K-1 **Carbon Sink Function of Terrestrial Ecosystems**
(Abstract of the Final Report)

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1. Introduction

Atmospheric CO2 concentration can be decreased not only by reducing fossil fuel burning but also by increasing the terrestrial ecosystems that serve as sinks for CO2. The Kyoto Protocol allows countries that are burdened with emission reduction commitments to use carbon sequestration by terrestrial sinks. In order to come up with an effective long-term climate regime, political decisions are necessary to realize an appropriate balance between the sink enhancement and the emission reduction. Although, the Kyoto protocol requires evaluating carbon balance CO2 removals by sinks in the in the article 3.3 and 3.4. We have had very few suitable methods to evaluate them. We try to establish such methods including models related to sink and source of carbon in soil ecosystems according to quantitative data obtained from field experiments. .

2. Research Objective

The purpose of our studies was two fold: 1) develop the methodology of scientific assessment that can predict the carbon sequestration potential of the specific activities under the Kyoto Protocol; and 2) answer the questions that are posed before coming up with political decisions on the definition/accounting options regarding carbon sink activities.

3. Research results and discussions

(1) Forest

This program has included several sub-program concerning to forestry and landuse changes which contribute to mitigate global warming. Then the program took up various outputs as follows.

① There is a keen demand for an accurate and objective mean of forest biomass measurement in order to count forest carbon sinks into the emissions reduction target, which was approved by Article 3 Paragraphs 3 and 4 of the Kyoto Protocol. LIDAR (LIght Detection And Ranging) is a progress of remote sensing sensors that can directly measure crown heights. We used LIDAR to estimate the stand crown height and stand volume of young conifer plantations in Hokkaido, northern Japan. There were the best correlations with the first quartile of the LIDAR-measured crown heights distributions. In addition, we estimated the local stand density, which is the second important parameter for estimating stand volumes, using variograms on the digitized aerial photos taken simultaneously with LIDAR.

② Soil organic matters and nutrients can be affected by land use changes derived from human activities. To estimate the effect of aforestation on organic carbon storage in forest soils, we investigated carbon accumulation of the forest soils at different stand ages and species after planting trees. The

relationship between the years after transplant and the accumulation of organic carbon in the soil was obtained. The carbon accumulation rate was very high, > 30 gC m-2 y-1, until 5 to 10 years after planting, and then, the rate gradually decreased, but it depended upon species. We estimated the carbon storage of the Ao layer in various type of forest vegetation in Japan. The carbon stock of the Ao layer was different among vegetation types, and the values were from 2.2(Hinoki forest) to 21.4(coniferous forest in subalpine zone) MgC/ha. Mostly the amount of carbon storage of the Ao layer in coniferous forest was larger than that of broad-leaved forest, but the carbon storage of Hinoki and Sugi forest were small. To estimate the effect of aforestation on organic carbon storage in forest soils, we tried to calculate the carbon accumulation in the forest soil using soil organic matter dynamics model "CENTURY". But the result from the model did not fit the result of field measurement. We made up structure of simple model suitable for forest soil in Japan.

③ Though a method using forestry statistics is realistic and low-cost for estimation of carbon stocks and uptakes by forest biomass, it has some questions such as parameters of conversion equations for stem volume to carbon weight, difference of forest areas by definitions of forest. To solve the questions, expansion- ratio models were developed, and forest areas on the forestry census and a digital map were compared. Using such improvements, carbon stocks by Japanese forests in 1995 were estimated to be 1.24 GtC, and carbon uptakes to be 22.5 MtC/yr. For more effective use of forestry statistics, combinations with other information such as remote sensing, digital maps might be important.

④ Databases on the forestry inventory survey results and climate factors in the Honshu, Shikoku and Kyushu Islands were built to estimate forest biomass growth rate. The forestry inventory surveys provided information on tree height, volume, DBH, timber density, etc. The climate database is composed of monthly temperature, precipitation and net radiation over the 10km grid system. They indicated that the average tree height (H) would be a reasonable indicator of the timber volume per ha (V). A formula derived was $V = 43.2 \times H - 179.4$, when H is below 12m. Comparison between forestry data and climate factors generally indicated that the total net radiation during the growing season was greater in the lower latitude and that there was no clear difference in the growth rate between the higher and lower latitudes. Therefore, respiration and/or water stress may well affect the growth rate.

These databases also indicated that averaging the outcomes of the forest survey plots would not simply provide a reasonable estimate of the forest biomass growth rate. It is because these plots were located in lower altitude in the higher latitude and in higher altitude in the lower altitude on the average. Therefore, a model approach is necessary to calibrate these biases. The present study employed a model based on multiple regression analyses for the area within the range of climatic conditions where the forest survey plots covered.

That is, $dV/dt=A*f1(V)**f2(WI)*f3(R)*\exp(-\delta(R/P)2)$, where V is timber volume, WI is warmth index, R is the amount of net radiation, P is the amount of precipitation during the growing season, $\exp(-\delta(R/P)2$ is a dryness index, A and δ are constants. The multiple regression analyses indicated that generally higher temperature would affect the growth rate negatively and that water stress would give negative affects in the southern part of Japan. Another model was composed in order to estimate the growth rate outside the area where the forest survey plots covered. The basic structure of this model was made of two parameters photosynthesis and respiration. The coefficients were determined after multiple regression analyses.

