## B-6.2.2 Evaluation of Carbon Sequestration with Forest Management

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**Abstract :** To clarify the reality of the soil carbon storage of natural forest in the subalpine zone (*Abies veichii* and *Tsuga diversifolia*) and in there the influence which reforestation (using *Larix kaempferi*) has given to the soil carbon storage (sequestration), this study was done in Makioka Town, Yamanashi Pref., in central Japan. The investigating elevation region is a range from 2000 to 2200. The basement rock consist of granite, and three of four soil profiles in this investigation were Dry Podzolic soils, one was a Dark brown forest soils according to the Classification of Forest Soil in Japan (1975)[2]. In an *Abies veichii* stand, a simple soil survey was done in 30 points, as a result it has been cleared that the soil carbon storage ranged from 157 to 308 tC/ha according to the topographic condition. The soil carbon storage showed the tendency to be large in the place of residual soil. Then, the terrain condition was limited to two place of residual soil and creep soil, in addition, the soil type was arranged in PDII in the place of residual soil, and in those places the soils were compared between *Larix* stand and *Abies-Tsuga* (or *Abies*) stand. *Larix kaempferi* were reforested 30 - 40 years ago after the felling of the natural forest. A remarkable difference was seen in the carbon storage of the upper part of illuvial horizon (B horizon) between both forest stands, the soil carbon storage of the *Larix* stand was less in comparison to *Abies-Tsuga* stand. There was a problem that the secular variation in the same forest stand was not investigated in this study, however, the tendency of which the soil carbon storage in *Larix* stand was less compared with *Abies-Tsuga* stand was clear, and it was thought that the soil carbon storage in *Larix* stand was a decrease in 50 tC/ha scale because of the *Larix* silviculture after the felling of the natural forest.

### 1. Introduction

It is very important to know the amount of the carbon storage in the biosphere and the amount of carbon released from biosphere to atmosphere by human activity. The forest ecosystem has performed a big role as a carbon storage place on the earth. But the evaluation of the soil carbon storage in the forest ecosystem still lacks accuracy. Then, it is necessary to obtain more information about the soil carbon storage through various researches. On the other hand, the forest is an important resources for the human being, there are many forest types from a forest which keeps a high nature degree to an artificial stand for harvesting. In natural forest the carbon circulates stably among the air, the plant and the soil. In an artificial

stand, however, the carbon cycling becomes unstable because the lumber is harvested. When the lumber is taken out outside the ecosystem by the felling, the supply of organic matter to the soil by litter fall and die of fine root stops. Afterwards, when the planted trees begin the growth, and the supply of the organic matter to the soil is restarted, but it takes a lot of time to becoming of the amount to the soil of the carbon supply to the level of the old growth[4]. On the other hand, it is thought that the amount of the organic matter decomposition in the soil after the felling dose not change greatly because the activity of the soil microbe will be supported by the soil organic matter which have been storaged before deforestation. Thus, after the reforestation, it is forecast that the carbon storage in the soil faces the decrease temporarily because the revenue and expenditure balance of the carbon falls into disorder. And it is very important to clarify how much scale the amount of the soil carbon decrease by the forest management in order to estimate the influence which the forest management exerts on the carbon cycling of the earth.

## 2. Research Objective

In this research, as follows two were aimed at. One was to clarify the reality of the soil carbon storage of natural forest in the subalpine zone (*Abies veichii* and *Tsuga diversifolia*). Another was to clarify the influence which reforestation (using *Larix kaempferi*) gave to the soil carbon storage (sequestration) in there.

## 3. Research Method

This study was carried out in the Enzan district for the forest management which Yamanashi Prefectual government has, which is located in Makioka Town, Yamanashi Pref., in central Japan. The investigating elevation region was a range from 2000 to 2200 m. The species composition in the natural forest were *Abies veichii*, *Tsuga diversifolia*, *Picer jezoensis*, *Betula ermanii*. The basement rock consist of granite. The mean annual temperature in 1994 was 3.6 C degree at the altitude of 2000 m.

In this investigating area, *Larix kaempferi* has been reforested since 1954 after the felling of a part of natural forest. Two *Larix* stands, which had been planted in 1966 after felling the natural forest in 1961, were selected for the soil profile investigation, and an *Abies veichii-Tsuga diversifolia* stand and an *Abies veichii* stand for the comparison were selected (Table 1, Fig. 1). In addition, a quadrat of 40 x 50m for multi point investigation (MPI plot) was set in the *Abies veichii* stand near On-5 to clarify the reality of the soil carbon storage of natural forest in this area. The floor stratum of *Larix* stands is the Sasa type in the present, but it is said that its floor stratum had been the Moss type before the felling of the natural forest.

