be made based on the causes of these changes.



2 Monitoring forest degradation (illegal and/or selective logging)

If forests are altered slightly through illegal logging, etc., the carbon accumulation declines, but because the forest is unbroken, such changes are hard to detect with conventional methods. By using high-resolution satellite images that can detect the canopies of individual trees and comparing images from different time to extract the lost canopy during the period, such canopy loss can be accurately detected and degradation can be determined. This method has a high probability of detecting the loss of higher trees that reach the canopy, as verified with field investigations in Cambodia. The ground survey also indicated that useful trees had been selectively logged. This newly developed technique can be a useful tool for wide and quantitative evaluation of degradation.

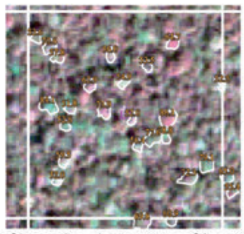


Wide area estimation regarding the loss of individual canopy trees

Tree species	frequency	Percentage
Anisoptera costata	117	26.53
Dipterocarpus costatus	111	25.17
Vatica odorata	70	15.87
Sindra siamensis	39	8.84
Eugenia spp.	29	6.58
Other	75	17.01

Tree species logged

Illegal logging in the field



Verifying the detection of logging

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D-02

Measuring the Above Ground Biomass of Tropical Seasonal Forests from Aircraft!!

Tetsuji Ota (Kyushu University), Tsuyoshi Kajisa (Kagoshima University), Nobuya Mizoue, Shigejiro Yoshida (Kyushu University), Gen Takao, Yasumasa Hirata, Naoyuki Furuya (FFPRI), Takio Sano (Asian Air Surveys), Sokh Heng, Ma Vuthy (Forestry Administration, Cambodia), Eriko Ito, Junpei Toriyama, Yukako Kadota, Hideki Saito, Yoshiyuki Kiyono (FFPRI), Chann Sophale, Ket Nang (Forestrt Administration, Cambodia)

Effective methods for measuring tropical forests are required. Here we report on results regarding the effectiveness of a method that uses an airborne laser survey to measure the above-ground biomass (AGB, total tree mass per unit area). We found that with this method it is possible to accurately measure AGB in a wide area of tropical forest. Such an approach will be useful for inaccessible and dangerous tropical forests.

1 The study sites

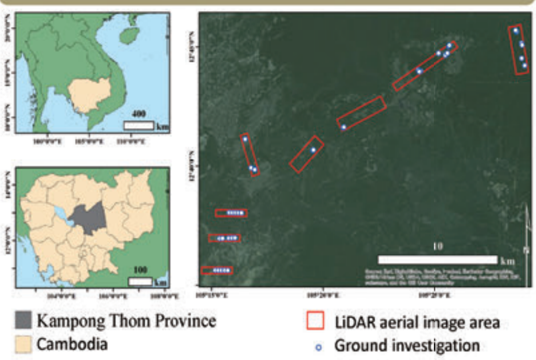

Figure 1. The study sites.

The study site was in Kampong Thom Province in Cambodia. both The ground measurements and laser surveys were conducted twice (in 2012 and 2014).

2 The LiDAR aircraft

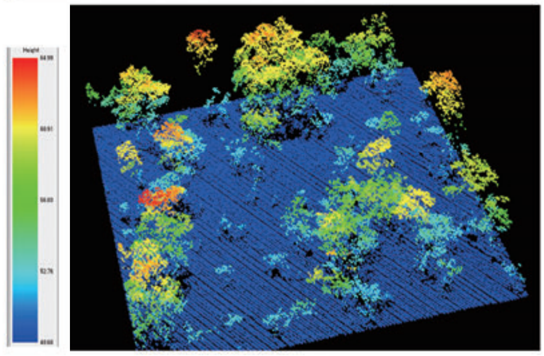

Figure 2. Example of the airborne laser data

The airborne laser emits a beam to show the 3-dimensional structure of the area above the ground. The figure shows a sample image of a forest. Blue shows the ground, while the green to red colors show trees.

3 Measuring above ground biomass in existing forests

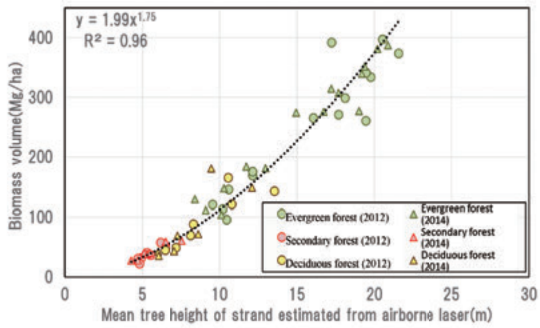

Figure 3. The relationship between the aerial laser and biomass

There is a strong relationship between the parameters measured by the aerial laser and the above ground biomass of the forest. The above ground biomass can be estimated through this relationship.

