POTENTIALS OF SUB URBAN FOREST: PROJECTING SUSTAINABLE BIOMASS YIELD ON DOMINANT SPECIES

A Thesis

By

MOHAMMAD NIZAM UDDIN 47-106826

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Advisor: Professor Yamamoto Hirokazu

Co-Advisor: Professor Makoto Yokohari

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ABSTRACT

Currently the sub urban (Satoyama) forests in Japan have become the important areas to restore management activities. Historically these forests derived multiple benefits to the environment and society. Before 1950-60s these forests were managed in a sustainable way to produce wood for fuels, leaf–litter for organic fertilizer etc and after abrupt shift to fossil fuel in 1950-60s these forests remained underused. In the last two decades thousands of volunteer groups have been formed for the conservation and restoration management of sub urban (Satoyama) forests. Recently, Japan government has also taken initiatives to manage the sub urban forests in a sustainable way to combat global warming in the light of low carbon society initiative. Therefore, determining strategy for sustainable management of sub urban forests can play a significant role in achieving the goal of sustainability. In this study our aim was to formulate a strategy for the sustainable management of sub urban forest in Japan and to ascertain the potential contribution of these forests to the environmental sustainability in their vicinages. The semi-natural sub urban (Satoyama) forest of Oaota, in Kashiwa, Chiba Japan was selected for the study with legal permission from non-profit organization (NPO). The sub urban (Satoyama) forest spans over a total area of 42 hectares, of which, only 4 hectares area is under NPO management. Within the NPO managed forest areas we identified Plantation Forest (PF) site and Natural Forest (NF) site and two quadratic plots were set in each site to get the forest inventory data. We measured sectional diameters at 2 m intervals starting from 0.3 m from the ground by diameter tap alongside the total canopy height of trees using the Criterion RD 1000. Lengths and diameters of branches were also measured from photographs by using ArcGIS 10.0. We then used these data to obtain existing biomass stock (in the year 2010) of the forest. Afterwards we cut 16 trees of four dominant species viz., *Quercus serrata*, *Chamaecyparis obtusa*, *Cryptomeria japonica*, and *Carpinus tschonoskii* and 139 stem discs of 5 cm thick were collected for the growth ring analysis by WinDENDRO Reg2002b software. According to our finding, most of the trees in this forest are 50 years in age (approximately). Based on the early growth pattern of the dominant species, *Quercus serrata* and *Carpinus tschonoskii* exhibited higher biomass yields in the Oaota forest followed by *Chamaecyparis obtusa* and *Cryptomeria japonica*. As per our biomass calculation using Mitscherlich growth model, the total wood biomass of Oaota forest in 2010 was 4994 m^3 which will reach 6654.27 m^3 by 2020 adding 1660.27 m^3 biomass to the stock; under the assumed 2 % mortality rate. We suggested that 80 % of the yield over this period be felled after keeping aside 20 % for estimation error or future risk, may be one of the options for sustainable forest management. The structured questionnaire based interview of the NPO members and local people in Oaota area revealed their interest in harvesting some wood from Oaota forest at 10 years interval. Therefore, the information on future wood biomass accumulation will assist them in sustainable management of the sub urban (Satoyama) forest. In addition, we measured the carbon contents of soil at 0-15 cm and 15-30 cm depth, tree leaves by taking five conical shaped leaf traps of 1 m diameter in each plot and wood of the forest (inventory in 2010). According to our calculation, the total carbon sequestered by Oaota forest stood at 3399.9 tC for soil, 68.67 tC for tree leaves / y and 3200.085 tC for wood upto the year 2010. In the light of projected future growth, we concluded that the sustainable management of sub urban (Satoyama) forest contributes not only towards wood production but also in environmental sustainability through providing substantial carbon sequestration service. However, to answer the question 'how much biomass needs to be conserved in the context of sustainable management', we need further research.

Key words: Satoyama, NPO, Dominant species, Semi-natural forest

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DEDICATION

This thesis is dedicated to NPO members who have helped me tremendously for my sample collection and research in the Oaota forest. I enjoyed my research with the help of NPO members in Oaota forest.

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LIST OF ABBREVIATIONS

NPO	Non-Profit Organization
CAI	Current Annual Increment
MAI	Mean Annual Increment
RD	Relative Dominance
BA	Basal Area
OC	Organic Carbon
DBH	Diameter at Breast Height
PF	Plantation Forest
NF	Natural Forest
MBA	Model Basal Area
MHt	Model Height
TN	Tree Number
TT	Total trees
TDW	Total Dry Weight of Wood
TCC	Total Carbon Content
AGV	Above Ground Volume
BGV	Below Ground Volume
DWD	Dry Wood Density
TDWV	Total Dry Wood Volume

LIST OF UNITS OF MEASUREMENT

^{O}C	degrees Celsius
cm	centimeter
ha	hectares
km	kilometer
%	percentage
y	year
t	time
dt	dry tonne
m	meter
mm	millimeter
m^3	cubic meter
m^2	square meter
g	gram
cc or cm^3	cubic centimeter

CHAPTER-1

1 INTRODUCTION

1.1 Background

The concept of sustainability is deeply rooted in forestry (Fox, 2000). Now-a-days, it is viewed in a broader ecosystem context and it is viewed as the combined outcome of the preservation of natural habitat, conservation of biodiversity, maintenance of esthetic qualities of the forests, and the conservation and restoration of native and old growth forest (Maser, 1994). Maser (1994) also stated that the outcome of sustainable forestry will be the perpetual productivity of goods and services for human use. On the other hand, American Forest and Paper Association (AFPA, 1999) defined the sustainable forestry as the ability to meet the needs of the present society for goods and services without compromising the ability of future generations to meet their own needs. United Nations Conference on Environment and Development (UNCED), and Kyoto protocol signified the practice of sustainable forestry both in tropical and in temperate countries (Sedjo *et al*., 1998).

The utilization of forest products deriving from the forest is related to the productivity of the forests. The long term success of forest management as a landuse mostly depends on the wood production and the evaluation of wood production requires information on growth pattern of tree species (Boot and Gullison, 1995).

The sub urban forest (Satoyama) which comprises 20 % of the land area of Japan; traditionally these forests were utilized as the source of fuel energy and other services till 1950-60s after which the forest was abandoned due to the shift to fossil fuel. Recently (1980-90s), in Japan, social concern has been raised nationally towards the conservation and utilization of sub urban (Satoyama) forests. The sub urban (Satoyama) forests were considered as biodiversity “hot spot” and a model of sustainable society that maximizes the use of ecosystem services but under use of these sub urban (Satoyama) forests has degraded these ideal ecosystems (Morimoto, 2010). On the other hand, by utilizing woods and litter from Satoyama as biomass resources can be an option to Satoyama maintenance (Yokohari *et al*., 2006). Now a days, social needs and values are well aligned with the services of sub urban forest as a source of renewable biomass energy which will contribute to reduce carbon emission as well as realizing the multifunctionality of sub urban wood lands (Yokohari and Bolthouse, 2011). Biomass being a local resource has the close contact with local economy and by utilizing the woody biomass as pellet for boiler or pellet stove can be an option for sustainable development (Miura, 2005). A new life style which utilizes forest biomass as a part of energy source helps to maintain the forest health (Kuroda, *et al*. 2012). Forest management combined with the contribution of local people and biomass utilization can be effective to maintain the forest health (Kuroda *et al*., 2009). However, in Satoyama areas information on species productivity is inadequate to formulate a sustainable management strategy. Accordingly, in this work we aimed at determining the species specific past growth patterns and formulating growth model which is important to project sustainable yield as well as determining the strategy for its sustainable management.

1.2 Statement of the Problem

Global warming is one of the significantly important issues concerning the world at present. Its effects on animals, plants and even human being are frightening. In combating the issues related to global warming, the proper utilization of wood biomass could be one of the options. Wood biomass has a great capability of trapping greenhouse gas from the environment, thus creating a low carbon society. A well-managed sub urban forest in Japan could be a better option of maintaining a low carbon society. Sub urban forest refers to an area found in rural districts that encompasses human settlements and ecosystems (e.g. agro-ecosystems, secondary forests, wetlands, grasslands and hills or mountains) that provide numerous vital services (e.g. food, forest products, non-timber forest products, economic, cultural services, etc.) for human well-being, and is created through prolonged interaction between humans and ecosystems (Alphonse *et.al*, 2008). The forest potential of Japan estimates up to 60 % of the land area (Yokohari *et al*., 2006). In addition 20 % of Japan's land area has been reported to be forest patches otherwise known as sub urban (Satoyama) forest. In recent years the overall functioning of sub urban (Satoyama) forest has been declining due to deterioration in its economic application and subsequent neglect over a period of time (Alphonse *et al*., 2008). The major challenges facing sub urban (Satoyama) forests in Japan have been attributed to the absence of human intervention as a result of lack of proper forest management activities. Due to inadequacies of forest management activities, majority of the Satoyama has become "Unmanaged Forest". As reported by Nakagoshi and Hong (2001), the rural forested landscape otherwise known as Satoyama has lost its ecological working functions and beauty due to abandonment of vegetation management. Therefore, it is very crucial to implement forest management activities which could involve maintaining the Satoyama forests, by regular pruning and thinning activities. These activities will improve the growth and reduction of the nutrient competitions among the tree species in the forest. As stated by Yamaba *et al*., 2009 the wood waste generated through forest management when harnessed properly could serve as a source of alternative energy which could replace conventional fuels such as gasoline, coal, diesel etc. The utilization of wood for energy thus reduces greenhouse gases in the environment.

As most of the researches on sub urban forest in Japan focused on the sub urban (Satoyama) forest maintenance through utilization of wood or forest resources, so there is need to determine the potential of the forest to produce different resources. Information on the growth of the species in sub urban forest is inadequate to ascertain the biomass stock of a particular sub urban forest and also to predict the future biomass accumulation. Depending on the present biomass stock and flow of a sub urban forest, the future management strategy can be taken for the better growth of the forest health. Previous work on sub urban forest management does not give the information on stock and flow of the resources from the forest. This work was taken to derive knowledge on the growth pattern of the dominant species found in the sub urban forest and also to predict the future biomass accumulation. Species which gives better growth can not only generate more biomass but also has the potentiality to sink more carbon dioxide from the atmosphere. The information on high yielding species and projection of future growth helps to take proper strategy to the sustainable management of sub urban forest.

1.3 Objectives

General objective

To estimate the future biomass accumulation of a sub-urban forest to formulate the strategy for the sustainable management.

Sub-objectives

- ❖ To ascertain the growth pattern of species to calculate future biomass accumulation in the forest.
- ❖ To estimate the potential of carbon sink by the forest.
- ❖ To assess the utilization of wood/leaves as alternative usage.
- ❖ To recommend the strategy for sustainable management of the forest.

1.4 Hypothesis

If local people are informed about biomass accumulation of sub urban forest, it is thought that it will be helpful for them to determine the strategy for sustainable management of sub urban forest.

1.5 Research Questions

What are the factors which assist in formulating the strategy for sustainable management of sub urban forest?

- What is the present biomass as well as carbon stock of the sub-urban forest?
- What are the growth patterns of dominant species of sub-urban forest?
- What is the amount of future wood biomass accumulation of the forest?
- What alternative utilizations are possible for the output from sub-urban forests?
- What are the recommendations for sustainable management of sub-urban forest?

1.6 Significance of the Study

The study will shed some light on sub urban forests' contributions towards making a sustainable society through cognitive management of sub urban (Satoyama) forests by introducing biomass (thought to be carbon neutral) utilization of those forests and as a potential sector of carbon sink. If these abandoned sub urban forest is managed focusing the maximization of productivity of the species then the mitigation of global warming challenges like CO_2 reduction from the atmosphere will be enhanced more which will ultimately impact on global CO_2 concentration reduction from the atmosphere. Traditionally these sub urban forests are managed by volunteer organizations (NPO for the primary purpose of recreation and conservation of local landscape. Introducing the scientific management together with traditional knowledge, called cognitive management (Japan Satoyama-Satoumi Assessment, 2010) in these abandoned forests in the light of carbon reduction from the atmosphere will be an option to face the challenges of global warming as well as enhancing low carbon society initiative in Japan. Management activities by NPO focusing the high yielding species will not only increase the productivity of the forest but also positively enhance the carbon sink potentiality of sub urban forest. The government of Japan also took Low Carbon Society Initiative to introduce local resource conservation and utilization and in that context this work will contribute some information to the local government and forest managers to the better management of the local sub urban (Satoyama) forest for their own benefit. By utilizing more forest biomass which is thought to be carbon neutral or comparatively less carbon emitter than fossil fuel, the low carbon society initiative will be enhanced in Japan.

1.7 Structure of the Thesis

This thesis is organized into six chapters. The first chapter deals with the background and justification of the research. The second chapter is for reviewing literatures on conservation and management of sub urban forest in Japan and determining the species productivity through growth ring analysis. Chapter three of the thesis discusses the materials used and methods employed for the study and data analysis technique. It also describes the procedure of projecting future growth of the species by developing growth model. Chapter four includes the results gathered from the study through forest inventory and growth ring analysis. Chapter five is the discussion on the findings of the research and previous work on the same aspect or species. Finally, chapter six is for conclusions and recommendations where future research aspects, limitation of the work and management prescriptions are included for the better management of the sub urban forest.

CHAPTER -2

2 LITERATURE REVIEW

2.1 Introduction

This chapter includes the concept of sub urban (Satoyama) forest in Japan, and it's historical and present status, Satoyama renaissance and present activities of NPOs for its conservation and management. Different works on the revitalization of Satoyama through forest biomass utilization by the local society and how the species growth is related to the better management to obtain maximum benefit from the sub urban forest. As there is inadequate data on the growth pattern of species in sub urban forest so literature on tree stem analysis in Japan is included to identify the high yielding species in these forests and future biomass yield potential.

2.2 Concept of Sub Urban (Satoyama) Forest in Japan

The oldest description of sub urban forest (Satoyama) is found in 1759, the Edo period as "Forests near the villages are called Satoyama". Professor Shidei is credited with the first using the word Satoyama to describe woodlands adjacent to villages. The sub urban forest in Japan is included in the context of Satoyama landscape. Sub urban forest "Satoyama" is a Japanese term applied to the border zone or area between mountain foothills and arable flat land. Literally, "Sato" means arable and livable land or home land, and "Yama" means mountain. "Satoyama" which has been developed through centuries of small scale agricultural and forestry use also promises biodiversity if properly maintained by human activities. The concept of sub urban "Satoyama" has several definitions. It includes the management of forests through local agricultural communities. During the Edo era, young and fallen leaves were gathered from community forests to use as fertilizer in wet rice paddy fields. Villagers also used wood for construction, cooking and heating. Recently, sub urban forest (Satoyama) has been defined not only as mixed community forests, but also as entire landscape that are used for agriculture. The term Satoyama was originally used to denote forests surrounding farm villages and managed by farmers for different needs; timber for buildings, wood for fuel and charcoal production, leaf litter and twigs were used as fertilizer for crops, particularly in the rice paddy fields situated in the lowlands. Different food products were also collected such as bamboo shoots, nuts of chestnut and mushrooms and young shoots of ferns and herbs (Kobori and Primach, 2003; Takeuchi, 2003). These areas might be called “Satoyama” wood lands, as they comprise uplands surrounding cultivated valleys dominated by rice paddy fields. The term “Satoyama” has been taken to refer to such areas for hundreds of years, at least from as far back as 1759.

2.3 Types of Sub Urban (Satoyama) Forest in Japan

There are many types of sub urban (Satoyama) forest in Japan. Depending on the local demand and geographical setting these various types of sub urban (Satoyama) forest were shaped. The following Figure 1, shows the different types of sub urban forest found in Japan.

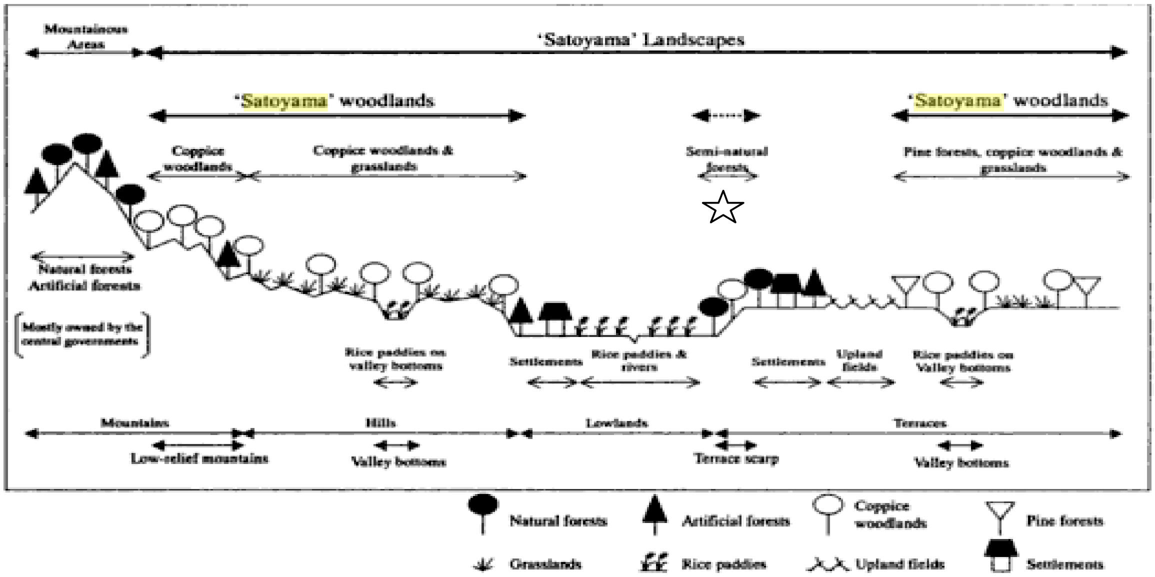


Figure 1, Schematic Diagram of Traditional Satoyama and Satoumi Landscape in Japan, Study Forest Type is Marked by Star Sign in this Figure (Source:Takeuchi *et al*., 2003)

2.4 History of Sub Urban (Satoyama) Woodlands in Japan

Farming in a Satoyama landscape has a long tradition, according to written sources, the extensive use of woodlands similar to the historical Satoyama woodlands can possibly be traced back to the Jomon period, the Japanese Stone Age. The forests had resources necessary for buildings, fuel, and food. Forest exploitation was first documented in CE 600, and three periods of predation, or severe deforestation, can be distinguished: ancient (CE 600-850), early modern (CE 1570-1670), and modern (CE 1900-1959) (Totman, 1980). The main causes are to be found in coal production (for metallurgy, house-warming etc.) and cutting of firewood and timber for house building, not least for monumental constructions, the negative environmental effects, e.g. erosion and flooding, were recognized fairly early in history, and already in the seventh century CE, authorities and landowners emphasized the importance of restricting general access to forest (Totman, 1980). The rulers of the Edo/Tokugawa period therefore initiated "regenerative forestry" in early modern Japan, around CE 1600 (Totman, 1980). Forest exhaustion approached an ecological catastrophe, but this was avoided thanks to strict regulations and large-scale afforestation projects that were implemented all over the country (Totman, 1980.; McMullen, 1999; Diamond, 2005). However, the expanding modern society around 1900 pushed Japan into a new phase of overcutting the mountain forests. A forest law from 1907 had altered forest policy from regulation to utilization because of increased timber production (Iwamoto, 2002). Around 1950-60 the situation changed again, but also because at the same time the use of coal as an energy resource diminished and the use of plant remains as fertilizer of the paddy fields came to an end. The traditional use of Satoyama woodland ceased definitely and uplands became available form of forestry (Iwamoto, 2002) or urbanization (Ichikawa *et al*., 2006). The present forest landscape in Japan is the result of the political change in forest management in the mid-twentieth century.

2.5 Present Status of Sub Urban (Satoyama) Forest in Japan

The Japanese forest ecologist Tsunnahide Shidei initiated active use of the term Satoyama. Most of the people in a community share the use of Satoyama as common land. There were many community agreements and rules, regulating, for example, the start day for gathering fallen leaves and the sizes of basket to carry leaves. Following the introduction of chemical fertilizers, the Satoyama lost its value as a fertilizer supply source. As new energies like oils, propane gas, as well as electricity were getting to be popularized, Satoyama's role as a fuel source became insignificant. These forests now have less use as common community land. As a result, the value of the Satoyama in the community has declined remarkably. Satoyama agreements and rules of use and their cultural significance became meaningless in the community. Satoyama were left untended, people no longer collect firewood. This leads to a dense growth of brush and a darkening of the forest. Only shade tolerant tree species can germinate and survive on the dark forest floor. However, in an abandoned Satoyama, fallen leaves accumulate, and nutrients in the soil increase. The forest floor becomes darker, preventing germination of pine trees of overcrowding and competitive pressure from other tree species. Different types of activities which were responsible to be the degradation of sub urban forest in Japan and what are the initiatives taken till now were shown in the following Table 1.

Now, the government and NPOs are much concerned about the sub urban forests revitalization in Japan. During 1980-90s NPO volunteer groups were formed to manage the sub urban forests. At present, about 2000 volunteer groups are found in Japan who can only manage 0.03 % of the sub urban forest (Terada *et al*., 2010). These volunteer groups manage the forest through the traditional knowledge such as conserving the species, collecting leaves or woods at a certain time, cutting the dead or dying / broken trees. They do not pay much concern about species growth e. g. which tree is better for this forest in terms of wood biomass production. Sometimes, they pay interest on particular species which they like most. As to the environmental concern the high yielding trees are better for carbon sequestration than low yielding species. If the sub urban forests are managed concerning more about high yielding species in an area, it can play a significant role in combating global warming. Therefore, it needs to know the species growth pattern and future biomass productivity of species for the sustainable management of the forest.

Table 1, Events Related to Sub Urban Forest Degradation and Revitalization from 1940 to 2010 in Japan

Time	Events of Satoyama degradation	Time	Events of Satoyama revitalization
1940	-Large deforestation during and after world war II	1988-89	-significance of biodiversity conservation in Satoyama areas focused
1960	-Fossil fuel revolution started, -Conifer plantation began and broad leaved forests turned to conifers	1991-1999	- Contest of beautiful scenes of Japanese village was organized and 100 best terraced paddy fields are selected by MOA
1970	-Huge urbanization in sub urban Satoyama areas	2003	- Identification of Satoyama as cultural landscape by ACA
	-	2004	Top 30 conservation activities in Satoyama by MOE
	-	2005	1000 monitoring sites included Satoyama
	-	2007	Satoyama initiative, first Satoyama quasi-national park was designed,
	-	2007-2010	Satoyama-Satoumi sub-global assessment begins in United Nations University
	-	2008	100 best Satoyama of Japan selected by Asahi Shimbun, Satoyama initiative by MOE

Source: (Morimoto, 2010. modified by author)

2.6 Tree Ring Analysis in Japan

Species growth pattern varies from region to region or species to species. The information on tree growth in sub urban forest in Japan is inadequate. In order to extract past growth information which is important to determine tree growth pattern, stem analysis is needed. Tree ring analysis (stem analysis) in Japan consists of two dissociated research traditions: dendrochronology and dendroclimatology oriented. In 1900s the scholars began to study dendroclimatology in order to reconstruct the past climate data. But dendrochronology oriented researches took shape as late as current decades (Yasushi, 1987). The earliest tree ring analysis was done in 1920s to 1930s by researchers in Japan in the interest to build past climate variability (Yamazawa, 1929.; Shida, 1935.; Enmoto, 1937). In the earlier time the scholars were interested in long term cyclical variance of tree growth rather than variance in annual growth for past climate interpretation. However, a few studies were conducted on dendrochronology in Japan between 1950s and 1970s. The current dendrochronology study in Japan is concerned on three species: *Chamaecyparis obtusa*, *Sciadositys verticillata*, *Cryptomeria japonica* due to the most commonly utilization of these tree wood for crafts and construction purposes in both historic and prehistoric times (Shimakura, 1975).

