BIOLOGICAL DIVERSITY OF PLANTS AND HUMAN ACTIVITIES FOR IMPROVING THE ENVIRONMENT IN THE SUBURBAN COPPICE FIELDS

A CASE STUDY IN OAOTA FOREST

A Thesis

by

YUMI YOSHIDA 47116818

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Co-advisor: Project Associate professor Matsuda Hirotaka

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ABSTRACT

The suburban coppice fields have been interacted with local people for a long time in Japan. Farmers in Japan have thinned and mowed in Satoyama since the *Jomon* era (Tsuji, 1997). Satoyama means “mountains close to villages”, and it is called as a place where the coppice fields exist (Arioka, 2004; Tanaka, 2011). However, vegetation on the forest floor has changed because the local people became less interacted with the Satoyama after 1960s when they started to rely on the crude oils for their energy source and chemical fertilizer for their compost. Suburban forest area has decreased as humans increase in population and develop land (Hamahashi, 1980; Saito et al., 2003; Nakashizuka and Iida, 1996). As a result of the social change in the interaction between the suburban coppice fields and humans, species diversity of plants decreased. For example, an introduced species, *Pleioblastus chino* (Bamboo), dominates the other diverse plant species. Moreover, *Polygonatum involcratum*, *Cephalanthera falcata* and *Ajuga nipponensis* those grow in the coppices where local farmers used to thin and mow became rare species and are under the threats of extinctions.

The extinction of diverse endemic plants causes problem for other creatures' survival, because insects and animals lose their foods. For example, the parent birds must fly further away from their nest to find and catch warms. Moreover, when rare species become extinct local people lose their tradition and kinship with them. For example, the *Polygonatum involcratum* is called "*Waniguchisou*" in Japan, named after a pray foyer of shrine, because its flower and fruit look like the pray curtain and the bell. Thus, maintaining human interaction with coppice fields is important for biodiversity conservation and living humanity. With this in mind, volunteers restarted the Satoyama activity such as thinning and mowing.

The purpose of this research is to examine the changes of ground flora in suburban coppice fields after the volunteer Satoyama activity. The hypothesis of this study was that the biodiversity of plants would increase as a result of Satoyama management. Moreover, rare plant species that sleep in the seed bank germinate supported by the improvement of the forest floor environment. Thus, there are two study objectives. 1) To clarify the biodiversity of plants after volunteer Satoyama activities and its changes from 2011 to 2013. 2) To clarify the characteristics of habitat environment of diverse plant species in Oaota forest and rare species *Polygonatum involcratum*.

This research area is in Oaota forest. Oaota forest is the largest secondary forest in Kashiwa city, Chiba prefecture in Japan (Fukushima and Takahashi, 1896). Kashiwa city is the suburb of Tokyo and it increased its population rapidly since 1995 (*Kashiwa-shi kokusei* *chosa* [census], 2012), and it is the second city that decreased the forest area the most from 2004 to 2010 in Tohkatsu area (*Chibaken Shinrin Ringyo Tokeisyo* [statistics], 2012). NPO Chiba Satoyama Trust has conducted Satoyama activities cooperating with the University of Tokyo since 2011.

This research was conducted using two methodologies. One is the plant survey and the other one is the habitat environment survey. The experimental plots were set in the Oaota forests in 2011(Table 1). The survey objectives were the plants whose heights are less than 130 cm. The overall coverage was measured in each small plot. The coverage and the maximum height of each species were measured for the all individual species.

The habitat environment survey was conducted in both Oaota forests and the habitats of *Polygonatum involvratum* in Kashiwa city. The canopy openness (%) and the soil water content (%) were measured.

The diversity index increased in all plots of different vegetation types of broad-leaved deciduous forest, coniferous mixed forest, and *Pleioblastus chino* plain. Especially in woodland plots, it increased in the third year after the Satoyama management.

Species richness in each plots from 2011 to 2013 showed that the species richness in *Pleioblastus chino* bush area that was mowed increased greatly since 2011. Contrary, the control plots remained the smallest. In the woodland plots, both Satoyama management and unmanaged control plots had the same change pattern.