The quadrat of 40 x 50m was delimited every 10 meters in length and breadth, and a simple soil survey and measurement of the amount of litter fall were done at 30 points on the intersection in the delimited line. Using a boring stick for 1m depth, the soil horizon was divided, the thickness of each horizon was measured and the soil sample of each horizon was collected. For calculation of the bulk density, the capacity of the boring stick was used.

In the soil profile investigation of four points (Table 1), both soil samples for the physical and chemical analysis in each horizon were collected. The soil sampling cylinder of 100 or 400 $g/cm^3$ was used for the sample collection for the physical analysis. The sample for chemical analysis was separated to the gravel, the root, and the fine earth perfectly, fine earth was analyzed by CN coder. Similarly, the sample collected by the soil sampling cylinder was separated to the gravel, the root, and the fine earth, the bulk density was calculated. The

following calculation types were used for the calculation of the bulk density and carbon storage.

$$Bd=Gs/Vt$$

$$Cs=Cc \times Bd \times T$$

Bd: bulk density ($g/cm^3$), Cs: soil carbon storage in each horizon (tC/ha), Gs: the amount of oven dry weight of fine earth (g), Vt: the volume of soil sampling cylinder ($cm^3$), Cc: carbon content (%), T: the thickness of horizon (cm)

In MPI plot, the amount of fine root (diameter < 1 mm) up to 30 cm in soil depth was mesured using the soil sampling cylinder ($400cm^3$), and in *Larix* stand (Od-L2), each amount of litter fall, deposited organic matter and fine root were measured in the same method in MPI plot.

## 4. Result and Discussion

### 4.1 Distribution of soil carbon storage in MPI plot in *Abies veitchii* stand.

The result of the Multi Point Investigation was shown in Fig. 2. The annual amount of the carbon supply to the soil by the litter fall was 2.8 tC/ha/yr in the average of 30 points, and the range of the dispersion was 1.1 - 5.1 tC/ha/yr. It was thought that the distribution of the amount of the litter fall depended on the tree age composition and the tree distribution. For instance, the amount of litter fall was a little along the stream with a low stand density. The dispersion of the carbon storage was in the range of 0.0 - 34.8 tC/ha in the deposited organic matter (O) horizon and 0 - 308 tC/ha in the mineral soil. When limiting to the points where the soil horizon develops, the dispersion of the carbon storage, which was in the range of 15.6 - 34.8 tC/ha in the O horizon and 157 - 308 tC/ha in the mineral soil, was large. The soil carbon storage showed the tendency to be large in the place of residual soil. The distribution of the amount of the litter fall did not correspond to the distribution of the amount of the deposited organic matter (O horizon) and the soil carbon storage. It was said that the amount of the organic matter in the O horizon and mineral soil was decided depending on the speed balance of the supply and disappearance by decomposition and movement[3], it was thought that the large dispersion of the soil carbon storage originated in the difference of the temperature moisture habitat by the toposequence.

### 4.2 Estimate the influence which reforestation which gave to the soil carbon storage after the felling of natural forest.

#### 4.2.1 Deposited organic matter (O) horizon

In two natural forest stands (Od-1, Od-5), F layer and H layer were plainly observed, but H layer was not in *Larix* stands (Table 2). The carbon storage in the whole O horizon was 39 tC/ha in Od-1, 24 tC/ha in Od-5, 9 tC/ha in Od-L5, and 11 tC/ha in Od-L2, the carbon storage of O horizon in two *Larix* stands was relatively little compared with two natural forest stands. This result cause was thought the disturbance by felling and the progress of decomposition of O horizon during low production on the juvenile stage of *Larix* stand.