CHAPTER-3

3 MATERIALS AND METHODS

3.1 Introduction

This chapter includes the materials which were used to do this research and also different methodologies adopted for the study. This chapter gives the general information on study area, site selection procedure, methods of tree inventory, different formula needed to estimate the wood volume, soil organic carbon, leaf biomass of the forest. It includes the procedure of tree stem analysis for future biomass accumulation by using Mitscherlich growth model. It also explains the interview of NPO and local people about the forest conservation and utilization, and data analysis techniques.

3.2 Materials

The materials used for this study were diameter tap, measuring tap, measuring pole, True Pulse, Criterion RD2000, compass, Earth Augar, soil corer, Sanding Machine, NC analyzer.

3.3 Methods

3.3.1 Selection of study area

The Oaota forest is selected for the study as it is a typical sub urban (Satoyama) forest and the NPO of this forest gave the legal permission to conduct the study on this forest. Study area is a semi natural forest of sub urban area in Kashiwa, Chiba, Japan. This forest has the both plantation and natural forest sites; a portion of the forest is managed by the Non-profit Organization (NPO). There are many types of sub urban (Satoyama) forest in Japan, of them this Oaota forest is one type of them. In plantation site *Chamaecyparis obtusa* is more in numbers but in natural forest site *Quercus serrate and Quercus acutissima, Carpinus tschonoskii* are greater in number. This forest has three layers of species composition where *Chamaecyparis obtusa*, *Quercus serrata*, *Carpinus tschonoskii*, *Quercus acutissima*, *Cryptomeria japonica* are in the upper canopy layer. The study area was selected by studying the aerial photo and also after discussion with the NPO of this forest. The research work was conducted from December 2010 to June 2012.

3.3.2 Experimental site selection

From the aerial photo of the Oaota forest, two sites, one is Natural Forest (NF) site (site A) and another is Plantation Forest (PF) site (site B) were randomly selected. Two experimental quadratic plots (20 m X 20 m) in each site were established during the study period to estimate the wood stock and general information of the forest.

3.3.3 Data collection

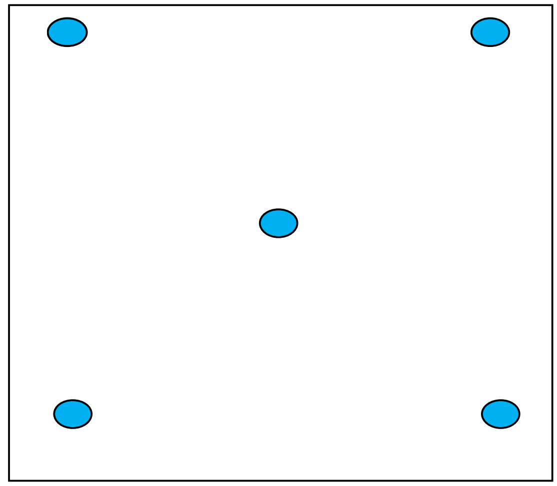
Individual tree diameter over bark at 0.3 m, dbh 1.37 m height were taken by diameter tap (in cm), and diameters at every 2 m interval along the stem of the tree, after dbh, were taken by using Criterion RD 1000 upto the limit to which the top diameter can easily be seen through criterion RD 1000 instrument. The top portions of trees whose diameter cannot be measured by Criterion RD1000, photographs were also taken, along with a pole having the demarcation of 1m length, by a digital camera for those portions of trees and marked and saved according to the tree number in camera memory. Those photographs were then analyzed by ArcGIS 10.0 to measure the length and diameter of those portions of trees. The branches of the trees were also measured by using photographs and ArcGIS 10.0 software. Total height of the tree was also measured by Criterion RD1000.

3.3.4 Preparation of tree map

After detecting the North direction of the plot by compass, true pulse was used to measure the horizontal angle of the tree distribution with a certain base point of the plot and horizontal distance of tree was measured by measuring tape. The data were recorded and tree map was prepared by using MS EXCEL.

3.3.5 Setting leaf traps

Five conical shaped leaf traps per plot were set in such a way so that all the traps were in the same distance from each other within the plot. The study was conducted in October 2011 to January 2012 to collect the falling leaves of the tree in the plot. Each trap was 1m diameter or 0.7854 m^2 area. Nylon nets of about 1.2 mm mesh were used so that fallen leaves can be collected easily. Traps were set 1m high which was 1 foot above the forest floor and traps do not touch the ground (Kimura *et al*., 1982). All traps were in the same height from the ground. Poles were used to erect the traps. After every 15 days interval the leaves were collected from the traps. Plastic bags were used to collect the leaves from each trap and marked by date and trap number. Then the leaves were oven dried for 48 hours at 65 ^{0}C in electric oven. Then the dry weight of leaves for each trap was measured by electric weighing machine. The leaf samples were preserved.



(a) (b) 20 m X 20 m

Figure 2, Leaf Traps in Experimental Plots; (a) Leaf Traps in Forest, (b) Position of leaf traps

3.3.6 Soil analysis

Soil samples were collected in that day of the week when there was no rain. Before collecting soil for analysis, samples of soil cores of 30 cm depth was taken from each of the plot and observed the variation of soil color. Depending on the soil color transition zone two layers of soil were identified to collect the soil samples. The depth of soil layers were 0-15 cm and 15-30 cm. For soil organic carbon measurement, 5 samples from each plot for every depth were taken by using earth Augar. Before collecting the soil samples the sampling point is cleared of leaves, roots, stones and partly decomposed leaves. Each soil sample was then mixed thoroughly and oven dried for 48 hours at 65 ^{0}C in electric oven. Approximately 200 g soil was oven dried for each sample. After oven drying 100 mg soil was taken and stones, dead parts of wood, leaves, fine roots etc. were cleaned from the soil. Then the soil was grinded by hand grinder and sieved by 250 mm wire mesh. From each prepared sample 15 mg soil was taken and measured by electric scale. Then samples were analyzed by NC analyzer in the laboratory. Before analyzing, the samples were calibrated and standard sample size was determined. The NC analyzer was used to measure the percentage of soil organic carbon content of the sample.

3.3.7 Soil bulk density and soil organic carbon content

For bulk density measurement the soil samples were collected in that day of the week when there was no rain. Three soil samples from each plot were collected. The leaves, dead or decomposed wood parts and loose soil on the forest floor were cleared from the sampling point before sampling. A 100 cm^3 core was used to collect the soil samples. The soil cores were then dried in electric oven for 48 hours in 65 ^0C so that the soil weight becomes constant. Then the dry weight is taken. The bulk density is calculated by the following formula:

$$\text{Soil Bulk Density} = \text{dry weight} / \text{volume} \quad (g/cc)$$

Calculation of soil organic carbon content

$$\text{Soil organic carbon (t/ha)} = (\%\ \text{soil organic carbon}) \times (\text{bulk density}) \times (\text{soil depth in cm})$$

(Guo and Gifford, 2002.; Mann, 1986.)

3.3.8 Calculation of wood volume and wood carbon content

Wood volume (including bark) is calculated for each section of the tree. From base point 0.3 m to 1.3 m, 1.3 m to 3.3 m, and so on. One meter interval is used only for 0.3 m to 1.3 m. The basal area for each point, say at 0.3 m, 1.3 m etc. were calculated by the formula πR^2, where R is the radius. Then the average basal area for each section was calculated by the following formula:

$$\text{Average Basal area} = [\Pi\sum(R^2_i + R^2_{i+1})] / 2$$

$$\text{Above Ground Volume} = \Pi R^2_i H_j$$

Below Ground Volume = 15 % of Above Ground Volume

Where, Π=3.1416 , R_i is radius at 'i' height

H_j is length of section 'j' between i^{th} and (i+1) th radius measuring point

For the top portion of the tree, of which, sometimes, the radius cannot be measured, the volume was calculated as;

Volume= Basal area at last (top) diameter X length of the portion to top of the tree X 0.3

(Here, factor 0.3 is used assuming conical shape of top portion of the tree)

Wood carbon content = Dry wood volume X 0.5

Leaves carbon content = Dry leaves weight X 0.5

(Shin *et al*., 2007.; WB, 1998.; McDicken, 1997.)

3.3.9 Wood volume calculation by ArcGIS 10.0

The photographs of the trees and branches were analyzed by ArcGIS 10.0 with a known dimension of length. One meter demarcated long pole of alternately colored was used while taking the photos. The length and diameter of the top portion and branches of tees were calculated as follows:

Length of tree portion (or branch) = (Number of pixels in the tree portion) / (Number of pixels in known length.

Volume was calculated as;

$$\text{Basal area}=\Pi\sum(R^2_i + R^2_{i+1}) / 2$$

$$\text{Volume} = \Pi R^2_i H_j$$

R_i is radius at i height

H_j is length of section '*j*' within i^{th} and $(i+1)^{th}$ radius measuring point

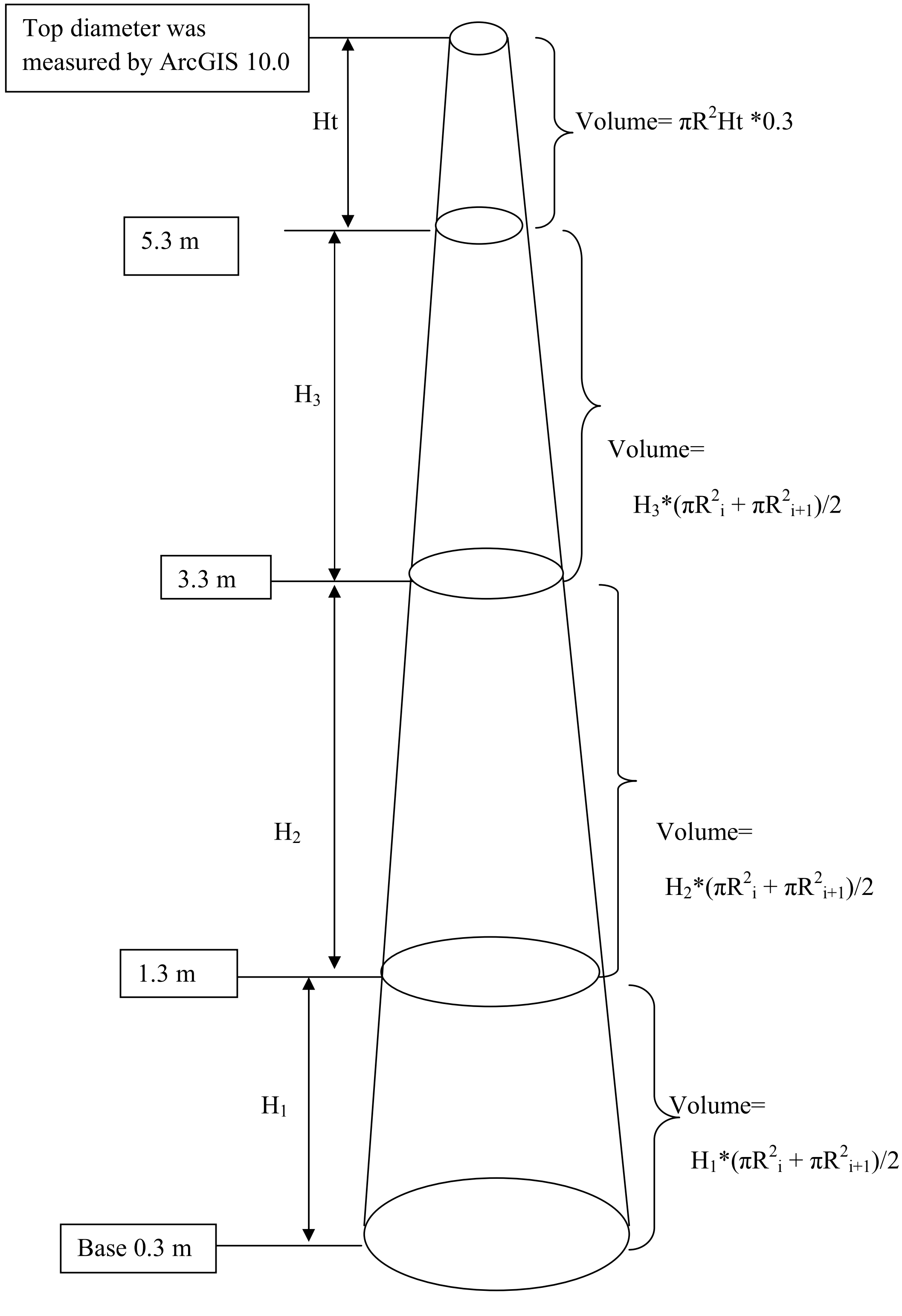


Figure 3, Stem Diameter Measurement and Volume Calculation

3.3.10 Tree growth ring analysis

3.3.10.1 Selection of trees

From both NF and PF sites, sample trees were selected to collect the tree stem discs for tree ring analysis. From PF site (plot B-1) 10 trees (1 *Cryptomeria japonica*, 2 *Carpinus tschonoskii*, 7 *Chamaecyparis obtusa*) and from NF site (plot A-1) 6 trees (4 *Quercus serrata*, 1 *Carpinus tschonoskii*, 1 *Chamaecyparis obtusa*) were selected by using tree map and field observation. The criteria to select the tree were: relative dominance, free from competition from next tree which is to be felled, free of vine or climber in the tree stem, free of any wound or defect on the bole in the experimental plot.

Stem discs were taken at base 0.3 m, 1.3 m, 3.3 m, 5.3 m, 7.3 m, 9.3 m, 11.3 m, 13.3 m etc. Tree stem discs were taken at 2 m interval up to top of the tree stem leaving last 1m of the tree top. Five centimeter thick stem discs were cut by chain saw after felling the tree. Tree no, disc height and site number were marked on the samples. North direction was predetermined before cutting the stem discs. After collection of the samples, they were polished by sanding machine (Appendix-A, photo-ii) by using different sand papers (80 mm, 120 mm) depending on the surface of the stem discs of species. The discs were then marked as north, south, east and west direction. The photograph for each stem disc was then taken and then transferred them to computer to cross-dating by using WinDENDRO Reg2002b software. Before analyzing the stem discs, the samples were calibrated by the software with a known scale of measurement. Growth rings were identified in four radial (north, south, east, and west) directions for each disc. The ring widths were calculated by the software in mm. The precision level of measurement was 0.01 mm. The false rings were identified by comparing with the visual counting and comparison with the discs.

3.3.10.2 Volume calculation by tree growth ring analysis

The average ring width for four measurements (in four directions) was calculated for every year's radial increment. Then basal area CAI (Current Annual Increment) and basal area MAI (Mean Annual Increment) were calculated by the following formula:

$$\text{BA MAI}_i = \pi\, R^2_i / i$$

$$\text{BA CAI}_i = \pi\, (R_i^2 - R^2_{i-1})$$

$$\text{Volume MAI}_i = \pi h\, (R_i^2 / i)$$

$$\text{Volume CAI}_i = \pi h\, (R_i^2 - R^2_{i-1})$$

Where, R= radius of the i^{th} growth ring

i= age of the growth ring

i-1 = growth ring lying immediate before of i^{th} growth ring

Volume was calculated from bark side to pith of the growth rings, the bark thickness was excluded from the cross-dating.

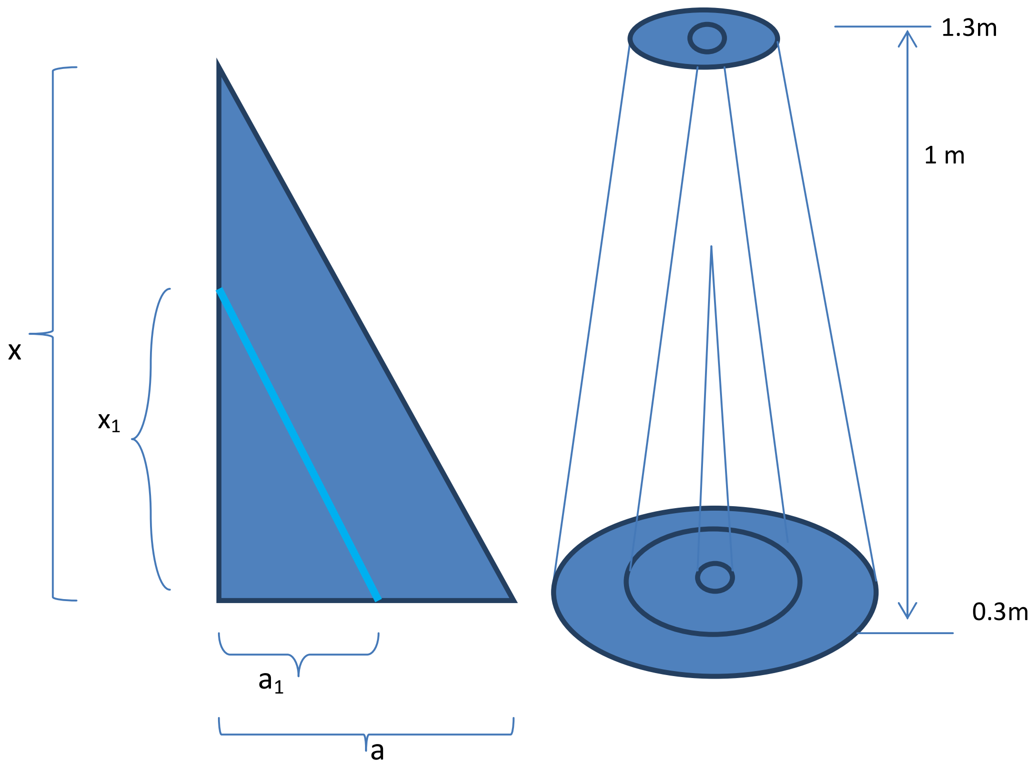


Figure 4, Method of Calculating Length of First few Years Growth Ring below DBH Height

From the Figure 4, according to similar triangle theory we get,

$$x / a = x_1 / a_1$$

$$\text{Therefore, } x_1 = (x/a) * a_1$$

In case of first few years the height of the tree can be calculated by this equation.

3.3.11 Mitscherlich growth model

German scientist Mitscherlich has developed the growth model for biological growth of species. Two parameters were used for Mitscherlich model for biological growth. This model shows that there is a linear relationship of increasing growth at a decreasing rate with the age at (t) and (t+1) which can be expressed as;

$X_{t+1} = aX_t + b$ ……………………………….(i)

Where, t= time or age,

a = coefficient of X variable

b = intercept

$M = \frac{b}{1-a} > 0$ …………………………..……..(ii)

and

$a = e^{-k}$

or, $-k = \ln(a)$ ……………………..…...…(iii)

By using this relationship of equation (i), (ii) and (iii); Mitscherlich Growth Model (Suzuki, 1979) is,

$X(t) = M(1-e^{-kt})$ ……………………………(iv)

Where,

X = the dbh (or height) at age‘t’

M = asymptotic dbh (or height) - the point where dbh (or height) growth equals zero and it was estimated by equation (ii)

e = the base of natural logarithm

3.3.11.1 Calculation of form factor

The form factor (Fadaei *et al*., 2008) was calculated by using the following equation:

$$Fr = v / (g*h)$$

Where, v = tree volume

Fr = form factor

g = basal area at 1.3 m height

h = total height of the tree

3.3.11.2 Future wood biomass calculation

$$\text{Wood volume} = MBA_{1.3} * MHt * Fr$$

Where,

$MBA_{1.3}$ = Basal area at 1.3 m of the tree calculated by using the model

MHt = Height of the tree obtained by the model

Fr = Form factor of the species

3.3.12 Social survey

Seven NPO key personnel were selected after discussing with the NPO leader for their permission to interview and they were interviewed following structured questionnaire (Appendix-E). Ten local people were randomly selected and interviewed by following the structured questionnaire. The local people were identified as those people who were living in the Oaota forest area for long time for generations. Mainly the local farmers were the respondents. Age of respondents was more than 65 years. The interview were conducted in the evening of the day as most of the people were available and chance of getting people for interview was more. Then the data were arranged to get the information about their view and interest on forest biomass utilization for future.

3.4 Data Analysis

Different statistical analysis was done to estimate the biomass yield from the dominant species. A series of calculations were done by using ArcGIS 10.0, WinDENDRO Reg2002b software. Future biomass yield and management information are also formulated through data analysis by using program EXCEL.

CHAPTER-4

4 RESULTS

4.1 Introduction

This chapter shows the potentials of Oaota forest. It includes the information on the species distribution in the experimental plot shown in the tree map, determination of dominant species and their growth pattern, silvicultural characteristics of dominant species and biomass stock of the forest stand. This chapter also gives the tree inventory data and growth ring analysis for the prediction of future stand biomass accumulation. This chapter focuses not only the biomass yield but also gives the idea about leaf biomass production and alternative utilization of biomass in a sustainable way for future. This chapter further includes the potential of atmospheric carbon sink by the sub urban (Oaota) forest including its associated soil. A social survey was also conducted to know the NPOs and local people's view on sub urban (Satoyama) forest conservation and biomass utilization.

4.2 Study Area

The study area is Oaota forest, Kashiwa, Chiba, Japan. The total area of the forest is 42 ha. This forest is privately owned by the local people. NPO (non-profit organization) members manage the forest as conservation and recreational site. The NPO manages 4 ha of the forest which is owned by one owner. There are 30 owners of this forest. The NPO has no legal rights to harvest trees without the prior permission of the owner. The boundary of each owner is not demarcated truly in the field to avoid the tax of the government. The average temperature of Oaota area is 15.9 ^{0}C and average rainfall is 124 mm. In 2010 the average maximum temperature was 37.5 ^{0}C and minimum temperature was 3.2 ^{0}C, maximum rainfall was 99 mm and minimum rainfall was 8.0 mm. Oaota area has 383 households, of them 63 are farmers (www.city.kashiwa.lg.jp). The NPO started work on this forest from 2004. After the interview of NPO leader of Oaota forest, it was known that the forest was dominant by Pine trees before 1950s and those trees died due to Pine wilt disease. Gradually the *Quercus* regenerated as dominant in NF site and the forest owners had also planted some of the species like Hinoki (*Chamaecyparis obtusa*), Sugi (*Cryptomeria japonica*) in PF site of Oaota forest. Forest resources are not harvested by the owners yet.

Photo 1, Map of Oaota Forest, Kashiwa, Chiba, Japan; Colored Boundary Indicates the NPO Managed Forest Area, (A) NF Site and (B) PF Site

4.3 Silvicultural Characteristics of Species

Four dominant species were identified by forest inventory analysis. These are *Quercus serrata*, *Carpinus tschonoskii, Chamaecyparis obtusa, Cryptomeria japonica*. The silvicultural characteristics of these species are given below:

4.3.1 Silvicultural characteristics of *Quercus serrata*

Quercus serrata is a deciduous tree. It becomes 20.0 m tall and 1.0 m in diameter. Its bark is grayish black. It is distributed from Hokkaido to Kyusu in Japan. Its local name is Konara. It is widely used for fuel wood; fallen leaves were used for fuel or fertilizer in the local area of Japan until 1960. Its growth is high and widely planted in dry soil area. Large trees are found at the place of shrine or old wooden buildings. In Nagano area this tree is found having the circumference of 7.2 m. It is widely distributed in Japan, is one of the main tree species in secondary forests. The *Quercus serrata* sapling is significantly biased to canopy gaps versus closed canopy. Leaf fall occurs from November to April (Iida, 2006.; Abe, *et al*., 1995). In Hokkaido it is found in south-western part where weather is warm. It is suitable for mushroom growing. In sub urban Satoyam forest areas *Quercus species* generally dominates. Secondary forests dominated by *Quercus serrata* are widely found in the warm-temperate and cool-temperate regions of Japan (Ito and Kawasato, 1978).