⑤ Among the CO2 reduction effects of wood utilization, carbon stock effect on building construction sector was quantitatively estimated, to which 71% of wooden primary products are shipped. From the fixed assets report on buildings, the floor area stock data of wooden, non-wooden, and tax exempt buildings are required. For tax exempt data were apportioned according to the ratio of wooden and non-wooden buildings data. Timber carbon stock in buildings was evaluated, using tentative timber input unit 0.2m3/m2 for wooden and 0.04m3/m2 for non-wooden buildings, and using unit 0.25t-C/m3 for timber carbon content. Timber carbon stock in buildings is monotonously increasing from 16 Mt-C in 1974 to 24 Mt-C in 2000. Even though annual change of carbon stock, which corresponds to CO2 reduction, is decreasing according to the decrease of wooden building ratio, there is 2 Mt-C of stock increase in 2000.

Average oven dry density of timber, which is related to timber carbon content, used in Japan was 0.46t/m3 through the investigation on domestic timber and imported logs in 1991, when statistical

investigation was done on the number of imported logs and their species.

Among the buildings, timber input unit of wooden houses was experimentally investigated. The unit was 0.168m3/m2 for a demolished house which was built in 1954 by Japanese traditional post and beam construction. The units obtained from timber preparation tables and building plans were 0.21m3/m2 and 0.18m3/m2 respectively, for the average of newly build 24 houses in 1994 to 1999. There appeared the problem in the unit from timber preparation tables.

Two approaches for estimating carbon stocks and emissions were compared to evaluate the effects of wood recycling. The current default approach didn't result in promoting wood recycling. The methodology for evaluating carbon stocks in harvested wood was considered to be needed.

⑥ Clean Development Mechanism (CDM) was regulated in Article 12 of Kyoto Protocol. It was agreed to include sink activities as afforestation and reforestation in CDM. In near future, it is expected to discuss CDM practices as plantation activities in various countries. Then, it will be important to provide the scientific information about carbon accumulation in man-made forests for policy makers in forestry sectors of CDM concerned. It is important how much carbon is accumulated if plantation forests are established as the CDM practices. Carbon accumulation of natural regenerated vegetations that is considered to be "baseline" without additional carbon sequestration activities is not regarded as the increment by CDM practices. And in order to be certified as the CDM practices, it is regulated that the carbon accumulation of man-made forest has to be higher than baseline.

⑦ The purpose of this research is to clarify the Influence which large-scale afforestation project as a means of CDM (Clean Development Mechanism) have on a community and the Leakage / Positive Spillover, the increase / decrease of net CO2 emissions outside the project, which occurred by the social changes of an area. S company's site of the industrial tree plantation (HTI, Hutan Tanaman Industri) in the East Kalimantan state of Indonesia was studied as the example. The framework to evaluate the influence consists of 3 steps; at first grasping the vector of change which a community holds, "Baseline", secondly clarifying the change before and behind the afforestation start, and thirdly extracting the influence and the Leakage / Positive Spillover. The influence and the Leakage / Positive Spillover were evaluated from 4 viewpoints: (1) competition of the land use between local people and S company, (2) the labor opportunity which S company brought about, (3) "Forest Village Community Development Program (PMDH, Pembinaan Masyarakat Desa Hutan) "and "HTI transmigration (Transmigrasi HTI)" which are implemented in connection with HTI, and (4) others. The Leakage / Positive Spillover were, in the present condition, small in general, while some activities which produce the increase / decrease of net CO2 emissions, such as "illegal logging" and paddy field development by the migration village resident, were also found. However, the community is continuing change and it is also foreseen in the future that the influence and the Leakage / Positive Spillover change. In conclusion, the influence and the Leakage / Positive Spillover appear as a result of the interaction of an afforestation project, the social economy situation and the natural environmental conditions of the area. Therefore, it is suggested that the influences and the Leakage / Positive Spillover differ if a situation of an area is different even when an afforestation project is implemented with same way, and they change if it changes with progress of time.

⑧ In this research Timber Supply-Demand Model, which developed for estimation of domestic timber supply and demand under the particular scenarios, is taken up to apply the modified Gentan probability theory (Yoshimoto 1996) to reflect the changes of economic factors such as timber price. As a result, to avoid the complexity of manageable forest problem it is required to adopt the function g(t) satisfying $g(0) = 0$ and $g(t) \rightarrow \infty$ when $t \rightarrow \infty$. The timber price model with monotonously increasing linear trends based on the time series model is proposed as proper g(t) and the parameters of that are estimated by ordinary least squared method, maximum likelihood method and so on. The model will make it possible to predict the changes of carbon budget affected by the changes of the elements of carbon policies such as carbon tax and subsidy.

(2) Agriculture

We have studied on ①relationship between regionality of soil cellulose decomposition and carbon storage dissociation, ② dynamics of soil organic carbon as revealed by natural abundance of carbon isotopes, ③ mechanisms of carbon stock change on tropical agro-ecosystems, ④ modeling of carbon dynamics in volcanic ash soils and ⑤ changes of carbon sequestration by artificial activities in