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ABSTRACT

A study of estimating of tree biomass and carbon stock in different restoration years was conducted at Mufu mountain in Nanjing, Jiangsu province. There are three plots for different period of restoration years on 1999, 2004 and 2008, respectively. This study was conducted at nine(9) subplots with 0.01 ha each. A total of 11 species from 10 genera of deciduous and evergreen broadleaved forest were recorded. All trees with diameter breast height (DBH) of ≥ 10cm were enumerated. *Wisteria sinesis* has the highest number of species with 10 species followed by *Magnolia denudate*, *Ligustrum lucidumis* and *Brounssoneta papyrifera.* As result, deciduous species were dominant than evergreen broadleaved species. The estimated biomass for restoration year 1999 was 60.5 t/ha, Restoration year 2004 recorded 100.9 t/ha and restoration year 2008 contributed 116.7 t/ha. Therefore, carbon stock for restoration year 1999 was 30.2 t C/ha, restoration year 2004 contributed 50.4 t C/ha and restoration year 2008 recorded 58.3 t C/ha. Thus, Mufu mountain can play serve as a carbon stock and provide other ecosystem services, it plays an important role in providing social, economic and environmental synergies benefit, and Mufu mountain forest can help to mitigate Nanjing city's climate change. However, Mufu mountain forest in Nanjing could also act as carbon stock.

Keywords: biomass, carbon stock, allometric equation, deciduous, evergreen broadleaved, Mufu mountain.

摘要

在江苏省南京市幕府山 1999、2004 和 2008 年三个时期不同恢复时期的树种生物量和碳储量进行了研究和评价。每个恢复期限设置 3 个 0.01 公顷的样方，共 9 个样地。样方中共记录落叶和常绿阔叶林树种 10 属，11 种。所有的树木胸高直径（DBH）中列举了≥10cm。在 11 种树种中紫藤具有最多的数量，其次是白玉兰、山腊树和构树。得出的结果是，落叶树种的数量远多于常绿阔叶树种。1999 年恢复区域的生物量为 60.5 吨/公顷，2004 年恢复区域的生物量为 100.9 吨/公顷，2008 年恢复区域的生物量为 116.7 吨/公顷。1999 年、2004 年和 2008 年恢复区的碳储量分别为 30.2 吨/公顷、50.4 吨/公顷和 58.3 吨/公顷。因此，幕府山可以发挥提供一个碳储量和其他生态系统服务的作用，它在社会、经济与环境的协同效益中起着重要的作用，且幕府山森林可以帮助减缓全球气候变化。在南京幕府山的森林也可以作为南京市的碳源。

关键词：生物量、碳储量、回归方程、落叶树种、常绿阔叶树种、幕府山

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Batbold Batchimeg

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LIST OF ABBREVIATIONS

AE	Allometric equation
AGB	Aboveground biomass
BA	Basal area
BGB	Belowground biomass
BEF	Biomass expansion factor
C	Carbon
CO_2	Carbon dioxide
DBH	Diameter at breast height
D	Deciduous
FAO	Food and agriculture organization
SG	Specific gravity
H	Height
V	Volume of tree
EB	Evergreen broadleaved
TV	Tree volume
Ws	Weight of stem
Wb	Weight of branch
Wl	Weight of leaf
UNFCCC	United Nations Framework Convention on climate Change
ha	Hectare
GHG	Greenhouse gases

CHAPTER I

INTRODUCTION

1.1 Forestry in China

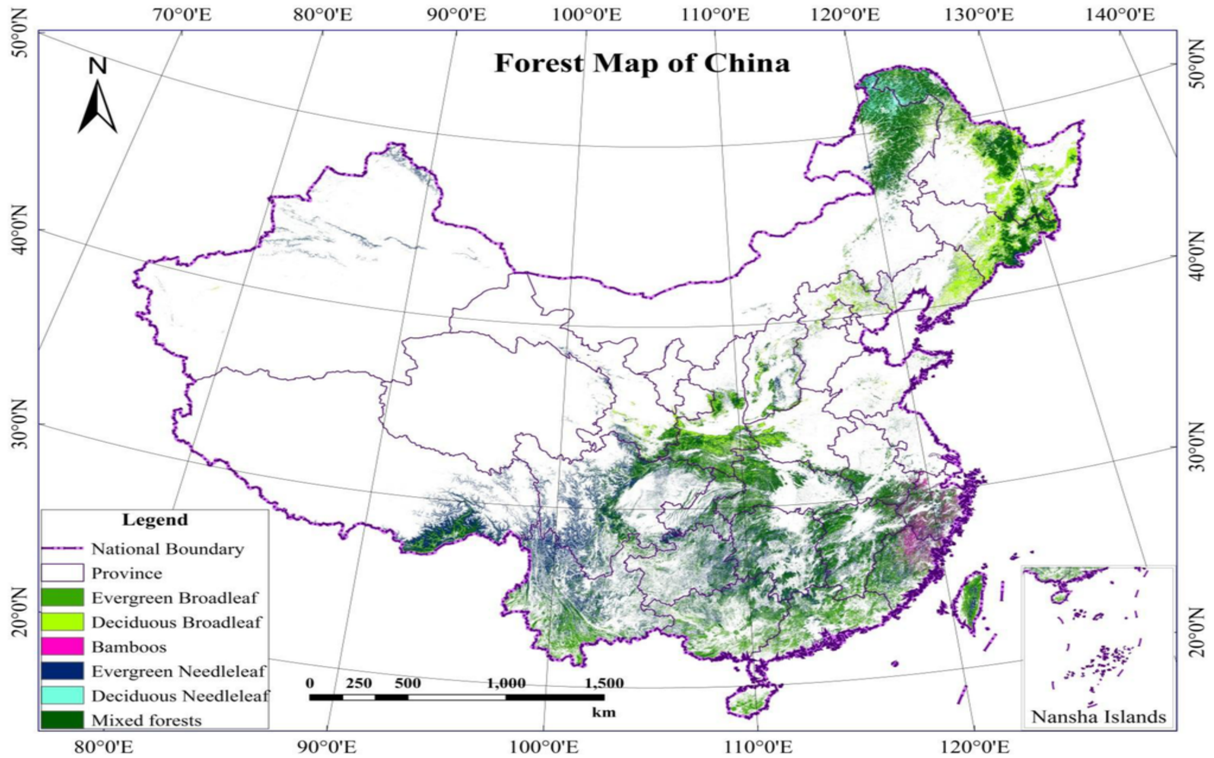
The territory of China lies approximately between major factors in the formation of complex and diverse climate as well as topography. Precipitation decreases from the coast to the inland areas. Three vegetation regions, namely forests, steppes, and deserts, correspond to moist, semi-arid, and arid climates, respectively (Zhong 1986). According to Chinese vegetation geography (Hou et al., 2001, Wu 1980) and geographic characteristics of forests, Chinese forests have been divided into five forest zones (Figure 1.1): Cold temperate zone (I), which is dominated by deciduous needle leaf forests; temperate zone (II), which is characterized by deciduous mixed broadleaf-needle leaf forests; warm temperate zone (III), including China's largest plain, with secondary broadleaved-mixed forests and intensive agricultural activity; subtropical zone (IV), with large formations of evergreen broadleaf forests (the western region of the subtropical zone is dominated by high mountains and affected by the southwest monsoon, while the eastern region is dominated by hills and affected by the southeast monsoon); tropical zone (V), whose annual average temperature is over 22 °C and average annual precipitation is above 1500 mm. Two other vegetation zones (not dominated by forests) were also used in this study (Figure 1): The Neimeng-Xinjiang arid zone (VI), which is distinguished by *Picea* and *Larix* in the Tianshan, Altai, and Qilian Mountain regions (most land areas in this zone are covered by steppes and deserts due to a continental climate with severe annual variations in temperature); and the Qinghai-Xizang plateau alpine zone (VII), which retains the largest area of virgin forest in China.

Therefore, the sixth national enumeration of forest resources (1999-2003) showed that China's total forest area was 175 million hectares, and its forest coverage rate was 18.21 percent. The total standing stock volume of China was 13.62 billion cubic meters. The stock volume of its forests stood at 12.46 billion cubic meters. Natural forests are concentrated in the northeast and the southwest, but scarce in the densely inhabited and economically developed eastern plains and the vast northwestern region. The forests in China are rich in tree species, with the number of arbor species alone exceeding 2,800. Rare and peculiar species include ginkgo and metasequoia (dawn redwood). In order to conserve environment and meet the needs of economic development, China has launched large-scale afforestation campaigns. The area of planted forests has reached

33.79 million hectares, accounting for 31.86 percent of the nation’s total forest area, making China a country with the largest area of planted forest in the world.

In addition, China, as one of the world’s fastest developing countries, needs to produce robust estimates of forest biomass and carbon stocks for successful implementation of climate change mitigation policies.

As one of the five most forest-rich countries (FAO 2013), China is rich in temperate forests and subtropical forests. Timely and accurate measurements of forest biomass and its distribution are increasingly needed to support a wide range of activities related to sustainable forest management and carbon accounting. Previous studies on estimates of forest biomass in China were based on statistical analysis of the biomass-volume relationship based on nationwide forest inventory data (Fang et al., 1998, Goetz et al., 2009). Despite the high precision of such inventories, they do not provide maps of biomass at a resolution useful for assessing land-use change. An AGB map of China with clear and detailed spatial distribution is urgently needed. However, the benchmark map of Saatchi *et al.* (Saatchi et al., 2013) did not cover the entire land of China. Similarly, the pan-tropical map generated by Baccini *et al.* only covered the area in southern China (below 30°N). More importantly, no field survey samples from the Chinese territory were included in the two studies.



Source: Li, C et al., 2010.

Figure 1.1 Forest map of China

Despite a forest cover of 175 million ha and a standing timber stock of 12.5 billion m^3 that place the country respectively at the fifth and the seventh world rank, China can still be considered forest-deficient. Its resources account for only 4% of world forests and less than 3% of world timber stock (FAO, 2003). Although China's forest coverage has recently increased up to 18.2%, it remains at half of the world average and China's forested area per capita of 0.13 ha is far below the world average of 0.65. Timber stock comparisons highlight similar gaps because the standing stock volume amounts to less than 10 m^3 per capita, whereas the world average stands at approximately 66. The forest deficit that characterizes China is the outcome of a long history of deforestation, which particularly intensified after the founding of the People's Republic in 1949. Both the quantity and the quality of forest resources in China sharply decreased during the collectivization period (1958- 82), notably during the Great leap forward and the Cultural Revolution. The deforestation trend has been even further exacerbated at the beginning of the 1980s, after economic transition from a planned system to a market economy started. In particular, insecure ownership rights over trees granted to rural households have led to massive forest clearings by the contracting farmers. At the same time, China's sustained economic growth during the reform period has led to a surge in demand for forest products, although per capita consumption of wood products remains low by international standards. The construction boom including house building in both cities and rural areas, and the rising demand for educational and cultural activities have been important factors driving the sharp increase in demand and in quality requirements for wood materials, furniture, paper and paperboard. Most recently, the national forest policy has been further shifted towards conservation with the launching of Six National Key Forest Programs from the end of the 1990s, which aim at restoring, conserving, expanding and commercially developing China's forests, especially in ecologically sensitive areas such as Yangtze and Yellow Rivers' areas in the western region. Moreover, the surge of Chinese imports is reported as causing severe ecological degradation and threatening the livelihood of local people in supplying countries, especially in the Asia-Pacific region where China is the dominant trade partner of many countries for forest products. Under these perspectives, any change in China's timber supply and demand may have important environmental, economic and social implications not only in China but also in the rest of the world.

1.1.1 Southern forest in China

Forests of southern China are distributed widely in tropical and subtropical areas. The forest biomass are mainly rainforest, monsoon and evergreen-broadleaf forests. The species composition of them is complicated and there are a lot of precious tree species and fast growing which have already been introduced well as artificial forest. In the aspect of diameter, most of trees are median and small-diameter trees (Nemoto, M.,1989) . At one time, a large scale of forests in southern China was destroyed by artificial disturbances, the main reason of which had been usage of fuel wood by local people and wood industry. Once vegetation was damaged, the landscape would be changed to devastate due to the degradation of surface soil (Wang 1984). Chinese government has realized the seriousness of forest loss and carried out a large number of afforestation and/or reforestation programs, such as the protective forest program on the middle upper basin of the Changjian River and so on.

Recent years, the intensive afforestation and reforestation are also conducted widely in southern China. Some of the reforestation conservation of natural forests and restoration of degraded land projects have been focused on ecological services of forest, such as the function of carbon sequestration of forests that is a governmental issue based on the 12th Five-Year Plan of China.

There is less information on carbon stock in Chinese forests and the general method to evaluate the carbon stock has been required. Usually, in order to estimate the carbon sequestration or biomass in each target site, destructive sampling method, harvesting and weighing of sample trees, might be needed. If the general allometric relations, diameter at breast height (DBH) and tree biomass, to regional forests could be available, it would not be necessary to cut down sample trees in various areas.

1.1.2 China Subtropical forest

China's subtropical zone has several unique features, including: (1) a humid and warm climate, even though other regions at the same latitude around the world are extremely arid; (2) a long disturbance history and intensive human activity over large areas that have left almost no mature forest, especially in the eastern coastal region; (3) the most rapid industrialization in China during the past 20 years, especially in the eastern part of the country, but accompanied by the creation of large areas of young forest or rapid conversion of bare land in mountainous areas into forest; (4) the presence of evergreen broad-leaved forest, which differs significantly from other forests in terms of the carbon cycle. There are considerable uncertainties about the carbon budgets in the subtropical forests of eastern China despite several previous studies of forest carbon budgets for the country as a whole using forest inventory data (Fang and Chen, 2001; Wang et al., 2001) and process based models (Cao et al., 2003).