#### 4.2.2 Comparison of carbon storage in mineral soil between *Abies-Tsuga* (or *Abies*) stand and *Larix* stand.

In Od-1 and Od-L5 in the place of residual soil (Table 1), the leaching part was observed

in soil surface. These soil profiles were defined as the Dry Podzolic soils (PDII) according to the Classification of Forest Soil in Japan (1975)[2]. The carbon storage of each soil horizon was shown in Table 2. The soil carbon storage in AE horizon was 47 tC/ha in Od-1 and 41 tC/ha in Od-L5. In Bhs horizon, the soil carbon storage was 81 tC/ha in Od-1 and 56 tC/ha in Od-L5. The comparisons in deeper part than Bs1 could not be simply compared because the thickness of the each level horizon was greatly different. Then, when Bs1 and Bs2 were matched , the soil carbon storage was 180 tC/ha in Od-1 and 123 tC/ha in Od-L5. In Bhs - Bs2 horizon, which were illuvial horizon of humus, iron and aluminum on podozolic soil[1], there was a clear difference in the soil carbon storage between Od-1 and Od-L5, the soil carbon storage in Od-L5 (*Larix* stand) was less compared with Od-1 (*Abies-Tsuga* stand). It was thought that the reason why there was no significant difference in AE horizon was that 30 years or more have passed since *Larix* had been reforested, and the amount of the soil organic matter had recovered. The tendency same as the case of the residual soil (Od-1 and Od-L5) was seen when comparing Od-L2 with Od-5 in creep soil, through it seemed that it was not the best comparison because the soil type was different. In addition, there was a problem that the secular variation in the same forest stand was not investigated in this study, however, the tendency of which the soil carbon storage in *Larix* stands was less compared with *Abies-Tsuga* or *Abies* stand was clear, and the soil carbon storage was a decrease in 50 tC/ha scale because of the *Larix* silviculture after the felling of the natural forest.

### 4.2.3 Forecasting of the soil carbon storage in the future in *Larix* stands.

The source of organic matter supply to the mineral soil is litter fall, deposited organic matter and fine root. Then, these amounts in the present were compared in order to forecast the soil carbon storage in *Larix* stand in the future. The amount of litter fall was 2.0t/ha (0.9tC/ha) in *Larix* stand (Od-L2) and 4.9t/ha (2.6tC/ha) in *Abies* stand (MPI plot). The amount of the deposited organic matter has already been described by 4.2.1. The amount of fine root (diameter <1mm, up to 30cm in soil depth) was 3.3t/ha (1.8tC/ha) in *Larix* stand and 8.7t/ha (4.7tC/ha) in *Abies* stand. Among of these amounts in *Larix* stand were less compared with *Abies* stand. As a result, it was thought that it was difficult for the soil carbon storage in *Larix* stands to be going to recover to the level of an original natural forest in the future.

## 5. Reference


1) E.M. Bridges (1978) World Soils,pp.128, Cambridge University Press

2) Forest Soils Division (1976) Classification of Forest Soil in Japan(1975), Bulletin of the Government Forest Experiment Station, 280:1 - 28

3) Nakane,K. (1986) Carbon cycling in forest ecosystems, Japan Journal of Ecology, 36: 29 - 39

4) Tadaki,Y. (1977) Studies on the production structure of forest.XVIII. Structure and primary production in subalpine "Dead trees strips" *Abies* forest near Mt.Asahi., Japan Journal of Ecology, 27: 83 - 90

