

**Study on Transparent and Verifiable Method of Evaluating Carbon Sinks  
( Abstract of the Interim Report )**

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### 1. Introduction

Though Japanese temporal figures to estimate carbon absorption by forests were submitted to the SBSTA Bureau, the amount of absorption that it was equivalent to Articles 3.3 and Articles 3.4 of Kyoto Protocol would not satisfy the required conditions of Articles 5,7, and 8. These temporary figures have derived from Administrative Statistics and rough parameters converting from forest growing stock to carbon stocks. Then it is required to establish a scientific inventory method of carbon sinks with transparency and verifiability. The Forestry and Forest Products Research Institute has managed 210 permanent experiment plots to monitor forest growth patterns. These plots are valuable to study basic parameters for converting from growing stock to carbon stocks as well as to factor out human induced effects and natural environmental effects on growth rate of forests. Soil carbon is another important carbon pool in forest ecosystem, though there is not any effective inventory system with the scientific reliability. Remote Sensing techniques are believed as useful measures to evaluate carbon stocks in a broad area with transparency and verifiability. These points mentioned above must be studied to introduce an effective system to evaluate carbon sinks under Kyoto Protocol.

### 2. Research Objectives

There are several problems to be solved for the establishment of carbon sinks inventory system that will satisfy conditions defined by Kyoto Protocol and Marrakesh Accords. These problems are as follows; a scientific conversion procedure from forest growing stock to carbon, an evaluating method of soil carbon, to develop a method direct human-induced changes in carbon stocks from changes in carbon stocks due to indirect human-induced and natural effects, and a method to avoid double accounting of ARD and forest management contribution of carbon sequestration using by remote sensing. This project is designed to study these problems and to provide useful information to establish a suitable inventory system of carbon sinks.

### 3. Results

#### (1) Estimating Forest Biomass Growth

A quantity of forest biomass is estimated by stand volume using the expansion factor. The expansion factor is needed to have transparency and possibility of inspection for Kyoto protocol, and there is not sufficient only literature data.

So we investigated forest biomass of 39 plots throughout Japan in 2001-2003 by the method we developed (Fig.1). We calculated the biomass expansion factor from the new data and the literature data according to a tree age class provided by IPCC. Estimated biomass expansion factors of Sugi cedar and Hinoki cypress above 21 years are 1.23, and that of Japanese Larix above 21 years is 1.15. They are so accurate that 95% reliability are 0.01 to 0.02.

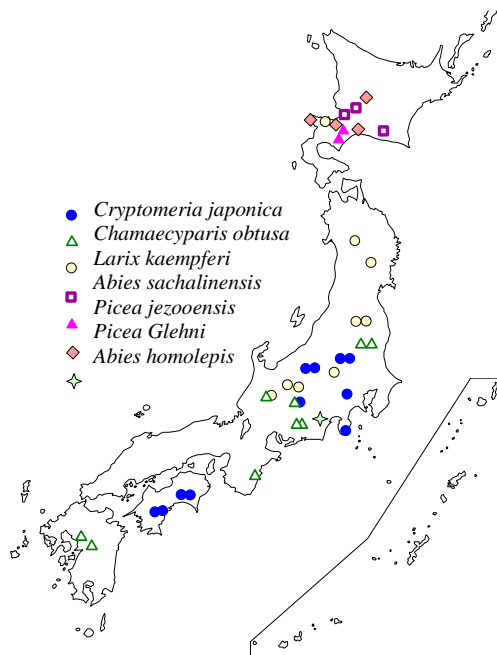


Fig.1 Location of Permanent Plots

#### (2) Changes in Organic Carbon Storage in Forest Soils

We selected three experimental sites of *Cryptomeria japonica*, *Chamaecyparis obtusa*, and *Larix kaempferi* plantations for intensive soil sampling sites. We estimated soil organic carbon (SOC) storage based on chemical analysis of totally 2700 surface soil samples. About 80 to 90 % of SOC accumulated in upper 30 cm soil of profiles in *Cryptomeria* stands. The 60 to 80 % of total SOC in *Chamaecyparis* stands distributed in upper 30 cm. Surface soil movement may have serious effect on SOC storage in *Chamaecyparis* stands. *Larix* forest soils showed more SOC distribution in subsoil. About 50 % of SOC accumulated in upper 30 cm soil. We could not detect effects of thinning practice on changes in SOC storage during short-term observation. Person-to-person variation in sampling techniques of forest soil may be one of critical factors that affects sampling errors.