1.1.3 Deciduous and Evergreen forest

Temperate deciduous forests in the northern hemisphere comprise some of the world's most substantial C sinks (Ciais et al. 1995, Myneni et al. 2001), thereby acting to counter anthropogenic increases of atmospheric CO_2 and the associated consequences. Evergreen broadleaved forests are the important natural resource in biodiversity conservation, and play a critical role in global carbon cycling. Currently, shrublands represent a large proportion (approximately 80%) of the vegetation types in subtropical China, due to long-term anthropogenic disturbances (Wang et al. 2005). Evergreen broadleaved forests (EBLFs) are a zonal vegetation type located in subtropical China (Song,Wang 1995; Feng et al. 1999).

1.1.4 Forest Resources of China

China has a vast territory, with abundant natural resources and diverse types of land resources. Its waterpower resources rank first worldwide. It is one of the countries in the world having the most species of wild animals, and has almost all kinds of vegetation found in the Northern Hemisphere. It has abundant mineral resources, with a great variety of minerals.

1.1.5 Land resources

China's land resources exhibit the following basic features: The land resources are large in absolute terms but small on a per-capita basis. There are more mountains than plains, with cultivated land and forests constituting small proportions. Various types of land resources are unevenly distributed among different regions. The cultivated land is mainly in plains and basins in the monsoon regions of east China, while forests are mostly found in the remote mountainous areas in the northeast and the southwest. Grasslands are chiefly distributed on inland plateaus and in mountains.

1.1.6 Cultivated Land

According to the Agricultural Census in 1996, China has 130.04 million hectares of cultivated land and 35.35 million hectares of land suitable for agricultural uses. The cultivated land is mainly distributed in the Northeast China, North China and Middle-Lower Yangtze plains, the Pearl River Delta and the Sichuan Basin.

This study has aimed using the allometric equation to estimating biomass and carbon stock of trees planted at Mufu Mountain forests in Nanjing, to be used to assess the different restoration period as biomass and carbon stock. The area-based estimates equations to assess the accuracy of similar estimates while using existing regional or global equations.

Once the equations for tree biomass, annual wood accumulation and carbon stock are derived, sample plot estimates can be obtained by applying the equations to the sampled plot tree diameter, height data.

1.2 Research framework:

1.2.1 Research questions.

1. How much biomass in different restoration years at Mufu mountain in Nanjing China?
2. How much carbon stock on different period restoration years at Mufu mountain in Nanjing China?
3. Different period restoration years will varied to biomass or not?

1.2.2 Research objectives

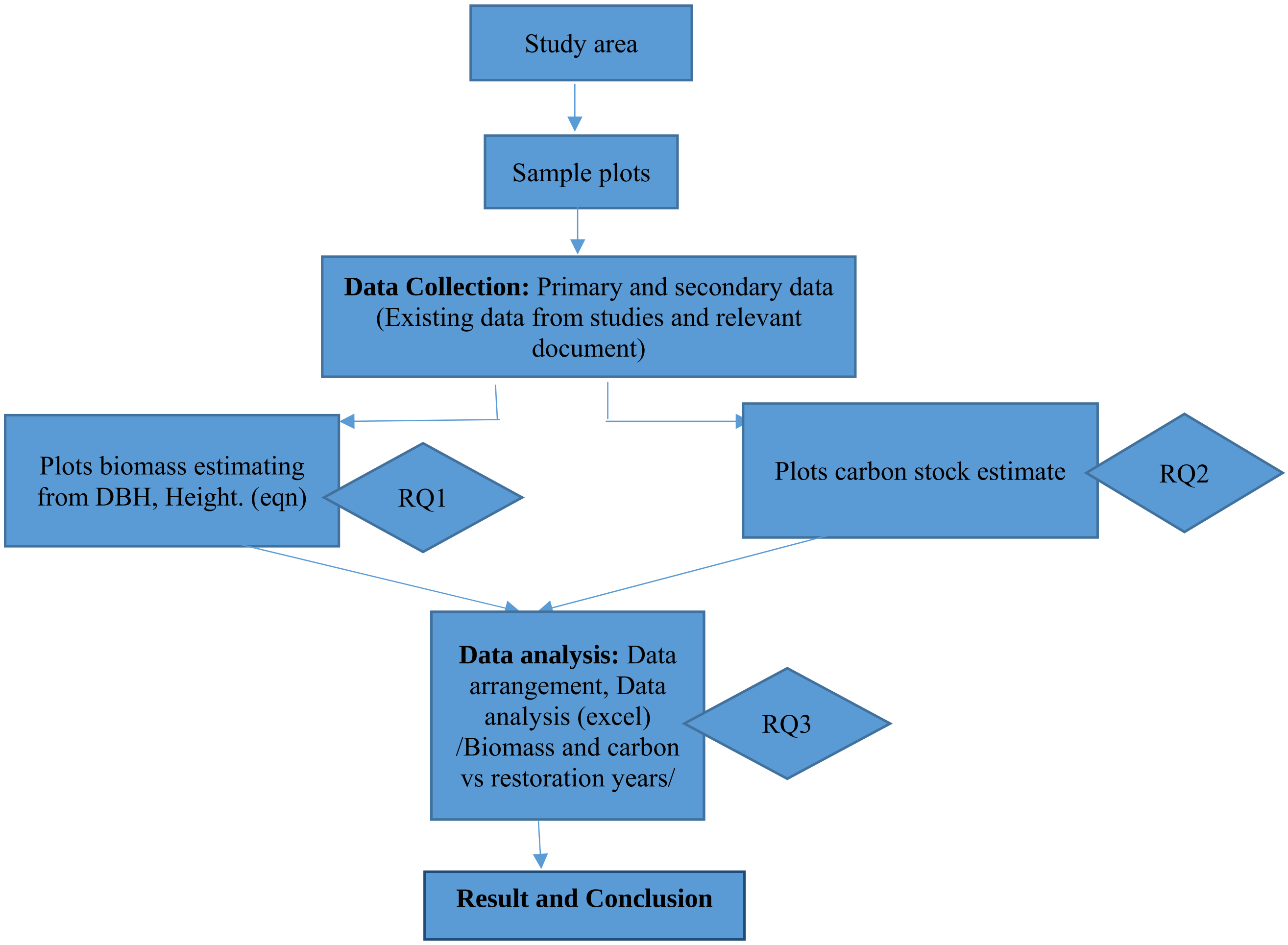
1. To compare and determine the biomass of tree in the Mufu mountain by different period restoration years.
2. To compare and estimate the carbon stock in the Mufu mountain by different period restoration years.

1.2.3 Research hypothesis

1. After different restoration years will be change the tree biomass and carbon stock at Mufu mountain in Nanjing China.

Biomass and carbon stock varies in the different restoration years.

1.2.4 Research approach.



Notes: RQ stand for research questions.

Figure 1.2 Flow diagram of research approach

1.3 Mining and destroyed of forestry in Mufu mountain:

The rising demand of industry and urban construction for building material of Mt. Mufu was mined, primarily as a big quarry, beginning in the 1930s, due to the large amount of high quality dolomite found there. The rate of extraction reached a peak in the 1980s and 1990s, when more than 800,000 t/y were mined.

As a result of long-time quarrying and refuse dumps, which were privately set up around the mountain, a large area of forests was destroyed. As a result, the environment of Mt. Mufu was seriously damaged (Zhao et al., 2005, Wang. J et al., 2011). As a result of long mining quarrying and kangaroo garbage soil field, there are nine quarry in Mufu mountain Mountain quarrying, Mufu mountain quarries and dump only area of 229.19 hectares, and damage is quite serious, form a bare cliff, abandoned mines, stone field, etc., accumulate many stone, slag, garbage, shocking. The terrain is rugged, potholes: Stinking garbage, rags, whenever kawakaze blowing, dust float in the sky, like the north sandstorm comes, the city of Nanjing, the air impact is very serious. Many accumulated slag, always sends out a smell of ammonia and sulfur, because of these reasons make large forest land have been damaged, Mufu mountain was riddled with holes, scarred, garbage piles, around the quarry slag is full, calcareous soil, such as waste soil, one of the biggest baiyun ore mining main from up to 205 meters down to 38 meters, suffered severe damage, the original vegetation ecological environment took place great changes.

In 1998, Nanjing City government decided to implement comprehensive control of the mountain and set up a special administration to conserve the dolomite and restore the vegetation of Mt. Mufu. In the next year, 1999, work at all eight quarries was stopped (Liu et al., 2007). In the same year, the reconstruction project began, and the first period of experimental planting was performed. By 2003, all production of dolomite and work in the related industries had ceased. By 2009, ten periods of planting for the reconstruction project had been carried out over the last 10 years, covering an area of 270hm^2. In that project, the most important task was re-vegetation of the site. Almost 3,000,000 seedlings from up to 100 species were planted to the mountain. Also, a proposal for the construction of a geological cultural park on Mt. Mufu was submitted. Many ecological studies have been done on this system, on such subjects as landscape ecological assessment and planning, restoration and reconstruction of forest vegetation, the dynamics of communities and populations, and biodiversity (Li et al., 2006; Liu et al., 2003, 2006; Zhao et al., 2003, 2005). All of these studies focused on the technology of ecological restoration or some aspects of the restored ecosystem.

An area of particular interest is the capacity of these restored forests to absorb atmospheric carbon dioxide and thereby enhance their role as a carbon stock. Accurate estimates of carbon stock in these restored forests require development of equations for accurately estimating tree biomass in mixed species stands.

In this research main goal is estimating to biomass and carbon stock after restoration in Mufu mountain. Firstly, all selected individuals and representing size were located Mufu mountain, we were measured diameter at breast height (DBH) and height (H) of all sample trees on the three different restoration years for 1999, 2004 and 2008.

CHAPTER II

LITERATURE REVIEW

2.1 Estimated biomass and carbon stock.

2.1.1 Estimated for biomass

Forest biomass, expressed in terms of dry weight of living organisms, is an important parameter for analyzing ecosystem productivity and also for assessing energy potential and the role of forests in the carbon cycle (FAO, 2010). According to Golley (1983) tree biomass for the rain forest ecosystem was the highest value of about 415 t/ha in the world, almost 90 % of which is represent for stem, 2 % for leave and 9 % for root. Biomass is defined as the total amount of living organic matter in trees and expressed in tonnes per hectare. The term has been widely used as a unit of yield since the 1970s as it is a more useful parameter than volume as it allows comparisons among different trees and tree components (Brown, 1997).

In addition, FAO (2005) has defined biomass as “the organic material both above and below the ground, and both living and dead, e.g, trees, crops, grasses, tree litter, roots, etc”. Above ground biomass may be defined as a combination of all tree components above ground level and is important in estimating the productivity of a forest (Kato *et.al*, 1978).
AGB includes all living biomass above the soil, while Below-ground biomass (BGB) includes all biomass of live roots excluding fine roots (<2 mm diameter). Above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter are the main carbon pools in any forest ecosystem. (FAO, 2005; IPCC, 2003; IPCC, 2006). Majority of biomass assessments are done for AGB of trees because these generally account for the greatest fraction of total living trees diameter at breast height (DBH) higher than 1.3 m. The AGB, thus defined, often make the field work more practical and reduces the risks of measurement errors (e.g double counting or omitting of trees in sample plots), especially in dense forests. Excluding the foliage biomass is justifiable as such biomass store carbon only temporarily.

Forest biomass is also useful for sustainable management of the forest, assessing forest structure and condition, and estimating forest productivity and carbon fluxes based on sequential changes in biomass (Brandeis et al. 2006; Cole and Ewel 2006). In the developing countries, about 38 % of the primary energy consumption is accounted by the forest biomass (Sims 2003), therefore, the evaluation of biomass stocks is an important management strategy for the recovery of the such forests. Moreover, for the successful implementation of mitigating policies to take advantage of the REDD (Reducing Emissions from Deforestation and Forest Degradation) program of United Nations Frame-work Convention in Climate Change (UNFCCC), these countries should have well-authenticated estimates of forest carbon stocks (Miah et al. 2011; Chaturvedi et al. 2011a).

Disturbances such as forest cutting and wood extraction affect the balance of this balance of carbon fixation in to rest ecosystems because forests become sources of CO2 to the atmosphere (Brown, 2002). The removal species with high wood density, large trunk diameter and high basal area may deplete carbon stock in forests up to 70% (Bunker *et al.*, 2005).

In natural conditions, carbon release is caused by respiration and decomposition biomass evaluation across world regions may help monitor carbon stocks and identify the impact of these changes in natural ecosystems. Aboveground plant biomass found in forests is mostly comprised of trees of different sizes and also of shrubs and herbs in the understory. Trees with diameter at breast height (DBH) higher than 10 cm comprise the vast majority of forest biomass, in many cases exceeding 90% of the total aboveground biomass. Also biomass accumulation is determined by net primary productivity, which consists of what is produced through photosynthesis and lost in plant respiration (Clark *et al.,* 2001). Compared to other terrestrial vegetation types, forests have higher rates of carbon fixation, due to greater accumulation in trees (Houghton, 2007).

These results come from the fact that wood is an important carbon reservoir in terrestrial ecosystems and represents around 50% of forest biomass (Houghton, 2007). Wood density is also a factor that can influence the amount of biomass stored in forests since it is an indicator of life history strategies that vary with ecosystem conditions (Muller-Landau, 2004). Wood density is influenced by tree species (Henry *et al.*, 2010).