4 Measuring changes in forests

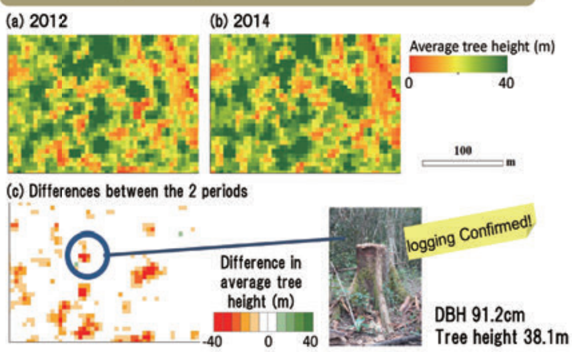

Figure 4. Change detection in the forests using the airborne laser

We were able to discover places where logging had taken place by using the aerial laser over two different time periods. From these results it can be said that it is possible to estimate changes in the forest using the airborne laser.

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How much Carbon is stocked in the Tropical Rain Forests of Borneo?

Keiko Ioki, Satoshi Tsuyuki, Wilson Wong (The University of Tokyo)
Mui How Phua (University of Malaysia Sabah)
Gen Takao, Hideki Saito, Yasumasa Hirata (FFPRI), Naohiro Miyasaku, Mai Hirase (Pasco Corporation)

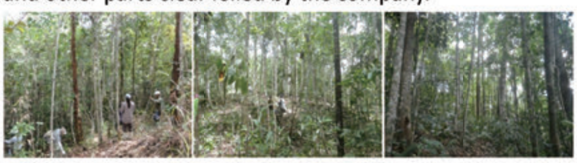
We are developing technology of estimating carbon stock with airborne laser survey, using the tropical rain forests of Borneo as a testing ground. Results so far indicate that by measuring canopy height and transmittance with the laser we can gain an accurate estimate of the carbon sequestration volume in tropical rain forests subjected to anthropogenic disturbance.

1 Estimates of carbon stock in tropical rain forests

Among the world's forests, the tropical rain forests are characterized by the high diversity of tree species and their complex multi-layered structure. However, many locations have been modified through anthropogenic disturbance, such as by local people through activities such as shifting cultivation and logging. We are developing a highly accurate means of estimating the forest carbon stock in rain forests using an airborne laser survey and are testing this on the tropical rain forests of Borneo. It is hoped that data such as that from surveys carried out in the limited number of plots used in the ground investigation can be used on a larger scale.

2 Study site

The study site in Borneo is in a steep mountainous region, in forest that is owned by the Sabah State government and managed by a paper manufacturing company. In addition to natural forests, areas of disturbance are apparent, with some parts used for shifting agriculture by local people and other parts clear felled by the company.

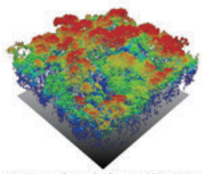


After clear-cut by a paper company | After shifting cultivation | Natural forest

3 Carbon stock estimation using airborne laser survey

The airborne laser survey can provide 3-dimensional point cloud data, which is particularly useful for ascertaining tree height. The effectiveness of this method in estimating carbon sequestration volumes has been confirmed in a number of forests.

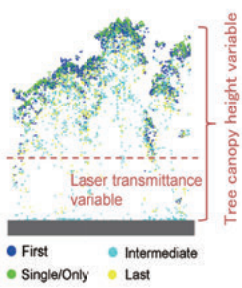
However, research among tropical forest, which has complex stand structure, has so far been limited. A means of developing this technology to improve its accuracy and versatility is required.



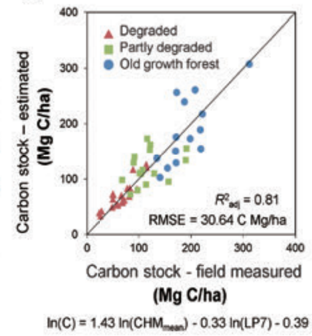
Point cloud data obtained from the airborne laser survey

4 Developing a carbon stock estimation model

We extracted the tree canopy height and canopy transmittance variables from the 3-dimensional point cloud data to create an estimation model for carbon sequestration. We found that using laser transmittance variables together with tree canopy height can provide a more accurate estimate of carbon stock in tropical rain forests than the tree canopy height alone.



variable extraction



Regression of carbon sequestration estimation model against data from field investigations.

We also discovered that the laser transmittance variable could be used to determine the differences in tree species composition in forests due to anthropogenic disturbances. We need to expand this research to continually improve our understanding on the uses of this laser survey technology in tropical rain forests.

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Elucidating the structure of tropical forests from the air: the use of high-resolution imaging.

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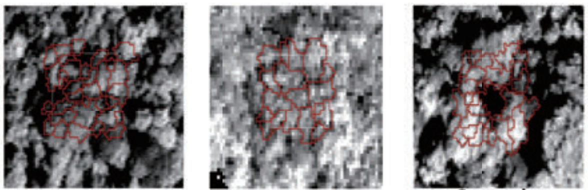
A canopy of individual tree that constitutes the tropical forest canopy can be identified on high-resolution satellite images or aerial photographs. We developed a technique to identify whether the forest has been disturbed and to estimate approximate tree size distribution from the size and color of the canopy. This technique makes it possible to gain an insight into forest structure in places where direct field work would be difficult to undertake.

