1b. Enhancement of CO_2 sinks by improvement of afforestation technology in tropical forest （Abstract of the Final Report）

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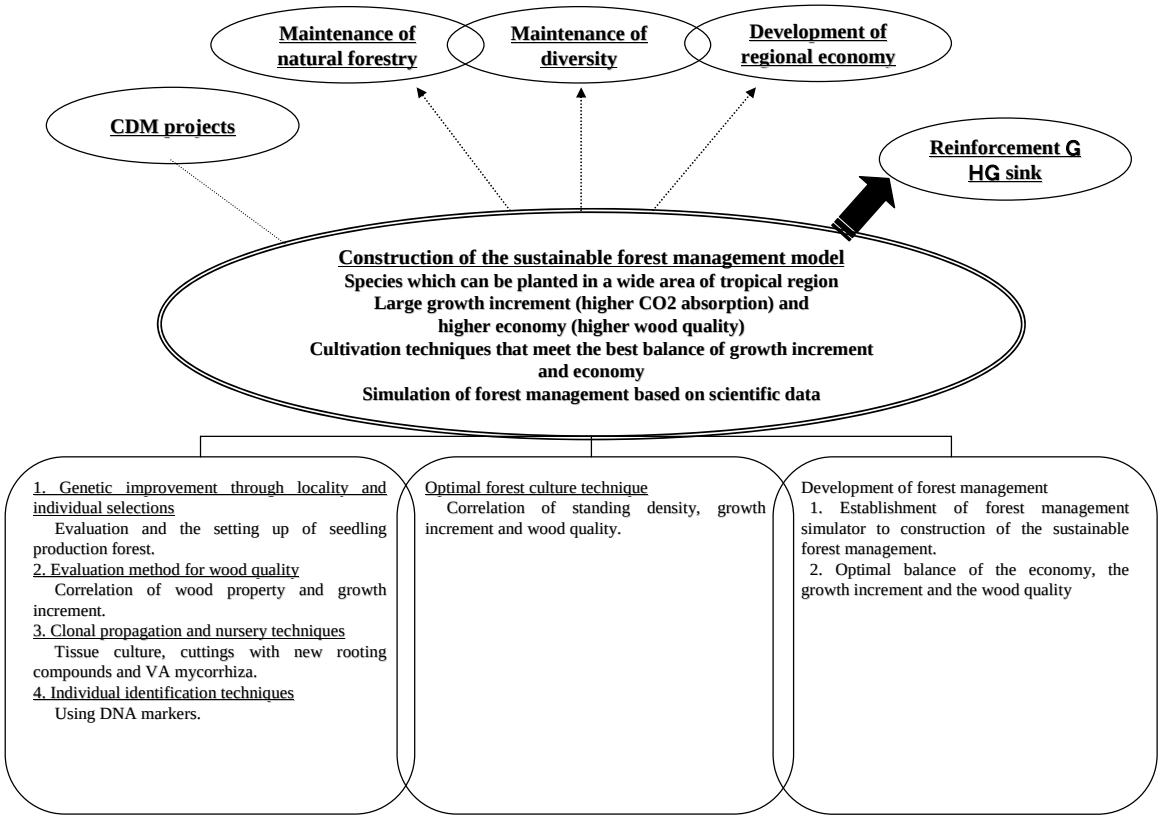
I. Overview

In this project, the enhancement of CO2 sink will be realized, if the sustainable forest management model is established. This model is based on the three technical groups and there are five themes in this project to develop these three techniques. To develop each theme, the data from a theme is fed back others among five themes.



II. Scientific outcome

1. The prediction of growth increment by the genetic improvement was enabled and then the evaluation of CO2 sink potential with an actual situation also was enabled in tropical fast growing trees.

2. The same tendency were recognized between trees of the temperate zone and tropical fast growing trees, because the inter-correlation was clarified between the growth increment, wood quality and wood properties in the tropical fast growing trees.

3. The clonal propagation was enabled from mature trees of *Paraserianthes falcataria* and the method of new rooting compounds was established.

4. We developed the technique to make a tracing of wood products using DNA markers. This technique practically helps us to recognize the products which are made of wood from sustainable managed clonal forests. We also clarified the genetic background and problems of the seedling seed orchards of *P. falcataria* and *G. arborea* established in our project. There is few genetic research discussing seedling seed orchards in detail. Therefore, this report is expected to accelerate genetic researches on seedling seed orchards in tropics.