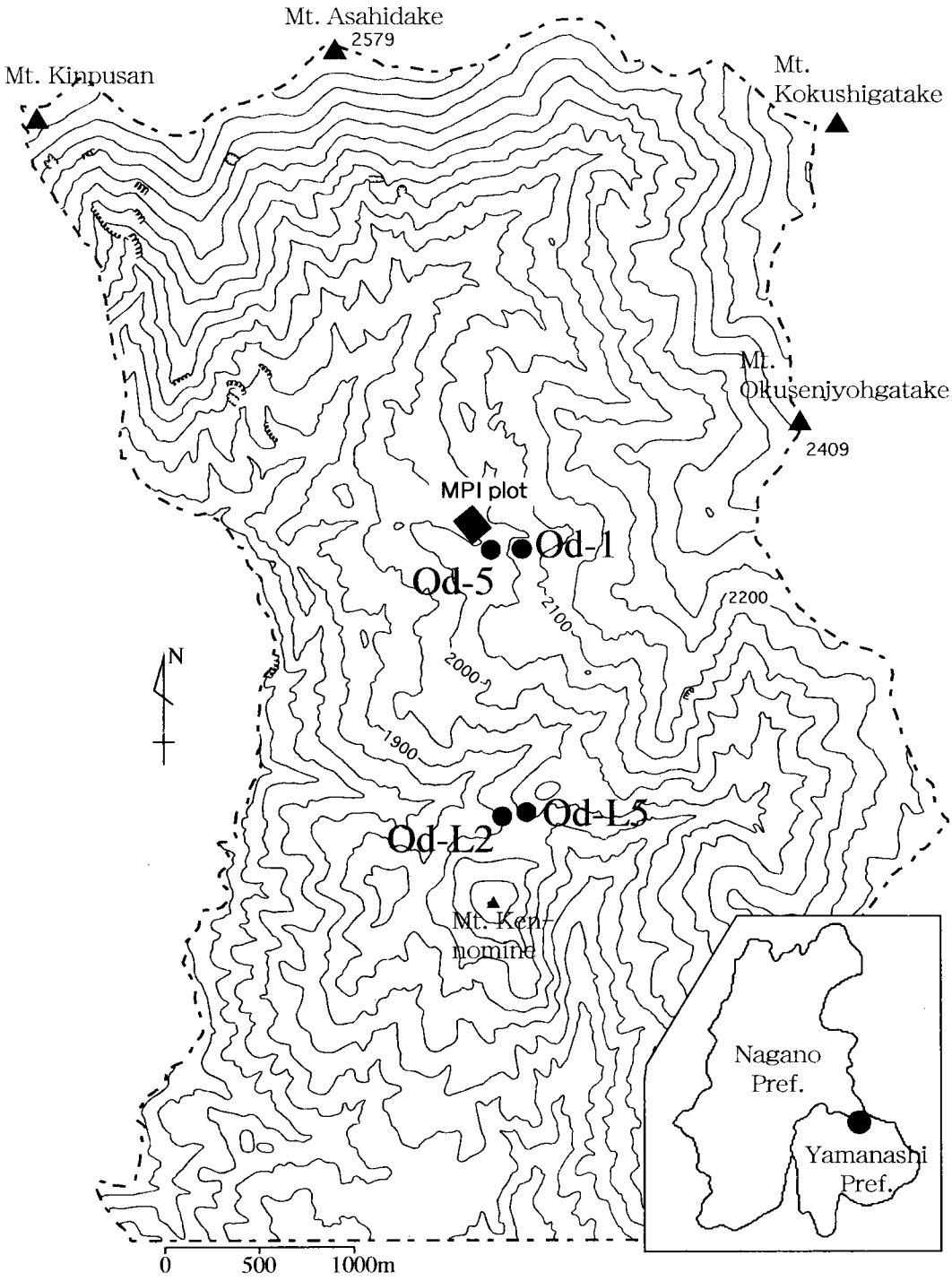
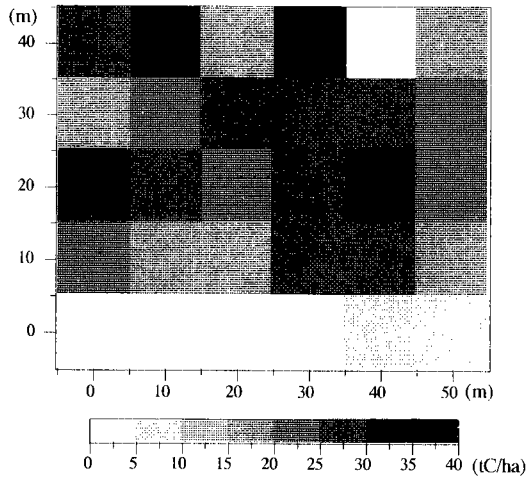
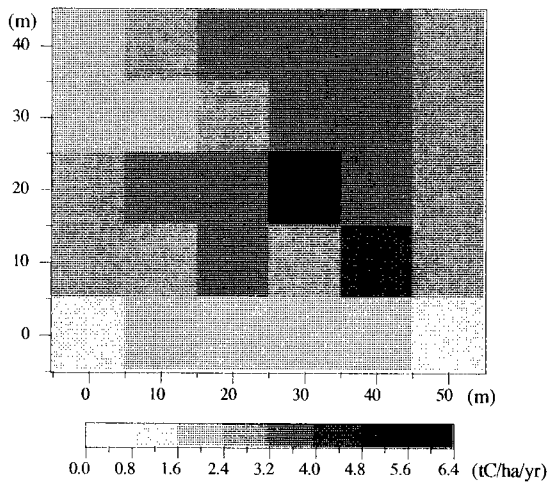