1 The forest canopy from the air

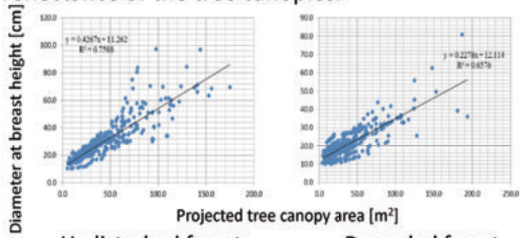
The tropical rain forests of Sabah State in Malaysia (Borneo; See Poster D-03) consist of not only undisturbed forests but also degraded forests after selective logging and severely degraded forests after intensive selective logging or that regenerated after shifting cultivation. When these places are observed from the air, a variation in canopy diameter among the different trees is visible.



Undisturbed forest　Degraded forest　Severely degraded forest

2 Large trees have a large canopy

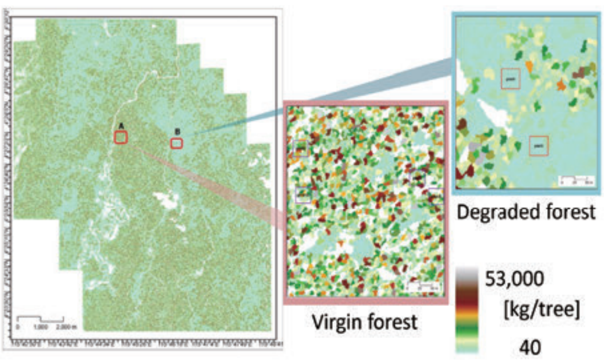
Direct measurement of tree trunk diameter is not possible from the air, but we found that the diameter and approximate tree size could be estimated by measuring the canopy area. The relationship between these variables is different in the undisturbed and degraded forests. However we found that these forest conditions could be distinguished from the spectral reflectance of the tree canopies.



Undisturbed forest　Degraded forest

3 Biomass distribution as estimated from the air

On the basis of tree size estimated from the air, we successfully estimated biomass distribution over a wide area with a high degree of precision.



Estimated wide area distribution of forest tree biomass

4 Sharing our findings

We introduced our findings at a seminar in Kota Kinabalu, Sabah State, in May 2014. The seminar was attended by people from the Sabah state government, a forestry company, NGOs and students from the Sabah University of Malaysia, and generated discussion and an exchange of ideas and experiences. Remote sensing technology is attracting a great deal of attention as a way of better understanding isolated forests. Consequently, the University of Malaysia Sabah agreed with the forestry company to provide more accurate and focused guidance to them.

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Mapping the Structure of Tropical Seasonal Forests using Airborne Laser Survey

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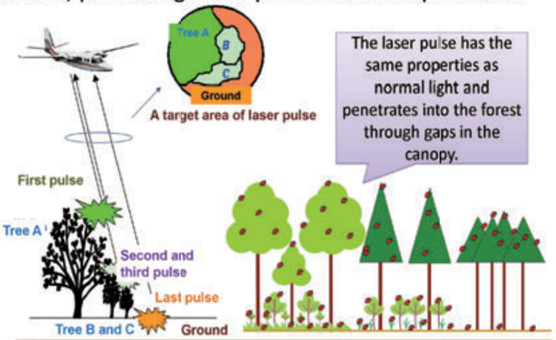
The seasonal forests in places like Southeast Asia are diverse, widespread mixtures of evergreen and deciduous forests. However they are being steadily deforested by operations such as large-scale land development and illegal logging. As part of efforts to understand the situation in more detail, we have developed an airborne laser survey to measure forest structure, which we are using in Cambodia, a country with a serious deforestation problem.

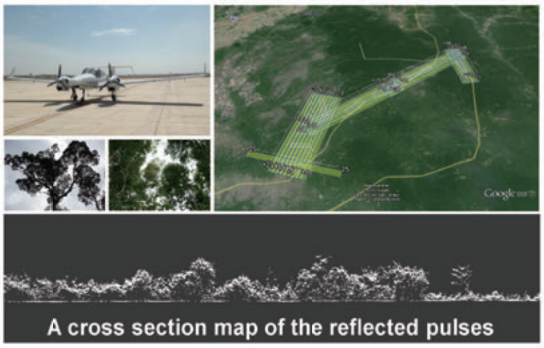
1 What is airborne laser survey?

The airborne laser survey is a device mounted on an aircraft that emits a laser beam towards the ground and measures the distance by calculating the time required for the beam to be reflected back to the aircraft off of the surface. Each laser pulse also strikes trees near the surface, producing a complex reflection spectrum.