#### (3) Model to Project Changes of Forest Biomass Utilizing Long-term Observation Data

Factoring out of direct human impacts occurring in and after 1990 from the other impacts can be required in estimating GHG removals by sinks (COP7). We proposed a methodology to factor out the influences of weather conditions and thinning on stand biomass changes, using the multiple regression analysis with the long term observation data of stem growth in the three permanent sample plots of *sugi* (*Cryptomeria japonica*) planted forests. The forests are located in Ibaraki, Shizuoka, and Yamaguchi Prefectures. To cross-check the results, we constructed a process model using tree physiology data of *hinoki* (*Chamaecyparis obtusa*) in Ibaraki Prefecture to analyze the carbon balance in canopy foliage. We obtained the following multiple regression equation and used it as a multiple regression model to predict chrono-sequential biomass change of *sugi* stands.

$$RGR_{stem} = 1.84 - 0.0000194 * Stem - 0.0670 * MAT - 7.06 / MAT - 0.266 * Ry - 0.199 / Ry + 0.00248 * SI40$$

• • • • • (R<sup>2</sup>=0.640)

**RGR Stem:** relative growth rate of  $\sum D^2 H$  ( m<sup>3</sup> m<sup>3</sup><sup>-1</sup> ha<sup>-1</sup> y<sup>-1</sup> ), **Stem:** initial  $\sum D^2 H$  ( m<sup>3</sup> ha<sup>-1</sup> ),

**MAT**: mean annual air temperature ( ), **Ry**: relative yield index, **SI40**: top height at 40-year-old (m)

The figure 2 shows a procedure to factor out the influence of mean air temperature on stand stem volume growth. The result of simulation with applying the procedure to a model of thinned stand suggests that changes in mean annual air temperature possibly mask the effect of ordinary thinning on stem volume growth. The analysis using the process model shows that the effect of thinning on leaf production depends on pre-thinning leaf area index, intensity of thinning, and air temperature in and after the thinning. These results are consistent with those by the multiple regression model mentioned above.

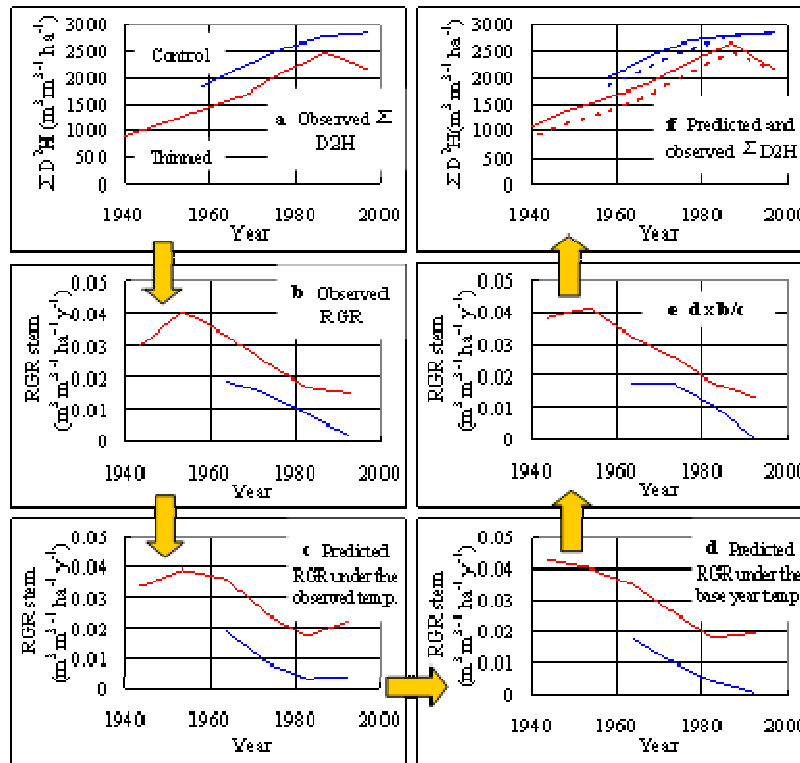


Fig.2 A procedure of factoring out influences of mean annual air temperature in stem volume growth of sugi (*Cryptomeria japonica*) planted forests.