Biomass storage, on the other hand, increases in advanced stages (Pregitzer and Euskirchen, 2004) where there is a marked presence of large diameter trees that accumulate higher biomass (Baker *et al.*, 2004b) and a high frequency of slow growth species. The production and accumulation of plant biomass is largely affected by the factors that influence productivity, such as latitude, altitude, precipitation and temperature. Regional or even local differences may influence a range of other factors, from variations in temperature, rainfall seasonality and soil type, to structure, floristic composition and disturbance regimes. Many studies have focused on the relationship between environmental variables and biomass production, indicating positive correlation between temperature, rainfall homogeneity (reduced seasonality) and soil fertility, with productivity, therefore elevating biomass storage (Laurance *et al*., 1999; Ter Steege *et al*., 2003; DeWalt and Chave, 2004; Raich *et al*., 2006; Saatchi *et al*., 2007). The accurate quantification of plant aboveground biomass (AGB) and belowground biomass (i.e., roots) is crucial for the evaluation of ecosystem carbon storage, and toward understanding carbon dynamics in response to global climatic changes (Flombaum and Sala 2007; Brassard et al. 2009)

According to Zhang et al. (2012) the study for seven plots located in subtropical secondary forest in the Yangdongshan Shierdushui Forest Reserve, Lechang, in the Nanling Mountains of southern China recorded AGB ranged from 65.5 t/ha to 124.5 t/ha. There are six vegetation types in the reserve: coniferous and broadleaved mixed forest, evergreen and deciduous forest, shrubs, grass and bamboo forest. The main vegetation type is subtropical evergreen broadleaved forest.

Previous study done by Zhang et al (2007) with main objective of that study was to evaluate the contribution of these forests to regional carbon storage and explore their carbon sequestration potential after ecosystem restoration. That study sampled 149 stands from 6 to 41 years old, covering 101,800 km^2, in Zhejiang Province, in China's eastern subtropical zone. The samples included four types of ecological service forest (ESF): evergreen broad-leaved forest, coniferous and broad-leaved mixed forest, pine (*Pinus massoniana*) forest, and Chinese fir (*Cunninghamia lanceolata*) forest. The mean values of biomass in evergreen broad-leaved forest, coniferous and broad-leaved mixed forest, pine forest, and Chinese fir forest were 89.19, 70.06, 51.25, and 54.15 t/ha, respectively. The net primary productivity (NPP) for the four types of ESF ranged from 4.41 to 8.35 t ha year. Carbon densities for the four types of ESF were lower than the mean values (36–57.07 t C ha) for China because the ESFs are relatively young in Zhejiang Province. Overall, biomass, litter production, NPP, and carbon density were all significantly lower in pine forest and Chinese fir forest than in evergreen broad-leaved forest, whereas the values for the coniferous and broad-leaved mixed forest were intermediate. These results suggest that the evergreen broad-leaved forest has great potential for offsetting CO2 emissions, and that promoting succession from coniferous forests to evergreen broad-leaved forest can enhance carbon sinks in the forests of subtropical China.

Based on study connected by Terakunpisut et al. (2007), study assessed the potential of carbon sequestration on aboveground biomass in the different forest ecosystems in Thong Pha Phum National Forest, Thailand. The assessment was based on a total inventory for woody stem at 4.5 cm diameter at breast height. Aboveground biomass was estimated using allometric equation and aboveground carbon stock was calculated by multiplying the 0.5 conversion factor to the biomass. As the results of that study, carbon sequestration showed varied in different types of forests. Tropical rain forest (Ton Mai Yak station) higher carbon stock than dry evergreen forest (KP 27 station) and mixed deciduous forest (Pong Phu Ron station) as 137.73± 48.07, 70.29± 7.38 and 48.14±16.72 tonne C/ha, respectively. Habitat variability caused differences of biomass accumulation, species composition and the allometric relationships of forests. In the that study area was, all forest had a similar pattern of tree size class, with a dominant size class at 4.5- 20 cm. The 4.5- 20 cm trees potentially provided a greater carbon sequestration in tropical rain forest and dry evergreen forest while the size of > 20- 40 cm gave potentially high carbon sequestration in mixed deciduous forest. Due to the trees have the lowest carbon sequestration but they considerably grow up to the further size classes. Apparently, they will be able to increase more biomass accumulation and store more carbon. In conclusion, the greatest carbon sequestration potential is in mixed deciduous forest and followed by tropical rain forest and dry evergreen forest in Thong Pha Phum National Forest. Finally, the appropriate forest ecosystem management can be an alternative solution for carbon dioxide reduction in terms of carbon sink role.

2.1.2 Estimated for carbon stock

Carbon stored in forest biomass has been increasingly attracting attention in recent decades, as deforestation and tropical land-use change lead to significant emissions of greenhouse gases (Fearnside 2000). A new international climate mechanism was proposed with the aim of providing financial incentives to developing countries to reduce carbon emissions from deforestation and forest degradation; this mechanism was called REDD (Gibbs et al. 2007; Brown and Bird 2008).

The carbon cycle of terrestrial ecosystems plays a key role in regulating CO2 concentration in the atmosphere (Moore and Braswell, 1994; Dixon et al., 1994; Houghton et al., 2000). Thus, enhancing carbon storage in terrestrial ecosystems, and especially in forests, will be a key factor in the maintenance of the atmosphere's carbon balance. Though not required by the Kyoto Protocol, China has planned to reduce carbon emissions, and determining how to increase the country's carbon sequestration capability will be an important issue in regional carbon budgets (IGBP Terrestrial Carbon Working Group, 1998; Liu and Diamond, 2005).

Accurately quantifying forest carbon stock sand flux is crucial for understanding the forest ecosystem services and the importance of forests on global climate (Watson 2000, Fang et al. 2001). The forest sink is large based on recent studies, but varies with locations (Pan et al. 2011). Previous results show that the forests in high latitudes are carbon sinks (Myneni et al. 2001), but data on carbon circles of subtropical forest are lacking.

Accurate estimation of forest biomass C stock is essential to understand carbon cycles. However, current estimates of Chinese forest biomass are mostly based on inventory based timber volumes and empirical conversion factors at the provincial scale, which could introduce large uncertainties in forest biomass estimation. Studied done by Yin et al. (2015) using Moderate-Resolution Imaging Spectroradiometer showed Chinese forest aboveground biomass is 8.56 Pg C, which is mainly contributed by evergreen needle-leaf forests and deciduous broadleaf forests. The mean forest aboveground biomass density is 56.1 Mg C ha, with high values observed in temperate humid regions. The responses of forest aboveground biomass density to mean annual temperature are closely tied to water conditions; that is, negative responses dominate regions with mean annual precipitation less than 1300 mm a year and positive responses prevail in regions with mean annual precipitation higher than 2800 mm a year. During the 2000s, the forests in China sequestered C by 61.9 Tg C y−1, and this C sink is mainly distributed in north China and may be attributed to warming climate, rising CO2 concentration, N deposition, and growth of young forests.

Therefore, Previous study done by Zhang et al (2013) for twenty-one individuals from 16 tree species were harvested to measure the above-ground biomass, which consist of each organ of trunks, branches and leaves. The coefficients of correlation between tree diameter at breast high (DBH) and each organ showed high values, ranging from R2=0.894 to 0.973. It was also found a relatively high correlation between DBH and total above-ground, of which the coefficient is 0.978. They calculated above-ground biomass 60.1 Mg ha-1 based on the equation of that study which is similar with other above-ground biomass determined by different authors for secondary subtropical forest.

Forestry is only the major option for carbon sequestration in the terrestrial ecosystem among agricultural systems and agroforestry systems (Kalpan 2003 cited from Singh 2005). Human activities such as forest removal and fossil fuel emission are major sources of CO2, causing changes in global climate and atmospheric composition (Brown *et al.*, 1989).

Plants store carbon for as long as they live, in terms of live biomass. Once they die, the biomass becomes a part of the food chain and eventually enters the soil as soil carbon. Carbon accumulation potential in forests is large enough that forests offer the possibility of sequestering significant amounts of additional carbon in relatively short periods-decades (Luxmoore 2001). The carbon sequestration process involved in individual tree is an important concern in environmental system (Sedjo & Marland 2003). So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as CO_2 emission, has a long term influence and impact. Therefore, the sustainable forest, as a carbon stocks, is the key factor to balance the GHGs emission (Levy et al. 2004). The process of carbon sequestration is the most rapid during the early stage of the life of tree while, as tree reaches maturity the above two processes become increasingly similar. Additionally, the rate of carbon sequestration is less particularly in over mature stage of the tree. Hence, the tree or forest expands the capacity of carbon sequestration also increases and vice-versa (Sedjo & Marland 2003). Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where GHGs is stored, as well stock (Pearce et al. 2003). Thus the forest is the complement of carbon sequestration. Conclusively, sustainable forests are reliable sinks of GHGs (Levy et al. 2004). Among these, the community forest management which is a successful example of sustainable forest management is the preferable option of carbon sequestration, primarily in developing countries (Klooster & Masera 2000).

Previous study, by (Zhang et al., 2007) the mean values of carbon stocks for Chinese forests range from 36-57.07 t C/ha. Using the national forest inventory data of China from 1949 to 1998, Fang et al., (2001) estimated the average carbon stocks of the north-east Chinese forests to be approximately 50 t C/ha. Tan et al., (2007) reported the average carbon stocks of nearly 55 t C/ha in Changbai mountain system that also covers the study area. Fang et al., (2006) reported that inventory-based forest carbon stock documented for major countries in the middle and high northern latitudes fall within a narrow range of 36-56 tons/ha with an overall area-weighted mean of 43.6 tons/ha. The average vegetation carbon density for all forests of Europe, USA and Japan at similar latitudes are 32, 61 and 34.7 ton/ha respectively (Zhang et al., 2007). Fang and Wang (2001) pointed out that forest carbon density in major temperate and boreal forest regions in the Northern Hemisphere has a narrow range from 29 to 50 ton/ha with global mean of 36.9 ton/ha.

Thus, the scope of the problem of Climate Change global response is contained in the United Nations Framework Convention on Climate Change adopted at the World Summit on Sustainable Development called “Earth Summit held in Rio de Janeiro, Brazil in 1997 and the Kyoto Protocol adopted at the third session of the conference of the Parties in December 1997 in Kyoto, Japan. Decisions which aimed at stabilizing concentrations of greenhouse gases in the atmosphere at a level which prevents dangerous interference with the global climate system were taken. Since the 13th Conference of the Parties (COP13) to the United Nations Framework Convention on Climate Change (UNFCCC) in Bali in 2007, the UNFCCC has progressively recognized the package of measures now known as REDD+, which stands for Reducing Emissions from Deforestation and forest Degradation, as well as the conservation and sustainable management of forests, and the enhancement of forest carbon stocks in developing country forests. At the COP16 in Cancun in 2010, REDD+ was officially incorporated into the UNFCCC’s agreement on climate change. At COP17 in Durban in 2011, negotiators agreed on monitoring guidelines as safeguards for REDD+ implementation and on the means for developing estimates of emissions that would have occurred in the absence of REDD+ (Barnes et al. 1998).

CHAPTER III

MATERIALS AND METHODS

3.1 Study area

Mufu mountain is located in the northwest region of Nanjing City, Jiangsu Province in China (118°44’58”–118°51’06”E, 32°07’47”–32º10’00”N) Figure 3.1. It lies along the southern bank of Yangtze River. The length of Mt. Mufu is about 6 km, and the width is about 1.5 km^2. The total area of the scenic zone is 7.08km^2. The mountain has five peaks, and the tallest peak, Bei Gu is 199.3 m. The main natural recovery structure of woods, artificial restoration of Mufu mountain are acacia, PiaoShuLin, etc. *Broussonetia papyrifera* a pioneer tree species. Since Mufu mountain natural vegetation’s was disturbed, *Broussonetia papyrifera* becomes the main vegetation in mine spoils of mufu mountain forest recovery currently. The arborous layer of recovery vegetation in mufu mountain are compose of *Broussonetia papyriera*, *Celtis tetrandra*, *Acer ginnada, Quercusa cutissima, Cudrania tricuspidata, Sapiumsebiferum, Platycarya strobilacea*, *Ulmus pumila* and artificial cultivation were *Robinia pseudoacacia* etc. Understory shrubs was composed of *Alangium chinense, Zanthoxylum planispium, Rhamnus davurica, Symplocos candata*, *Morus alba* etc. Forests of sapling are composed of *broussonetia papyrifera* and hackberry. *Broussonetia papyrifera* play an important role in the community which decide the current satiation of community and in the future.

The climate here belongs to humid northern sub-tropical climate. The mean annual temperature is about 15.5ºC. The average temperature of the hottest month is 28ºC, and the average temperature of the coldest month is −2.9ºC. The mean annual rainfall is 900–1100mm and the frost free period is about 237d.