4.3.2 Silvicultural characteristics of *Chamaecyparis obtusa*

Chamaecyparis obtusa is a small to medium sized tree. *Chamaecyparis obtusa* is a massive evergreen coniferous tree reaching 35 meters in height, and with a trunk up to a meter in diameter. It has a special place in Japanese culture, revered mostly for its wood, but also for the fragrant essential oils found throughout its tissues (http://botanyboy.org). Its local name is Hinoki in Japan. A common companion of the Japanese cedar (*Cryptomeria japonica*) is Japanese Hinoki (*Chamaecyparis obtusa*). In ancient times massive ones existed-alas those forests of old are long gone. The bark is reddish brown to silvery and grows in long strips. The bark of young Hinoki often peels off in strips and older trees have more stable, tight bark. The common conifer is found in southern Japan, from western Honshu, Shikoku, and Kyushu. This tree can be in mixed stands with other conifers or most often with broad leaf trees, both deciduous and evergreen (Liguo, 1999). Hinoki wood has been cherished throughout the centuries as a building material for traditional structures such as shrines and temples since it is resistant to rot (Takao, 2004). The wood is fragrant, clean, and beautiful to look at. Hinoki is widely grown throughout warm temperate to cool temperate climates. It is more drought tolerant than its common companion *Cryptomeria japonica*. This tree likes warm to hot summers with ample moisture.

4.3.3 Silvicultural characteristics of *Cryptomeria japonica*

Cryptomeria japonica is a monotypic genus of conifer in the cypress family. Cupressaceae formerly belonging to the family Taxodiaceae. It includes only one species, *Cryptomeria japonica*. It is endemic to Japan where it is known as Sugi (Japanese). The tree is often called Japanese Cedar in English. It is a very large evergreen tree, reaching up to 70 m (230 feet) tall and 4 m (13 feet) trunk diameter, with red-brown bark which peels in vertical strips. *Cryptomeria* grows in forests on deep, well-drained soils subject to warm, moist conditions, and it is fast-growing under these conditions. It is intolerant of poor soils and cold, drier climates. Sugi pollen is a major cause of hay fever in Japan. Sugi is the national tree of Japan, commonly planted around temples and shrines, with many hugely impressive trees planted centuries ago (Suzuki, 1997; Suzuki and Tsukahara, 1987). It is also extensively used in forestry plantations in Japan, China and the Azores islands, and is widely cultivated as an ornamental tree in other temperate areas, including Britain, Europe, North America and eastern Himalaya regions of Nepal and India. The wood is scented, reddish-pink in color, lightweight but strong, waterproof and resistant to decay. It is favored in Japan for all types of construction work as well as interior paneling etc. In Darjeeling district and Sikkim in India, where it is one of the most widely growing trees, is called Dhuppi and is favored for its light wood, rot resistant, extensively used in house buildings, bridges, furniture, and paper making.

4.3.4 Silvicultural characteristics of *Carpinus tschonoskii*

Carpinus tschonoskii is deciduous broad leaved tree. It grows about 25 m tall in maturity (http://www.efloras.org/florataxon.aspx). Its timber is very hard. Dried heartwood billets are nearly white and are suitable for decorative use. For general carpentry, it is rarely used, partly due to the difficulty of working it. Its hardness has, however, lent it to use for carving boards, tool handles, piano actions and other situations where a very tough, hard wood is required, perhaps most interestingly as gear pegs in simple machines, including traditional windmills. It is sometimes coppiced to provide hardwood poles (http://en.wikipedia.org). This tree is attractive in a park or woodland setting (http://www.backyardgardener.com). It grows well on most soils, including clay and chalk. It is a most useful and pretty tree for poor planting conditions (http://www.barcham.co.ur).

4.4 Survey on Tree Species Distribution in Oaota Forest

4.4.1 Preparation of tree map

Tree map is prepared for each plot in order to locate the relative position of tree species distributed in the experimental plots starting from a fixed point of measurement. Tree map helps to find out the each species position on the ground for accurate study for long time and check the validity of the study or making correction of measurement. It also helps to understand stand structure over a long period of time if it is well preserved. From the study of tree map it can easily be said that what trees were during the study and what are the emerging trees or new trees in the forest. It gives the clear view of the forest and some cultural activities such as thinning, pruning can be undertaken by studying the tree map.

From the Figure 5, Figure 6, Figure 7 and Figure 8, we can get the information about how the trees are distributed in the experimental plot of Oaota forest. We can decide where the trees are densely distributed and what the size of the species is, where there are canopy gaps and where there is possibility to enhance the natural regeneration. All these information will help in proper management of the forest.

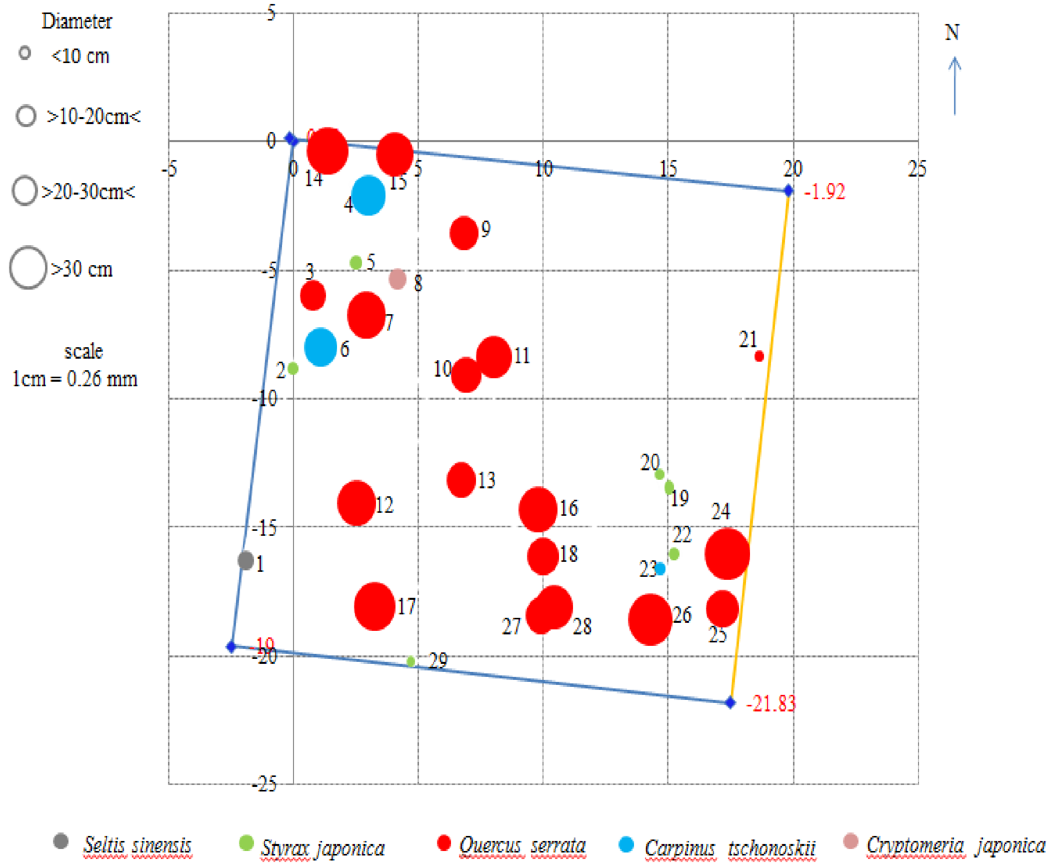


Figure 5, Tree Map of the Species Distribution in NF Site (Plot-A1)

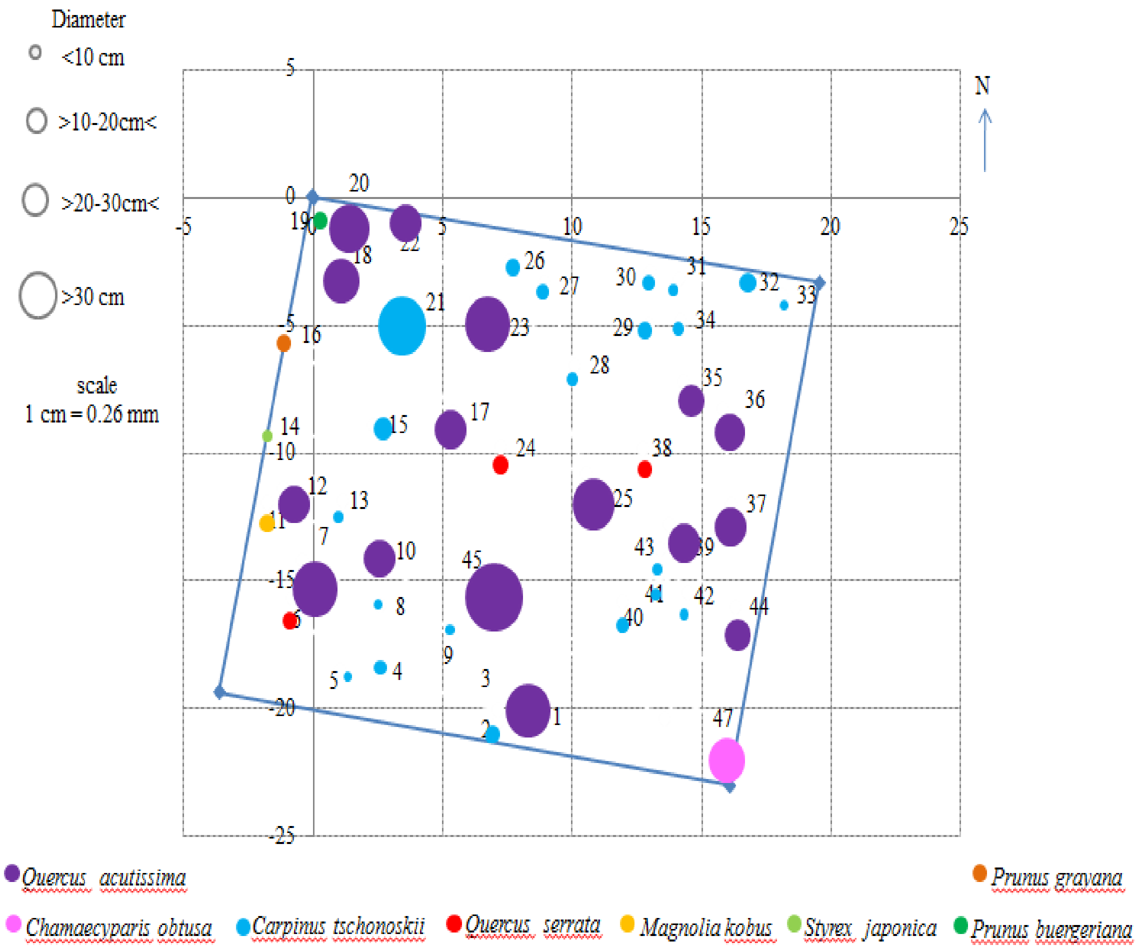


Figure 6, Tree Map of the Species Distribution in NF Site (Plot-A2)

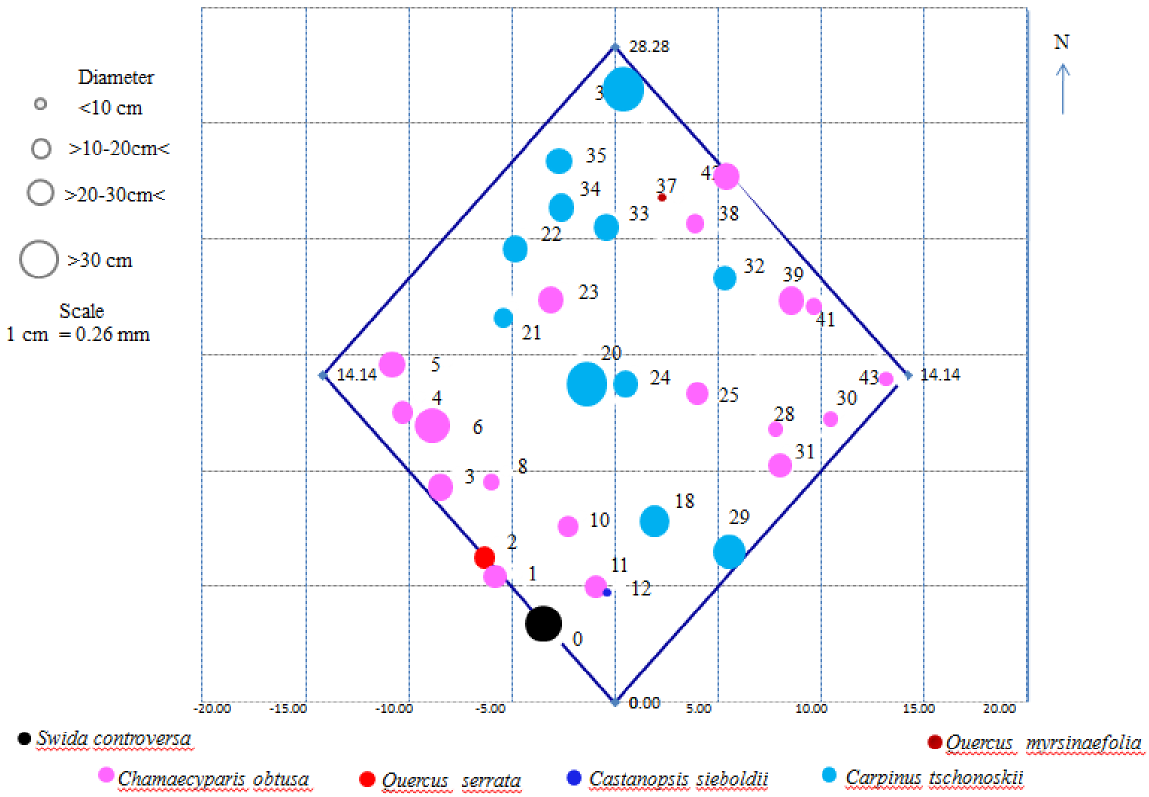


Figure 7, Tree Map of the Species Distribution in PF Site (Plot-B1)

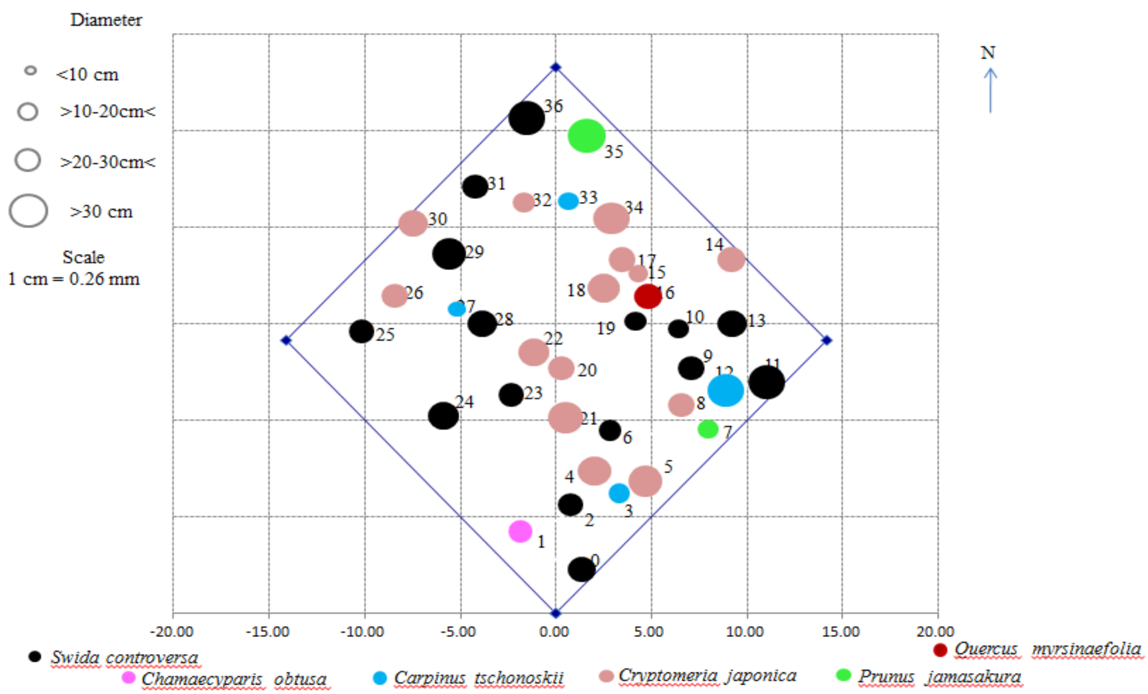


Figure 8, Tree Map of the Species Distribution in PF Site (Plot-B2)

4.5 Present Biomass Stock of Oaota Forest

Tree inventory in Oaota forest reveals that there are 14 different tree species in the experimental plot both natural forest (NF) and plantation forest (PF) sites. In NF site the species available are *Quercus serrata*, *Carpinus tschonoskii*, *Cryptomeria japonica*, *Styrax japonica*, *Seltis sinensis*, *Quercus acutissima*, *Prunus grayana*, *Prunus buergariana* and in PF site the available species are *Swida controversa*, *Chamaecyparis obtuse*, *Quercus serrata*, *Castanopsis sieboldii*, *Carpinus tschonoskii*, *Quercus myrsinaefolia*, *Cryptomeria japonica*. Table 2, shows the general characteristics and distribution of tree species in PF and NF site of Oaota Forest. The most abundant species in natural forest site are *Quercus serrata*, *Quercus acutissima* and *Carpinus tschonoskii*. In the PF site the abundant species are *Chamaecyparis obtusa*, *Carpinus tschonoskii*, *Swida controversa* and *Cryptomeria japonica*. In the NF site it was evident that the genus *Quercus* is dominant in terms of number but in PF site there is no single dominant genus of any species. The *Quercu serrata* is the biggest in diameter and height in NF site. The total wood volume of *Quercus serrata* in plot A1 is 9.37 $m^3/400m^2$ and 9.04 $m^3/400m^2$ in plot of the forest than other species in the NF site.

Table 2, General Characteristics of Tree Species in the Plots

Plot	Species Name	Number of trees	DBH (cm)	Ht (m)	Total BA (cm^2)/plot	Total vol (m^3)/400m^2
A1	*Quercus serrata*	18	26.96	18.71	10944.76	9.37
	Carpinus tschonoskii	3	19.90	16.02	1144.68	1.03
	Cryptomeria japonica	1	13.00	3.10	132.73	0.01
	Styrax japonica	6	6.36	5.22	195.74	0.03
	Seltis sinensis	1	11.50	8.47	103.87	0.02
Total		*29*			*12521.78*	*10.47*
A2	*Quercus acutissima*	16	27.33	19.38	9880.64	9.04
	Quercus serrata	3	10.56	9.61	264.42	0.07
	Carpinus tschonoskii	22	8.85	10.50	2091.03	1.26
	Prunus buergeriana	1	10.50	11.30	86.59	0.02
	Prunus grayana	1	10.50	11.38	86.59	0.02
	Chamaecyparis obtuse	1	27.00	14.50	572.56	0.33
	Styrax japonica	1	6.30	7.96	31.17	0.007
	Magnolia kobus	1	10.50	12.10	86.59	0.03
Total		*46*			*13099.59*	*10.82*
B1	*Swida controversa*	1	27.20	16.20	581.07	0.44
	Chamaecyparis obtuse	19	16.87	14.81	4514.32	3.19
	Quercus serrata	1	16.10	15.50	203.58	0.14
	Castanopsis sieboldii	1	5.10	5.60	20.43	0.003
	Carpinus tschonoskii	12	22.77	19.20	5298.06	4.65
	Quercus myrsinaefolia	1	5.00	4.50	19.64	0.002
Total		*35*			*10637.10*	*8.44*
B2	*Swida controversa*	15	21.54	16.08	5670.56	4.16
	Chamaecyparis obtuse	1	18.50	12.90	268.80	0.17
	Carpinus tschonoskii	4	17.87	15.15	1119.93	0.81
	Cryptomeria japonica	14	22.24	15.55	5591.92	4.13
	Prunus jamasakura	2	22.35	15.70	864.95	0.85
	Quercus myrsinaefolia	1	21.00	16.40	346.36	0.24
Total		*37*			*13862.52*	*10.38*

(For scientific names; Hara *et al*., 1989.)

The highest density of species found in plot A1, is *Quercus serrata* (62%) followed by *Styrax japonica* (20%) in plot A1. The *Quercus serrata* had the maximum average diameter (26.96 cm) and the highest average height (18.71 m) whereas the minimum average diameter was of *Styrax japonica* as 6.36 cm in plot A1. The lowest average diameter and height in plot A1 were 6.36 cm and 3.10 m for *Styrax japonica* and *Cryptomeria japonica* respectively. It is seen from the Table 1, that the maximum basal area (10944 cm^2/400m^2) in plot A1 is for *Quercus serrata* which indicates that *Quercus serrata* is the biggest in diameter in relation to among the trees in the plot. *Styrax japonica* is the second highest in density and its basal area is 5.22 $cm^2/400\ m^2$ in plot A1. On the other hand *Carpinus tschonoskii* having the three individuals is the second highest in terms of basal area (1144.68 $cm^2/400\ m^2$) in the plot A1 which implies that *Carpinus tschonoskii* is second larger tree in terms of diameter after the *Quercus serrata*. Basal area of a single *Quercus serrata* is 608.04 cm^2 which is 1.5 times of the basal area of a single *Carpinus tschonoskii* and 18.6 times of the basal area of *Styrax japonica* in plot A1. In case of total wood volume accumulation upto year 2010, the highest volume was accumulated by *Quercus serrata* as 234.41 m^3/ha in plot A1 followed by *Carpinus tschonoskii* (25.75 m^3/ha). Average volume of a single *Quercus serrata* is 0.52 $m^3/400\ m^2$ which is 1.51 times of a single *Carpinus tschonoskii* in the plot A1.

Carpinus tschonoskii shows the highest density (47%) followed by *Quercus acutissima* (34%) and *Quercus serrata* (6%) in plot A2. Other trees in the same plot show least density with having one individual in the experimental plot. According to diameter and height growth, it is evident that the average highest diameter and height were for *Quercus acutissima* as (27.33 cm) and 19.38 m respectively. The other two species *Quercus serrata* and *Carpinus tschonoskii* do not show much variation in both diameter and height. *Styrax japonica* is also showing least diameter, height and wood volume production. In terms of basal area and wood volume *Quercus acutissima* showed the maximum basal area (9880.64 $cm^2/400\ m^2$) and wood volume 226 m^3 / ha followed by *Carpinus tschonoskii* (31.67m^3/ha) and *Quercus serrata* (1.89 m^3/ha) in plot A2. Here, in plot A2, the average wood volume of a single *Quercus acutissima* is 0.56 $m^3/400m^2$ which is 9.81 times of the average wood volume of a single *Carpinus tschonoskii* and 22.6 times higher than that of a single *Quercus serrata* in plot A2. Basal area of a single *Quercus acutissima* is 617.54 $cm^2/400m^2$ which is 6.49

times of a single *Carpinus tschonoskii* and 7.0 times of a single *Quercus serrata* in the plot A2. From the discussion in natural forest site it is evident that *Quercus serrata* and *Quercus acutissima* are high yielding species in the NF site. Between these two species in the NF site in terms of wood volume production, it was revealed that *Quercus acutissima* is relatively more productive than *Quercus serrata* in Oaota forest.