Species composition showed that turnover of species was greater in the first period (2011-2012) than in the second period (2011-2013). What is more, the share of life forms for appeared species showed that more variety of life forms appeared in the first period than in the second period. A rewarding result was that some rare species, *Cephalanthera falcata* and *Ajuga nipponensis*, appeared as a result of the volunteer Satoyama management.

The relative dominance in Satoyama management plots have increased more in 2013 than that in 2012 and 2011. In control plots, however, it decreased over the three years except in one plot B2.

The habitat environment survey in Oaota for species diversity found that mean canopy openness is larger in Satoyama activity plots than that in control plots. The activities improve the light condition of forest floor. The characteristics of habitat were revealed that *Polygonatum involcratum* inhabited in the coppice of dark and tree-shaded area. The observation found that *Polygonatum involcratum* inhabited along pathways where growth of *Pleioblastus chino* was suppressed, and grew with diverse species next to each other.

Therefore, the hypothesis was verified in this study. The volunteer Satoyama management plays an important role in maintaining the species diversity of plants and conserving rare species. The habitats of *Polygonatum involcratum* and some rare species have interaction with humans care and passes.

Key words: Biodiversity, Species diversity of plants, Satoyama, Suburban coppice field

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The fieldwork activities and plant surveys were conducted in this research. They were achieved with substantial support from volunteers of NPO Chiba Satoyama Trust.

Especially, my deepest gratitude goes to Mr. Mitsumasa Sasaki for guiding me to the habitats of *Polygonatum involcratum* in Kashiwa city, teaching me name of plants and seasonal managements in the coppice fields. This research reflects their continuous efforts and kinship with the local coppice fields in Kashiwa city and my respect to them is beyond words. My interest in the biodiversity of suburban coppice fields was inspired by a number of people who supported the Satoyama activities. NPO *Konbukuro-ike Shizenno Mori* volunteers led me to the natural forests and taught me about the various animals such as rabbits, snakes, and eagles and about the rare plants that inhabit in the forest.

I have been supported by my laboratory members in completing this thesis. I would like to thank Dr. Sonomi Shibuya and Mr. Tamio Yajima for teaching me about plant surveys and for providing me with some valuable data. Their leadership encouraged me so much in researching on the biodiversity. I also wish to express my sincere gratitude to my laboratory seniors and colleagues who kindly supported my field surveys and encouraged me by improving my knowledge on frontier ecology. Especially, Ms. Yoko Takishita kindly encouraged me and supported my plant survey and habitat environment survey of *Polygonatum involcratum*.

Finally, I express my deepest gratitude to my family. Their hearts were always with me, and encouraged me. I respect my family from the bottom of my heart.

DEDICATION

This master thesis is devoted to my grandfather.

I could not finish my master thesis without many people's support. Especially, my family and friends supported me fundamentally. My parents encouraged me to research on whatever I am passionate about, and Jiji the cat always supervised me in daily life and helped my presentation practices. Jiji the cat never scratches even though he was challenged by humans and other cats, he has such a moral mind and I respect him from the bottom of my heart. Richard was always kind and supportive. Today I dedicate this important achievement to them, because their daily love, support and understanding made me strong enough to achieve my goal.

One day, two swallows started to make their nest in my apartment during the rainy season. Even though they failed to attach large branches and leaves to their nest, they never gave up, which I was encouraged to write my thesis. A very hot summer came, and the mother bird looked anxious before baby swallows were hatched from the eggs. Once they came out, the parent birds flew strongly like arrows to feed their babies. They never stopped flying under the hot sunlight. The babies grew up little by little. On my master thesis presentation day, the swallow babies flew into the sky in the early morning. Still sometimes, they come back and see their nest for a long time, recalling old memories with their family in their minds.

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1 INTRODUCTION

1.1 Purpose of this research

The purpose of this research is to examine to what extent the ground flora in suburban coppice fields changes after thinning and mowing. These activities are called Satoyama management. This research examines the biodiversity of plants in three plots that were set in different dominant tree stands. In the plots, different Satoyama activities were conducted. The hypothesis of this study was that the biodiversity of plants would increase as a result of Satoyama management (Yamazaki et al., 2000; Nakashizuka and Iida, 1996). Moreover, rare plant species that sleep in the seed bank are expected to reappear supported by the improvement of the forest floor environment (Kameyama, 1996).