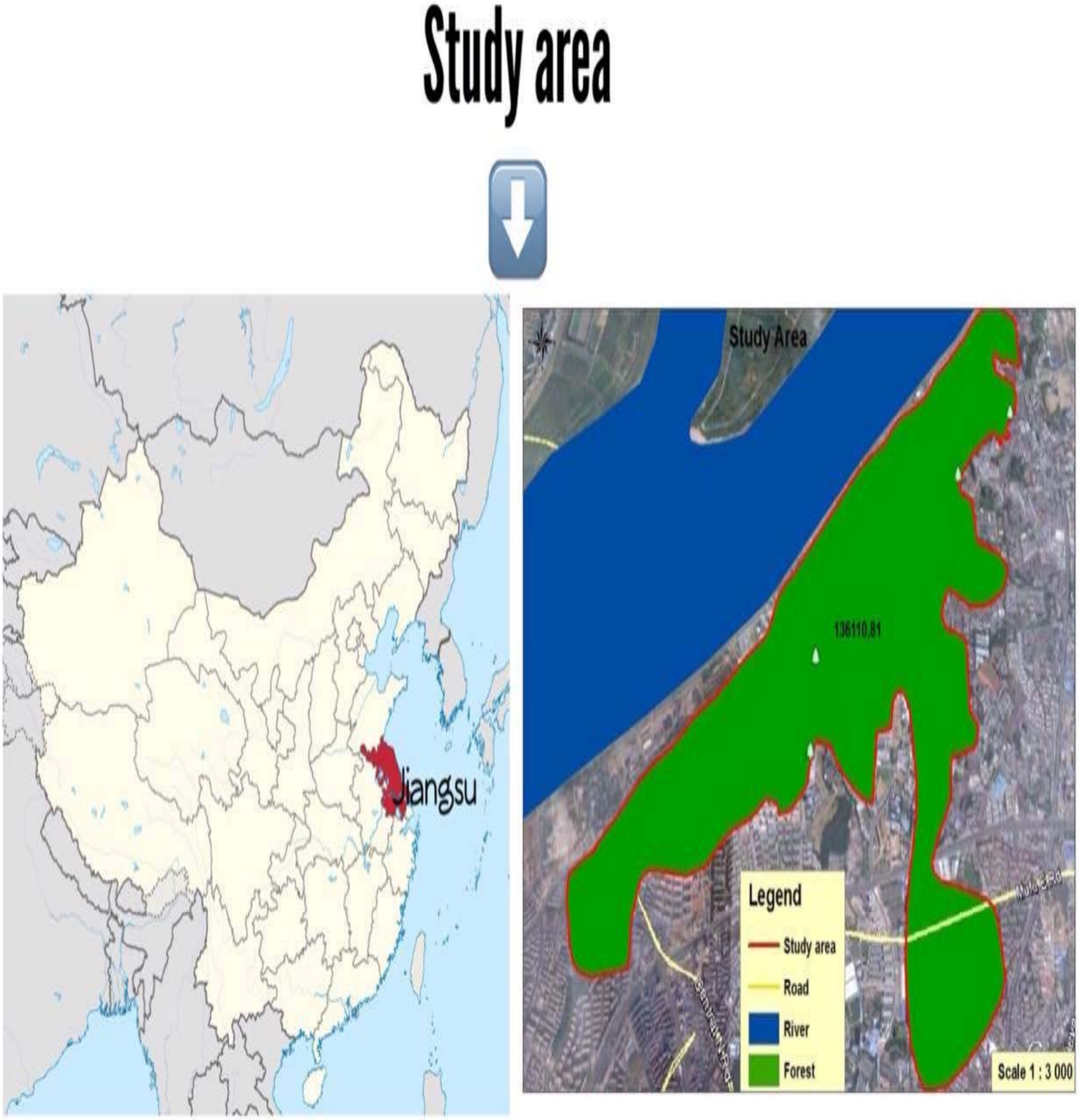


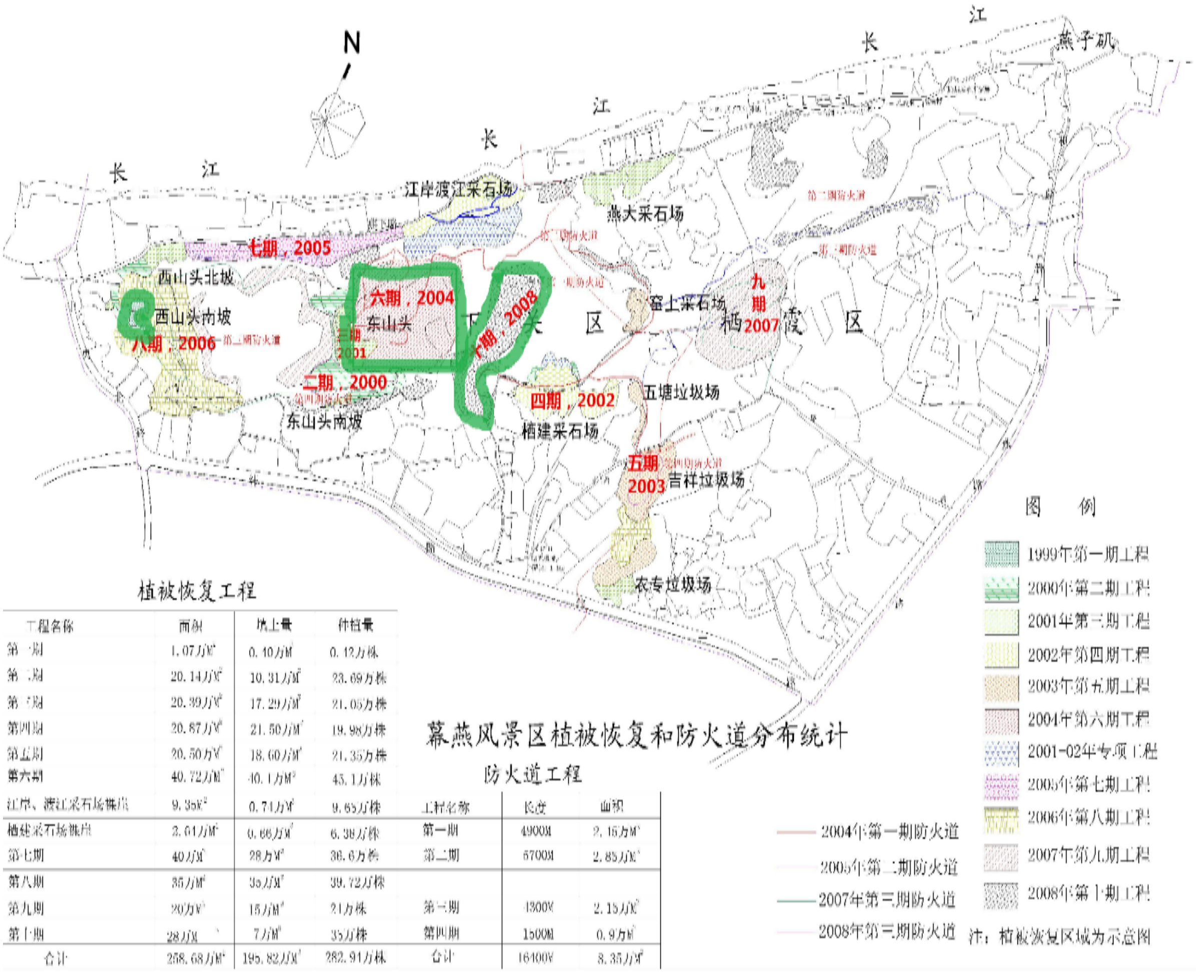
Figure 3.1 Study area, Mufu mountain, Nanjing, Jiangsu province, Southeast China

3.2 Methodology:

Subplot site selection:

Pre-requite to the research is selection of study area. Several criteria were employed to select the study area. (Figure 3.2)

- The study area should be representative of the forest.
- The study area should be accessible by foot or by car.
- The study area should have recent secondary data available for use in this study.
- Support staff should be available during the field measurement.



幕燕风景区植被恢复和防火道分布统计

植被恢复工程

工程名称	面积	填土量	种植量
第一期	1.07万M²	0.40万M³	0.12万株
第二期	20.14万M²	10.31万M³	23.69万株
第三期	20.39万M²	17.29万M³	21.05万株
第四期	20.87万M²	21.50万M³	19.98万株
第五期	20.50万M²	18.60万M³	21.35万株
第六期	40.72万M²	40.1万M³	45.1万株
江岸、渡江采石场株片	9.35M²	0.74万M³	9.65万株
栖建采石场株片	2.61万M²	0.66万M³	6.38万株
第七期	40万M²	28万M³	36.6万株
第八期	35万M²	35万M³	39.72万株
第九期	20万M²	15万M³	21万株
第十期	28万M²	7万M³	35万株
合计	258.68万M²	195.82万M³	282.91万株

防火道工程

工程名称	长度	面积
第一期	4900M	2.15万M²
第二期	5700M	2.85万M²
第三期	4300M	2.15万M²
第四期	1500M	0.9万M²
合计	16400M	8.35万M²

Figure 3.2 Three (3) different restoration years in study area

3.2.1 Experimental design:

First we chosen three (3) different restoration years. The total resorted area for restoration year of 1999 is 1.07 ha, restoration year 2004 is 40.72 ha and restoration year 2008 is 28.0 ha at Mufu mountain. The detail information about three (3) restoration plots were shows in Table 3.1.

Table 3.1 General information in restoration year 1999, 2004 and 2008.

Restoration years	**Resorted area (ha)**	**Soil type**	**Planted tree**	**Status of tree**	**Note**
1999	1.07	Light soil	*Photinia serrulta, Poplar, Liquidambar formosana, Ligustrum lucidum* etc…	Growth is good	Soil is from outside soil
2004	40.72	Light soil	*Ligustrum lucidum, Magnolia grandiflora, Prunus persica, Malus spectabilis, Koelreuteria Paniculata, Cinramomum camphora, Eucalypthus microcoryc, Gardenia jasminoides, Lagerstroemia, Osmanthus delavayi* etc…	Growth is good	Soil is from outside soil
2008	28.0	Light soil	*Ligustrum lucidum, Mahonnia fortunie, Photinia serrulata, Liquidambar formosana, Magnolia, Pittosporum tobira, Osmanthus fragrans, Prunus cerasus, Fagaceae, Lagerstroemia, Fabaceae, Jupinerus, Chimonathus praecox, Chaenomeles sea, Malus spcectabilis, Broussonetia papyrifera, Sapium sebiderum, Hibiscus*, etc…	Growth is good	Soil is from outside soil

And after that were selected to sample site for subplots on each different restoration years for 1999, 2004, 2008 by 10*10m ($100m^2$) quadrats Figure 3.3.

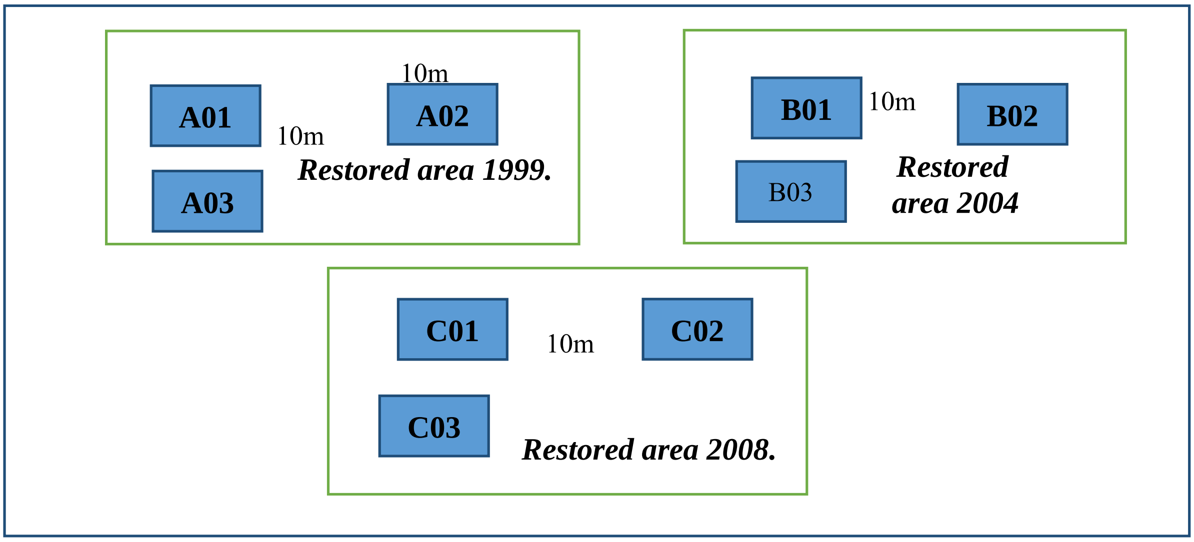


Figure 3.3 Experimental design for subplots in study sites

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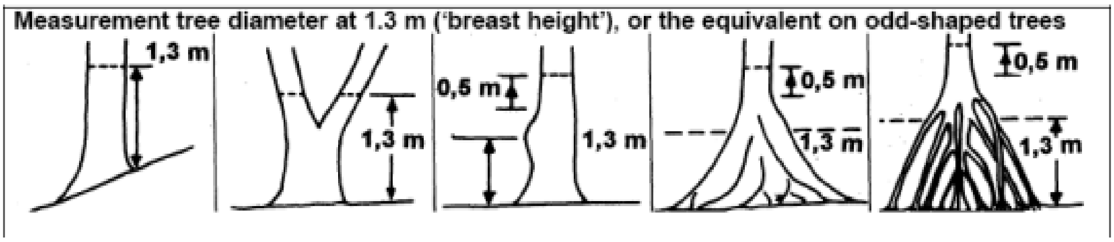
Tree selection:

The tree selection method for destructive sampling was similar to that of Monserud and Marshall (1999). Trees that were not dying, diseased, defoliated, or seriously deformed were candidates for sampling. A total of trees were sampled that covered a diameter ≥10 cm. Since live trees contain the majority of tree biomass in forests, the careful assessment and verification of models applied to derive estimates of live tree biomass is perhaps the most important step in forest biomass inventories. Chave et al. (2004)

Tree Basel Area's Formula:

Basal area was estimated from DBH measurements (Whittaker et al., 1974). The basal area of a tree stem is calculated from a tree diameter measurement (DBH) by assuming that the tree stem is perfectly circular and the base of the tree has the same diameter as the stem at 1.3 m above ground. (Figure 3.4) The area of a circle is calculated as:

$$\text{Basel area} = \Pi \ (d/2)2$$



Source: Hairiah et al. (2001).

Figure 3.4 Method for measure DBH

Where:

$\Pi = 3.14159$

d = diameter of breast height.

The units of the area calculation depend on the units that diameter is expressed in. If diameter is expressed in units of meters (m), then the area calculation will have units of m2 .

Tree Volume Equation:

Carbon and biomass are directly related to tree volume (Kershaw). Tree volume per hectare for each species was calculated using general Eq (Lu et al. 2003)

$$V=0.42*BA*H$$

Where:

V-tree volume (m^3ha^{-1}),

0.42-fixed general value used for form factor because it can be used in the absence of local equations to estimate the cubic volume of standing tree (Mangnussen et al. 2004),

BA-tree basal area (m^2ha^{-1}),

H-tree height (m).