In case of PF sites, in plot B1, the highest relative density of species found for *Chamaecyparis obtusa* (54%) followed by *Carpinus tschonoskii* (34%). Other species in this plot possess only one individual. It is interesting to notice that though *Swida controversa* in plot B1 is only one individual its diameter is the highest among the trees in this plot. *Carpinus tschonoskii* showed that the tallest tree in this plot B1 having average height 19.20 m and the smallest tree in this plot is *Quercus myrsinaefolia* having least diameter and height as 5.0 cm and 4.50 m respectively. Basal area of a single *Carpinus tschonoskii* is 441.50 $cm^2/400m^2$ and basal area of a single *Chamaecyparis obtusa* is 237.59 $cm^2/400m^2$. Maximum volume production of species was for *Carpinus tschonoskii* 4.65 $m^3/400m^2$ followed by 3.19 $m^3/400m^2$ for *Chamaecyparis obtusa*. Wood volume of a single *Carpinus tschonoskii* is 9.68 m^3/ha and 4.19m^3/ha for *Chamaecyparis obtusa*. *Carpinus tschonoskii* volume is 2.31 times of *Chamaecyparis obtusa* in plot B1.

Swida controversa showed maximum density (40 %) followed by 37 % for *Cryptomeria japonica* as the second highest in density among the tree species available in plot B2. The maximum diameter (22.35 cm) of the tree was for *Prunus jamasakura* and the tallest tree here was *Quercus myrsinaefolia* (16.40 m) in plot B2. Basal area of a single *Swida controversa* is 378 $cm^2/400\ m^2$ and 399 $cm^2/400\ m^2$ for *Cryptomeria japonica*. Wood volume of a *Swida controversa* was 6.93 m^3/ha whereas for *Cryptomeria japonica* was 7.37 m^3/ha. In terms of wood volume production *Cryptomeria japonica* showed the better growth than

Swida controversa in plot B2. Among the species of *Carpinus tschonoskii*, *Chamaecyparis obtusa*, *Swida controversa* and *Cryptomeria japonica* wood volume production of a single tree is highest for *Carpinus tschonoskii* followed by *Cryptomeria japonica*, *Swida controversa* and *Chamaecyparis obtusa* in plantation site. Therefore, in this Oaota forest, management strategy focusing to the highest growth species in both natural and plantation site can play significant role to increase wood production of the stand.

4.6 Dominant Tree Species in Oaota forest

For the intensive analysis of growth pattern we focused the study on some dominant species in Oaota forest. In table 2, we got the idea about wood volume production of tree species until the year 2010. But to know the pattern of growth for certain species, it needs to find out dominant species in the plot rather than determining the growth pattern of all species. Because, sub urban (Satoyama) forests are dominated by *Quercus serrate, Quercus acutissima* (Terada, *et al.,*2010). Relative dominance was used to identify the dominant species in each plot. We considered percentage basal area of a species more than 40 % as the criteria to be dominant species in that plot.

In NF site, Figure 9, we found two dominant species namely *Quercus serrata* (87.4 %) and *Quercus acutissima* (75 %) in plot A1 and A2 respectively. Other species are less than 40 % of basal area in that plot. The lowest basal area is for *Seltis sinensis* (0.82 %) in plot A1 and 0.23 % is for *Styrax japonica* in plot A2.

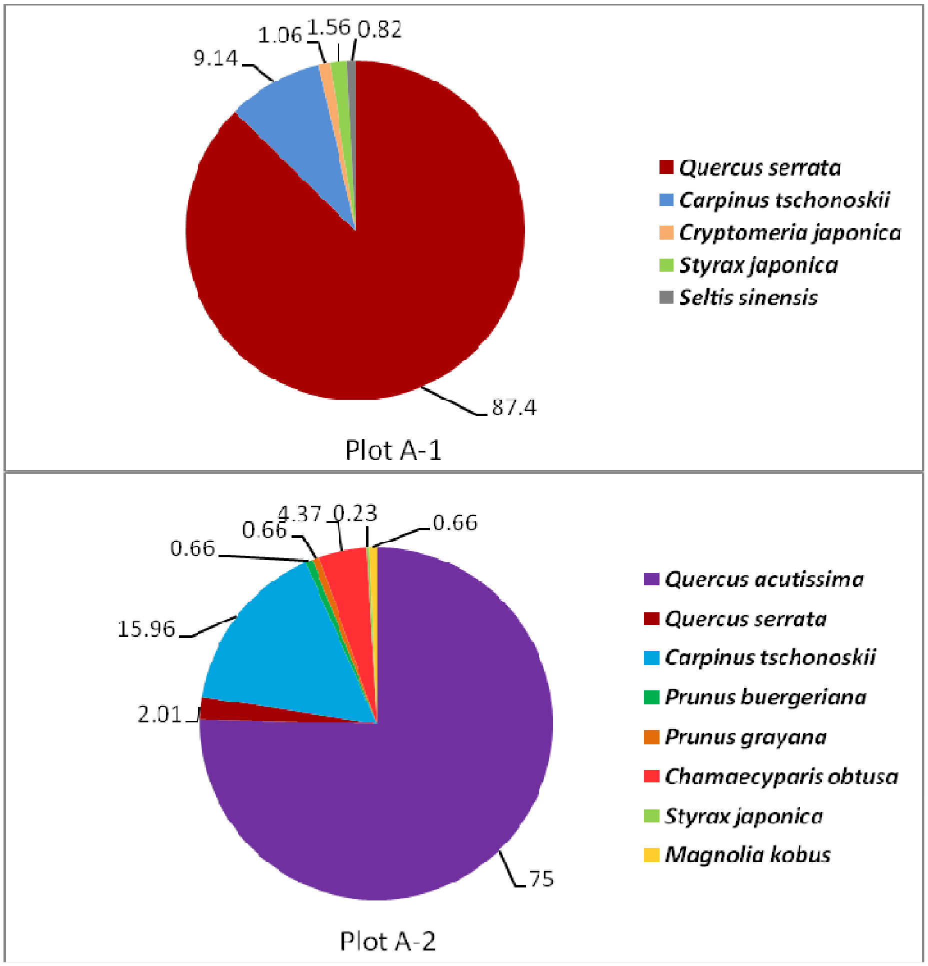


Figure 9, Identification of Dominant Species on Basal Area (%) in NF Site

In PF site, Figure 10, revealed that the dominant species are *Chamaecyparis obtusa* (42.43 %) and *Carpinus tschonoskii* (49.80 %) in plot B1 and the least dominant species is *Quercus myrsinaefolia* (0.18 %). On the other hand, in plot B2, the dominant species are *Swida controversa* (40.90 %) and *Cryptomeria japonica* (40.33 %). Here, in B2, *Swida controversa* is more in number than in plot B1. Therefore, the species variety and distribution is widely varied in each of the plot within the same site of the forest.

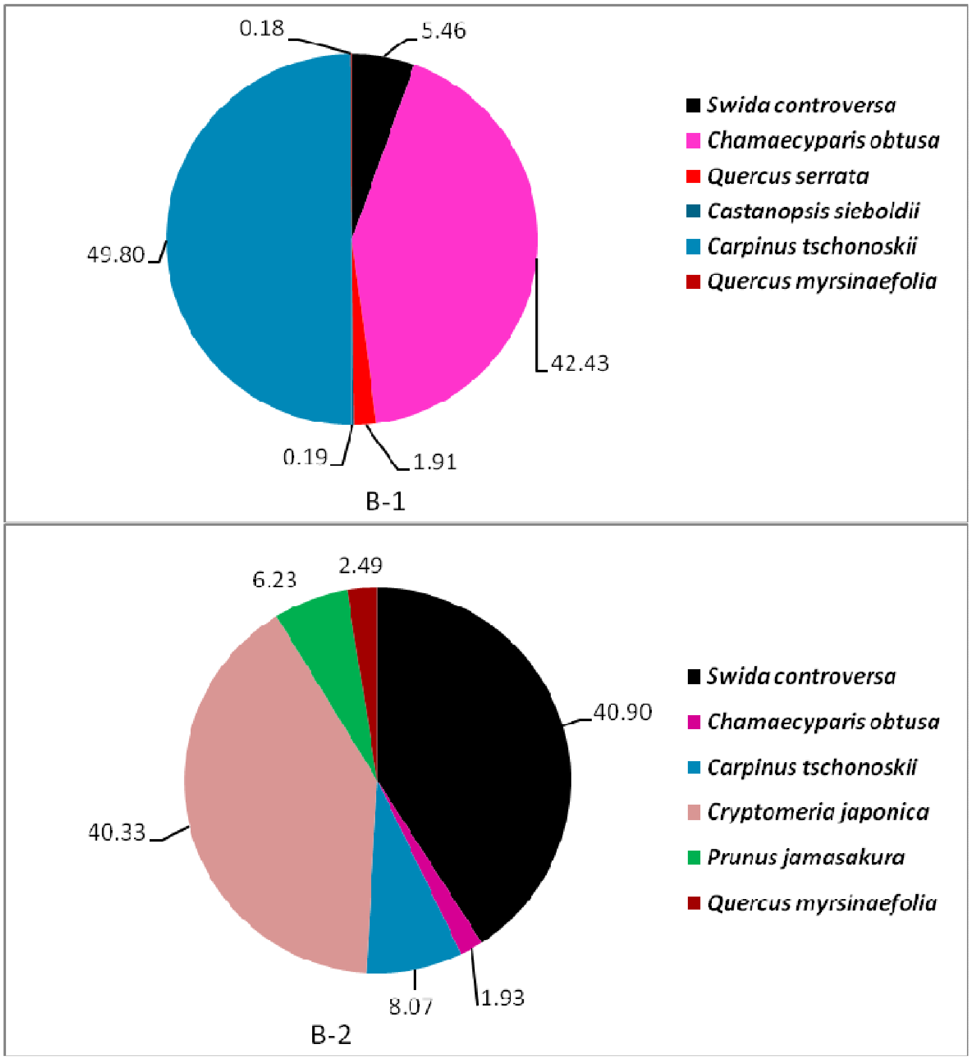


Figure 10, Identification of Dominant Species on Basal Area (%) in PF Site

4.7 Growth Ring Analysis

Out of the six dominant species in the experimental plots we have selected four species *Cryptomeria japonica*, *Chamaecyparis obtusa*, *Carpinus tschonoskii* and *Quercus serrata,* depending on the permission from the NPO people and also by studying the tree map for species distribution, to cut the required tree species for growth ring analysis. Stem discs of four species and growth ring analysis are shown in Photo 2 and Photo 3 respectively.

4.7.1 Sampling of stem discs for growth ring analysis

For growth ring analysis trees in NF site (plot A1) and PF site (plot B1) were cut with the help of NPO members. Stem discs were cut by using the chain saw in the field at the demarcated point on the stem. Red and white chalks were used to mark the North direction and points to cut the stem discs. The table 3, showed the number of trees for each species and their corresponding stem discs which were collected for stem analysis.

Table 3, Sampling of Stem Discs of Species for Growth Ring Analysis

Site	Species	Total trees cut	Total stem discs
B-1	*Chamaecyparis obtusa*	7	51
	Carpinus tschonoskii	2	15
	Cryptomeria japonica	1	10
C-1	*Quercus serrata*	4	45
	Carpinus tschonoskii	1	10
	Cryptomeria japonica	1	8
Total	Four species	16	139

(a)

(b)

(c)

(d)

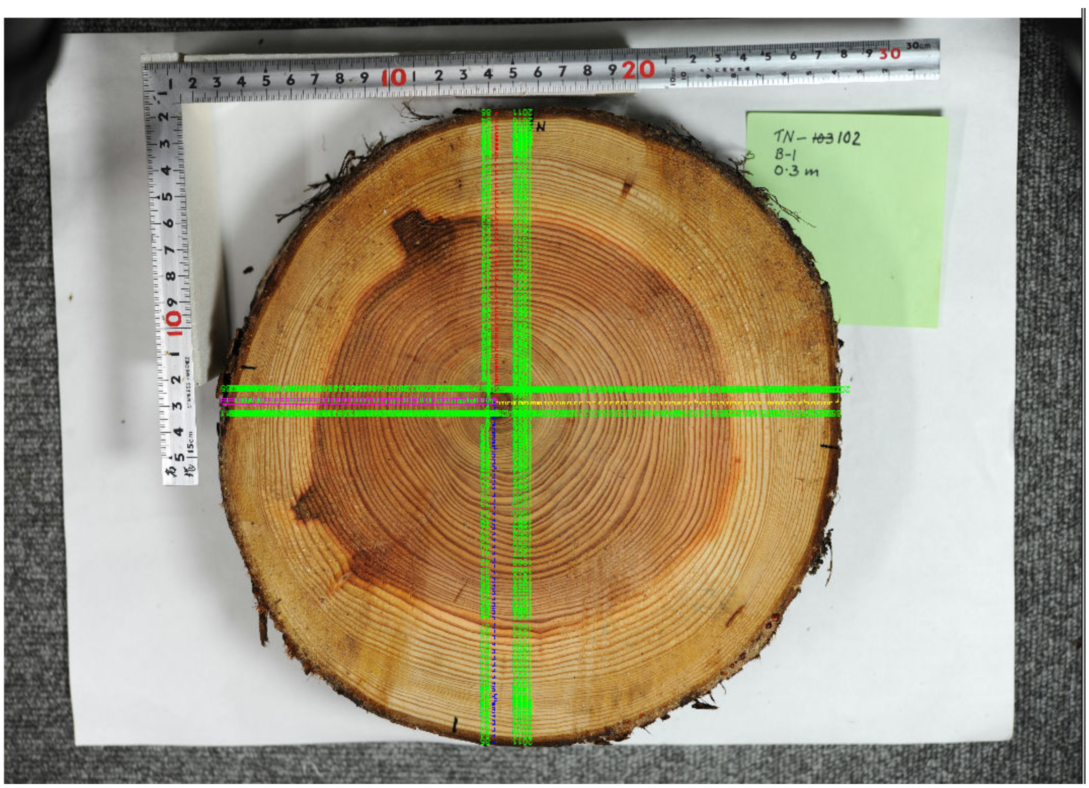
Photo 2, Samples of Stem Discs of four species at DBH; (a) *Carpinus tschonoskii* (b) *Cryptomeria japonica* (c) *Chamaecyparis obtusa* (d) *Quercus serrata*

(*photographs by author*)

The stem discs are shown in the Photo-2. They are one of the samples of a tree at a height of 1.3 m from the tree base. After polishing the photographs were taken by the author by using a digital camera.

4.7.2 Growth ring analysis by WinDENDRO Reg2002b software

Stem discs of four dominant tree species were analyzed by using the WinDENDRO Reg2002b software. Photographs of stem discs were taken to analyze the growth rings of stem discs. Photo-3 and Photo 4 showed the view of stem analysis. The growth rings were identified by the software and false rings were identified by comparing with the manual computation of the rings in stem discs. The tree rings were identified at a precision level of 0.01 mm. The data were saved in the excel file for each species and calculation was made later on.



(*photograph by author*)

Photo 3, Growth Ring Analysis by WinDENDRO Reg2002b Software; Cross-dating in Four Directions

(*photograph by author*)

Photo 4, Growth Ring Analysis by WinDENDRO Reg2002b Software; Cross-dating from Pith to Bark

4.8 Growth Pattern of *Quercus serrata*, *Cryptomeria japonica* and *Carpinus tschonoskii* in NF site

After doing the stem analysis the growth curves for (a) *Quercus serrata* (b) *Cryptomeria japonica* and (c) *Carpinustschonoskii* in NF site were made according to current annual increment (CAI) and mean annual increment (MAI) by volume per hectare of each species. From the Figure 11, it is observed that *Quercus serrata* grows very faster than other two species followed by *Carpinus tschonoskii* and *Cryptomeria japonica* in NF site.The CAI and MAI curves started to rise from very beginning of the growth period. Growth ring analysis showed that the average age of *Quercus serrata*, *Carpinus tschonoskii* and *Chamaecyparis obtusa* is approximately 50, 53 and 86 years respectively in NF site. According to stem analysis at the age of 50 years the total average volume of wood production was 7.5 m^3/ha for *Qurecus serrata*, 0.1 m^3/ha for *Cryptomeria japonica* and 0.13 m^3/ha for *Carpinus tschonoskii*. Growth of *Quercus serrata* starts from the very early age of the tree. At the age of 5 years growth of *Quercus serrata* starts very sharply. From the Figure 11(a), it is seen that the tree is still growing very sharply, both CAI and MAI are showing rising tendency which means that the same growth will continue in the coming years also. This tree is very suitable for getting maximum wood volume production in Oaota forest.

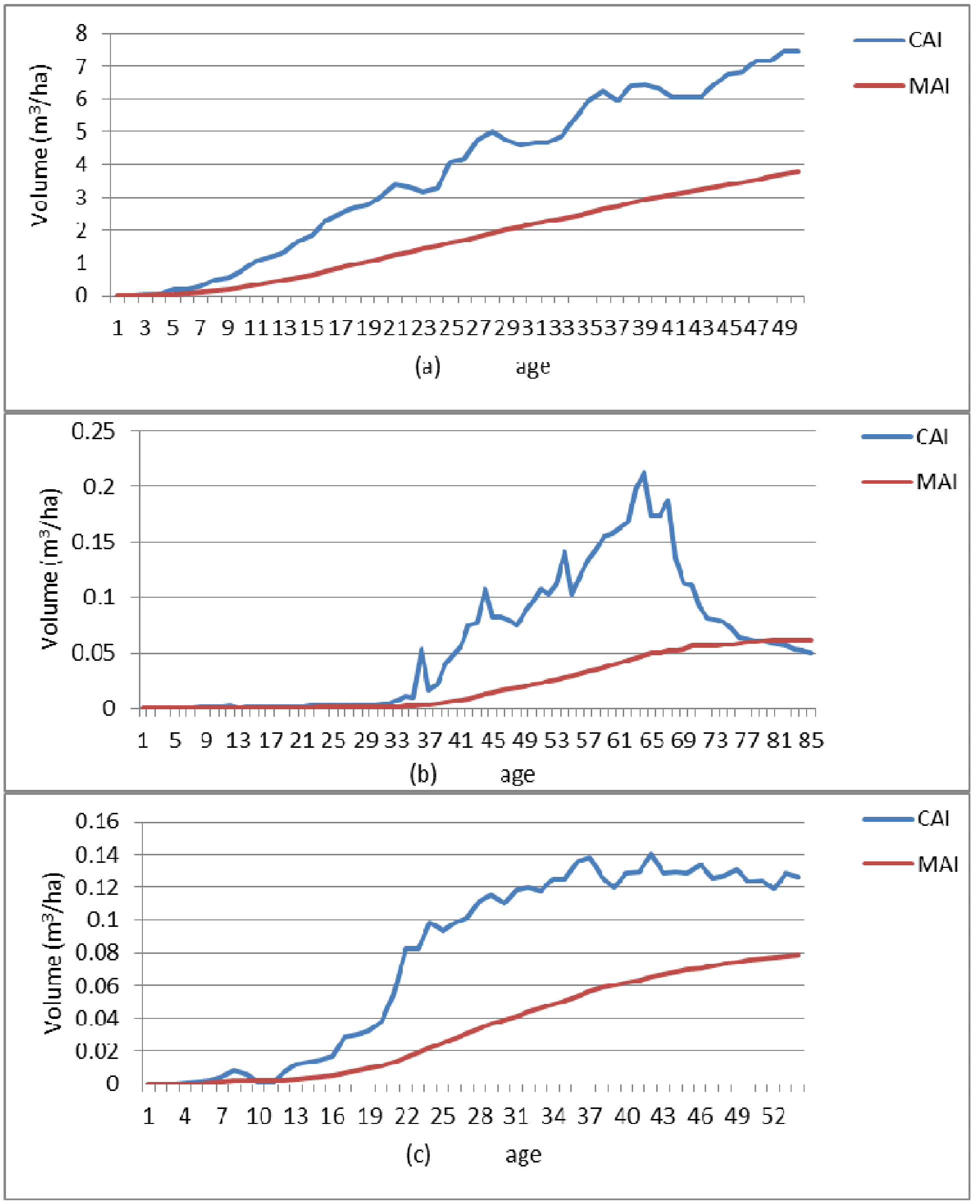


Figure 11, CAI and MAI Growth Curves of Species in NF Site; (a) *Quercus serrata* (b) *Cryptomeria japonica* (c) *Carpinus tschonoskii*

Cryptomeria japonica is the slowest among these three species (Figure 11) in NF site. Its growth starts rising around the age of 30 years but *Carpinus tschonoskii* showed increasing growth a little bit later than *Quercus serrata* in NF site. But *Carpinus tschonoskii* showed moderate increment than *Cryptomeria japonica*. In case of *Cryptomerial japonica* it is evident that its growth rises to a maximum at the age of 60-65 years and afterwards CAI curve starts falling very sharply. Here, it is seen that the CAI and MAI curves of *Cryptomeria japonica* intersects at the age of 75-80 years which indicates that *Cryptomeria japonica* shows optimum productive age 75-80 years in Oaota forest. This 75-80 years is the rotation age of *Cryptomeria japonica* in Oaota forest. For, other two species *Quercus serrata* and *Carpinus tschonoskii* did not reach the rotation age yet.

In NF site the growth of *Curpinus tschonoskii* stand (Figure 11c) is much slower than that of PF site (Figure 12f) because of the higher number of *Curpinus tschonoskii* in PF site which increased the total volume of wood of this species in PF site. But in case of NF site, the *Curpinus tschonoskii* is only one individual which is lying outside of the plot though the calculation was taken at per hectare basis to make the calculation homogenous.

4.9 Growth Pattern of *Chamaecyparis obtusa*, *Cryptomeria japonica* and *Carpinus tschonoskii* in PF site

Figure 12, shows the growth curves (CAI and MAI) of *Chamaecyparis obtusa*, *Cryptomeria japonica* and *Carpinus tschonoskii* in PF site. It is evident from the growth curves that *Carpinus tschonoskii* is the fast growing species followed by *Chamaecyparis obtusa* and *Cryptomeria japonica*. The CAI curve of *Chamaecyparis obtusa* starts rising after a few years and reaches its maximum increment approximately at 40 years of age and then it showed increase in growth at a decreasing rate.