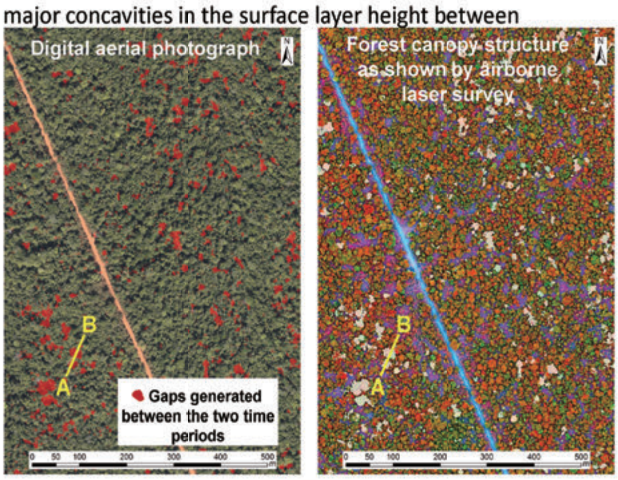
2 Understanding the structure of the forest by using airborne laser survey

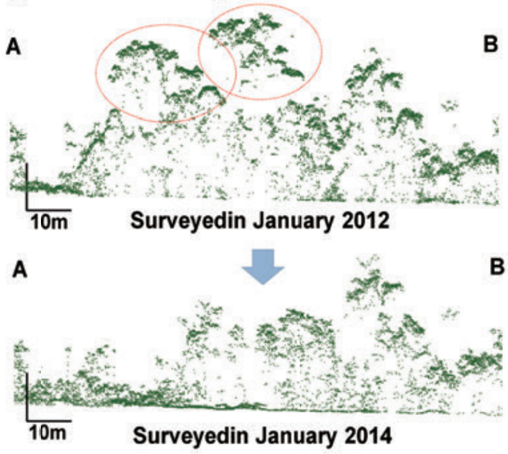
The laser was emitted at 200,000 pulse/second from an aircraft and the pulses reflected from the forest were recorded. As shown below, this provided us not only with information regarding the surface layers, but also enabled us to understand the multi-layered complexity of the forest trees and the forest floor.



3 Comparing the structure change of the forest during two different time periods

We carried out airborne laser survey on two different time periods and compared the height of the reflected pulse from the surface layers of the forest. When the areas with major concavities in the surface layer height between the two periods are examined from a bird's eye view, it can be clearly seen that these have been penetrated by logging. when the places where these gaps occur are examined in cross section, two tall trees that have disappeared can be clearly identified.





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Developing Airborne Survey Technology to Determine the 3-dimensional Forest Structure of Tropical Rain Forests

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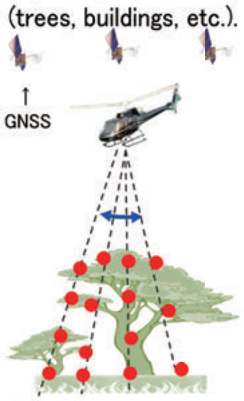
Gen Takao, Hideki Saito, Yasumasa Hirata (FFPRI)

Airborne laser survey shows promise as a way of monitoring carbon stock in tropical rainforests. We investigated methods of measurement that were appropriate for tropical rainforests based on the results of high-resolution measurements carried out including areas of tightly packed canopies of tropical rainforests. Up to this point, what we have found is that it is possible to estimate biomass using even low-resolution versions of the data acquired.

1 What is airborne laser survey?

Airborne laser survey uses a laser device mounted in an aircraft to acquire highly accurate high-resolution data regarding the surface of the ground and other objects (trees, buildings, etc.).



●: Emitted Data points

【Equipment configuration】

・Laser survey device

A device that gathers data while emitting laser pulses in a band from the air .

・GNSS/IMU(＊)

Data on the position and orientation (pitch) of the aircraft is calculated by GNSS and IMU.

(＊)
GNSS : Grobal Positioning System
IMU : Inertial Measurement Unit
The IMU is configured as part of the device.

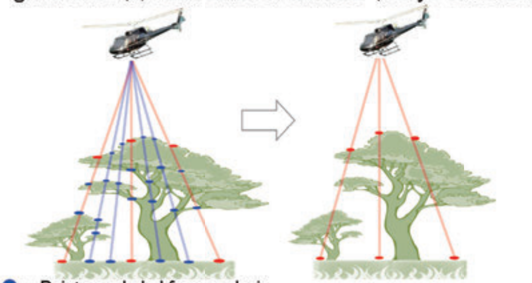
2 Surveyed site and survey plan

Study site	Malaysia, Sabah district
Platform	Bell 206 B3
Laser device	RIEGL LMS-Q560
Digital camera used	Canon 1D Mark III
Height above ground	400m
Field of view	45°
Pulse rate	240 kHz
	The aircraft (left) and laser device (right) used

3 Low-resolution simulation images

【Aim】Airborne laser survey is capable of high-resolution data capture. Considering the broad scope of the area to be surveyed and cost reduction involved, our aim was to determine how low in terms of resolution we could go while still being able to successfully use the airborne laser survey data from tropical rainforests.