The traditional Satoyama activities that were conducted until the 1960s at the study site ceased after the fuel conversion in 1962 when importation of crude oils was liberalized and became the major energy source in Japan (Agency for Natural Resources and Energy, 2007). Voluntary Satoyama activities have started with various purposes such as maintenance of abandoned forests, biomass utility, and a relief place for volunteers. They improve the environments in the coppice fields such as opening canopies, changes in plant communities, and removal of dominant species. It was expected that biodiversity of plants increases after these human activities. It was also expected that rare species would sprout. Therefore, it is important to verify the vegetation changes that occurred after recent Satoyama activities by volunteer citizens. This study provides fundamental records of plant surveys and scientific approaches to document the biodiversity of plants over the three years from 2011 to 2013. The habitat environment of the ground flora and the rare species of *Polygonatum involcratum* was also surveyed.

1.2 Social background

Conservation of biodiversity is an important global issue that each nation should take measures. Humans depend on natural resources and humans need to conserve nature and biodiversity. The Convention on Biological Diversity (CBD) is an international legally binding treaty (Ministry of Foreign Affairs cited on May 18th, 2013). It is stated in the COP11 decisions that each nation should take responsibility in implementing the biodiversity conservation activities (Convention on Biological Diversity cited on May 30th, 2013).

In Japan, the overview of the National Biodiversity Strategy 2012-2020 reports that although Japan has rich biotas on its inland area, there are four types of biodiversity crises: (1) crises caused by human activities including land development, (2) crises caused by reduced human activities, (3) crises caused by artificially-introduced factors, and (4) crises caused by changes in the global environment (Ministry of the Environment, 2012). Among the four crises, the relationship between human activities and biodiversity is central, excessive human activities such as deforestation and overexploitation has caused deterioration of the habitats of wild plants and animals. On the other hand, “effects from reduced or discontinued human activities as a result of changes to the industrial structure” are deteriorating the quality of Satoyama landscapes and leading to extinction of species (Ministry of Environment, 2012). It is pointed out that both excessive development and stop of human management have negative effects on the Satoyama biodiversity.

Many studies have done on Satoyama biodiversity. The species diversity of plants is especially important for the endemic insects and animals to feed themselves. The secondary forests are the habitat of flora and fauna. The secondary forests, however, have decreased in the suburbs as human population has increased and urbanization has expanded (Hamahashi, 1980; Saito et al., 2003; Nakashizuka and Iida, 1996), and the coppices in suburbs became more and more isolated and fragmented. In a recent study, it was found that the number of species predicted to become extinct is roughly proportional to the area destroyed (Storch et al., 2012). Nemoto (2006) reported that urbanization has negative effects on the vegetation in the secondary forests of *Quercus serrata* Thunb. Such negative impacts include the increase in weedy plants and decrease in woody plants, the disturbance of species compositions by invading of garden plants and decline in forest floor plants by stepping on them as forest area decreases. These studies reported that excessive human development caused loss of endemic biodiversity.

On the other hand, previous studies have shown that the interaction between humans and habitats is important for maintaining and increasing the species diversity of plants in coppices. Research on the conservation of spring ephemeral species in the deep mountain which has no access infrastructure found that they became extinct because of the lack of human management (Yamamoto et al., 1998). They suggested the importance of human access to the forest ground flora and mowing for the spring ephemeral species to grow (Yamamoto et al., 1998). Katoh and Yachi (2003) found that after stop of Satoyama activities, the period after the last management activity greatly impacted on species richness, in deciduous broad-leaved and coniferous forests. Therefore, the coppice fields in suburbs are important habitats for a variety of creatures including endemic plant species, where volunteer citizens who are in charge of Satoyama activities can access them.