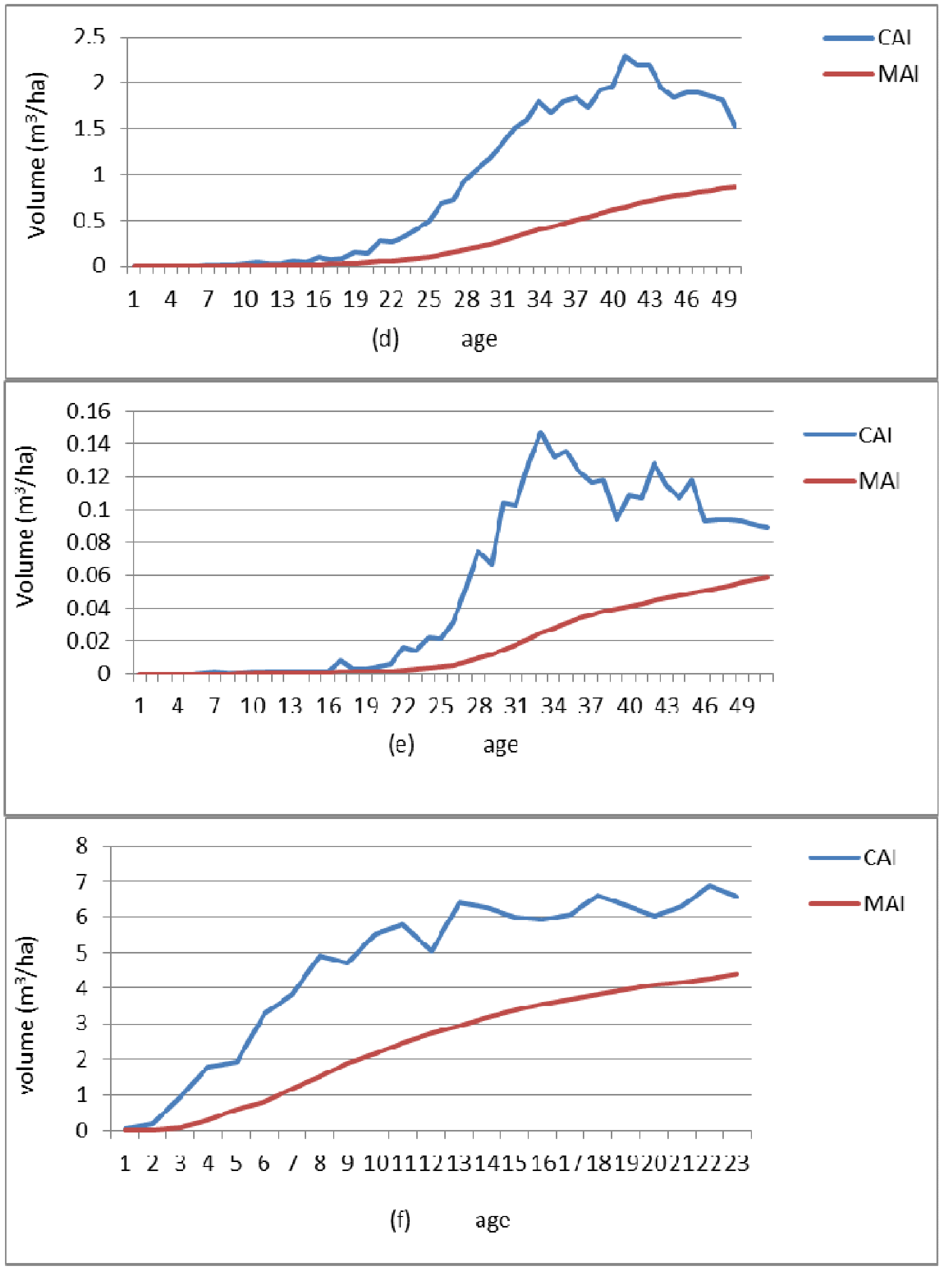


Figure 12, CAI and MAI Growth Curves of Species in PF Site; (d) *Chamaecyparis obtuae* (e) *Cryptomeria japonica* (f) *Carpinus tschonoskii*

The CAI curve of *Chamaecyparis obtusa* in Figure 12d, showed falling tendency but MAI is still rising which means that the tree can grow steadily still now and can continue until the CAI and MAI curves culminate. The CAI curve of *Cryptomeria japonica* shows a little slow growth than *Chamaecyparis obtusa*. But as it starts growing, the rate of growth sharply increases at an increasing rate and continues to reach its maximum growth approximately at the age of 32-35 years and then the growth increases at a decreasing rate. Both the CAI and MAI curves (Figure 12e) of *Cryptomeria japonica* are still rising which indicates that the tree can grow steadily until the time at which CAI and MAI curves intersect. In Figure 12f, *Carpinus tschonoskii* showed rapid growth from the very beginning of the age and CAI curve showed growth increment at an increasing rate. The average age of this species in PF site is 25 years determined by growth ring analysis. The CAI and MAI curves showed that this tree can continue steady growth for a long period of time in Oaota forest.

From the discussion on the growth pattern of species in NF site and PF site, it can be concluded that the high yielding species in NF site is *Quercus serrata* followed by *Carpinus tschonoskii* and *Cryptomeria japonica*. On the other hand, in PF site, the high growing species is *Carpinus tschonoskii* followed by *Chamaecyparis obtusa* and *Cryptomera japonica*. Among the dominant species in both the sites, the chronological order of high yielding forest stand are *Quercus serrata* ≥ *Carpinustschonoskii* > *Chamaecyparis obtusa* > *Cryptomeria japonica.*

4.10 Future Growth of Species

The future wood biomass accumulation can be predicted by developing the growth model or by using some growth model which was developed before and well suited with the species concerned. In sub urban forests of Japan the data are inadequate to develop such type of growth model. Most of the growth models were developed based on the data obtained from well managed forests. As the sub urban forests were not scientifically managed so the growth model developed for managed forest species might not give good information of sub urban forest biomass accumulation. Through stem analysis the previous data on tree growth were obtained and by developing growth model for diameter and height of the species, the future biomass accumulation can be calculated. We used Mitscherlich Growth Model for the prediction of future biomass accumulation because of ease of use and less complexity which might be suitable for the NPO also to use for sub urban forest.

4.10.1 Growth model of *Chamaecyparis obtusa* for diameter

For diameter growth model of Hinoki (*Chamaecyparis obtusa*), the diameter at age of first year and its corresponding diameter of second year were plotted in the scattered graph (Figure 13a). In the same way all the data of diameter for 50 years of *Chamaecyparis obtusa* were plotted and the relationship of diameter growth is expressed by the linear equation as shown in Figure 13(a). Then according to Mitscherlich Growth Model for the diameter, growth data were plotted for more than 200 years as shown in the Figure 13b. The diameter growth model was developed from which we can calculate the future diameter growth where dependent variable is species diameter and independent variable is age of the tree species. Here, R^2 value showed that the next year growth is highly correlated with the growth of previous year about 99 %. From stem analysis, it was revealed that the *Chamaecyparis obtusa* is about 50 years old at the time of study in March 2012. For diameter model the diameter was taken from the age of 10 years (Figure 13b), because this diameter is considered for 1.3 m height of the tree at which some of the tree might not reach at that height in 10 years of their early growth period. The maximum growth of diameter for *Chamaecyparis obtusa* was calculated as 94.96 cm.

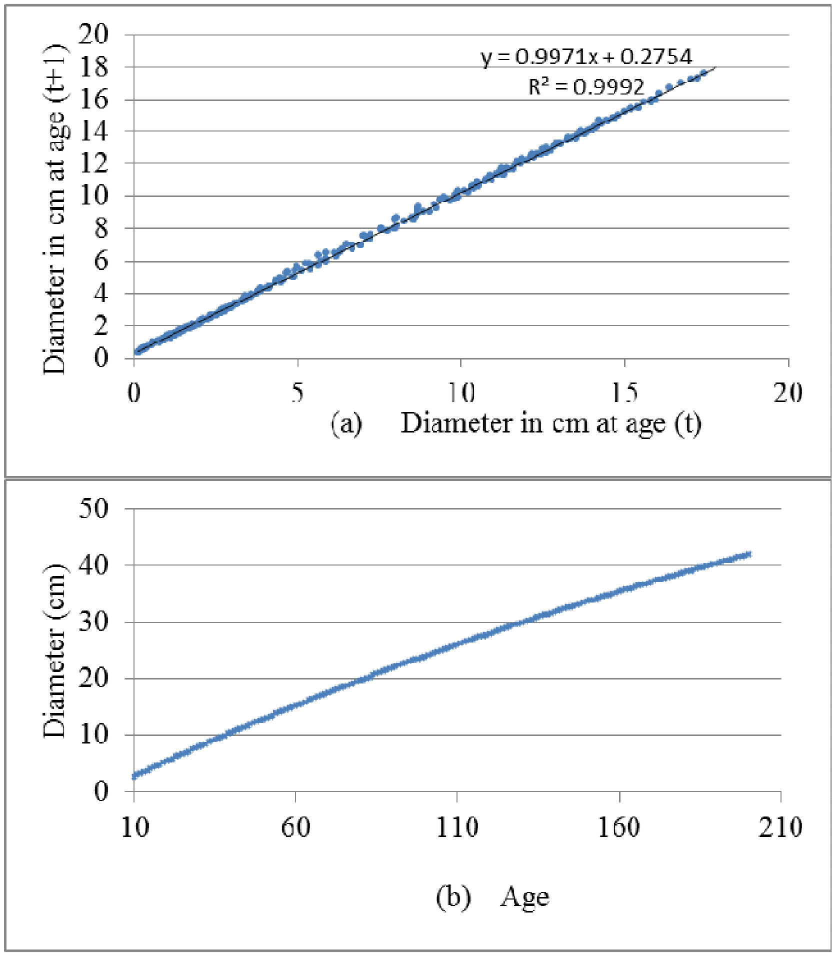


Figure 13, Mitscherlich Diameter Growth Model for *Chamaecyparis obtusa*, (a) Relationship of Diameter Growth in cm at Age (t) and (t+1); (b) Average Diameter Growth Model

Here, from the relationship of diameter equation, Y = 0.9971x + 0.2754 we get; a = 0.9971 and b = 0.2754, therefore, M = 0.2754 / (1-0.9971) = 94.96552, k = ln (0.9971) = -0.0029

4.10.2 Growth model of *Chamaecyparis obtusa* for height

From the following Figure 14(c), it is ascertained that the height growth of *Chamaecyparis obtusa* is a little bit inconsistent although R^2 value is high as 0.99 The asymptotic height for this species was calculated as 36.24 meter for the model. The height growth starts from the first year of the tree growth as shown in the Figure 14(d).

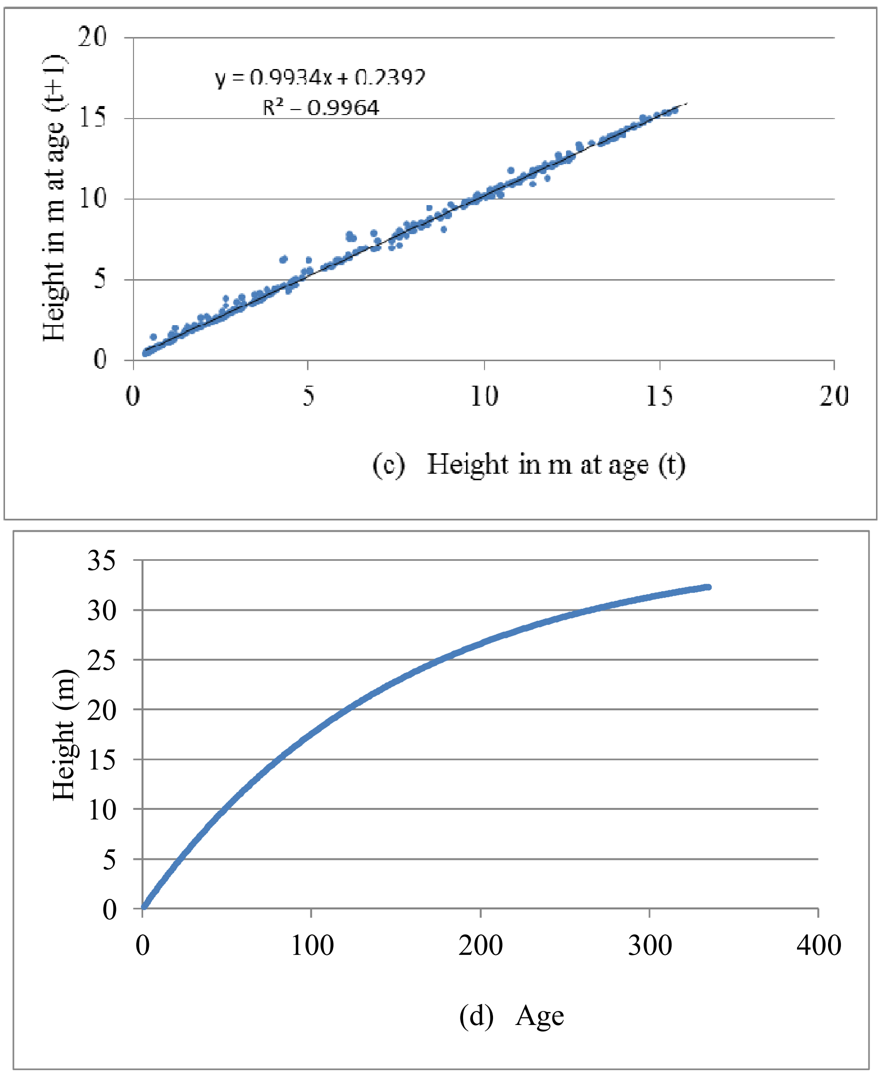


Figure 14, Mitscherlich Height Growth Model for *Chamaecyparis obtusa*, (c) Relationship of Height Growth in m at Age (t) and (t+1); (d) Average Height Growth Model

Here, from the relationship of height equation (Figure 14), Y = 0.9934x + 0.2392 we get; a = 0.9934 and b = 0.2392, therefore, M = 0.2392 / (1-0.9934) = 36.24242, k = ln (0.9934) = -0.00662

4.10.3 Growth model of *Quercus serrata* for diameter

From the following Figure 15(e), it is ascertained that the height growth of *Quercus serrata* is consistent enough and its R^2 value is high as 0.99. The asymptotic diameter for this species was calculated as 77.07 meter for the model. Here, from the relationship of diameter equation, Y = 0.9929x + 0.5472 we get; a = 0.9929 and b = 0.5472, therefore, M = 0.5472 / (1-0.9929) = 77.07042, k = ln (0.9929) = -0.00713

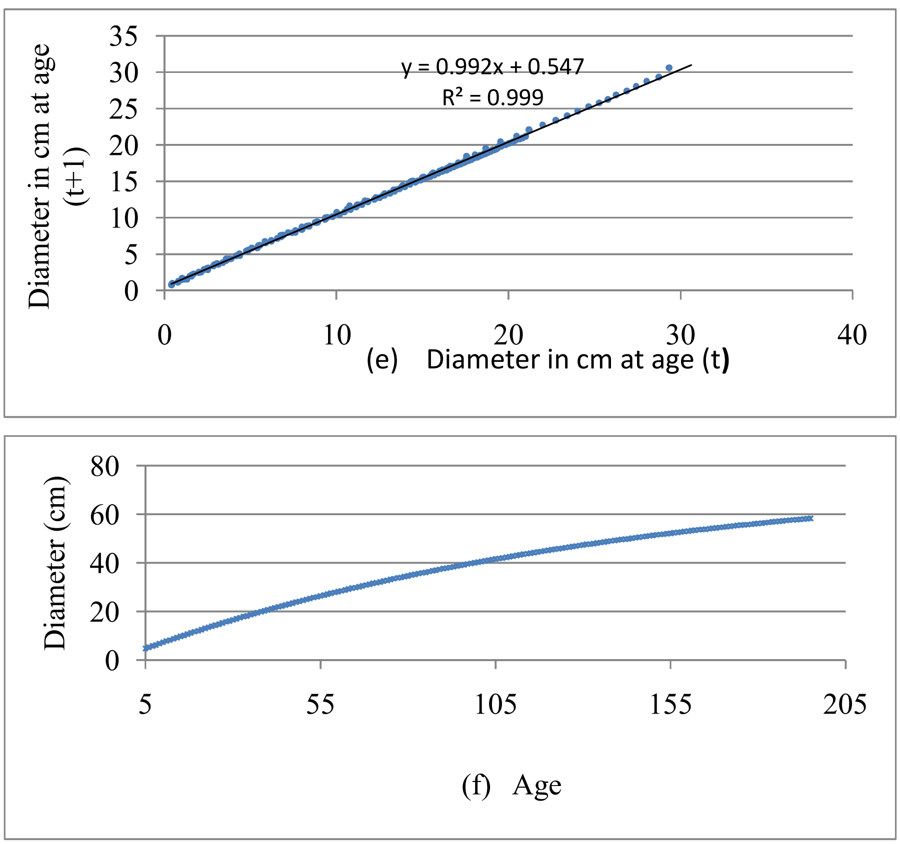


Figure 15, Mitscherlich Diameter Growth Model for *Quercus serrata*, (e) Relationship of Diameter Growth in cm at Age (t) and (t+1); (f) Average Diameter Growth Model

4.10.4 Growth model of *Quercus serrata* for height

The maximum attainable height for this species was calculated as 33.19 meter for the model. The height growth starts from the first year of the tree growth as shown in the Figure 16(h). Here, from the relationship of height equation, Y = 0.9798x + 0.6977 we get; a = 0.9798 and b = 0.6977, therefore, M = 0.6977 / (1-0.9798) = 33.19048, k = ln (0.9798) = -0.02122, and R^2 value is 0.9986 in Figure 16(g).

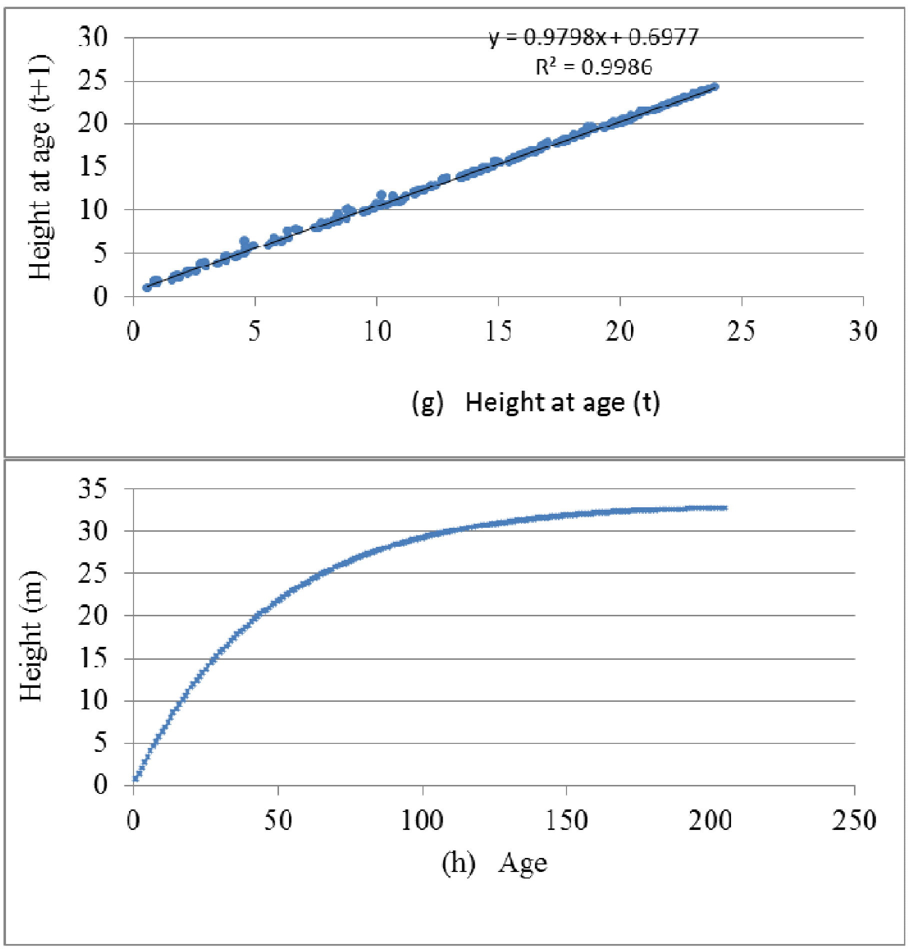


Figure 16, Mitscherlich Height Growth Model for *Quercus serrata*, (g) Relationship of Height Growth in m at Age (t) and (t+1); (h) Average Height Growth Model

4.10.5 Growth model of *Cryptomeria japonica* for diameter

From the Figure 17(i), it is seen that the equation for diameter relationship at age (t) and (t+1) is Y= 0.9983 X + 0.1602 and from this equation we get, a= 0.9983, b= 0.1602, M = 0.1602/(1-0.9983)= 94.23529, k=ln(0.9983)= -0.0017, goodness of fit is 0.9992

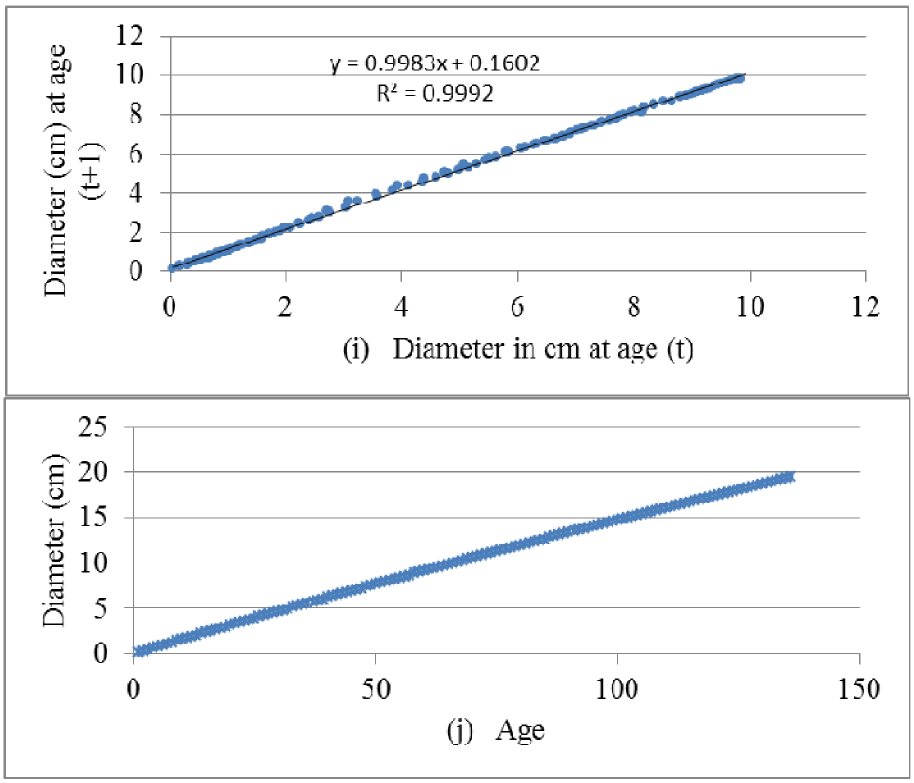


Figure 17, Mitscherlich Diameter Growth Model for *Cryptomeria japonica*, (i) Relationship of Diameter Growth in cm at Age (t) and (t+1); (j) Average Diameter Growth Model

4.10.6 Growth model of *Cryptomeria japonica* for height

From the Figure 18(k) it is revealed that the height relationship equation is Y= 0.9955 X + 0.1954 and we get; a= 0.9955, b= 0.1954, M=0.1954/(1-0.9955)=43.4222, k=ln(0.9955)= -0.00451. Here, R^2 is 0.999

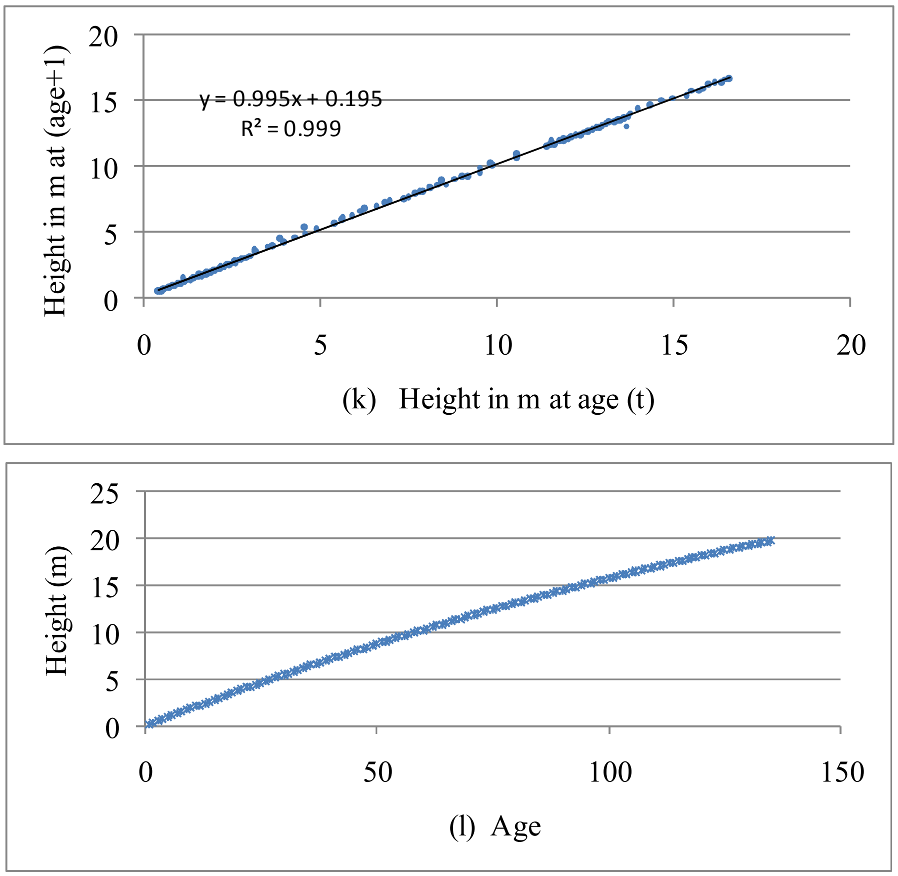


Figure 18, Mitscherlich Height Growth Model for *Cryptomeria japonica*, (k) Relationship of Height Growth in m at Age (t) and (t+1); (l) Average Height Growth Model