5. In the plantation of the tropical region, the yield prediction model was established and the optimal plantation plan was enabled by the simulator of forest management with this model.

III. Contribution to policy of global environmental issues for decision makers

We held the first International Workshop “Enhancement of CO_2 Sink and Wood Production through Genetic Improvement of Tropical Fast Growing Tree Species” in Tokyo, 2005 and about 130 specialists from various organizations, the Indonesian Embassy, the Forestry Agency, independent research institutes, many universities and companies, participated. Some experts provided valuable information and the members of this project reported results. In 2007, we held the second International Workshop “Improvement of Tropical Forest for Global Environment” with Gadja Madah University in co-sponsoring in Yogyakarta, Indonesia and about 100 specialists including the chief secretary participated. We reported results in a region where the results of this project will be used well and actively exchanged information. Furthermore, we announced by the theme “Research project on Afforestation” in the International Seminar for Tacking Illegal logging, 2007 in Yokohama, “A credible and distributable system for verifying Goho (=legal) wood and wood products”, with 200 attendants including the Minister of Agriculture, Forestry and Fisheries, and the related international organization of Finland, USA, Canada, Indonesia, Malaysia, China, UK. We think that we can show that CO2 sink control by afforestation which Japanese think about is effective for the global warming to other countries through these international symposiums.

1. Introduction

Intermediate to long-term strategies for the stabilization of atmospheric greenhouse-gas (GHG) concentration are needed. New technologies to support the Japanese global environmental policy option should be developed, targeting the term after the Second Commitment Period of the Kyoto Protocol. Among the possible technologies, GHG sink/source control through conservation

and efficient management of terrestrial ecosystem is promising because of its large potential impact on GHG concentrations, low cost and high reliability and applicability before the establishment of soft energy systems that rely only on renewable energy resources. However the technical background needed to make such systems, such as basic technologies and scientific knowledge, is still insufficient. The promotion of the development of these technologies and the accumulation of scientific knowledge are needed, including assessment of the environmental effects of the use of such new technologies, some of which can be effective measures for CDM (Clean Development Mechanism) and JI(Joint implementations) in the near future.

2. Research Objective

In this project, three typical ecosystems are studied: 1) forestry, 2) tropical wet land, and 3) artificial agricultural (i.e., cultivated, slash-and-burn, agricultural, and cattle lands). Two themes (a, b) are identified for each ecosystem and GHG sink/source control technology development will be promoted. The first objective of this project is to establish suitable systems of technologies for each ecosystem.

Further, a common platform will be established for sharing information among researchers in this area (research team 4), by gathering essential information about GHG sink/source control technologies of the three ecosystems from six research teams (1a-3b). The second objective of this project is to evaluate the possible GHG concentration reduction in the atmosphere, effects on environments, cost for such control strategies, etc.

3. Methods, Results and Discussions

Paraserianthes falcataria (L.) Nielsen and *Gmelina arborea* ROXB. is one of leguminous and a fast growing tree species in tropical regions. This species can be planted in a widely tropical region because this species lives together with a nitrogen-fixing bacteria. In this year, this species was used as the object of this study continuously from last year.

(1) Genetic improvement through provenance and individual selections

1) Evaluation and the establishment of seedling seed orchards with new provenances

To evaluate an increase in CO_2 sink potential of the fast wood plantations with provenance and individual selections, three provenance-spacing trials and two seedling seed orchards of *Paraserianthes falcataria* were established during 2003 to 2004 at Jember in East Java province, then they were measured twice per year. 86 plus trees were selected in the orchard at age 30 months old and within plot thinning was conducted in the half portion of the orchard. The simple and non-distractive wood density evaluation method, suggesting that Pilodyn reading can be applied effectively to genetically improve program of this species. Pilodyn measurement was also revealed that statistically significant variations among provenance, plant density and those interaction. As a result of periodic measurement of trials, statistically significant variations among provenances and families were found in most of the growth and trunk form traits measured. These results indicate that certain amount of genetic