3.2.2 Estimation of carbon stock and tree biomass:

Estimation of above ground biomass:

We use previously derived regression equations to estimate live aboveground tree biomass from tree DBH and height measurements. Aboveground biomass calculation by summing the stem, branches and leaf mass of individual trees, using the allometric equations of (1) for evergreen trees, and (2) for deciduous trees, as the following:

$$\text{Stem } (Ws) \quad =0.0509*(D^2H)^{0.919}\ldots\ldots\ldots\ldots(1)$$

$$\text{Branch } (Wb) \quad =0.00893*(D^2H)^{0.977}$$

$$\text{Leaf (WI)} = 0.0140*(D^2H)^{0.669}$$

And

$$\text{Stem (Ws)} = 0.0396*(D^2H)^{0.9326} \text{............}(2)$$

$$\text{Branch (Wb)} = 0.003487*(D^2H)^{1.027}$$

$$\text{Leaf (Wl)} = ((28.0/Ws+Wb)+0.025)^{-1}$$

Source: Terakunpisut, J. et al. (2007)

Where:

Ws= stem mass (kg),

Wb=Branches mass (kg),

Wl=Leaf mass (kg),

D= deameter breast height (cm)

H=height of tree (m)

Estimation of Belowground Biomass:

Compared with aboveground biomass, it is not practical to measure the below ground biomass (BGB) of an area of interest directly. Instead, BGB can be estimated indirectly using available equations that reliably predict root biomass based on shoot (i.e. aboveground) biomass. A commonly applied root: shoot ratio developed by Mokany et al. (2006; also reported in the IPCC 2006 GL) offers specific ratios based on forest type and climate zone. These ratios are applicable when the aboveground biomass estimate (shoot) is reported at the stand level and not for individual trees. For an individual tree, Mokany et al. (2006) propose the following relationship:

$$BGB=0.20*AGB\ (R^2=0.80)$$

Estimation of the total biomass:

The total biomass (Biomass Mg/ha) would obtain by adding the aboveground and belowground biomasses.

$$Biomass=AGB+BGB$$

Estimation of Carbon content:

Estimation of Carbon content Total biomass (only living) was obtained as the sum of biomass of tree. The calculate aboveground carbon content of each tree multiply the conversion factors (0.5), while estimating the belowground, and after that carbon content by multiplying the standard constant of 0.5 with the below ground carbon content.

Estimate carbon sequestration by allometric equations for above-ground biomass, based on non-destructive sampling. Variables are DBH and tree height.

AG tree carbon content (kg)= AGB of tree (kg)*0.5

BG carbon content= BGB (kg)*0.5

Total carbon content= AG Carbon+BG Carbon

3.3 Statistical analysis:

The data would process and analyze with the Excel 2013. The statistical analysis employs with the software SPSS, version 20.

SPSS is a Windows based program that can be used to perform data entry and analysis and to create tables and graphs. SPSS is capable of handling large amounts of data and can perform all of the analyses covered in the text and much more. Windows (SPSS Inc., Chincago, IL, U.S.A) using untransformed data and a power function of the form:

$$Y=aX^{b}$$

Where:

Y=the dependent variable (e.g., aboveground biomass:kg)

X=the independent variable (DBH [cm] and basal diameter[mm] and scaling exponent derived from the regression fit to the empirical data.

Many authors note that the nonlinear power function in equation (10) is the most common mathematical model used in biomass studies (e.g., Ter-Mikaelian & Korzukhin 1997, Zianis & Mencuccini 2004, Pilli et al. 2006), it has become conventional practice to linearize data by means of logarithmic transformation (Niklas 2006).

Goodness of fit for all regression equations was determined by examining *P*- values, the mean square of the error (MSE), the coefficient of determination (R^2), the coefficient of variation (CV), and by plotting the residuals (observed minus predicted values) against dbh. R^2 was calculated as 1 minus the sum of squares of the residuals (SSR) divided by the total sum of squares of deviations from the overall mean (Corrected SST). The best-fit models were selected as having the highest R^2; the lowest *P*-value, MSE, and CV; and the least amount of bias for under or over prediction of biomass across the entire range of sizes.

3.4 Research approach:

Sampling approach as described in Chapter I (Figure 1.2) was used for estimation of biomass and carbon sequestration. The first phase respectively comprised enumeration of sample plots and measurements of sample trees. Inside the sample plots all the trees were measured for DBH and height. After validation, biomass data obtained from the measurements of sample trees were used in a regression analysis, together with tree variables DBH and height. The developed biomass equations (height, DBH).

3.5 Data collection:

Sample subplots:

A Total of 9 square subplots of 0.09 ha area were measured, of which, three subplots were enumerated in 1999, three subplots in 2004 and three subplots in 2008. Square plots was preferable because it is easy to implement in field, and determination of trees inside less problematic. The size of the square subplot is 0.01 ha.

The data collected in the sample plots is necessary in determining the mean above-ground biomass per hectare estimate and the total above-ground biomass estimate of the study area. It is also important in determining the precision of the estimates to be determined. Field data collection is measure to all trees height and DBH. Trees in the operational area were measured in October 2015. Heights were measured using clinometer, diameter at breast height (DBH) using DBH tape location of the trees.

CHAPTER IV

RESULT

4.1 Composition of trees

Nine (9) plots of 10 m×10 m (0.01 ha) each were measured for this study. Based on the result, a total of 10 families represented for 11 genera were recorded in the 0.09 ha plot at Mufu mountain. That mountain has been 285 trees in per ha. The tree species observed in the plots were *Quercus acutissima, Brounssoneta papyrifera, Ulmus parrifolia, Wisteria sinesis, Liquidambar formonsana, Magnolia denudate, Sophora japonica, Ligustrum lucidumis, Sabina chinesis, Symplocos paniculata, Photina serratifolia* (Table 4.1). Three (3) highest number of tree were recorded for *Wisteria sinesis* (185 no/ha), followed by *Magnolia denudate* (180 no/ha) and *Ligustrum lucidum* (173 no/ha). Species deciduous contributed 72.8 % of total species, while evergreen broadleaved species contributed the other 27.2 % of total species. Tree density (number of tree per ha) in eleven (11) species ranged from 10-185 no/ha with *Wisteria sinesis* is the most common (Table 4.2).

Table 4.1 Diameter at breast height (DBH), height (H) and trees type of each sampled tree (large (L), medium (M) and small (S), deciduous (D), and evergreen broadleaved (EB) for 11 tree species assessed by the direct method to quantify biomass.

Botanical family	**Genus**	**Species**	**Tree type**	**DBH (cm)**			**Height (m)**		
				L	**M**	**S**	**L**	**M**	**S**
Oleaceae	*Ligustrum*	*L.lucidum*	EB	50	22	13	12	5.1	2.6
Ulmaceae	*Ulmus*	*U.parrifolia*	D	40	31	27	8.1	7.3	6.2
Fabaceae	*Wisteria*	*W.sinesis*	D	35	25	19	7.5	5.3	3.9
Moraceae	*Brounssonetia*	*B.papyrifera*	D	37	20	10	8	5.5	3
Altingiaceae	*Liquidambar*	*L.formosana*	D	27	18	14	8.2	5.4	4.5
Cupressaceae	*Juniperus*	*S.chinesis*	EB	68	50	43	8.6	7.5	7
Magnoliaceae	*Magnolia*	*M.denudate*	D	45	20	13.1	13.1	6.2	3.5
Fabaceae	*Styphnolobium*	*S.japonicum*	D	62	45	30	12.5	11	10.2
Fagaceae	*Quercus*	*Q.acutissima*	D	78	35	13	15.8	6.5	2.9
Rosaceae	*Photinia*	*P.serratifolia*	D	30	17	10	8	3.5	2.5

Symploceae	*Symplocos*	*S.paniculata*	EB	41	20	10	12.4	5.4	2.2

At the species level, the five (5) most species accounting for the largest proportion of biomass were *Quercus acutissima* (101.4 t/ha), *Magnolia denudate* (72.05 t/ha), *Ligustrum lucidumis* (51.2 t/ha), *Sophora japonica* (36.6 t/ha) and *Wisteria sinesis* (27.75 t/ha). The species *Quercus acutissima* contributes the highest among basal area at 21.6 m^2 per hectare, *Magnolia denudate*, *Wisteria sinesis* in each contribute the basal area of 14.68 m^2 per hectare and 11.10 m^2 per hectare Table 4.2.

Table 4.2 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) by species.

Species name	**Tree density n/ha**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total Biomass (t/ha)**
Q. acutissima	166	39.3	21.6	84.5	16.9	101.4
M. denudata	180	31.1	14.68	60.05	11.95	72.05
L. lucidumis	173	29.2	13.12	42.7	8.5	51.2
S. japonica	30	49.35	6.165	30.5	6.1	36.6
W. sinesis	185	27.15	11.105	23.1	4.55	27.75
S. chinesis	20	55.5	5	15.6	3.12	18.7
S.paniculata	73.3	22.5	3.41	12.6	2.4	15.1
U.parrifolia	40	31.5	3.2	8.1	1.6	9.7
B. papyrifera	72	19.5	2.49	5.6	1.1	6.8
L. formosana	60	20.1	2	4.8	0.9	5.7
P. serratifolia	10	17	0.2	0.3	0.06	0.36

Assuming that 50 % of the tree biomass is C, the five (5) most species accounting for the largest proportion of carbon were *Quercus acutissima* (50.7 t C/ha) followed by, *Magnolia denudate* (36 t C/ha), *Ligustrum lucidumis* (25.6 t C/ha), *Sophora japonica* (18.3 t C/ha) and *Wisteria sinesis* (13.8 t C/ha) Table 4.3.

Table 4.3 Biomass (t/ha) and carbon (t C/ha) by species

Species name	**AGB (t/ha)**	**BGB (t/ha)**	**Total tree Biomass (t/ha)**	**Carbon (t C/ha)**
Q.acutissima	84.5	16.9	101.4	50.7
M.denudata	60.05	11.95	72.05	36
L.lucidumis	42.7	8.5	51.2	25.6
S.japonica	30.5	6.1	36.6	18.3
W.sinesis	23.1	4.55	27.75	13.85
S.chinesis	15.6	3.12	18.7	9.3
S.paniculata	12.6	2.4	15.1	7.5
U.parrifolia	8.1	1.6	9.7	4.8
B.papyrifera	5.6	1.1	6.8	3.4
L.formosana	4.8	0.9	5.7	2.8
P.serratifolia	0.3	0.06	0.36	0.18

4.2 Estimated tree biomass

4.2.1 Estimated aboveground and belowground biomass

Biomass (above-ground, belowground) was estimated at the different restoration years in order to indicate the proportion of biomass. Table 4.4 shows the biomass of the forest in the Restoration year 1999. Total aboveground biomass was estimated to be 60.5 t/ha. Above-ground biomass in Restoration year 1999 was 50.4 t/ha. While below-ground biomass was 10 t/ha. The stand-level biomass in subplots ranged from 54.3 to 67.2 t/ha, with an average of 60.5 t/ha.

Table 4.4 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Restoration year 1999.

Subplots number	**Tree density (No/ha)**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total Biomass (t/ha)**
A01	390	26.7	22.96	50	10	60
A02	470	24.3	23.62	56	11.2	67.2
A03	250	27.1	17.23	45.3	9	54.3
Average	**370**	**26**	**21.27**	**50.4**	**10**	**60.5**

The subplots biomass of Restoration year 2004 was represented the maximum biomass 131.4 t/ha, while the minimum biomass was 83.1 t/ha, with an average of 100.9 t/ ha. Above-ground biomass in restoration year 2004 recorded 84.1 t/ha. While below-ground biomass was 16.8 t/ha Table 4.5.

Table 4.5 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Restoration year 2004.

Subplots number	**Tree density (no/ha)**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total Biomass (t/ha)**
B01	310	26.9	20.02	69.3	13.8	83.1
B02	190	30.3	15.7	73.6	14.7	88.3
B03	240	36.1	27.21	109.5	21.9	131.4
Average	**246**	**31.1**	**20.97**	**84.1**	**16.8**	**100.9**

Table 4.6 shows the biomass of restoration year 2008. The stand-level biomass in plots ranged from 107.8 t/ha to 124.5 t/ha, with an average of 116.7 t/ha. Above-ground biomass in restoration year 2008 contributed 97.2 t/ha. While below-ground biomass was 19.4 t/ha.

Table 4.6 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Restoration year 2008.

Subplots number	**Tree density (no/ha)**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total Biomass (t/ha)**
C01	150	39.3	24.03	98.2	19.6	117.9
C02	250	34.8	28.1	89.9	17.9	107.8
C03	320	27.6	23.29	103.7	20.7	124.5
Average	**240**	**33.9**	**25.14**	**97.2**	**19.4**	**116.7**

These study areas has tree densities ranged from 240 to 370 trees per hectare and the basal areas ranged from 20.97 m^2 to 25.14 m^2. The average number of trees per ha in these subplots were 285 no/ha. The average DBH ranged from 26 cm to 33.9 cm. In this study, tree density of three different restoration year (1999, 2004, 2008) was found 370no/ha, 246 no/ha and 240 no/ha, respectively. The restoration year 1999 contained the highest tree density, while smallest was found in restoration year 2008. The highest average DBH was represented in restoration year 2008 (33.9 cm), followed by restoration year 2004 (31.1 cm), and the lowest was in restoration year 1999 (26 cm). The basal area was recorded highest in restoration year 2008 (25.14 m^2) and lowest in restoration year 2004 (20.97 m^2).

There are variation in values of biomass density among each restoration year. Among three restoration years at Mufu mountain, Nanjing. Restoration year 2008 has the highest biomass, followed by restoration year 2004, and restoration year 1999 on Table 4.7.