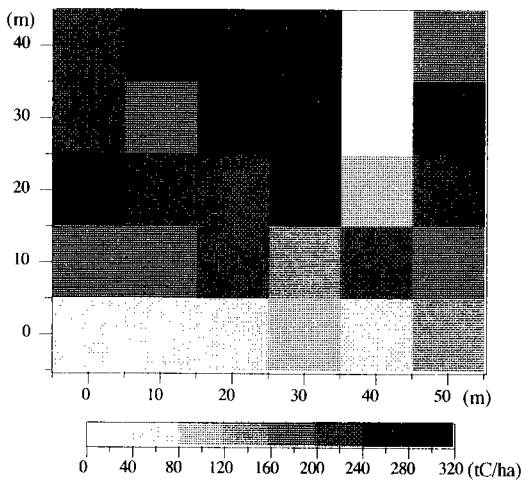

Fig. 1 Study Area



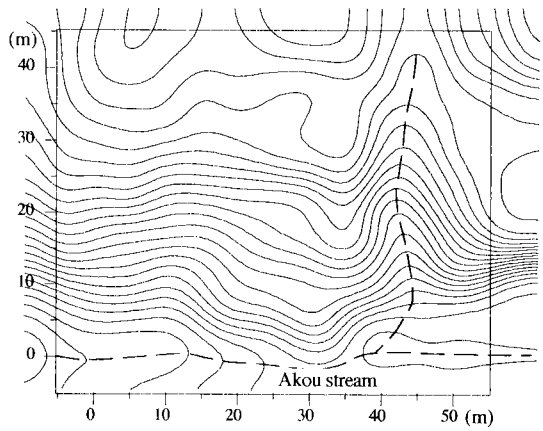

Carbon storage of O (A0) horizon




Total annual litter fall (in weight of carbon)




Carbon storage in mineral soil horizon (from A to BC horizon)




Topography of *Abies veichii* stand

* The interval of the contour line is 0.48m

Fig. 2 Cabon storage of O(A0) and mineral soil layer, annual litter fall and topography in MPI plot (*Abies veichii* stand)

Table 1. Description of soil sampling site

| profile name | elevation (m) | parent material type | slope aspect | slope angles | forest type | floor stratum |
|---|---|---|---|---|---|---|
| Od-1 | 2100 | residual | N80° W | 7° | *Abies−Tsuga* | Moss |
| Od-L5 | 2000 | residual | N80° W | 9° | *Larix* | Sasa |
| Od-5 | 2000 | creep | S70° W | 27° | *Abies* | Moss |
| Od-L2 | 2000 | creep | N 8° W | 26° | *Larix* | Sasa |

Table 2. Selected chemical and physical properties related to soil carbon storage

| Profile name | Horizon | thickness cm | Bulk density g/cm$^3$ | Carbon content % | Carbon storage tC/ha |
|---|---|---|---|---|---|
| Od−1 | LF | 3 | | | 14 |
| PDII | H | 5 | | | 25 |
| | AEh | 10 | 0.50 | 9.3 | 47 |
| | Bhs | 10 | 0.46 | 17.7 | 81 |
| | Bs1 | 18 | 0.51 | 11.9 | 109 |
| | Bs2 | 22 | 0.70 | 4.6 | 71 |
| | BC | 12 | 0.83 | 3.6 | 36 |
| | C | 18 | 0.95 | 1.1 | 19 |
| | 計 | | | | 401 |
| Od−L5 | LF | 10 | | | 9 |
| PDII | AEh | 9 | 0.34 | 13.5 | 41 |
| | Bhs | 11 | 0.40 | 12.7 | 56 |
| | Bs1 | 30 | 0.56 | 5.3 | 89 |
| | Bs2 | 15 | 0.63 | 3.6 | 34 |
| | Bs3 | 23 | 0.70 | 2.5 | 40 |
| | BC | 22 | 0.97 | 0.5 | 11 |
| | 計 | | | | 280 |
| Od−5 | LF | 4 | | | 19 |
| PDIII | H | 1 | | | 5 |
| | Ah | 5 | 0.41 | 18.2 | 37 |
| | Bhs | 15 | 0.34 | 14.4 | 73 |
| | Bs1 | 20 | 0.40 | 8.2 | 66 |
| | Bs2 | 55 | 0.52 | 4.0 | 114 |
| | C | 5 | 0.86 | 0.1 | 1 |
| | 計 | | | | 315 |
| Od−L2 | LF | 11 | | | 11 |
| dBD | Ah1 | 10 | 0.22 | 27.7 | 61 |
| | Ah2 | 10 | 0.23 | 22.4 | 52 |
| | B1 | 18 | 0.20 | 11.7 | 42 |
| | B2 | 22 | 0.45 | 2.8 | 28 |
| | 計 | | | | 193 |

Soil profile was described by "Guidlines for Soil Description, FAO, 1990". Soil classifications followed the Classification of Forest Soil in Japan, Forest Soils Division, 1975.