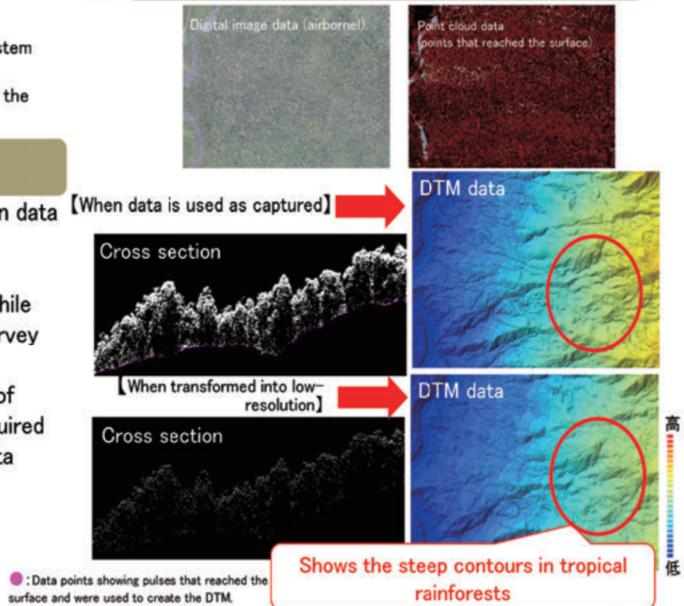
【Verification Method】(1) Data acquisition (2) Thinning of pulse per unit of acquired data (3) Processing of all acquired data except intermediate points. (4) Low-resolution data generation (5) Estimation of biomass (Tokyo University)



●: Points excluded from analysis.
●: Points used

Final low-resolution data image

4 Acquired data and low-resolution images



5 Future development and challenges

- Establishing a low-resolution data creation technique
- Verify the resolution required for low-resolution airborne laser survey data that is suitable for estimating biomass.
- Arranging the airborne laser survey specifications required for tropical rainforests.

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Recent Deforestation and Changes in Carbon Stock in Central Cambodia

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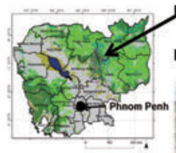
We analyzed deforestation in central Cambodia using time-series forest cover maps in 2002, 2006, 2010, and 2014. Deforestation accelerated after 2010 due to large-scale rubber plantations and local cassava farming, which resulted in drastic carbon stocks decline.

1 Study area and method



Forest cover map in 2010
created by Forestry Administration, Cambodia

- Evergreen forest
- Evergreen/deciduous mixed forest
- Deciduous forest
- Other forest
- Bamboo thicket
- Non-forest (including scrub)
- Water

■ The Chinit River Basin in the eastern part of Kampong Thom Province.
■ Two types of deforestation are in progress

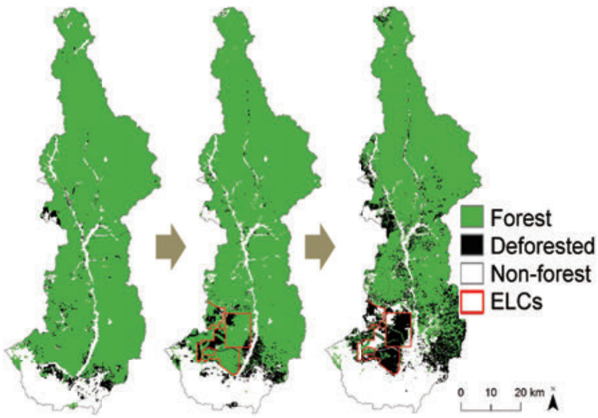
(1) Large-scale rubber plantation in Economic Land Concessions (ELC).

(2) Local agricultural development (Cassava cash crop farming dominates).

■ Deforested areas were delineated using time series forest cover maps created by interpretation and object-based classification of Landsat imagery.

■ We estimated carbon stock changes by multiplying the area of each forest cover (evergreen forest , deciduous forest, rubber plantations at different ages) at each year and its mean above ground biomass carbon.

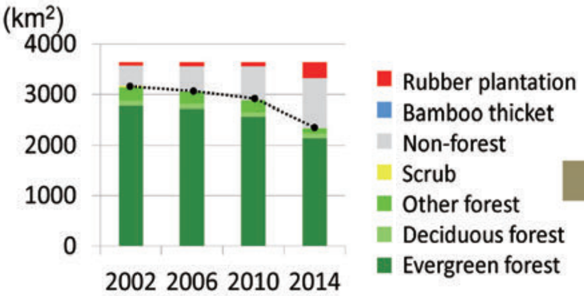
2 Accelerated deforestation

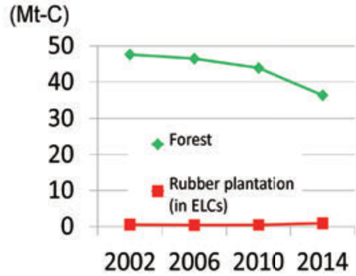


■ Large-scale rubber plantations have been developed in the ELCs.

■ Local agricultural developments have been expanding outside of the ELCs.

3 Decline in carbon stock due to deforestation





■ Deforestation has accelerated after 2010.

■ Decline in carbon stock due to deforestation.