The estimated biomass by each species in the study plots include the estimated AGB and BGB. Biomass AGB and BGB showed variation among the study areas (restoration year 1999, 2004 and 2008). The AGB in the restoration year 1999 was 50.4 t/ha while below ground biomass was 10 t/ha, AGB in the restoration year 2004 have been showing 84.1 t/ha while below ground biomass was 16.8 t/ha and Restoration year 2008 AGB was contained 97.2 t/ha and belowground biomass was 19.4 t/ha. In addition, this study found biomass in three different restoration years (Restoration year 1999 to Restoration year 2008) was 60.5 t/ha, 100.9 t/ha, and 116.7 t/ha, respectively. Total biomass in the three different restoration years estimated to be 278.1 t/ha. Which the highest biomass was found in restoration year 2008, meanwhile the lowest biomass in restoration year 1999.

Table 4.7 Comparison of biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in three different restoration years.

Restoration years	**Tree density**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total Biomass (t/ha)**
1999	370	26	21.27	50.4	10	60.5
2004	246	31.1	20.97	84.1	16.8	100.9
2008	240	33.9	25.14	97.2	19.4	116.7
			Total	**231.7**	**46.2**	**278.1**

4.2.2 Estimated aboveground and belowground biomass by major group species

Figure 4.1 shows wide variation of biomass between deciduous and evergreen broadleaved species. Most of the biomass in each study area (1999, 2004, 2008) is contributed by the deciduous species which ranged from 51.1% to 86.8%. In this case evergreen broadleaved species show ranged from 13.2% to 48.9% of the total of biomass (Table 4.8). Therefore, biomass of evergreen green broadleaved species 48.9 %, while deciduous species is 51.1 % in restoration year 1999. The biomass of evergreen broadleaved species 26.2 %, while deciduous species was 73.8 % in the restoration year 2004. Evergreen broadleaved species estimated 13.2 %, while deciduous species 86.8% in the restoration year 2008. The largest biomass volume of deciduous species gave in restoration year 2008 (86.8 %) of the total biomass density while the smallest biomass in restoration year 1999 (51.1%). Evergreen broad leaved species value was obtaining highest biomass in restoration year 1999 (48.9 %) of the total biomass. While the lowest biomass of evergreen broadleaved species value was belong in restoration year 2008 (13.2 %). The AGB have a higher value of biomass (84.5 t/ha) for deciduous species while BGB was showing 16.9 t/ha in the restoration year 2008. Furthermore, deciduous species lowest value showing AGB 25.7 t/ha, while BGB had been 5.1 t/ha in the restoration year 1999. This study area also showing highest AGB of evergreen broadleaved species found 24.7 t/ha, which BGB 4.9 t/ha in the restoration year 1999. As result evergreen broadleaved species contained lowest AGB was 12.7 t/ha, while BGB 2.5 t/ha in the restoration year 2008.

Table 4.8 Comparison of biomass in different restoration years by deciduous species and evergreen broadleaved species.

	DECIDUOUS								**EVERGEEN BROADLEAVED**							
Restoration year	**Tree density no.ha**	**%**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**	**%**	**Tree density no.ha**	**%**	**Average DBH (cm)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**	**%**
1999	216	58.5	24.5	11.59	25.7	5.1	30.8	51.1	153	41.5	26.8	9.67	24.7	4.9	29.6	48.9
2004	180	73.1	36.3	14.88	62.1	12.4	74.5	73.8	66	26.9	11.3	6.09	22	4.4	26.4	26.2
2008	166	69.4	39.3	21.6	84.5	16.9	101.4	86.8	73	30.6	22.5	3.54	12.7	2.5	15.3	13.2

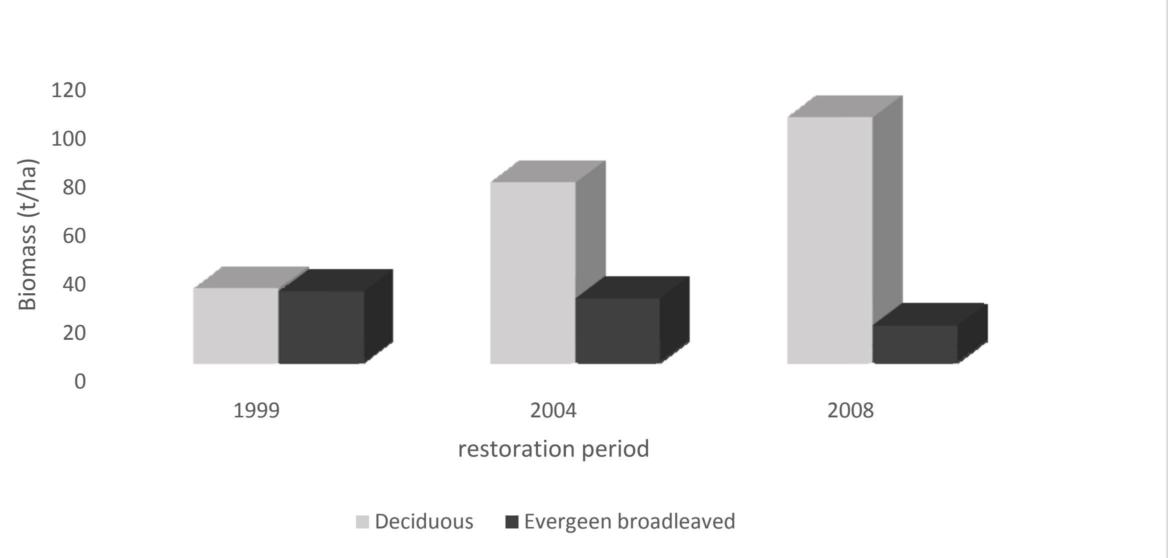


Figure 4.1 Comparison of biomass in different restoration years by deciduous species and evergreen broadleaved species

4.2.3 Estimated aboveground belowground biomass by diameter class sizes.

The distribution of the tree DBH size is based on the 10 cm class starting at 10 cm up to >60 cm. From the overall DBH distribution it is stated that DBH class with 40.0-49.9 cm has the highest number which is 50 trees in restoration year 2004 followed by, restoration year 2008 was 43 no/ha, and restoration year 1999 contributed the smallest 16 no/ha. All the data for the class distribution is shows the in Figure 4.2.

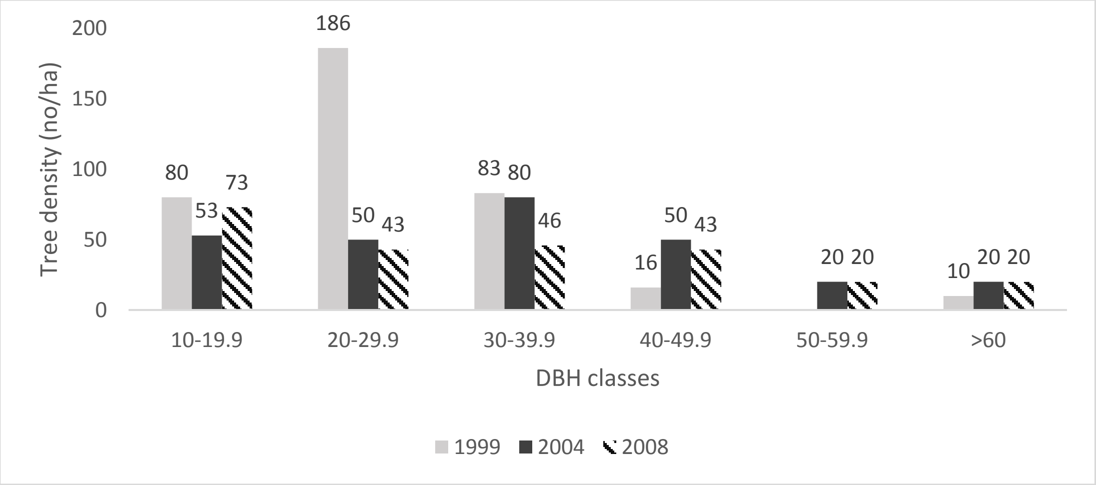


Figure 4.2 Tree density (no/ha) by diameter size classes

It was found that DBH of trees were distributed different size classes. Table 4.9 shows the distribution of diameter class for biomass values of restoration year 1999. The DBH classes (20.0-29.9 cm) was contributed highest biomass 24.3 t/ha which among the DBH class, while the smallest proportion of biomass was found in DBH class (10.0-19.9 cm) contributed 4.3 t/ha.

Table 4.9 Total biomass (t/ha) by different diameter size classes and tree density (no/ha) in the restoration year 1999.

DBH (cm)	**Tree density (no/ha)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**
10-19.9	80	1.67	3.56	0.7	4.3
20-29.9	186	9.11	20.33	4	24.3
30-39.9	83	6.9	16.4	3.2	19.6
40.49.9	16	2.34	6.2	1.2	7.4
>60	10	3.63	11.5	2.3	13.8
Total	**375**	**23.65**	**57.99**	**11.4**	**69.4**

The biomass values by diameter size classes of restoration year 2004 was found the highest biomass in diameter size class (40.0-49.9) contributed 37.5 t/ha while lower proportion of biomass among was found 2.4 t/ha in diameter size class (10.0-19.9) in Table 4.10.

Table 4.10 Total biomass (t/ha) by different diameter size classes and tree density (no/ha) in the restoration year 2004

DBH (cm)	**Tree density (no/ha)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**
10-19.9	53	1	2	0.4	2.4
20-29.9	50	2.31	7.5	1.4	8.9
30.39.9	80	7.15	26.9	5.3	32.3
40-49.9	50	7.06	31.3	6.2	37.5
50-59.9	20	4.33	22.1	4.4	26.5
>60	20	5.84	26.6	5.3	31.9
Total	**273**	**27.69**	**116.4**	**23**	**139.5**

Table 4.11 shows biomass values by diameter size classes of restoration year 2008. The diameter size classes (>60) was contributed 39.3 t/ha which the highest biomass while diameter size class (10.0-19.9) contributed the smallest biomass 3.8 t/ha.

Table 4.11 Total biomass (t/ha) by different diameter size classes and tree density (no/ha) in the restoration year 2008.

DBH (cm)	**Tree density (no/ha)**	**BA (m^2/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**
10-19.9	73	1.52	3.2	0.6	3.8
20-29.9	43	1.96	5.8	1.1	6.9
30-39.9	46	4.31	15.6	3	18.8
40-49.9	43	6.67	27.3	5.4	32.7
50-59.9	20	4.49	18.5	3.6	22.2
>60	20	7.66	32.8	6.5	39.3
Total	**245**	**26.61**	**103.2**	**20.2**	**123.7**

All the characteristics of diameter size classes of different restoration years were given in Table 4.12. Based on results, distribution of biomass among the diameter size classes showed variability. The comparison value of biomass for different restoration years had been showing in (Figure 4.3). Consequently, based on diameter size class 10.0-19.9 cm showed higher biomass in restoration year 1999 (4.3 t/ha) followed by, restoration year 2008 (3.8 t/ha) and restoration year

2004 (2.4 t/ha). Furthermore, diameter size class 40.0-49.9 cm recorded highest biomass in restoration year 2004 (37.5 t/ha) followed by, restoration year 2008 (32.7 t/ha) and restoration year 1999 (7.4 t/ha). While diameter size class >60 cm contributed highest biomass in restoration year 2008 (39.3 t/ha) followed by, restoration year 2004 (31.9 t/ha) and restoration year 1999 (13.8 t/ha).

Table 4.12 Comparison of biomass (t/ha) by different diameter size classes and tree density (no/ha) in the different restoration years.

Restoration years	DBH (cm)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
1999	10-19.9	3.56	0.7	4.3
2004	10-19.9	2	0.4	2.4
2008	10-19.9	3.2	0.6	3.8
1999	20-29.9	20.3	4	24.3
2004	20-29.9	7.5	1.4	8.9
2008	20-29.9	5.8	1.1	6.9
1999	30-39.9	16.4	3.2	19.6
2004	30.39.9	26.9	5.3	32.3
2008	30-39.9	15.6	3	18.8
1999	40.49.9	6.2	1.2	7.4
2004	40-49.9	31.3	6.2	37.5
2008	40-49.9	27.3	5.4	32.7
2004	50-59.9	22.1	4.4	26.5
2008	50-59.9	18.5	3.6	22.2
1999	>60	11.5	2.3	13.8
2004	>60	26.6	5.3	31.9
2008	>60	32.8	6.5	39.3

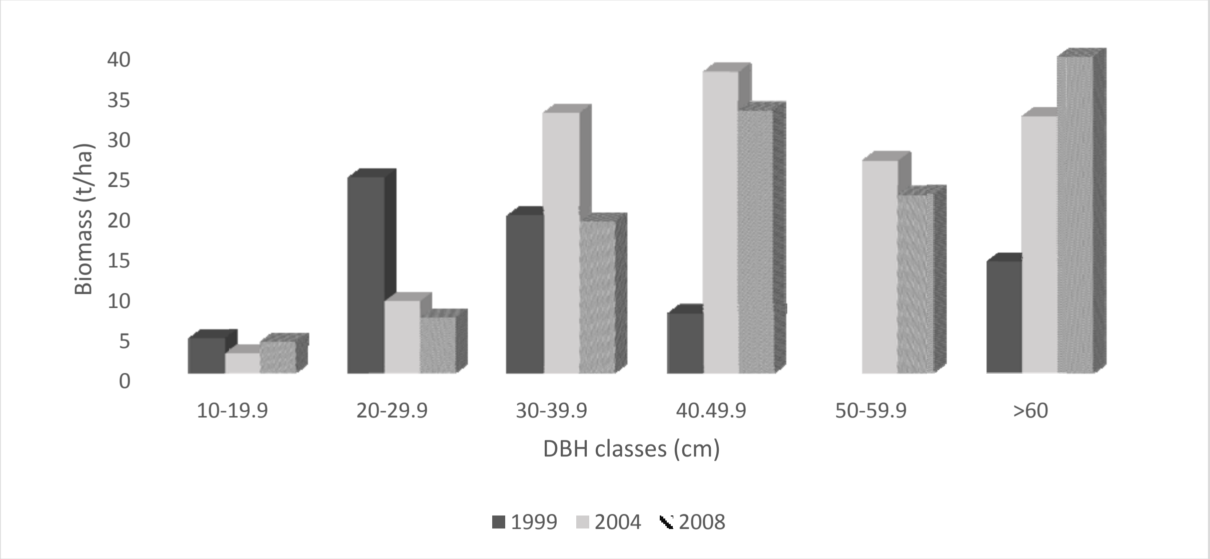


Figure 4.3 Comparison of biomass (t/ha) by different diameter size classes in the different restoration years

4.3 Estimated carbon stock

The total biomass and carbon stock aboveground and belowground showed in Table 4.13. Figure 4.4 also shows in term of carbon value there are variation in each restoration year. Based on results, in the 1999 restoration year total biomass was 60.5 t/ha, so that the value of carbon stock was 30.2 t C/ha. Furthermore, in 2004 restoration year biomass indicates 100.9 t/ha, while carbon stock recorded 50.4 t C/ha. Result recorded in third restoration year total biomass showed 116.7 t/ha, calculated carbon stock values 58.3 t C/ha. Consequently, the study found in restoration year 2008 is higher carbon stock, while in 1999 restoration year is lower carbon stock.