4.10.7 Growth model of *Carpinus tschonoskii* for diameter

From Figure 19(m), the relationship between diameter at age (t) and (t+1) is expressed by the equation as Y= 0.9846 X + 0.6422 and the value of a= 0.9846, b= 0.6422, M= 0.6422/(1-0.9846)= 41.7013, k= -0.01552 and the goodness of fit of this relationship is 0.9966

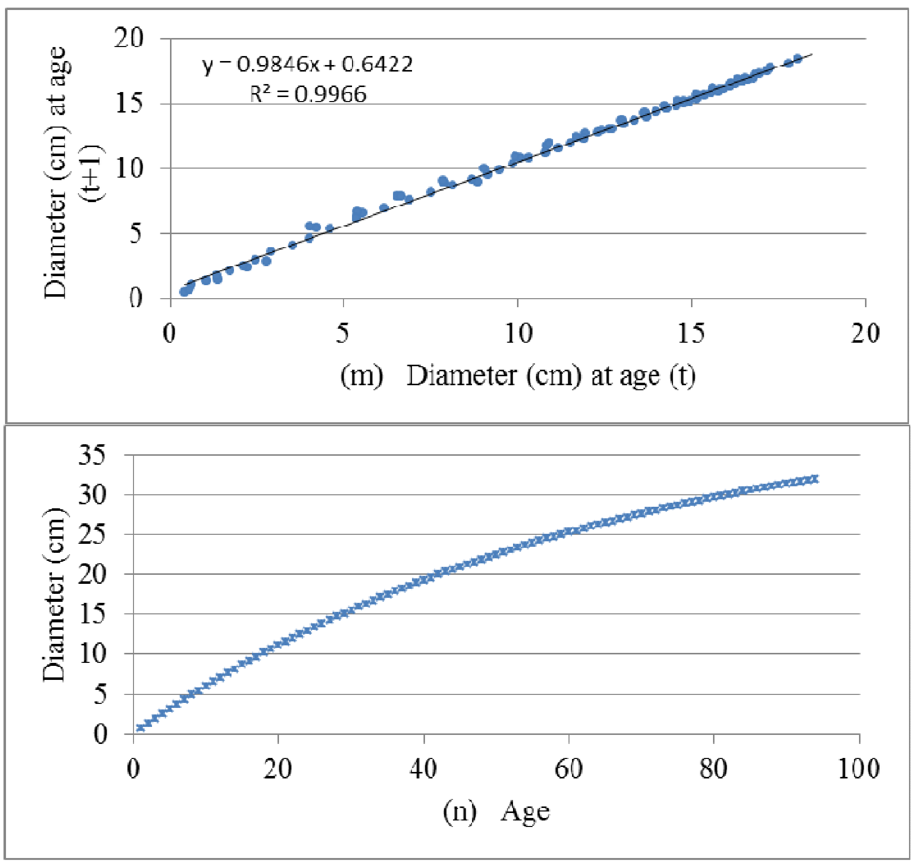


Figure 19, Mitscherlich Diameter Growth Model for *Carpinus tschonoskii*, (m) Relationship of Diameter Growth in cm at Age (t) and (t+1); (n) Average Diameter Growth Model

4.10.8 Growth model of *Carpinus tschonoskii* for height

Similarly from the Figure 20(o), the relationship expression of height at age (t) and (t+1) is Y= 0.9885 X + 0.5492 which indicates that; a= 0.9885, b= 0.5492,

M= 0.5492/(1-0.9885)=47.75652 and k=ln(0.9885)= -0.01157. R^2 value for this model is 0.9956

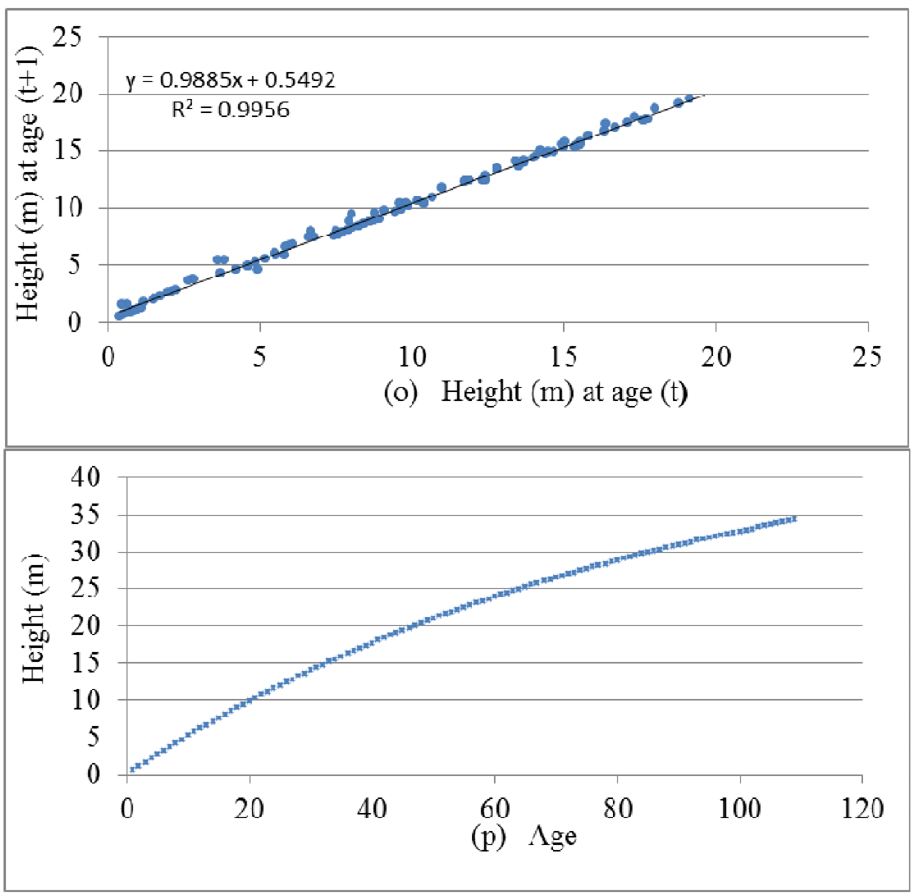


Figure 20, Mitscherlich Height Growth Model for *Carpinus tschonoskii*, (o) Relationship of Height Growth in m at age (t) and (t+1); (p) Average Height Growth Model

All growth models for diameter and height of four dominant species in Oaota forest can be summarized as in the table 4 and Table 5. By using these growth models the future diameter and height of the species can be calculated and we can further calculate the future wood volume accumulation of these species.

Table 4, Paremeters of Mitscherlich Diameter Growth Function for the Dominant Species and the Indicator of Fit

Species	a	b	M	k	Growth function for Diameter (cm)	R^2
Chamaecyparis obtusa	0.9971	0.2754	94.96552	-0.0029	$Y = 94.96552\ (1-e^{-kt})$	0.9992
Quercus serrata	0.9929	0.5472	77.07042	-0.00713	$Y = 77.07042\ (1-e^{-kt})$	0.9992
Cryptomeria japonica	0.9983	0.1602	94.23529	-0.0017	$Y = 94.23529\ (1-e^{-kt})$	0.9992
Carpinus tschonoskii	0.9846	0.6422	41.7013	-0.01552	$Y = 41.7013\ (1-e^{-kt})$	0.9966

Table 5, Paremeters of Mitscherlich Height Growth Function for the Dominant Species and the Indicator of Fit

Species	a	b	M	k	Growth function for Height (m)	R^2
Chamaecyparis obtusa	0.9934	0.2392	36.24242	-0.00662	$Y =36.24242\ (1-e^{-kt})$	0.9964
Quercus serrata	0.9798	0.6977	33.19048	-0.02122	$Y = 33.19048\ (1-e^{-kt})$	0.9986
Cryptomeria japonica	0.9955	0.1954	43.4222	-0.00451	$Y = 43.4222\ (1-e^{-kt})$	0.999
Carpinus tschonoskii	0.9885	0.5492	47.75652	-0.01157	$Y =47.75652\ (1-e^{-kt})$	0.9956

From the Table 4, the asymptotic diameter for *Chamaecyparis obtusa* and *Cryptomeria japonica* showed similar diameter as 94.96 cm and 94.23 cm respectively; followed by *Quercus serrata* (77.07 cm) and *Carpinus tschonoskii* (41.70 cm). Similarly for height growth, Table 5, showed the asymptotic highest height is for *Carpinus tschonoskii* as 47.75 m followed by *Cryptomeria japonica* (43.42 m), *Chamaecyparis obtusa* (36.24 m), *Quercus serrata* (33.19 m).

4.11 Form Factor of Selected Species in Oaota Forest

In calculating future wood biomass accumulation by using growth model, form factor is an important parameter to be used to predict the accurate wood volume as the shape of the tree is not cylindrical. There are various types of form factor but for the calculation here we used the real form factor which is calculated by measuring the stem volume of the tree at every 2 meter interval divided by the cylindrical volume of the same tree having same diameter and height. Different species has the different form factor depending on the shape of the tree. We calculated the form factor of those species which are relatively more in number in the experimental plots of the study area. Calculation of form factor is shown in Appendix-B and table 6, shows the average form factor of selective species. In calculating the future volume of the species shown in Table 6, the respective form factor was used and for other species we did not use any form factor. Due to inadequate data on tree form factor of this area we calculated the selected specie's form factor and used it.

Table 6, Form Factor Calculated for the Selected Species of Oaota Forest

Number	Species	Form factor
1	*Quercus serrata*	0.398
2	*Chamaecyparis obtusa*	0.461
3	*Carpinus tschonoskii*	0.373
4	*Cryptomeria japonica*	0.453
5	*Styrax japonica*	0.300
6	*Quercus acutissima*	0.438
7	*Swida controversa*	0.450

4.12 Future Wood Biomass Accumulation

By using the growth model for diameter and height of the species the future wood biomass was calculated. If the climatic condition of the forest, nutrient status into the soil and management remains unchanged then this prediction of biomass accumulation will be good interpretation of future biomass projection. By this prediction the future management or usage of wood biomass can be determined.

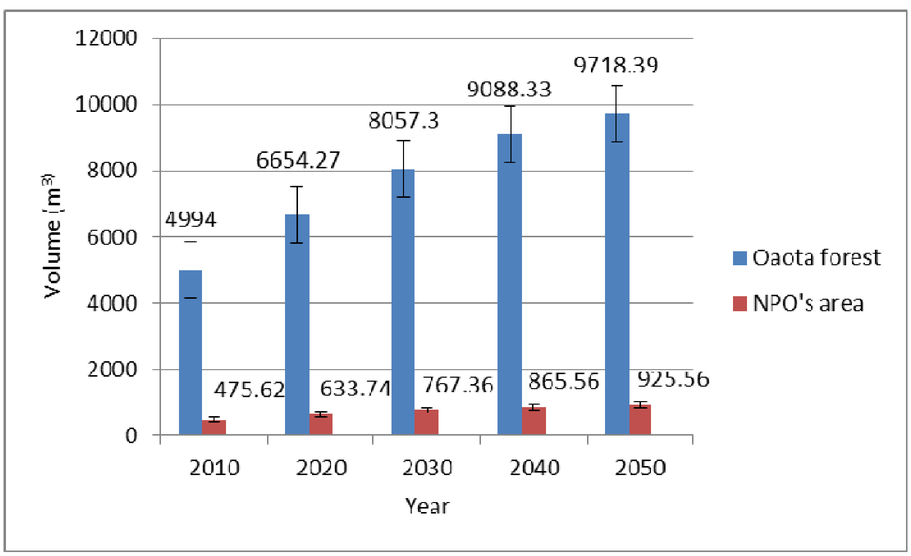


Figure 21, Projected Total Wood Biomass Stock (2010 to 2050) at 10 Years Interval in Oaota Forest

The total above ground wood biomass stock of the forest in the year 2010 is 4994 m^3 which does not include the wood volume of branches. This amount of biomass yield was projected by using the Mitscherlich Growth Model for the four dominant species and by using the relative growth comparing with the growth of *Quercus serrata* the total volume of all other species found in the experimental plot were calculated (Appendix-C). Figure 21, showed the increasing trend of total wood biomass accumulation of the forest at a decreasing rate which is observed after the year 2040. Most of the dominant species, except *Carpinus tschonoskii,* were found to be average age of 50 years according to growth ring analysis on the basis of number of growth rings found at the stem disc of 0.3 m height of the tree. The age of *Carpinus tschonoskii* was 25 years on an average at the year of 2010 which indicates that the tree is very early in its growth period. Age of other species found in the experimental plots of the forest was not determined due to the lack of time of the work. Therefore, from the graph it can be said that the total wood biomass of the forest will not increase after the year 2050 at an increasing rate. In other words, most of the species will attain the optimum competition at the year of 2050 or at the age of 90 years. We can then determine that the maximum productive age of the dominant species in Oaota forest is 90 years on an average. Of course some of the other species may vary at their productive age as their growth patterns were analyzed by comparing with the growth of *Quercus serrata*.

For the sustainable management of the forest it is said that light thinning is beneficial for the growth of the trees, because, light thinning reduces the competition of the species for light and nutrient. The non-profit organization (NPO) members also like to harvest some of the wood from the forest at a regular interval like 10 years (interview with Chief of NPO in Oaota forest). The increment of wood biomass accumulation in the forest from the year 2010 to the year 2020 is 1660.27 m^3 and if the NPO extract 80 % of that increment i.e. 1328.216 m^3 of wood biomass then it will be a sustainable way of forest management. Rest of 20 % is left for the case of risk like natural hazard, disease damage etc. Excess of that amount of wood biomass harvesting will reduce the stock of the forest for the year 2010. As the NPO is managing only the 4 ha of the forest so the stock and wood biomass to harvest by the NPO people is very less compared to the whole forest. About 2.3 % of the whole forest is managed by this NPO but they have no legal right to harvest the wood from the forest. The wood biomass production in 4 ha area at the year of 2010 is 475.62 m^3 which is 9.5 % of the wood volume of whole forest in that year. The NPO can harvest 80 % of the increment of wood biomass in the next 10 years at the year of 2020 which is 126.49 m^3 and they have to leave remaining 20 % wood for risk of natural calamities. In this way the stock of the forest will sustain for long. For large scale of harvesting the NPO needs the legal right to harvest the trees. Those harvested wood will also need to cut at the market size of 40 cm length for firewood use. Otherwise that wood will be treated as waste material by the local government and will be burnt as solid waste rather than utilization according to the law of Japanese solid waste disposal. The harvesting cycle should be 15-20 years which is observed in the sub urban forest in Japan.

4.13 Intensity of Leaf Fall on Forest Floor

In the Figure 22, it is seen that the maximum leaf fall occurred during the time of November to December. At that time leaf harvesting will be suitable to get maximum amount of leaf. If one tries to collect leaf at the end of December it may be possible to get maximum amount of leaf but some leaves may be decomposed by that time.

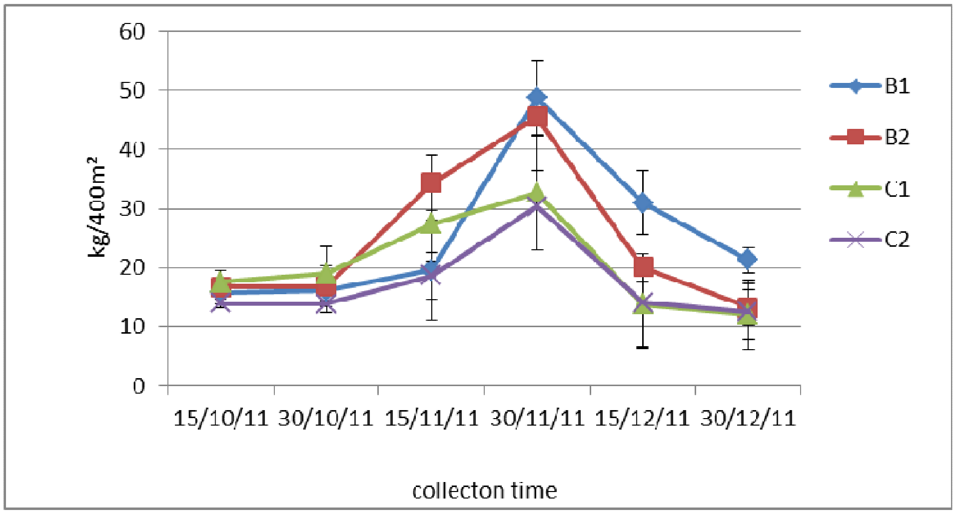


Figure 22, Intensity of Total Leaf Fall in Experimental Plots from October-December, 2011

And harvesting all the leaves from the forest floor may hamper the nutrient accumulation into the soil also. Therefore, it will be helpful and sustainable for the forest environment to collect the leaves at the time of maximum amount of leaf fall. The leaf collection from the forest floor also needs to follow a cycle of leaf harvesting. According to Tochigi prefecture in Japan the Midori-kan biomass factory collects the forest leaves following a 2 years cycle so that the forest floor is not hampered for nutrient accumulation. In Oaota forest there is total of 3.281 tonne/ha or 137.80 tonne of leaves was produced during the winter in the whole 42 ha of Oaota forest. By using these leaves mixing with the household biodegradable waste in the area compost can be prepared which is a valuable organic fertilizer for the plants.

4.14 Present Carbon Sink by Oaota forest

For calculating carbon content of the wood we used dry wood density of the species applicable to Japanese species. By using the dry wood density (Table 7) we calculated the total dry tonne of wood of each species in the experimental plot which was converted to carbon content of the wood in the forest.

Table 7, Dry Wood Density of Species for the Wood Volume Measurement

Species Name	Wood density (dt/m^3)
Swida controversa *Carpinus tschonoskii* *Prunus jamasakura* *Quercus myrsinaefolia* *Prunus burgueriana* *Seltis sinensis* *Styrax japonica* *Prunus grayana*	0.469
Quercus serrata	0.624
Cryptomeria japonica	0.314
Quercus acutissima	0.668
Magnolia kobus	0.368
Chamaecyparis obtusa	0.407
Castanopsis sieboldii	0.646

Source: http://www.rinya.maff.go.jp

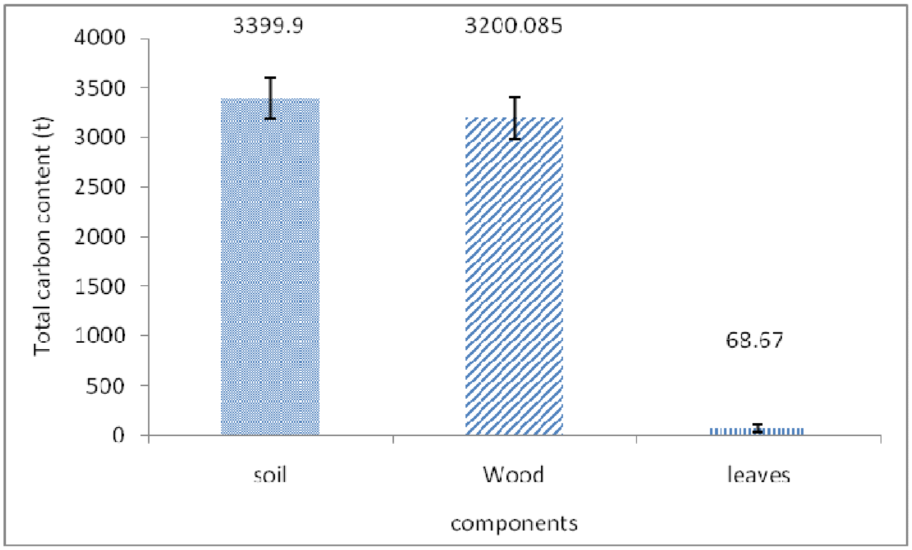


Figure 23, Total Carbon Sink by Oaota Forest in Soil, Wood Biomass and Leaves

Figure 23, showed the total carbon storage by the forest at present (up to year 2010) which is equivalent to (3399.9 + 3200.085 + 68.67) = 6668.65 tonne carbon in the whole 42 ha of Oaota forest. Soil organic carbon content at the depth of 30 cm contains highest carbon than other components of carbon storage sector of the forest. Here, the soil organic carbon content of two layers (0-15 cm and 15-30 cm) were added to express as soil organic carbon content for one layer (0-30cm) of soil in the Figure 23. Tree wood biomass including branches of the trees contained 3200.085 tonnes of carbon while tree leaves shading in a year contains less amount of carbon (68.67 tonnes). The 30 cm depth of soil contains 50.98 % of total carbon storage of the forest followed by 47.98 % for wood biomass and 1% for the leaves of the trees for one year.

4.15 NPO and Local People's Response on Forest Conservation and Biomass Utilization

Interview survey results, according to structured questionnaire (Appendix-E) of local people, revealed that most of the local people are of 65 years old and NPO members are of different in ages ranging from 45-65 years or more and they are not using the wood biomass for any of the energy source for their daily life. They are interested to use the wood biomass for energy if it becomes cheaper in cost and easy to use than the other sources of energy. At present they are not using the wood biomass because other energy source is ready to use and cheaper than wood biomass. They replied that wood biomass is costly and are not easy to use. Some farmers used to make compost from their agricultural residues but due to radiation now they are not making the compost for their agricultural farming. While it was asked to them "what type of forest do you like Oaota to be and what benefit do you want from it?' all the respondents answered the forest to be as a green landscape like conservation and recreational place for them. Local people said that they do not have the legal right to use the forest resources and if the owner of the forest gives them permission to use the forest then they will collect some forest resources for their consumption. And in reply to the question 'who should take the responsibility to manage this forest? And what are the major threats to this forest?' they replied that the central or local government should take the leading responsibility to manage the forest by engaging the NPOs. For the conservation of the forest, conversion of the forest land to commercial development or agricultural land is a serious threat according to their opinion.