#### (4) Evaluating Forestry Operation Effects on Stand Biomass Increment Utilizing Long-term Observation Data

To prove the influence which the silvicultural operation such as thinnings has on the carbon uptake, the biomass growths of *Cryptomeria japonica*, *Chamaecyparis obtusa* and Japanese larch in 22 long-term permanent plots were examined. In this research, the allometric equation which presumed the biomass of the trunk, the branch, and the leaf was made from the breast height diameter and the tree height of the individual tree. The amount of the aboveground biomass of the entire forest zone was presumed by using this allometric equation. As a result, the annual biomass increment of the thinned zone was reversed after the thinning and often became to exceed a unthinned zone regardless of tree species though it decreased temporarily compared with a unthinned zone. So if periods of about 5 or ten-odd years after the thinning are assumed, the possibility of the thinning to promote the biomass growth will be high. When neither the fork nor the amount of the thinning were added to the increment, it was reconfirmed that the total growth of the thinned zone often fell below the total growth of a unthinned zone.

#### (5) Estimates of Basic Density of Major Tree Forest Species for plantations

In order to obtain biomass and basic density of major plantation species, oven-dried weight of individual trees, basic density at breast height and variation of air-dried density within trees were analyzed. The density of sugi (*Cryptomeria japonica* D. Don) and hinoki (*Chamaecyparis obtusa* Endl.) calculated for each site was nearly fixed, while karamatsu (*Larix kaempferi* (Lamb.) Carr.) showed significant difference between sites. The difference of the density between trees growing under different silvicultural treatment (thinning) was not significant, though the trees from thinned stands tended to have lower density than the trees from not thinned stands. The averages and 95% confidence limits of basic density in sugi, hinoki, karamatsu, ezomatsu (*Picea jezoensis* (Sieb. et Zucc.) Carr.), todomatsu (*Abies sachalinensis* (Fr. Schm.) Mast.) and akaezomatsu (*Picea glehnii* (Fr. Schm.) Mast.) were  $0.314 \pm 0.008 \text{ g/cm}^3$ ,  $0.401 \pm 0.010 \text{ g/cm}^3$ ,  $0.409 \pm 0.013 \text{ g/cm}^3$ ,  $0.338 \pm 0.008 \text{ g/cm}^3$ ,  $0.323 \pm 0.007 \text{ g/cm}^3$ ,  $0.370 \pm 0.010 \text{ g/cm}^3$ , respectively.

#### (6) Developing Monitoring Method of Afforestation, Reforestation and Deforestation with Satellite Remote Sensing

Kyoto protocol article 3.3 defines afforestation, reforestation and deforestation (ARD) and provides ARD from 1990 be monitored clearly and verifiably. Middle resolution satellite image (ex. LANDSAT TM) is useful for monitoring land cover and land cover change for the scale of river basin or the larger scale, but hardly discriminates between land use change (i.e. ARD) and forest practice (ex. forest cutting and tree planting). The objective of this study is to develop monitoring system of ARD using vegetation map in 1980, forest base map in 2001, time series of TM image, and air photo on GIS (Geographic Information System). The algorithm is as follows: 1) combining vegetation map in 1980 and forest base map in 2001, land use change from 1980 to 2001 was extracted. 2) Land cover change which includes land use change and forest practice from 1989 to 2001 was extracted using LANDSAT TM in 1989 and 2001. 3) ARD was extracted combining land use change from 1980 to 2001 and land cover change from 1989 to 2001.

The algorithm was tested in the Shimanto river forest planning area (2970km<sup>2</sup>). We could extract lump places of deforestation, extracting probable ARD places with the algorithm and monitoring them with air photos, while we could hardly extract line places of deforestation (ex. road) because satellite imagery resolution was not enough. Interpreting time series of air photo is necessary for extracting the places from forest to road. AR was not extracted in this area, because the area of afforested farmland in mountainous place was 0.1 ha or so and they were too small for monitoring with remote sensing method.