improvement for CO2 sink ability could be expected. Provenance trials for *Gmelina arborea* established at three locations in 2006 January were measured twice a year periodically. One out of three trials shows statistically significant provenance variations in growth traits. Periodical measurement in the thirty-two permanent plots was done as a collaborative study with Gadjah Mada University for three years. A model to predict a stand growth of *P. falcataria* was developed with the three years' measurements and the predictions were in good agreement with the observed basal area and the quadratic mean diameter. The model shows that 10% genetically improvement on height mean 12% increase of stand volume as well as 18% increase of average stand stock in case 8 years in rotation age. Moreover, the other model was developed to estimate utilizable stem volume for sown timber. The model shows that 10% genetically improvement on height means 22% increase of sown timber volume.

2) Development of the evaluation method for superior tree indicated by wood quality and growth increment

For establishing the evaluation method for superior tree, the inter-correlation of the growth increment and the wood quality parameters such as wood property (released strain of surface growth stress, density, microfibric angle and fiber length, wood processing performance), and the processability must be clarified: moreover, preferable technique for selecting superior tree should be developed. The parameters of wood properties and processability in *P. falcataria*, from Solomon and Java, and *Gmelina arborea*, from 3.5- to 7-y-old, were investigated. Consequently, there were no correlation between parameters of growth increment, wood quality and processability both species. It is thought that the quality of the material and processability do not fall both species even if it gathers growth speed.

(2) Upgrading of forest cultivation techniques with fast growing trees

1) Upgrading of seedling culture techniques

The optimal nursing technique for shorter nursing period and for more growth in the initial stage, the clonal propagation technique by cutting with new rooting compound and tissue culture technique from mature tree will be developed. To reduce a high contamination rate, a new sterile method, a dip in NaClO for 24 to 48 h, was tested. A dip in 0.1% of NaClO for 48 h was effective for survival rate. All results including this result, clonal propagation by shoot apex culture from mature trees was established. In the cuttage method, the efficacy of a newly-developed rooting compound, IBL, was reinvestigated. The results confirmed the efficacy of IBL and the concomitant effect of IBL and KODA and the patent was applied. However, it was found that the overnight immersing treatment with IBL was too long and gave a toxic effect to the plant. On the other hand, last year, it was reported that KODA showed a dramatic rooting-promotive effect on the cottage of *Prunus* x *Yedoensis* of which rooting is known to be difficult. In this spring (2008), the 2-year-old rooted trees that had been treated with KODA was able to flower in contrast to that the non-treated control rooted trees were almost unable to flower. Therefore, KODA was found to show not only a rooting effects on cutting. But also a possible canceling effect on the juvenility of the plant. In the

nursery techniques, the infection of VA mycorrhiza and Rhizobium and the effect of the growth in seedlings were examined. VA myacorrhiza and Rhizobium were infected well in the soil which nourishment is poor and the growth of seedlings improved by increasing of the amount of VA myacorrhiza.

2) Development of individual identification technique using DNA markers

For marker development, Dual-suppression PCR method was employed. Total DNA was isolated from plywood using a modified CTAB method. The DNA was amplified by PCR with the developed primers. The PCR products were separated and detected using an ABI PRISM 3130 Genetic Analyzer. In order to clarify the genetic background of breeding materials of seedling seed orchards, for *P. falcataria*, eight artificial forests in Java Island and 11 materials from 6 provenances, which are introduced by our project, and for *G. arborea*, five seed lots introduced from Costa Rica, are analyzed using microsatellite markers developed in this study and genetic diversity of each population and genetic differentiation among populations are calculated. Nine primer sets of microsatellite locus for *P. falcataria* and 8 primer sets for *G. arborea* are designed. These primer sets were issued patents. Five primer sets for *P. falcataria* and 5 primer sets for *G. arborea* are useful for individual identification from the point of fragment amplification and polymorphism. DNA extracted from the plywood of *P. falcataria* and *G. arborea* were amplified by PCR, and the genotype could be identified. In the process of plywood production, veneers are heated for drying and during hot pressing. DNA extracted from heated veneers of *G. arborea* could be genotyped, and this was possible even for veneers heated up to 230°C. Thus, genotyping was possible irrespective of heating. The results suggest that the source of wood can be traced by this technique. For the genetic diversity of breeding materials of *P.falcataria*, the materials from PNG provinance have highest genetic variation. The artificial forests in Java Island, materials from Flores and East-timor have no private alleles, and on the other hand, Irian Jaya has many private alleles. The materials from Solomon showed linkage disequilibrium at 5 locus pairs and it is suggested to be originated from a few mother trees. Moreover, the gene pools of Irian Jaya, PNG and Solomon are different from that of Java Island. For *G. arborea*, there are enough genetic differentiations among seed lots. But three seed lots showed high inbreeding coefficient. We developed the technique to make a tracing of wood products using DNA markers. This technique practically helps us to recognize the products which are made of wood from sustainablly managed clonal forest. We also clarified the genetic background and problems of the seedling seed orchards of *P. falcataria* and *G. arborea* established in our project. For *P. falcataria*, the introduced provenances have high genetic diversity and are genetically different from the artificial forests in Java Island. Therefore the breeding materials introduced into Java Island by our project are expected to have new genetic characters. But it is suggested that Solomon material is need to gather from more number of mother trees. For *G. arborea*, we introduced genetically variable materials, but three seed lots are considered to be consisted of seeds produced by inbreeding. Therefore we need to check the inbreeding depression in the seedling seed orchard of *G. arborea*.