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Changes in Occupation & Income Structure in Frontier Villages near Tropical Forests: An Issue that should not be Ignored when Considering REDD+ Support for Local People

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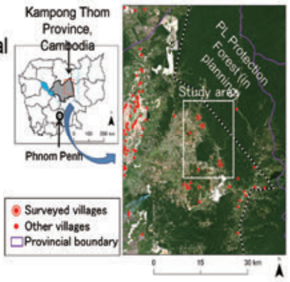
Bora Tith, Sophal Chann (FWRDI)

The livelihood supports for villagers have been implemented in many REDD+ projects. Nonetheless, few studies clarified the realities in occupation and income of villagers, particularly the changes stemmed from globalization. We studied the changes during nine years in forest clearing villages to encourage effective supports. Our results showed that the change in agricultural structures yielded the increase of average household income, meanwhile it bred the widening disparity.

1 Characteristics of study site and data analysis

- Three villages (435 households, 2012) in central Cambodia, the site of a planned REDD+ project, were investigated in 2013. The villagers were converting forests to cultivate cash crops.



Satellite image: Landsat 8 (January 24, 2014).

- More than 30% of households in each village were targeted for data of 2012.
- Comparisons were made with McKenny et al. 2004, which focused on data of 2003.

2 Livelihood activities of households in the study site

- There were many households that newly started businesses or wage labors in 2012. However, in both years, almost all households were engaged in agriculture.

Study Year		2003[1]	2012[2]
Activity		(N=85) (%)	(N=146) (%)
Agricultural production	Rice / Other Crop cultivation	94	97
	Livestock raising	59	69
Forest products collection	Resin gathering	72	61
	Fuelwood collection	79	NA
	NTFPs collection	69	64
	Timber cutting	4	7
Fishing		39	NA
Wage labor		12	64
Business	Grocer, Broker	NA	32

1. Mckenney et al. [2004]; 2. Kurashima et al. (in process)

3 Average household income and largest income source

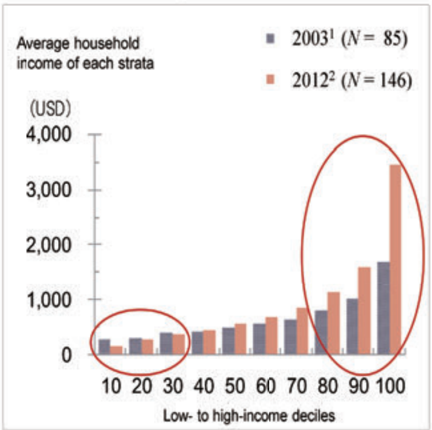
- In nine years the income went up 1.8 times. In both years agriculture was the most important income source, but the relative positions of rice and crop production (almost cassava in 2012) were reversed.

Study year	2003[1] (N=85)		2012[2,3] (N=146)	
Income source	Average (US$) (USD)	% of total (%)	Average (US$) (USD)	% of total (%)
Wet rice production	199	37	93	10
Crop production	66	12	412	43
Livestock raising	32	6	29	3
Resin gathering	116	22	156	16
Wildlife hunting	20	4	27	3
Other NTFPs collection	91	17	3	0
Logging	NA	-	11	1
Business/ Wage labor	9	2	226	24
Fishing	4	1	NA	-
Total	538	100	957	100

1. McKenney et al. 2004, 2. Kurashima et al. (in process), 3. Adjusted for inflation according the Cambodian CPI.

4 Average household income divided into deciles

- In nine years the income of the high-income group increased a great deal. On the other hand, there was a drop in terms of real income in the low-income group.



1. McKenney et al. 2004, 2. Kurashima et al. (in process), 3. Adjusted for inflation according to the Cambodian CPI.

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Characteristics of the Rubber Tree and its Water Use

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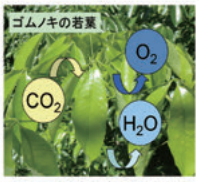
Rubber trees grow quickly, produce latex that stores abundant carbon, and could therefore be expected to be efficient at sequestering carbon dioxide from the atmosphere. However, they require a great deal of water. In this investigation we describe ways of producing fast-growing rubber trees that still protect themselves against water loss, by controlling the opening of stomata.

1 The rubber tree

The rubber tree originated in the Amazon, but most rubber plantations are in Southeast Asia. The tree latex is an ingredient in natural rubber, mainly used in tire production. Japan has the 4th highest volume of rubber imports after China, the US and India. Rubber trees require high temperatures, high rainfall and a sufficient number of sunny days to grow. However, recently improved varieties that can grow well in colder and drier conditions have been developed, and planting with these varieties is proceeding rapidly.

2 Why are we studying water use in trees?

Plants take in sunlight, carbon dioxide and water to produce carbohydrates (photosynthesis), and use these for growth and respiration.



Carbon dioxide is taken into the leaves through small pores called stomata, but this means that water inside the plant can be lost through evaporation (transpiration). For a plant, rapid water loss, and the drying up of water around its roots, can be fatal. If stomata could be made to close, this would reduce water loss, but at the same time, the plant may not be able to carry out sufficient photosynthesis. Among plants, there are those that control the stomata to save water, and those with no regulation, where growth is rapid. It is necessary to know which type of plant the rubber tree is in predicting photosynthetic rates.