Table 4.13 Comparison of biomass (t/ha) and carbon (t C/ha) in three restoration years.

Restoration years	AGB (t/ha)	BGB (t/ha)	Total Biomass (t/ha)	AG Carbon (t/ha)	BG Carbon (t/ha)	Total Carbon (t/ha)
1999	50.4	10	60.5	25.2	5	30.2
2004	84.1	16.8	100.9	42.0	8.4	50.4
2008	97.2	19.4	116.7	48.6	9.7	58.3
Average	**77.2**	**15.4**	**92.7**	**38.6**	**7.7**	**46.3**

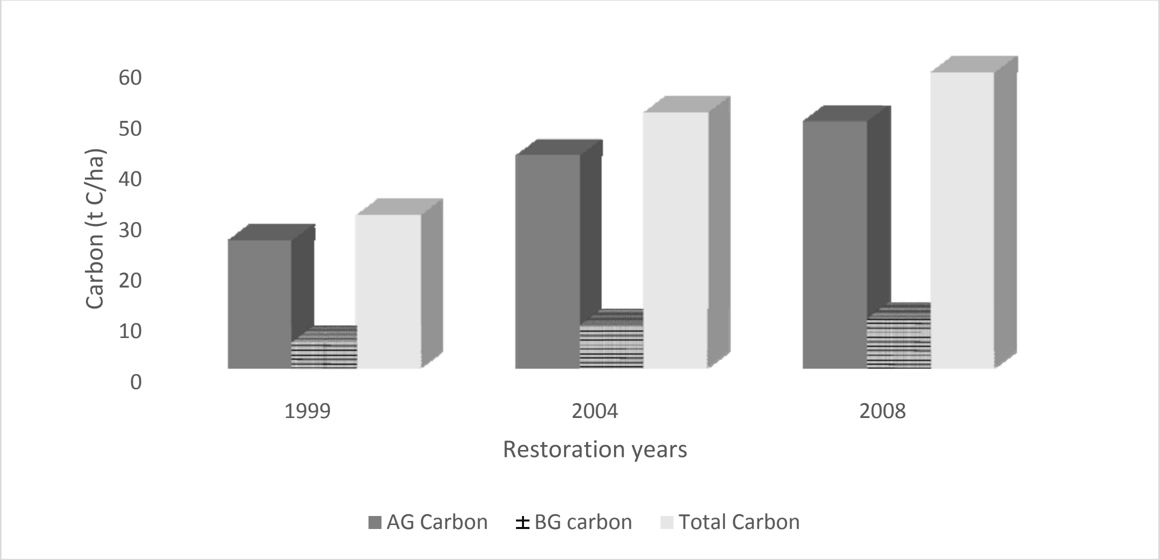


Figure 4.4 Comparison for carbon stock (t C/ha) in different restoration years

From the study, result of carbon value has given in Table 4.14. The highest carbon contained in deciduous species was found in 2008 restoration year (50.7 t C/ha), followed by 2004 indicates 37.25 t C/ha and 1999 showed 15.4 t C/ha, respectively. In addition, largest carbon values for evergreen broadleaved species recorded in 1999 restoration year (14.8 t C/ha), followed by 2008 indicates 7.65 t C/ha and 2004 was 13.2 t C/ha, each. Consequently, deciduous species contributed the highest carbon than evergreen broadleaved species Figure 4.5.

Table 4.14 Comparison of carbon by deciduous and evergreen broadleaved species in the three restoration years.

	DECIDUOUS		**EVERGREEN BROADLEAVED**	
Restoration years	Biomass (t/ha)	Total Carbon (t C/ha)	Biomass (t/ha)	Total Carbon (t C/ha)
1999	30.8	15.4	29.6	14.8
2004	74.5	37.25	26.4	13.2
2008	101.4	50.7	15.3	7.65

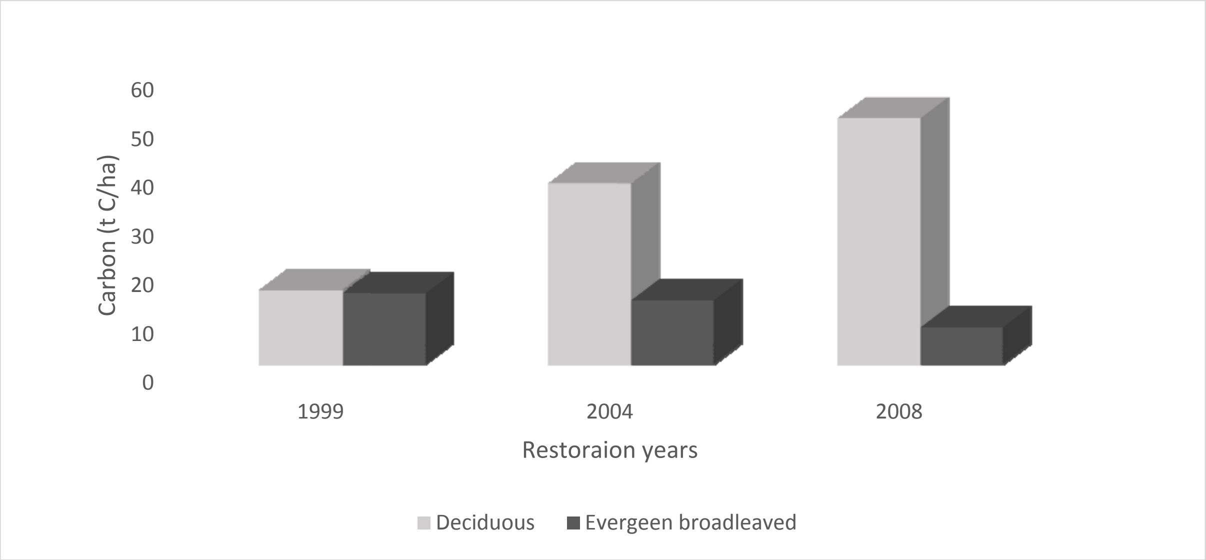


Figure 4.5 Comparison of carbon by deciduous and evergreen broadleaved species in the three restoration years.

Based on results, distribution of carbon stock among the diameter size classes showed variability. Table 4.15 shows of carbon stock in three restoration years by diameter size classes. The comparison value of carbon stock for three restoration years had been showing in (Figure 4.6). Carbon stock potential in different restoration years to be correlated to diameter size classes. Consequently, based on diameter size class 10.0-19.9 cm showed higher carbon in restoration year 1999 (2.13 t C/ha) followed by, restoration year 2008 (1.9 t C/ha) and restoration year 2004 (1.2 t C/ha). Furthermore, diameter size class 40.0-49.9 cm recorded highest carbon in restoration year 2004 (18.7 t C/ha) followed by, restoration year 2008 (16.3 t C/ha) and restoration year 1999 (3.7 t C/ha). While diameter size class >60 cm contributed highest carbon in restoration year 2008 (19.6 t C/ha) followed by, restoration year 2004 (15.9 t C/ha) and restoration year 1999 (6.9 t C/ha).

Table 4.15 Comparison of carbon (t C/ha) by diameter size classes in the different restoration years

Restoration years	**DBH (cm)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**	**AG Carbon (t C/ha)**	**BG Carbon (t C/ha)**	**Total Carbon (t C/ha)**
1999	10-19.9	3.56	0.7	4.3	1.7	0.35	2.13
2004	10-19.9	2	0.4	2.4	1	0.2	1.2
2008	10-19.9	3.2	0.6	3.8	1.6	0.3	1.9
1999	20-29.9	20.3	4	24.3	10.1	2	12.1
2004	20-29.9	7.5	1.4	8.9	3.75	0.7	4.4
2008	20-29.9	5.8	1.1	6.9	2.9	0.5	3.4
1999	30-39.9	16.4	3.2	19.6	8.2	1.6	9.8
2004	30.39.9	26.9	5.3	32.3	13.4	2.6	16.1
2008	30-39.9	15.6	3	18.8	7.8	1.5	9.3
1999	40.49.9	6.2	1.2	7.4	3.1	0.6	3.7
2004	40-49.9	31.3	6.2	37.5	15.65	3.1	18.7
2008	40-49.9	27.3	5.4	32.7	13.65	2.7	16.3
2004	50-59.9	22.1	4.4	26.5	11.0	2.2	13.2
2008	50-59.9	18.5	3.6	22.2	9.2	1.8	11.0
1999	>60	11.5	2.3	13.8	5.7	1.15	6.9
2004	>60	26.6	5.3	31.9	13.3	2.65	15.9
2008	>60	32.8	6.5	39.3	16.4	3.25	19.6

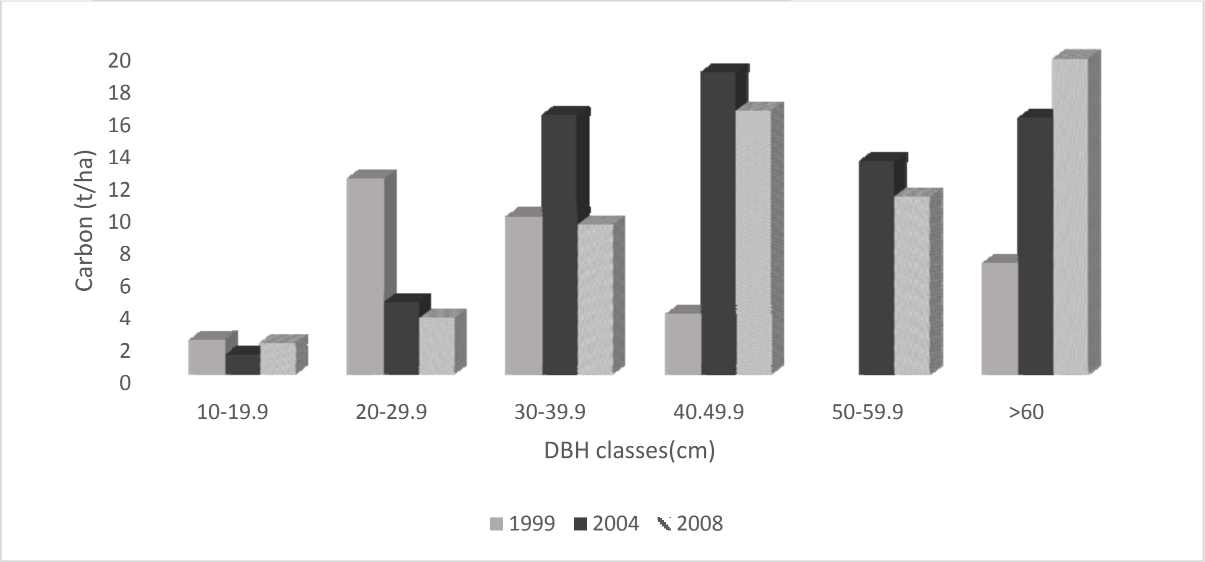


Figure 4.6 Comparison of carbon (t C/ha) by diameter size classes in the three restoration years

CHAPTER V

DISCUSSION and CONCLUSION

Generally, in this study, biomass (AGB plus BGB) was estimated at the different restoration years in order to indicate the proportion of biomass. The biomass calculated from the field inventory data of this study in restoration year 1999 estimated to be 60.5 t/ha, restoration year 2004 recorded 100.9 t/ha and restoration year 2008 was contributed 116.7 t/ha, respectively. The highest biomass was in restoration year 2008 while biomass in restoration year 1999 was lower than restoration year 2004. Carbon content would be about 50 % of the amount of biomass that means carbon stocks of 58.3 t C/ha, 30.2 t C/ha and 50.4 t C/ha, respectively.

The tree diameter size at restoration year 2008 were quite large when compared to other restoration years so calculated carbon stocks are the highest in this restoration year. It indicated that carbon stocks potential was rely on tree diameter size class. It does not mean that other restoration years are not important, because the mainly groups of small tree size at 10.0 –19.9 cm will grow to bigger size in the near future. They will have greater potential for future carbon stocks if the forests are under appropriate management without human disturbance. Huston and Marland (2003) showed that carbon stocks depended not only on rates of productivity but also on the size of the tree. Disturbance of landscapes can result in rapid release of large amount of carbon that will be recaptured slowly as forest regrowth. In (Table 5.1) showed the comparison of carbon stocks in varies forest types. As the results of this study, carbon stocks was considerably in agreement with mean values of carbon stocks for Chinese forests range from 36-57.07 t C/ha (Zhang et al., 2007). Using the national forest inventory data of China from 1949 to 1998, Fang et al., (2001) estimated the average carbon stocks approximately 50 t C/ha in the north-east Chinese forests. According to Tan et al., (2007) reported the average carbon stocks was nearly 55 t C/ha in Changbai mountain. For comparison with other results were show in Table 17. In this present study showed aboveground biomass ranged from 50.4 t/ha to 97.2 t/ha. This result is in line with Fang et al., (2013) which calculated aboveground biomass approximately to be 60.1 Mg/ha for secondary subtropical forest. Therefore, previous study in Subtropical forests in China presented average biomass estimates of 164 Mg ha (Fang et al., 1998) and 223 Mg ha (Lin et al., 2012).