On the other hand the NPO members replied that they do not use the wood for any of their energy need but they are very interested to use the wood biomass in different form of use like wood chips or charcoal. They are making the compost by using the tree leaves inside the forest and using it to young plants inside the forest only. The NPO likes to maintain the

Oaota forest as a place of conservation, recreation and yearly thinning of some of woods. The composition of the species in the forest the NPO liked to be the combination of young, medium and old aged trees. They showed strong opinion to conserve the forest and the commercial development by converting the forests is a serious threat for the conservation of natural forest landscape. NPO members are interested to increase the forest land under their management but it needs the forest owner's permission to take responsibility of that forest land. At present, there are 30 owners of Oaota forest; NPO members are managing only one owner's land which includes only 4 ha (about 10 % of the total land area of Oaota forest). There is no special preference of species to be in the forest but they showed that they are not interested to have some of the trees like *Cryptomeria japonica*, *Chamaecyparis obtusa* as they are very slow in growth. Trees which have the large crown are not liked by NPO members replied by NPO leader of Oaota forest. *Quercus serrata* is liked by them very much as it is fast growing and they can produce mushroom over the cut portion of *Quercus serrata*. Rather than recreation and conservation, the NPO members are willing to harvest some of the wood biomass at 10 years interval. Preferred species to be in Oaota forest are Sakura, Khaki, Kuri, Kunumi, Mijuki, Konara and undesired species are Shirakashi, Mochinoki. The NPO likes the government, whether city or central government should take the leading role for the management of sub urban forest and they need government's (technical / financial) support for the management of the forest.

CHAPTER-5

5 DISCUSSION

The sub urban (Satoyama) forest is treated as one of the potential site to contribute different services not only to the local society but also to the global environmental sustainability. The study on Oaota forest showed that this semi natural forest has different potentials to give benefit to the local society by providing wood as an alternative carbon less energy source, natural green landscape, recreational facility to the society and a healthy environment. This forest can also play a significant contribution to the local people in case of emergency. The present wood stock until the year 2010, it was shown that in plots A1, A2, B1 and B2 the wood volume production was 261.75 m^3/ha, 270m^3/ha, 211m^3/ha and 259.5m^3/ha respectively while the density of trees in those plots were 725 trees/ha, 1150 trees/ha, 875 trees/ha and 925 trees/ha respectively. According to Figure 9 and Figure 10, it was evident that the sub urban 'Oaota forest' is mainly dominated by *Quercus serrata, Quercus acutissima, Chamaecyparis obtusa, Cryptomeria japonica, Carpinus tschonoskii and Swida controversa.* It was also said by previous study on sub urban forest in Japan that the characteristic species in sub urban (Satoyama) forest is dominated by deciduous Oaks *Quercus serrata* and *Quercus acutissima* (Terada *et al*., 2010). Study on 80 years old *Chamaecyparis obtusa* plantation forest showed wood volume accumulation was less than 600 m^3/ha while for *Cryptomeria japonica* it was greater than 600 m^3/ha although these two species are slow in growth (Fukuda,*et al*., 2003). The wood volume accumulation is much lower than the plantation of the same species in Southwestern part of Japan (Fukuda,*et al*., 2003). In comparison to the PF site in Oaota forest which is dominated by *Chamaecyparis obtusa* and *Cryptomeria japonica* showed wood biomass accumulation as 42.0 m^3/ha and 51.71 m^3/ha respectively while the tree density of *Chamaecyparis obtusa* and *Cryptomeria* *japonica* were 250 tree/ha and 175 tree/ha respectively; which, may be, due to remaining unmanaged for a long time in the sub urban forest areas. The wood biomass accumulation in Oaota forest for the species *Chamaecyparis obtuse* and *Cryptomeria japonica* were much lower than the study result of Fukuda *et al*. (2003) for 80 years old plantation forest in Japan. Therefore, this sub urban forest species needs to be managed properly to enhance the growth of the species. The growth pattern of species like *Cryptomeria japonica*, *Chamaecyparis obtusa* in Oaota forest in Figure 11(b), Figure 12(e) and Figure 12(d) showed that they are slow in the early stage of growth but rapidly grows in middle age and now (year 2011) the growth is increasing in a decreasing rate. It is evident from the growth curve that these tree faced competition for light, nutrient etc with other species in the forest. But as the forest was remained abandoned for long time and no silvicultural activities (thinning, pruning) were undertaken, the growth became much less than the other area of forest plantation in Japan. Tree ring analysis showed that the average age of *Quercus serrata*, *Chamaecyparis obtusa*, *Cryptomeria japonica* were 50 years old in the year 2011 while the average age of *Carpinus tschonoskii* was 25 years. In this stage of growth the trees are facing competition. Light thinning or pruning may be an option to enhance the growth of the trees in Oaota forest. From the growth curve of dominant species in Oaota forest it was revealed that rapidly growing species are *Carpinus tschonoskii* and *Quercus serrata* and the slow growing species are *Chamaecyparis obtusa* and *Cryptomeria japonica* if we consider the early stage of growth for the species. Interview result on NPO's preference on species composition it was also known that they like to see the *Quercus species* in Oaota forest as this species is high yielding and can produce mushroom on its logs.

According to interview result it was known that the NPO likes to manage the forest in sustainable way and they also like to harvest some wood at 10 years interval. In sub urban (Satoyama) forests woodlands were clear cut on a 15-20 years rotational cycles since this time interval provided abandoned and well sized firewood resources (Inui,1996). In order to ascertain the future potential to produce wood biomass by the Oaota forest Mitscherlich growth model was developed for the dominant species and the future wood biomass accumulation was calculated for every ten years interval. We considered the annual mortality rate of trees as 2 % for this forest because the previous mortality rate was not known and the forest comprises three different types of layers with species in various ages of young, medium aged and old trees. Mortality of deciduous broad leaved forests in Japan ranges from 0.6-4.3 per year (Takahashi *et al*., 2001.; Nakashizuka *et al*., 1992.; Hara *et al*., 1995.; Masaki *et al*., 1999.;Umeki *et al*., 1999.). Based on growth model for future biomass prediction it was found that in 2010 the total above ground wood biomass stock in Oaota forest is 4994 m^3 and in every ten years interval it increases as 1660 m^3, 1403 m^3, 1031 m^3 and 630 m^3 for the year 2020, 2030, 2040 and 2050 respectively (Figure 21). From the year 2010 to the year 2020 the average increase of above ground wood biomass is 166 m^3 per year in the total 42 ha of Oaota forest indicating that the NPO and local people can harvest some of the wood biomass every year by not decreasing the stock that of the year 2010 in a sustainable way. This sustainability of wood biomass harvest can not only enhance the forest growth but also contribute to biomass utilization which will, in turn, help to reduce the carbon emission by substituting a part of the fossil fuel energy.

The sub urban forest in Japan can be treated as a multifunctional ecosystem by providing wood biomass for energy, leaves for compost making which was very important to the farmers before 1950-60s as fertilizer for the agricultural field and forest soil as a source and sink of atmospheric carbon dioxide. Experiment on leaf fall in Oaota forest resulted that the leaf shading starts from early October and completes at December during which intensive leaf fall occurred in the month of November. Leaf fall of *Quercus serrata* stand increases during the month of October (Watanabe and Yogi, 1984). The people can get more leaves to collect at time of November and leaves at the later time should be remained in the forest floor to sustain the soil fertility. Excess leaves sometimes do not permit the seeds to come into contact with soil or restricts the light to germinate the seeds hampering the regeneration of the specie in the forest. The total amount of leaves fell on the forest floor in the year 2011 was calculated as 137.34 dt / y on an average (Figure 22). Therefore, there is potential amount of leaf biomass in Oaota forest which can be utilized for making compost for the local area. According to Motegi Machi Recycle Centre (Midori-kan), Tochigi prefecture, Japan we can follow the 2 years leaf collection cycle (personal interview with the staff of Midori-kan) for making compost by mixing with household biodegradable waste (like vegetable and animal wastes).

The role of Oaota forest as a potential carbon sink, results on carbon content of wood stored into the standing trees, carbon content of fallen leaves and soil organic carbon measurement showed that the total carbon content in Oaota forest is 6668.65 tonne contributing soil as the highest sector to sink more carbon than wood biomass or leaves. Generally the soil contains almost three times carbon than the above ground biomass (Eswaran, *et al*., 1993). Because soil carbon is stored in the soil for a long time and gradually it is also stored into the deeper soil layers. Here in this study we took only 0-30 cm (including two layers) soil depth to measure the organic carbon content of the soil that is why the soil carbon did not show about three times higher carbon than wood.

From the discussion above it is evident that the Oaota forest, as a semi natural sub urban forest, has various potentials to contribute to the local and global environmental sustainability. By managing the sub urban forest adopting scientific information on growth and productivity of the species can generate more biomass as well as sink more atmospheric carbon dioxide which will, in turn help to build a sustainable society. The success of sustainable forest management needs knowledge of NPOs on forest growth and legal rights to manage the forest as the sub urban forests are owned by the different owners. The NPO manages only the 4 ha of one owner's forest out of 42 ha forest of 30 owners in Oaota forest. The initiative should be taken by the central or local government to enhance the movement to proper management of sub urban forest and to get various benefits from the forest. Interview survey result also revealed that the NPO needs government support, both technical and financial, to manage the forest.

CHAPTER-6

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The sub-urban forest in Japan has become important to the national government and local people, especially NPOs to revitalize the national ecosystem in the last two decades. The central government of Japan also took initiatives like Biomass Nippon strategy to introduce biomass utilization in the society and also to conserve the biodiversity. Much research work focused on biomass utilization from the sub urban forest as a means to maintenance of the sub urban (Satoyama) forest. This study focused on biomass productivity of sub urban forest which is closely related to utilization of biomass which can be extracted in a sustainable way. For the future biomass accumulation of the Oaota forest we developed Mitscherlich Growth Model for dominant species and it was revealed that at 2010 the total biomass stock of the forest is 4994 m^3 and after 10 years later, in the year 2020, it will be 6654.27 m^3 which is 1660.27 m^3 higher than that of the year 2010. If the amount of biomass equivalent to 80 % of 1660.27 m^3 is harvested then it may be a sustainable way of harvesting. The remaining 20 % is considered for risk factors of biomass damage by that period of time in the forest. The concept of sustainable harvesting depends on how much to be conserved and from when to be conserved? NPO likes to harvest some of the wood at an interval of 10 years and they have preference on some species to retain in the forest for regeneration like *Quercus serrata*, *Quercus acutissima* because they grow fast and mushroom can be grown on the cut stem of those species. The NPO did not prefer the species like *Cryptomeria japonica*, *Chamaecyparis obtusa* and other species which has large crown. Because some trees are slow in growth and some suppresses the other species to grow. In case of leaf biomass utilization, the NPO was not interested to collect leaves from the forest floor because they think that harvesting of leaves may hamper the regeneration of species. But excessive leaves on forest floor in temperate forest increase the fire hazard; reduces the seed germination by imparting the sun light to seed germination and increase of insect population causing disease of trees. Therefore, information combined with scientific knowledge and traditional practice might be an option to better management of sub urban forest. This study revealed the following limitations:

This study focused on species productivity by stem analysis of four dominant tree species of Oaota forest. By developing Mitscherlich Growth Model we predicted future biomass accumulation of the whole forest on the basis of these four dominant species which might not be accurate estimation for the productivity of whole forest because every species has different patterns of growth. Further research on the growth pattern of other species needs to be done.

The information on growth pattern of *Quercus serrata*, *Carpinus tschonoskii*, *Cryptomeria japonica*, *Chamaecyparis obtusa* are inadequate in the sub urban forest of Japan. This research gave some new information by developing Mitscherlich Growth Model for these species.

Mitscherlich Growth Model uses two parameters for growth prediction; diameter or height as dependent variable and age as an independent variable. In a forest ecosystem there are other parameters like spacing, crown area, climate, soil nutrient, different management factors which may influence the growth of the species. Those factors were not considered for the growth modeling in this study. This model was not tested for the same species in other areas of sub urban forest because of limit of time of the work. If it can be tested further then this model can be widely used.

6.2 Recommendations

Based on the results the following recommendations can be proposed for the sustainable management of the Oaota forest:

(a) From the growth pattern of dominant species in Oaota forest it was revealed that the *Quercus serrata* and *Carpinus tschonoskii* showed high yield than the *Chamaecyparis obtusa* and *Cryptomeria japonica* at the early stage of growing period. Further, these two spceis *Quercus serrata* and *Carpinus tschonoskii* are also growing at an increasing rate than other species in the forest. The interview on NPO members also revealed that they have the preference on *Quercus serrata* and *Carpinus tschonoskii* to retaing them in Oaota forest because these two species grow faster and mushroom can be grown on the cut portion of the trunk of *Quercus serrata*. On the other hand, *Cryptomeria japonica* and *Chamaecyparis obtusa* are slow grown species and the NPO does not like these species in the forest. The NPO likes to harvest some wood from the forest at 10 years interval and therefore, if they harvest slow growing species then it will enhance the growth of other fast growing species in the Oaota forest. Retaining *Quercus* species may help to enhance the regeneration of this species.

(b) In the NF site most of the species like *Quercus serrata, Quercus acutissima* are deciduous and complete leaf shading occurs during the winter. The leaves of these species are bigger in size and do not readily degrade on the forest floor. Sometimes it imparts the light to come in contact with the seeds on the forest floor and subsequently hampers the natural regeneration of the species. More leaves on the forest floor cause the increase of insects and fire hazard. If some of the leaves are collected and utilized for the organic fertilizer or other means of energy usage then it would be better to maintain the forest health. For example: in Tochigi Prefecture, Motegi Machi Recycle Centre (Midori-kan) is using household biomass with the forest leaves for making organic fertilizer. Oaota forest produces 137 dt of leaves every year in its 42 ha forest area. The NPO can extract some of the leaves from their managed area which can be utilized as compost for the plants.

(c) The NPO manages only the 4 ha (9.5 % of total Oaota forest) forest area. In order to get more benefit the whole area of Oaota forest should be drawn under systematic management either by NPO or collaboration with forest owners, NPOs and government.

(d) The interview survey result also predicted that the Local Government or Central Government should take the initiative to manage the sub urban forest. The NPO needs financial and technical help from the government.

(e) The NPO members are willing to use the wood biomass for a part of their energy needs rather than local people. Therefore, at first the NPO should be the target group to introduce the wood biomass utilization. Then gradually the wood biomass usage can be expanded to local people.

(f) Some technical information like thinning, pruning, carbon sequestration potential of species should also be given to NPO so that their management can contribute not only to enhance forest health but also to the atmospheric carbon sink.

(g) NPO can harvest 31 m^3 of wood which is equivalent to 80% of the yield in 2020 (39 m^3) and in the next felling year it will be suitable to follow 15-20 years felling cycle. But as the trees grow the growth decreases and the felling cycle will be more than 20 years. From 2010-2020 biomass yield is 31 m^3 /ha (leaving 20 % for risk) which is equivalent to *Quercus serrata* 58 trees or *Chamaecyparis obtusa* 319 trees or

Carpinus tschonoskii 222 trees or *Cryptomeria japonica* 1020 trees. The NPO can adjust the felling of trees depending on their interest on which trees to be retained more and which trees to be felled.

Finally, this research showed that sub urban forest can be managed in a sustainable way by having the information of future biomass accumulation but it also identified the question of how much to be conserved within the ecosystem? To answer this question further research is needed to clarify the concept of sustainable forest managed.

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APPENDICES

Appendix-A

(i) (ii)

Photo 4, (i) Electric Weighing Machine Used to Take Dry Weight of Leaf Biomass and, (ii) [1]Sanding Machine to Prepare the Tree Stem Discs for Growth Ring Analysis.

[1]Sanding machine was used to polish the surface of the dry stem discs by using sand paper of 80 mm or 120 mm suitable for the discs. Tissue paper was used to clean the dust on the surface of the discs so that growth rings could be easily identified by the WinDENDRO Reg2002b software. (*photographs by author*)

Appendix-B, Form Factor of Species in Oaota Forest

Table 1, Form Factor of *Styrax japonica*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
B-02	6.5	4.44	0.00442	0.014733	0.3
B-05	8.1	4.2	0.006493	0.021643	0.30001
b-19	6	6.86	0.005819	0.019396	0.300007
b-20	5.6	5.5	0.004064	0.013547	0.300002
b-22	7	6.25	0.007216	0.024053	0.300006
b-29	5	4.1	0.002415	0.00805	0.299987
a-14	6.3	7.96	0.007444	0.024813	0.3
			Average form factor		0.300002

*indicates the wood stem volume calculated by taking the diameter from base to top of the tree at every 2 meter interval at a top point whose diameter can be measured by Criterion RD1000.

Table 2, Form Factor of *Quercus serrata*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
B1-3	20	18.5	0.19904	0.581196	0.342466
B1-7	31	20.5	0.799851	1.547277	0.516941
B1-9	22.4	18	0.304203	0.709348	0.428849
B1-10	22.8	20.2	0.316911	0.82473	0.38426
B1-11	27.8	20.4	0.513667	1.238257	0.414831
B1-12	31	19.7	0.762301	1.486896	0.51268
B1-13	23.5	19.3	0.337301	0.837113	0.402934
B1-14	32	17.5	0.597246	1.407437	0.42435
B1-15	29.5	18.4	0.498604	1.25763	0.396463
B1-16	31.7	21.2	0.671832	1.67319	0.401528
B1-17	33.2	20.5	0.78364	1.774684	0.441566
B1-18	25	20.9	0.406179	1.025929	0.395913
B1-21	5.9	5.8	0.004757	0.015857	0.299992
B1-24	36.3	18.2	0.681848	1.883543	0.362003
B1-25	25	17.4	0.420595	0.854123	0.492429
B1-26	35.3	21.9	0.889919	2.143307	0.415208
B1-27	23.5	19.1	0.314663	0.828438	0.379827
B1-28	29.4	19.4	0.510227	1.317005	0.387415
A-6	11.1	9.42	0.027347	0.091157	0.3
A-24	11.1	9.11	0.026447	0.088157	0.3
A-38	9.5	10.32	0.021945	0.073151	0.299998
C1-202	16.1	15.5	0.149337	0.315554	0.473253
			Average form factor		0.398768

Table 3, Form Factor of *Carpinus tschonoskii*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
B-4	26.8	20.2	0.477848	1.139494	0.419351
B-6	26.4	20.6	0.4884	1.127628	0.433121
B-23	6.5	7.27	0.007237	0.024124	0.29999
A-2	5	7.79	0.004589	0.015296	0.30002
A-3	9.3	11.39	0.023211	0.077371	0.299995
A-4	8.1	9.58	0.01481	0.049366	0.300005
A-5	5.3	6.27	0.00415	0.013833	0.300012
A-8	5.5	7.7	0.005488	0.018294	0.29999
A-9	6.4	10.67	0.010298	0.034325	0.300011
a-13	6	7.96	0.006752	0.022506	0.300003
a-15	12.8	15.7	0.117496	0.202027	0.581584
a-21	37	20.3	0.869048	2.182682	0.398156
a-26	11.4	12.2	0.037358	0.124526	0.300001
a-27	8	11.23	0.016934	0.056448	0.299991
a-28	7	10.89	0.012573	0.04191	0.300002
a-29	9.8	11.21	0.025367	0.084557	0.299999
a-30	7.7	9.5	0.013271	0.044238	0.299991
a-31	5.6	9.69	0.00716	0.023867	0.300001
a-32	11.53	12.3	0.038528	0.128426	0.3
a-33	5.4	7.48	0.005139	0.017131	0.299984
a-34	7	10.86	0.012538	0.041794	0.299993
a-40	8.7	11.29	0.020135	0.067116	0.300005
a-41	6.3	10.81	0.010109	0.033698	0.299993
a-42	5	7.48	0.004406	0.014687	0.299994
a-43	6	8.74	0.007414	0.024712	0.300018
218	24.5	20.6	0.364561	0.971159	0.375388
220	33.5	20.8	0.598158	1.833344	0.326266
			Average form factor		0.373022

Table 4, Form Factor of *Cryptomeria japonica*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
B-08	13	3.1	0.012344	0.041147	0.299997
404	25.3	16.1	0.354302	0.80939	0.43774
405	26.3	15.7	0.431704	0.852908	0.506156
408	20.8	15.8	0.230965	0.536877	0.430201
414	21.8	17.3	0.279241	0.645729	0.432443
415	13.9	13.5	0.093185	0.204859	0.454875
417	21.5	17.2	0.248917	0.624448	0.398619
418	24.3	16.4	0.357776	0.760584	0.470396
420	20.8	15.9	0.221183	0.540275	0.40939

421	26.9	15.7	0.44524	0.892268	0.498998
422	24	15.4	0.314407	0.696681	0.451292
426	20.6	12.1	0.186154	0.403284	0.461596
430	22	16.6	0.338682	0.631022	0.53672
432	16.1	12.5	0.132095	0.254479	0.519079
434	27.1	17.5	0.503513	1.00941	0.498819
			Average form factor		0.453755

Table 5, Form Factor of *Quercus acutissima*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
a1	33.8	21.2	0.732452	1.902217	0.385052
a7	35.2	20	0.925177	1.946284	0.475356
10	24	18.4	0.32119	0.832398	0.385861
12	23.2	15.1	0.196054	0.638328	0.307137
17	24	18.2	0.375365	0.823351	0.455899
18	26.8	19.8	0.43381	1.116929	0.388395
20	30.2	19.9	0.605354	1.425469	0.42467
22	23.2	15.6	0.273646	0.659465	0.414952
23	35	21.7	0.789884	2.08779	0.378335
25	32	21.6	0.809851	1.737179	0.466187
35	18.9	16.4	0.221303	0.460106	0.480982
36	22.8	21.4	0.410733	0.873724	0.470095
37	23.4	20.4	0.396849	0.877309	0.452348
39	23.5	18.2	0.329181	0.789402	0.417001
44	19.8	19.9	0.453592	0.612737	0.740272
45	41.5	22.4	1.135153	3.029948	0.374644
			Average form factor		0.438574

Table 6, Form Factor of *Swida controversa*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
c1-200	27.2	16.2	0.442264	0.941334	0.469827
d400	21.1	15.3	0.268194	0.534992	0.501305
402	19.2	16.4	0.271255	0.474829	0.571269
406	17.1	17	0.17345	0.39042	0.444265
409	22.6	18.4	0.300869	0.738118	0.407617
410	15.2	15.4	0.126299	0.279447	0.451961
411	29.2	19.2	0.505005	1.285754	0.39277
413	22.5	16.2	0.30387	0.644126	0.471755
419	16	15	0.12092	0.301594	0.400937
423	19.2	14.5	0.149071	0.419818	0.355085

424	23	15.4	0.275899	0.639834	0.431204
425	19	14.5	0.170547	0.411118	0.414837
428	22.6	15.2	0.270928	0.609749	0.444327
429	26.2	16.2	0.413365	0.873391	0.473288
431	20.9	16.8	0.274457	0.576359	0.476191
436	29.4	15.8	0.539697	1.072612	0.503161
			Average form factor		0.450612

Table 7, Form Factor of *Chamaecyparis obtusa*

Tree no.	DBH (cm)	Height (m)	*Volume (m^3)	Cylindrical volume (m^3)	Form factor
A-47	27	14.5	0.338276	0.830207	0.40746
201	17	13.8	0.141495	0.313233	0.451724
203	20.1	15.6	0.238831	0.495003	0.482484
204a	17.7	14.3	0.192448	0.351863	0.54694
204b	18.5	14.5	0.173681	0.389765	0.445605
205	19.5	15.8	0.226274	0.471864	0.479532
206	26.2	20.4	0.473916	1.099825	0.430901
208	12.1	13.3	0.08073	0.152937	0.527864
210	15.8	12.9	0.113824	0.252927	0.450028
211	17.4	16.9	0.155891	0.401861	0.387922
223	20.2	16.3	0.275956	0.522374	0.528273
225	17.9	20.7	0.194742	0.520916	0.373846
228	10.4	10.6	0.055601	0.090046	0.617475
230	10.8	11.7	0.06074	0.107183	0.566696
231	18.1	17.2	0.188688	0.442564	0.426351
238	13.7	12.6	0.086929	0.185739	0.468018
239	21.4	16.8	0.194821	0.604265	0.32241
241	12.4	11.8	0.083599	0.1425	0.586658
242	21.2	15	0.226641	0.529485	0.42804
243	10.2	11.2	0.027456	0.091519	0.300005
			Average form factor		0.461412