3 Seasonal changes in water use and the degree of stomatal opening

The rubber plantations used in this study were situated in central Cambodia (Fig. 1). This area is characterized by obvious rainy and dry seasons lasting from May to November and December to April, respectively. As well as monitoring temperature, humidity and rainfall, we also measured the speed at which water was absorbed from the soil (sap flow rate), to calculate the amount of transpiration.

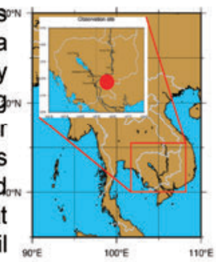


Figure 1. Study site region. (●: Principal cities, ●: Survey site)

Transpiration rate tended to be higher in the rainy season and lower in the dry season (Fig. 2), matching the trend in trunk growth and latex production.

To better understand patterns of water use in rubber plants, we investigated the relationship between stomatal opening and the degree of dryness or humidity in the atmosphere and the soil. Stomatal opening was reduced in response to dry conditions in either the atmosphere or soil. However, compared with other tree species, the response to atmospheric conditions was average, and the response to soil conditions was weak. It has been suggested that while this means photosynthesis can continue in the dry season, the continuous transpiration dries up the soil.

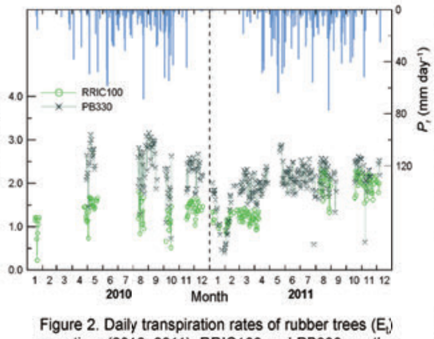


Figure 2. Daily transpiration rates of rubber trees (E_t) over time (2010–2011). RRIC100 and PB330 are the names of the varieties that were investigated. The bars show precipitation rate (P_r).

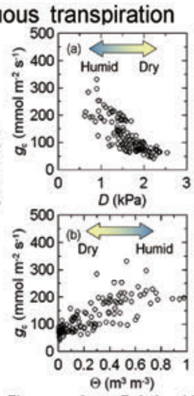


Figure 3. Relationship between stomatal opening (g_c), atmospheric dryness (D) and soil humidity (Θ).

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The Relationship between Soil Water Content and Soil Respiration Rates in Tropical Dry Evergreen Forests

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(FFPRI)

Forests absorb carbon dioxide (CO_2) through photosynthesis, but emit it by respiration. CO_2 is also emitted from the soil as soil respiration. Our research showed that if precipitation would decline in the tropical dry evergreen forests in Cambodia due to climate change, the soils will dry up, and there is a possibility that the soil would change from the sink of CO_2 to the source.

1 Carbon dioxide balance and soil respiration in forests (Table 1)

Unit: (tCO2ha−1year−1)

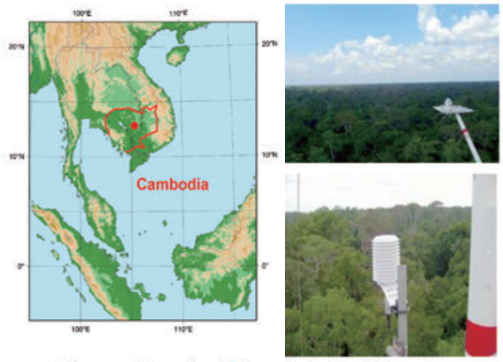
Forest type	Carbon balance (absorption-emission)	Absorption	Emission		Reference
	NEP (net production)	GPP (Gross photosynthesis production))	Respiration rate from above ground biomass	Soil respiration rate	
Larch Forest (Tura, central Siberia))	2.9	7.3	2.9	5.1	Calculated from Osawa et al. 2009
Larch forest (Tomakomai, Hokkaido)	6～7	57～65	14～23	36～39	Calculated from Oikawa et al. 2013
Oak forest crispula (Takayama, Gifu))	11～17	31～53	0～15	23～28	Calculated from Oikawa et al. 2013
Japanese red pine (Fujiyoshida Yamanashi))	15～28	46～60	19～29	13～15	Calculated from Oikawa et al. 2013
Tropical rainforest (Pasoh, Malaysia)	2.9～5.5	117.3～120.2	56.1～58.3	56.1～58.3	Calculated from Kosugi et al. 2008

The soil respiration rate shares larger percentage in the total carbon balance in the tropical rainforest than other forest types, which means even a slight percentage variation in soil respiration can lead to a gain (the forest is a sink for CO_2) or loss (the forest is a source for CO_2).

Notes. 1) The measurement methods for each item are different.
2) A slight terms on carbon balance is not shown in the table.
3) The variables describe maximum and minimum values over a number of years, These cause that the values in tables do not fit balance.

2 Observed dry evergreen rainforests

Site: Kampong Thom Province, Cambodia (12° 44' N, 105° 11' E).