According to Guo et al., (2014) estimated biomass C stocks of woodlands and trees on non-forest land by using the provincial biomass-volume conversion equations derived from the data of low-canopy forests, and estimated the biomass C stocks of shrubberies using the provincial mean biomass density. Total tree outside forest (TOF) biomass C stock increased by 62.7% from 823 Tg C (1 Tg=1012 g) power initial period of 1977–1981 to 1339 Tg C in the last period of 2004–2008. As a result, China's TOF have accumulated biomass C of 516 Tg during the study period, with 12, 270, and 234 Tg in woodlands, shrubberies, and trees on non-forest land, respectively. The annual biomass C stock of China's TOF averaged 19.1 Tg C yr−1, offsetting 2.1% of the contemporary fossil-fuel CO2 emissions in the country. These estimates are equal to 16.5–20.7% of the contemporary total forest biomass C stock and 27.2% of the total forest biomass C stock in the country, suggesting that TOF are substantial components in China's tree C budget. The biomass obtained from this study is compared with other tropical forest areas in Table 5.2.

Table 5.1 Carbon estimations (t/ha) in Asia countries from 1981-2007

Region	**Area/ Types**	**Carbon (t C/ha)**	**References**
*Linchuan, Jiangxi	Huitong, Hunan	70.37	Pan et al. (1981)
*Tonggu, Jiangxi	Huitong, Hunan	70.37	Pan et al. (1981)
*Linchuan, Jiangxi	Huitong, Hunan	132.63	Pan et al. (1981)
*Tonggu, Jiangxi	Huitong, Hunan	132.63	Pan et al. (1981)
DoiSuthep-Pui National Park, Chiang Mai	Evergreen forest and mixed deciduous	15.97-87.75	Viriyabuncha et al.
KP 27 station, Thailand	Dry evergreen forest	70.29±7.38	J.Terakunpisut et al 2007.
Pong Phu Ron station, Thailand	Mixed deciduous forest	48.14±16.72	J.Terakunpisut et al 2007.
*Subtropical, China	PA, MAB	24.98-47.05	Chen (2004)
*Subtropical, China	PA, MAE	28.49-37.49	Lin at al., (1999.)
*Subtropical, China	PA, MAF	25.97-84.67	Zhang (2008)
*Subtropical, China	PA, MAH	62.17-83.67	Wu (2005)
*Subtropical, China	MAB	83.58	Huang et al (2005)
Subtropical, Zhejiang, China	Evergreen broadleaved forest	36-57.07	J. Zhang et al., (2007)
Nanjing, China	Deciduous evergreen broadleaved forests	30.2-58.3	Present study, 2016

*Source from B. Wang et a.,2012

Note: P, Pure plantation; M, Mixed plantation; A, *Chinese fir*; B, *Michelia macclurei* Dandy; E, *Magnolia officinal* (Rehd. Et Wils.) Cheng.; F-*Taiwania flousiana Gaussen*., H-*Phoebe bourmei (Hemsl.)*

Table 5.2 Biomass estimations (t/ha) in Asia countries from 1981-2015

Region	**Area/ Types**	**Biomass (t/ha)**	**References**
*Linchuan, Jiangxi	Huitong, Hunan	146.4	Pan et al. (1981)
*Tonggu, Jiangxi	Huitong, Hunan	146.4	Pan et al. (1981)
*Linchuan, Jiangxi	Huitong, Hunan	275.9	Pan et al. (1981)
*Tonggu, Jiangxi	Huitong, Hunan	275.9	Pan et al. (1981)
*Jianou Fujian	PA, MAC	27.73-49.89	Ma et al (1998)
*Nanping, Fujian	PA, MAD	42.93	Chen (2009)
*Shunchang, Fujian	PA, MAB	49.96-68.69	Chen (2004)
*Dehua, Fujian	PA, MAF	123.1-169.3	Zhang (2008)
*Sanming, Fujian	PA, MAI	124.3-167.3	Wu (2005)
*Huitong, Hunan	PA, MAB	64.76-83.58	Huang et al., (2005)
*Mingxi, Fujian	MAE	56.97	Lin et al., (1999)
*Changtai, Fujian	MAB	53.9	Wang et al., (2009)
“China	Subtropical	164	Fang et al., (1998)
“China	Subtropical	223	Lin et al.,(2012)
China	DNF	56.6	Yin et al (2015)
China	ENF	51.6	Yin et al (2015)
China	MF	97.4	Yin et al (2015)
China	DBF	53.3	Yin et al (2015)
China	EBF	73	Yin et al (2015)
KP 27 station, Thailand	Dry evergreen forest	140.58±14.76	J.Terakunpisut et al 2007.
Pong Phu Ron station, Thailand	Mixed deciduous forest	96.28±33.44	J.Terakunpisut et al 2007.
China	Subtropical zone	9.21-466.67	H. Chi et al 2015
Subtropical, Zhejiang, China	Evergreen broadleaved forest	89.19	J.Zhang et al., (2007)
Subtropical, Zhejiang, China	Coniferous forest	70.06	J.Zhang et al., (2007)
Subtropical, Zhejiang,	Broad-leaved mixed forest	51.25	J.Zhang et al., (2007)

China				
Subtropical, China	Zhejiang,	Pine forest	54.15	J.Zhang et al., (2007)
Nanjing, China		Deciduous, evergreen broadleaved forest	60.5-116.7	Present study, 2016

*source from B. Wang et a.,2012, “source from M.F.Rosenfield., and A.F. Souza. 2013.
Note: P, Pure plantation; M, Mixed plantation; A, *Chinese fir*; B, *Michelia macclurei* Dandy; C, *Alniphyllum fortune* (Hemsl.) Makino; E, *Magnolia officinal* (Rehd. Et Wils.) Cheng.; I, *Tsoongiodendrom odorum* Chun., DNF-deciduous needle leaf forests, ENF-evergreen needle leaf forests, MF-needle leaf and broadleaf mixed forests, DBF-deciduous broadleaf forests, EBF-evergreen broadleaf forests.

In this study, comparison of the size class distribution and aboveground biomass showed some evidences of biomass reduction in larger size classes, 50.0 cm – 59.9 cm. Additionally (Nizami et al.,2009) reported that the tree biomass increases with the increasing diameter size class. Diameter size class 30.0-39.9 cm and 40.0-49.9 cm restoration year in 1999 showed reduction reflected of tree to survive in destroyed area. In the study plot, all restoration year had a similar pattern of tree diameter size class, with diameter size class at 10.0 – 19.9 cm showed the highest tree density for restoration year 1999 followed by, restoration year 2008, and restoration year 2004, respectively.

DBH and tree density showing relationship in each size class. Biomass at diameter size class 40.0-49.9 cm showed the highest was found in restoration year 2004, and the lowest was recorded in restoration year 1999. The main conclusion showed an relationship between biomass and diameter size class the most biomass accumulation was found in big trees of size class at >60 cm. Because these trees had the highest stem volume and large diameter, and also had the lowest number of tree density.

The abundant of carbon stock was recorded highest in deciduous species than evergreen broadleaved species in the three restoration years. Moreover, the highest carbon stock was given by restoration year 2008. This result might be due to natural regrowth of that occur in this study area compared to restoration year 1999 that was planted trees. In fact, restoration year 1999 had restored soil from Xuanwu lake, so that effect the carbon stocks value and showed the lowest values of carbon stocks among restoration year. But it is important to preserve this study plot as a carbon stock reservoir that could substitute natural in the future.

Mufu mountain is generally at the early stage of succession and is recovering from earlier disturbances. In general conclusion from biomass and carbon stocks studies, under the different restoration years, new period of restoration year forest had more carbon stocks than long restoration year. Each diameter size class had a different carbon stocks potential. Almost small up to medium sizes of trees had a greater potential for carbon stocks than big trees due to the forest type because the growth rate will slowly in bigger trees. Therefore, to conserve and manage the small tree at 10.0–19.9 and 30–39.9 cm can considerably increase carbon stocks potential in the near future. If the forest is deforested and changed by human activities, it will potentially cause the severe carbon loss to atmosphere from terrestrial ecosystems.

The comparison of biomass and carbon stocks in various restoration years showed the varied values due to different stage of forest growth cycle, habitat variation, tree density and soil condition. Nanjing City government implemented comprehensive control of the Mufu mountain and set up a special administration to conserve the dolomite and restore the vegetation in 1998, which showed the positive effect to Mufu mountain.

Additionally, Mufu mountain provides many other ecosystem services. They may provide to humanity social, economic, and environmental synergies benefit because of their multiple ecosystem services function, including the service of carbon stock that helps to mitigate global climate change. However, it is possible that Mufu mountain forest in Nanjing could also act as carbon sources.

Lastly, The Kyoto protocol clearly affirms the importance of increasing our understanding of forest carbon budgets and the role of forests in offsetting global carbon emission. This study has contributed in that direction. Forest managers interested in forest carbon management for stewardship purposes or to attain certification in sustainable forest management may benefit from these findings. It can also serve as basis for entry into Clean Development Mechanism (CDM) markets.

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APPENDIX

Appendix A. Table of Increment for species

Table A. Tree density (n/ha), biomass (t/ha) and carbon (t C/ha) by species increment in restoration year 1999.

Species name	Tree individual	Tree density n/ha	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total Biomass (t/ha)	Carbon (t C/ha)
L. lucidumis	14.66	147	25.52	7.98	19.51	3.90	23.42	11.71
U. parrifolia	1.33	13	31.5	1.06	2.7	0.54	3.25	1.62
W. sinesis	12.33	123	27.15	7.40	15.45	3.09	18.53	9.27
B. papyrifera	5.66	57	21.9	2.36	5.87	1.17	7.04	3.52
L. formosana	2	20	20.1	0.67	1.6	0.3	1.92	0.96
S. chinesis	0.66	7	55.5	1.67	5.2	1.04	6.23	3.1
P. serratifolia	0.33	3	17	0.07	0.1	0.02	0.12	0.06
Total	**37**	**370**	**28.38**	**21.20**	**50.43**	**10.06**	**60.51**	**30.23**

Table B. Tree density (n/ha), biomass (t/ha) and carbon (t C/ha) by species increment in restoration year 2004.

Species name	Tree individual	Tree density n/ha	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total tree Biomass (t/ha)	Carbon (t C/ha)
M. denudata	12	120	31.1	9.79	40.1	8.0	48.0	24.0
B. papyrifera	4	40	17.1	0.96	1.8	0.4	2.1	1.05
S. japonica	2	20	49.3	4.11	20.4	4.1	24.4	12.2
L. lucidumis	6.7	67	33	6.09	22	4.4	26.4	13.2
Total	**24.6**	**246**	**32.6**	**20.97**	**84.1**	**16.8**	**101.0**	**50.50**

Table C. Tree density (n/ha), biomass (t/ha) and carbon (t C/ha) by species increment in restoration year 2008.

Species name	Tree individual	Tree density n/ha	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total tree Biomass (t/ha)	Carbon (t C/ha)
Q. acutissima	16.7	167	39.3	21.61	84.53	16.9	101.4	50.7
S. paniculata	7.3	73	22.5	3.53	12.7	2.5	15.3	7.53
Total	**24**	**240**	**30.9**	**25.14**	**97.2**	**19.4**	**116.7**	**58**

Appendix B. Table of Increment for deciduous species and evergreen broadleaved species.

Table D. Biomass and carbon for deciduous species and evergreen broadleaved species in restoration year 1999.

Subplots	Species type	Tree density no.ha	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
A01	E	130	23.3	5.91	12.5	2.5	15	7.5
A02	E	200	24.3	10.18	26.5	5.3	31.8	15.9
A03	E	130	33	12.93	35.1	7	42.2	21.1
Average		**153**	**26.8**	**9.67**	**24.7**	**4.9**	**29.6**	**14.8**
A01	D	260	28.5	17.04	37.5	7.5	45	22.5
A02	D	270	24.4	13.44	29.5	5.9	35.4	17.7
A03	D	120	20.6	4.29	10.2	2	12.2	6.1
Average		**216**	**24.5**	**11.59**	**25.7**	**5.1**	**30.8**	**15.4**

Notes: E- Evergreen broadleaved species, D-Deciduous species

Table E. Biomass and carbon for deciduous species and evergreen broadleaved species in restoration year 2004.

Subplots	Species type	Tree density (no/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
B01	D	310	26.9	20.02	69.3	13.9	83.1	41.6
B02	D	190	30.4	15.7	73.6	14.7	88.4	44.2
B03	D	40	51.7	8.93	43.5	8.7	52.2	26.1
Average		**180**	**36.3**	**14.88**	**62.1**	**12.4**	**74.5**	**37.3**
B03	E	200	33.9	18.28	66	13.2	79.2	39.6
Average		**66**	**11.3**	**6.09**	**22**	**4.4**	**26.4**	**13.2**

Table F. Biomass and carbon for deciduous species and evergreen broadleaved species in restoration year 2008.

Subplots	Species type	Tree density (no/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
C01	D	100	51.6	23.13	96.5	19.3	115.8	57.9
C02	D	200	36.1	24.27	75.5	15.1	90.6	45.3
C03	D	200	30.3	17.42	81.6	16.3	97.9	48.9
Average		**166**	**39.3**	**21.6**	**84.5**	**16.9**	**101.4**	**50.7**
C01	E	50	14.6	0.9	1.7	0.3	2	1
C02	E	50	29.8	3.88	14.4	2.9	17.3	8.6
C03	E	120	23.2	5.86	22.1	4.4	26.6	13.2
Average		**73**	**22.5**	**3.54**	**12.7**	**2.5**	**15.3**	**7.6**

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