3) Development of optimal forest culture technique and the evaluation of CO_2 absorption

Approach for forest managements with combinations of standing density controls, fertilizing, planting and harvest plan that meet both of maximum economic balance and CO_2 absorption was developed in this study. Study site was established in about 100ha cacao plantation of PTPN XII in Jember, East Java, Indonesia. Soil type of the study site is Ochric Andosol[1)] and soil fertilities might be very high with application of N, P, K and organic fertilizers (e.g. barnyard manure) for the last 20 years for cacao cultivations. In 2004, 41,118 *Paraserianthes falcataria* seedlings, which were introduced from Papua New Guinea, were planted in 14ha of the study site. From 2004 to 2006, fertilizing was carried out in four times and measurements of heights and diameters at breast height (dbh) of planted seedlings were carried out. In addition to the studies about *P. falcataria*, the same type of studies (stand density trial and fertilizing examination) was started with *Gmelina. arborea* in 2006. The seeds from 4 seed orchards of open pollination among 37, 33, 26 and 22 genetically selected clones were introduced from Costa Rica. For this study, 22,308 of *G. arborea* seedlings were planted in 5ha of three sites of PTPN XII (BANJARSAEI, MUMBUL and KALISEPANJANG). The seedlings were established in MUMBUL and BANJARSARI, however, were fed by larvae of some kind of beetles in KALISEPANJANG. Planting examinations has been carried out, in order to present optimal forest managements of fast growing timber species, in view of improvement of carbon sink capacities in forest plantations. The forest management is composed with stand density controls, fertilizing regimes and planning of planting and harvesting time in a project periods. We try to clarify the growth responses in various stand densities and/or fertilizing. In a study of 1b, yield prediction model[2)] and stem taper equation[3)] of *Paraserianthes falcataria* was developed. Other studies of 1b clarified that wood qualities and processability of *P. falcataria* were not affected by their growth speeds. The yield prediction model made us possible to simulate growth responses *P. falcataria* trees to any changing of stand density in regular manner of forestry. Density control trial suggested that parameters of the model would be refined and improve its accuracy by data collecting. Fertilizing examination clarified that there is no effects on height growths of *P. falcataria* trees, 1.4 years after planting. Based on the results of these studies, we could simulate economic balances and carbon fixations of various forest managements. We demonstrated the approaches to the forest managements that maintain their profitability and improve carbon fixations with some cases.*Gmelina arborea* trees in BANJARSARI showed better growths than those in MUMBUL. Significantly differences of growths among strains were not be detected. Frequency of fertilizing did not effect on growths but the growths of seedlings are significantly different among amount of fertilizers. An approach to optimal forest management would be applicable to all regions where *Paraserianthes falcataria* could be planted. A series of studies in 1b might be applicable to other species and we had started studies for *Gmelina arborea*. Increasing of number of handling species makes us possible to think combinations of the species. Forest plantations with several species might have merits not only of species diversities, tolerance to pest and disease, but also catering to various

demands of market. Next issue of our studies is application our methodology to other species.

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