Observation site (●) and state of forest.

3 Characteristics of soil respiration

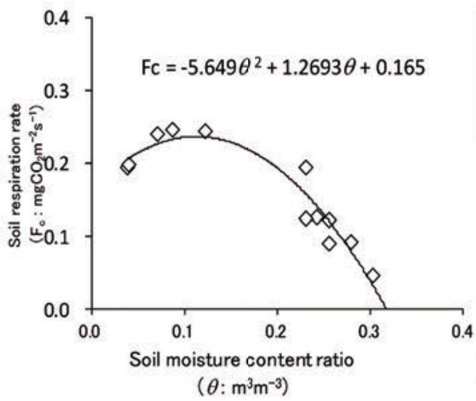


Figure 1. The relationship between soil moisture content ratio and soil respiration rate for dry deciduous forests in Kampong Thom Province, Cambodia.

Characteristics

・Soil moisture has a huge influence on respiration rate.
・Respiration rate was at the maximum when the soil moisture content was $0.11 m^3m^{-3}$

Effect of climate change (Table 2)

・It is reported that climate change will reduce precipitation in the rainy season.
・When soil would become dryer, soil respiration would be expected to increase to 1.2 - 3.0 times.
・Under this scenario, there is the possibility that dry evergreen forests will change from a sink to a source of CO_2.

Table 2. Expected soil respiration rates in a rainy season when soil would become drier.

	Present situation	Reduced case in precipitation
Soil moisture content ratio(m^3m^{-3})	0.20～0.30	0.15～0.25
Soil respiration rate ($mgCO_2m^{-2}s^{-1}$)	0.04～0.19	0.13～0.23

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Trends in Forest Development in Cambodia

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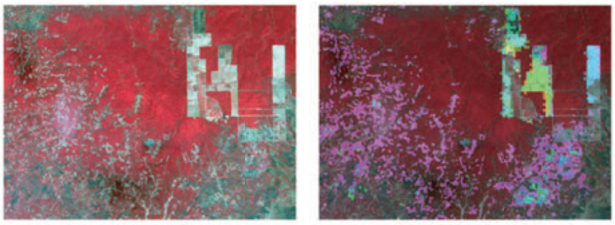
Haruo Sawada (Asian Institute of Technology)

Forests make up 50–60% of the land surface in Cambodia, but each year widespread logging continues to be carried out. We estimated the size of the logged area and the proportion of the plantation area as a proportion of logged sites from 2002 to 2010 using a variety of satellite data (MODIS, PALSAR, etc.)

1 Year-by-year logging characteristics

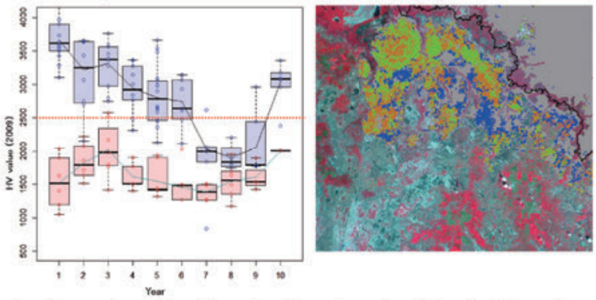
We used the Cambodian forest distribution map created in 2002 to investigate the extent of evergreen broadleaf forests in that year. We compared this map with land cover data maps produced from MODIS data between 2001 and 2010 to determine the logging points for each year. In order to detect smaller logging sites, we used PALSAR data from the period between 2007 and 2010.



Left: Extensively logged site (right) and scattered logged site (left).
Right: Logging sites determined through MODIS (blue-green/yellow) and detected by PALSAR (pink).

2 Land use after logging

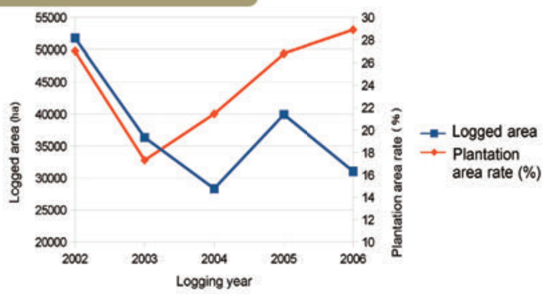
The land use for sites showing signs of logging was divided into agriculture and plantation. A comparison of post-logging agricultural and silvicultural land was taken using PALSAR data from 2009 and 2010. Several years after logging, the two types of land cover could still be distinguished.



Left graph: The threshold value (red line) taken from plantation (blue) and agricultural land (red). The different types of land use can be distinguished in the image on the right: agriculture (brown), plantation (green) and logged site (blue).

3 Changes in forest area and percentage replanted

From the satellite data, it is estimated that between 2002 and 2010, 4,225 km^2 of evergreen broadleaf forest in Cambodia was logged, or 2.33% of the land area of the country. In addition, up to 25% of forest logged between 2002 and 2006 was replanted for forestry. The trends for each year and province could be better understood if such values were calculated.



Yearly changes in logged area (blue) and plantation area rate (red)

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Utilizing Forests under Climate Change