Appendix-C

Table 8, Future Wood Biomass Accumulation in Oaota Forest by Mitscherlich Growth Model

Species	TT	$^{a}V_{2010}$	TT_{2010}	MR/y (2%)	TTP_{2010}	TV_{2010}	$^{a}V_{2020}$	TV_{2020}	$^{a}V_{2030}$	TV_{2030}	$^{a}V_{2040}$	TV_{2040}	$^{a}V_{2050}$	TV_{2050}
Quercus serrata	22	0.363	5775	0.98	5659.5	2054.77	0.539	2541.44	0.737	2901.11	0.953	3126.16	1.180	3226.42
Chamaecyparis obtusa	21	0.061	5512.5	0.98	5402.25	329.48	0.099	447.31	0.149	558.375	0.209	655.52	0.281	734.42
Carpinus tschonoskii	41	0.063	10762.5	0.98	10547.25	666.61	0.142	1251.48	0.249	1829.05	0.378	2307.94	0.519	2645.94
Cryptomerai japonica	15	0.018	3937.5	0.98	3858.7	71.09	0.031	98.56	0.047	125.608	0.067	150.51	0.092	172.06
Styrax japonica	7	0.002	1837.5	0.98	1800.7	2.92	0.002	3.61	0.003	4.126	0.004	4.45	0.005	4.59
Seltis sinensis	1	0.026	262.5	0.98	257.25	6.79	0.039	8.39	0.054	9.586	0.069	10.33	0.086	10.66
Quercus acutissima	16	0.248	4200	0.98	4116	1020.2	0.368	1261.9	0.503	1440.5	0.651	1552.2	0.805	1602.0
Prunus buergariana	1	0.029	262.5	0.98	257.25	7.55	0.044	9.34	0.060	10.662	0.077	11.49	0.095	11.86
Prunus grayana	1	0.030	262.5	0.98	257.25	7.60	0.044	9.40	0.060	10.737	0.078	11.57	0.096	11.94
Magnolia kobus	1	0.031	262.5	0.98	257.25	8.09	0.047	10.00	0.064	11.416	0.083	12.30	0.102	12.70
Swida controversa	16	0.130	4200	0.98	4116	533.92	0.192	660.38	0.263	753.84	0.341	812.32	0.422	838.37
Castanopsis sieboldii	1	0.003	262.5	0.98	257.25	0.88	0.005	1.09	0.007	1.247	0.009	1.34	0.011	1.39
Quercus myrsenifolia	2	0.125	525	0.98	514.5	64.25	0.185	79.46	0.254	90.708	0.328	97.74	0.406	100.88
Prunus jamasakura	2	0.427	525	0.98	514.5	219.79	0.634	271.85	0.868	310.32	1.121	334.40	1.388	345.12
Total	*147*					*4994.0*		*6654.2*		*8057.3*		*9088.3*		*9718.3*

TT=total trees in 4 experimental plots (1600 m^2) ; V_{2010}=single tree volume is calculated by using Mitscherlich Growth Model for diameter and height of the respective species for the year 2010; TT_{2010}= total trees in the whole foest (42ha) in 2010; MR=Assumed mortality rate for all the species in Oaota forest as 2% per year considering natural calamity and disease; TTP_{2010} =total trees at present in the forest in 2010 multiplied by mortality rate per year; TV_{2010}=total volume in the whole forest area in m^3; ^{a}=above ground stem volume of each tree for the year 2010, 2020, 2030, 2040 and 2050 of *Quercus serrata*, *Chamaecyparis obtuse*, *Carpinus tschonoskii* and *Cryptomeria japonica* were calculated by using the Mitscherlich Growth model for diameter and height. Stem volume of other species were calculated by taking the proportional volume of a single tree to the volume of *Quercus serrata* for 2010 multiplied by the single tree volume of *Quercus serrata* for that respective year. For example, single tree volume of *Styrax japonica* for the year 2020 is (0.002/0.363)*0.539=0.002

Appendix-D

Table 9, Carbon Content of the Species in Plot A1

TN(A1)	Species name	AGV (m^3)	BGV (m^3)	AGV+BGV	WD(t/m^3)	TDW (t)	TCC (t)
A1-01	*Seltis sinensis* Pers.	0.026393	0.003959	0.030352	0.469	0.014235	0.007118
A1-02	*Styrax japonica* Sieb. Et Zucc.	0.00442	0.000663	0.005083	0.469	0.002384	0.001192
A1-03	*Quercus serrata* Thunb. Ex Murray	0.199004	0.029851	0.228855	0.624	0.142805	0.071403
A1-04	*Carpinus tschonoskii* Maxim	0.477848	0.071677	0.549525	0.469	0.257727	0.128864
A1-05	*Styrax japonica* Sieb. Et Zucc.	0.006493	0.000974	0.007467	0.469	0.003502	0.001751
A1-06	*Carpinus tschonoskii* Maxim	0.54813	0.08222	0.63035	0.469	0.295634	0.147817
A1-07	*Quercus serrata* Thunb. Ex Murray	0.905639	0.135846	1.041485	0.624	0.649887	0.324943
A1-08	*Cryptomeria japonica* (L.fil.) D. Don	0.012344	0.001852	0.014196	0.314	0.004457	0.002229
A1-09	*Quercus serrata* Thunb. Ex Murray	0.304203	0.04563	0.349833	0.624	0.218296	0.109148
A1-10	*Quercus serrata* Thunb. Ex Murray	0.316911	0.047537	0.364448	0.624	0.227415	0.113708
A1-11	*Quercus serrata* Thunb. Ex Murray	0.513667	0.07705	0.590717	0.624	0.368607	0.184304
A1-12	*Quercus serrata* Thunb. Ex Murray	0.762301	0.114345	0.876646	0.624	0.547027	0.273514
A1-13	*Quercus serrata* Thunb. Ex Murray	0.337301	0.050595	0.387896	0.624	0.242047	0.121024
A1-14	*Quercus serrata* Thunb. Ex Murray	0.597246	0.089587	0.686833	0.624	0.428584	0.214292
A1-15	*Quercus serrata* Thunb. Ex Murray	0.498604	0.074791	0.573395	0.624	0.357798	0.178899
A1-16	*Quercus serrata* Thunb. Ex Murray	0.671832	0.100775	0.772607	0.624	0.482107	0.241053
A1-17	*Quercus serrata* Thunb. Ex Murray	0.78364	0.117546	0.901186	0.624	0.56234	0.28117
A1-18	*Quercus serrata* Thunb. Ex Murray	0.451632	0.067745	0.519377	0.624	0.324091	0.162046
A1-19	*Styrax japonica* Sieb. Et Zucc.	0.005819	0.000873	0.006692	0.469	0.003138	0.001569
A1-20	*Styrax japonica* Sieb. Et Zucc.	0.004064	0.00061	0.004674	0.469	0.002192	0.001096

A1-21	*Quercus serrata* Thunb. Ex Murray	0.004757	0.000714	0.005471	0.624	0.003414	0.001707
A1-22	*Styrax japonica* Sieb. Et Zucc.	0.007216	0.001082	0.008298	0.469	0.003892	0.001946
A1-23	*Carpinus tschonoskii* Maxim	0.007237	0.001086	0.008323	0.469	0.003903	0.001952
A1-24	*Quercus serrata* Thunb. Ex Murray	0.746452	0.111968	0.85842	0.624	0.535654	0.267827
A1-25	*Quercus serrata* Thunb. Ex Murray	0.472429	0.070864	0.543293	0.624	0.339015	0.169508
A1-2 6	*Quercus serrata* Thunb. Ex Murray	0.986154	0.147923	1.134077	0.624	0.707664	0.353832
A1-27	*Quercus serrata* Thunb. Ex Murray	0.314663	0.047199	0.361862	0.624	0.225802	0.112901
A1-28	*Quercus serrata* Thunb. Ex Murray	0.510227	0.076534	0.586761	0.624	0.366139	0.183069
A1-29	*Styrax japonica* Sieb. Et Zucc.	0.002415	0.000362	0.002777	0.469	0.001303	0.000651

Total Carbon Content =3.66053

Table 10, Carbon Content of the Species in Plot A2

TN(A2)	Species name	AGV (m^3)	BGV (m^3)	AGV+BGV	WD(t/ m^3)	TDW (t)	TCC (t)
A-1	*Quercus acutissima Carruthers*	0.806717	0.121008	0.927725	0.668	0.61972	0.30986
A-2	*Carpinus tschonoskii Maxim*	0.004589	0.000688	0.005277	0.469	0.002475	0.001238
A-3	*Carpinus tschonoskii Maxim*	0.023211	0.003482	0.026693	0.469	0.012519	0.006259
A-4	*Carpinus tschonoskii Maxim*	0.01481	0.002222	0.017032	0.469	0.007988	0.003994
A-5	*Carpinus tschonoskii Maxim*	0.00415	0.000623	0.004773	0.469	0.002238	0.001119
A-6	*Quercus serrata Thunb.ex Murray*	0.027347	0.004102	0.031449	0.624	0.019624	0.009812
A-7	*Quercus acutissima Carruthers*	0.945406	0.141811	1.087217	0.668	0.726261	0.36313
A-8	*Carpinus tschonoskii Maxim*	0.005488	0.000823	0.006311	0.469	0.00296	0.00148
A-9	*Carpinus tschonoskii Maxim*	0.010298	0.001545	0.011843	0.469	0.005554	0.002777
A-10	*Quercus acutissima Carruthers*	0.365973	0.054896	0.420869	0.668	0.28114	0.14057

A-11	*Magnolia kobus DC*	0.031432	0.004715	0.036147	0.368	0.013302	0.006651
A-12	*Quercus acutissima Carruthers*	0.293457	0.044019	0.337476	0.668	0.225434	0.112717
A-13	*Carpinus tschonoskii Maxim*	0.006752	0.001013	0.007765	0.469	0.003642	0.001821
A-14	*Styrax japonica Sieb. Et Zucc*	0.007444	0.001117	0.008561	0.469	0.004015	0.002007
A-15	*Carpinus tschonoskii Maxim*	0.117496	0.017624	0.13512	0.469	0.063371	0.031686
A-16	*Prunus grayana Maxim*	0.029562	0.004434	0.033996	0.469	0.015944	0.007972
A-17	*Quercus acutissima Carruthers*	0.375365	0.056305	0.43167	0.668	0.288355	0.144178
A-18	*Quercus acutissima Carruthers*	0.433810	0.065072	0.498882	0.668	0.333253	0.166626
A-19	*Prunus buergeriana Miq.*	0.029354	0.004403	0.033757	0.469	0.015832	0.007916
A-20	*Quercus acutissima Carruthers*	0.624503	0.093675	0.718178	0.668	0.479743	0.239872
A-21	*Carpinus tschonoskii Maxim*	0.869048	0.130357	0.999405	0.469	0.468721	0.234361
A-22	*Quercus acutissima Carruthers*	0.273646	0.041047	0.314693	0.668	0.210215	0.105107
A-23	*Quercus acutissima Carruthers*	0.789884	0.118483	0.908367	0.668	0.606789	0.303394
A-24	*Quercus serrata Thunb. Ex Murray*	0.026447	0.003967	0.030414	0.624	0.018978	0.009489
A-25	*Quercus acutissima Carruthers*	0.809851	0.121478	0.931329	0.668	0.622128	0.311064
A-26	*Carpinus tschonoskii Maxim*	0.037358	0.005604	0.042962	0.469	0.020149	0.010075
A-27	*Carpinus tschonoskii Maxim*	0.016934	0.00254	0.019474	0.469	0.009133	0.004567
A-28	*Carpinus tschonoskii Maxim*	0.012573	0.001886	0.014459	0.469	0.006781	0.003391
A-29	*Carpinus tschonoskii Maxim*	0.025367	0.003805	0.029172	0.469	0.013682	0.006841
A-30	*Carpinus tschonoskii Maxim*	0.013271	0.001991	0.015262	0.469	0.007158	0.003579
A-31	*Carpinus tschonoskii Maxim*	0.00716	0.001074	0.008234	0.469	0.003862	0.001931
A-32	*Carpinus tschonoskii Maxim*	0.038528	0.005779	0.044307	0.469	0.02078	0.01039
A-33	*Carpinus tschonoskii Maxim*	0.005139	0.000771	0.00591	0.469	0.002772	0.001386
A-34	*Carpinus tschonoskii Maxim*	0.012538	0.001881	0.014419	0.469	0.006762	0.003381
A-35	*Quercus acutissima Carruthers*	0.221303	0.033195	0.254498	0.668	0.170005	0.085002
A-36	*Quercus acutissima Carruthers*	0.443222	0.066483	0.509705	0.668	0.340483	0.170242
A-37	*Quercus acutissima Carruthers*	0.396849	0.059527	0.456376	0.668	0.304859	0.15243
A-38	*Quercus serrata Thunb. Ex Murray*	0.021945	0.003292	0.025237	0.624	0.015748	0.007874
A-39	*Quercus acutissima Carruthers*	0.367975	0.055196	0.423171	0.668	0.282678	0.141339
A-40	*Carpinus tschonoskii Maxim*	0.020135	0.00302	0.023155	0.469	0.01086	0.00543
A-41	*Carpinus tschonoskii Maxim*	0.010109	0.001516	0.011625	0.469	0.005452	0.002726

A-42	*Carpinus tschonoskii Maxim*	0.004406	0.000661	0.005067	0.469	0.002376	0.001188
A-43	*Carpinus tschonoskii Maxim*	0.007414	0.001112	0.008526	0.469	0.003999	0.001999
A-44	*Quercus acutissima Carruthers*	0.453592	0.068039	0.521631	0.668	0.348449	0.174225
A-45	*Quercus acutissima Carruthers*	1.441548	0.216232	1.65778	0.668	1.107397	0.553699
A-46	*Pinus densiflora Sieb. Et Zucc*	1.236928	0.185539	1.422467	0.451	0.641533	0.320766

Total Carbon Content=3.946

Table 11, Carbon Content of the Species in Plot B1

TN(B1)	Species name	AGV (m^3)	BGV (m^3)	AGV+BGV	WD(t/m^3)	TDW (t)	TCC (t)
200	*Swida controversa* (Hemsl.) Sojak.	0.442264	0.06634	0.508604	0.469	0.238535	0.119268
201	*Chamaecyparis obtusa* (Sieb. Et Zucc)	0.141495	0.021224	0.162719	0.407	0.066227	0.033113
202	*Quercus serrata* Thunb. Ex Murray	0.149337	0.022401	0.171738	0.624	0.107164	0.053582
203	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.238831	0.035825	0.274656	0.407	0.111785	0.055892
204(A)	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.192448	0.028867	0.221315	0.407	0.090075	0.045038
204(B)	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.173681	0.026052	0.199733	0.407	0.081291	0.040646
205	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.226274	0.033941	0.260215	0.407	0.105908	0.052954
206	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.473916	0.071087	0.545003	0.407	0.221816	0.110908
208	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.08073	0.01211	0.09284	0.407	0.037786	0.018893
210	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.113824	0.017074	0.130898	0.407	0.053275	0.026638
211	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.155891	0.023384	0.179275	0.407	0.072965	0.036482
212	*Castanopsis sieboldii* (Makino) Hatusima ex	0.003432	0.000515	0.003947	0.646	0.00255	0.001275
218	*Carpinus tschonoskii* Maxim	0.422302	0.063345	0.485647	0.469	0.227769	0.113884
220	*Carpinus tschonoskii* Maxim	0.705253	0.105788	0.811041	0.469	0.380378	0.190189
221	*Carpinus tschonoskii* Maxim	0.141928	0.021289	0.163217	0.469	0.076549	0.038274
222	*Carpinus tschonoskii* Maxim	0.283158	0.042474	0.325632	0.469	0.152721	0.076361
223	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.275956	0.041393	0.317349	0.407	0.129161	0.064581
224	*Carpinus tschonoskii* Maxim	0.411493	0.061724	0.473217	0.469	0.221939	0.110969
225	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.194742	0.029211	0.223953	0.407	0.091149	0.045574

228	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.055601	0.00834	0.063941	0.407	0.026024	0.013012
229	*Carpinus tschonoskii* Maxim	0.419702	0.062955	0.482657	0.469	0.226366	0.113183
230	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.06074	0.009111	0.069851	0.407	0.028429	0.014215
231	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.188688	0.028303	0.216991	0.407	0.088315	0.044158
232	*Carpinus tschonoskii* Maxim	0.19821	0.029732	0.227942	0.469	0.106905	0.053452
233(A)	*Carpinus tschonoskii* Maxim	0.359209	0.053881	0.41309	0.469	0.193739	0.09687
233(B)	*Carpinus tschonoskii* Maxim	0.35288	0.052932	0.405812	0.469	0.190326	0.095163
234	*Carpinus tschonoskii* Maxim	0.275714	0.041357	0.317071	0.469	0.148706	0.074353
235	*Carpinus tschonoskii* Maxim	0.308948	0.046342	0.35529	0.469	0.166631	0.083316
236	*Carpinus tschonoskii* Maxim	0.776535	0.11648	0.893015	0.469	0.418824	0.209412
237	*Quercus myrsinaefolia* Blume	0.002651	0.000398	0.003049	0.469	0.00143	0.000715
238	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.086929	0.013039	0.099968	0.407	0.040687	0.020344
239	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.194821	0.029223	0.224044	0.407	0.091186	0.045593
241	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.083599	0.01254	0.096139	0.407	0.039129	0.019564
242	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.226641	0.033996	0.260637	0.407	0.106079	0.05304
243	*Chamaecyparis obtusa* (Sieb. Et Zucc.) Endl.	0.06037	0.00905	0.06942	0.407	0.02825	0.006425

Total Carbon Content= 2.185036

Table 12, Carbon Content of the Species in Plot B2

TN(B2)	Species name	AGV (m^3)	BGV (m^3)	AGV+BGV	WD(t/m^3)	TDW (t)	TCC (t)
D400	*Swida controversa* (Hemsl.) Sojak.	0.268194	0.040229	0.308423	0.469	0.14465	0.072325
D401	*Chamaecyparis obtusa* (Sieb. Et Zucc)	0.170849	0.025627	0.196476	0.407	0.079966	0.039983
D402	*Swida controversa* (Hemsl.) Sojak.	0.271255	0.040688	0.311943	0.469	0.146301	0.073151
D403	*Carpinus tschonoskii* Maxim	0.140738	0.021111	0.161849	0.469	0.075907	0.037954
D404	*Cryptomeria japonica* (L. fil.) D. don	0.354302	0.053145	0.407447	0.314	0.127938	0.063969
D405	*Cryptomeria japonica* (L. fil.) D. don	0.431704	0.064756	0.49646	0.314	0.155888	0.077944
D406	*Swida controversa* (Hemsl.) Sojak.	0.17345	0.026018	0.199468	0.469	0.09355	0.046775
D407	*Prunus jamasakura* Sieb. Ex Koidz.	0.11353	0.01703	0.13056	0.469	0.061232	0.030616

D408	*Cryptomeria japonica* (L. fil.) D. don	0.230965	0.034645	0.26561	0.314	0.083401	0.041701
D409	*Swida controversa* (Hemsl.) Sojak.	0.300869	0.04513	0.345999	0.469	0.162274	0.081137
D410	*Swida controversa* (Hemsl.) Sojak.	0.126299	0.018945	0.145244	0.469	0.068119	0.03406
D411	*Swida controversa* (Hemsl.) Sojak.	0.505005	0.075751	0.580756	0.469	0.272374	0.136187
D412	*Carpinus tschonoskii* Maxim	0.504559	0.075684	0.580243	0.469	0.272134	0.136067
D413	*Swida controversa* (Hemsl.) Sojak.	0.30387	0.045581	0.349451	0.469	0.163892	0.081946
D414	*Cryptomeria japonica* (L. fil.) D. don	0.279241	0.041886	0.321127	0.34	0.100834	0.050417
D415	*Cryptomeria japonica* (L. fil.) D. don	0.093185	0.013978	0.107163	0.314	0.033649	0.016825
D416	*Quercus myrsinaefolia* Blume	0.247102	0.037065	0.284167	0.469	0.133274	0.066637
D417	*Cryptomeria japonica* (L. fil.) D. don	0.248917	0.037338	0.286255	0.314	0.089884	0.044942
D418	*Cryptomeria japonica* (L. fil.) D. don	0.357776	0.053666	0.411442	0.314	0.129193	0.064596
D419	*Swida controversa* (Hemsl.) Sojak.	0.12092	0.018138	0.139058	0.469	0.065218	0.032609
D420	*Cryptomeria japonica* (L. fil.) D. don	0.221183	0.033177	0.25436	0.314	0.079869	0.039935
D421	*Cryptomeria japonica* (L. fil.) D. don	0.44524	0.066786	0.512026	0.314	0.160776	0.080388
D422	*Cryptomeria japonica* (L. fil.) D. don	0.314407	0.047161	0.361568	0.314	0.113532	0.056766
D423	*Swida controversa* (Hemsl.) Sojak.	0.149071	0.022361	0.171432	0.469	0.080401	0.040201
D424	*Swida controversa* (Hemsl.) Sojak.	0.275899	0.041385	0.317284	0.469	0.148806	0.074403
D425	*Swida controversa* (Hemsl.) Sojak.	0.170547	0.025582	0.196129	0.469	0.091985	0.045992
D426	*Cryptomeria japonica* (L. fil.) D. don	0.186154	0.027923	0.214077	0.314	0.06722	0.03361
D427	*Carpinus tschonoskii* Maxim	0.048834	0.007325	0.056159	0.469	0.026339	0.013169
D428	*Swida controversa* (Hemsl.) Sojak.	0.270928	0.040639	0.311567	0.469	0.146125	0.073063
D429	*Swida controversa* (Hemsl.) Sojak.	0.413365	0.062005	0.47537	0.469	0.222948	0.111474
D430	*Cryptomeria japonica* (L. fil.) D. don	0.338682	0.050802	0.389484	0.314	0.122298	0.061149
D431	*Swida controversa* (Hemsl.) Sojak.	0.274457	0.041169	0.315626	0.469	0.148028	0.074014
D432	*Cryptomeria japonica* (L. fil.) D. don	0.132095	0.019814	0.151909	0.314	0.0477	0.02385
D433	*Carpinus tschonoskii* Maxim	0.11755	0.017633	0.135183	0.469	0.063401	0.0317
D434	*Cryptomeria japonica* (L. fil.) D. don	0.503513	0.075527	0.57904	0.314	0.181819	0.090909
D435	*Prunus jamasakura* Sieb. Ex Koidz.	0.740875	0.111131	0.852006	0.469	0.399591	0.199795
D436	*Swida controversa* (Hemsl.) Sojak.	0.539697	0.080955	0.620652	0.469	0.291086	0.145543

Total Carbon Content=2.425

Appendix-E

Sample Questionnaire for Interview Survey of NPO and local people. Here, local people means those people who are staying generations in Oaota area, mainly the farmers were the respondents of the survey. Keeping in mind the questions were asked with the help of native speaker. The survey was conducted on May to June 2012. The information was then compiled. (Q.8-11 were not asked to local people).

Q.1 Age

Q.2 Occupation

Q.3 Do you use wood fuel for household energy?

Yes No

Q.4 Are you interested to use wood biomass of the forest?

Yes No

Q.5 What benefit do you want to get from the Oaota forest?

Q.6 What type of forest do you like Oaota to be?

Q.7 Do you use compost for the agricultural work?

Q.8 Who should take the leading role for the management of Oaota forest?

Q.9 What are the species do you prefer to retain in Oaota forest? Why?

Q.10 Do you want to harvest some wood from the Oaota forest and when (felling cycle)?

Q.11 Do you need any support from the government.