Traditional Satoyama activity (thinning, mowing, and collecting the fallen leaves for local farmers' livelihoods) used to be the important management of secondary forests in historical times since the *Jomon* era in Japan (Tjuji, 1997). The coppices were utilized until 1960s in the Kanto Plain and created regionally unique forest cultures (Kameyama, 1996). The current environmental policy tries to promote volunteer Satoyama activities and restore biodiversity in secondary forests. For example, the Basic Act of Biodiversity is under the Basic Environment Law and it sets the basic principles of conservation of biodiversity and its sustainable utilization (Basic Act of Biodiversity, 2008). The act aims to promote strategies for conserving biodiversity by clarifying the responsibilities of the national government, municipal and public authorities, business operators, individual citizens, and civilian organizations (Basic Act of Biodiversity, 2008). In the Basic Act of Biodiversity, biodiversity is defined as various existing ecosystems, and various differences exist between species and within the species. The New National Biodiversity Strategy of Japan which was planned under the Basic Act of Biodiversity explains the importance of *Satochi-Satoyama*. *Satochi-Satoyama* has been changed since the socio-economic situations reduced the human activities in them. Satoyama, the secondary forests, have been maintained by human activities. They are important areas for biodiversity conservation in Japan.

In recent years, managing secondary forests has been aimed at promoting as a practical measure for sustainable development (Okano, 2012). The Man and the Biosphere Program (MAB) of UNESCO was established in 1971 to promote interdisciplinary approaches to management, research, and education in ecosystem conservation. The biosphere reserves, however, are not widely recognized in each region, whereas the UNESCO world heritage sites are well-known. The core function of sustainable development in the Biosphere Reserves has not been put into practice (Okano. 2012). How to promote the recent Satoyama activities is suggested and three causes are pointed out (Okano, 2012):

1. The understanding of the importance and values of biodiversity is not communicated, and so most people are ignorant of the problems. The citizens' participation in various activities has not been promoted.

2. The status of biodiversity has not been identified. The evaluation based on the scientific perceptions and fundamental knowledge for the strategies has been insufficient.

3. The activities for biodiversity conservation such as nature recovery and conservation of *Satochi-Satoyama* have not been shared, and frontier strategies have not been promoted.

Okano (2012) suggests that secondary forests, *Satochi-Satoyama*, should be included in the objective of the buffer zone. The buffer zone has the National Biodiversity Strategy's second threats of shrinking interaction with human activities because of social changes, and such buffer zones are often the habitats of the rare species. Both controlling the large development and sustainable utilization are necessary to mitigate the first and second threats. Therefore, it is important to conduct the volunteer Satoyama activity and document the biological diversity based on the scientific approaches to promote and to share biodiversity conservation management strategies.

Recently, Satoyama activities are conducted by local citizens. Local citizens took initiative in starting volunteer Satoyama activities. They remember the traditional skills in managing the Satoyama and put them into practice. Therefore, this research documents the status of biodiversity of plants in the Satoyama activity area, and verifies the vegetation changes after the volunteer Satoyama management.

1.3 Literature review

A number of studies have been carried out in efforts to examine the effects of

Satoyama management on the ground flora of secondary forests. Natural factors and human factors determine the species diversity of ground flora at community level (Nakashizuka and Iida, 1996). Natural factors include micro-topography, soil condition, and forest structure. Human factors include management methods of coppices. In coppices, human factors can have a stronger effect on the species diversity than natural factors. Thus, it is important to survey on various Satoyama management methods as well as habitat environment condition.

Previous studies researched various Satoyama managements. They are 1) mowing, 2) thinning, 3) thinning, mowing and collecting leaves and litter. Moreover, there are two different cases. One case is the research on plants after *abandonment* of Satoyama activities. The other case is the research on plants after the *start* of Satoyama activities.

As for the mowing activity after *abandonment* of Satoyama activities, stopping mowing increases the coverage of shrub layer and changes the herb compositions in *Quercus serrata* secondary forests (Tsuji and Hoshino, 1992). Mowing and the access to the forest are important for the conservation of spring ephemeral species (Yamamoto et al., 1998). The study on the impact of mowing and collecting fallen leaves on ground flora found that more species appear than disappear due to human management (Shimada and Fujiwara, 2002). They also found that species appeared due to the abandonment of managements, and such species are common in the climax forests (Shimada and Fujiwara, 2002). The previous studies suggest that in order to discover management methods, it is important to capture the features that cause species to appear by examining the corresponding relationships between current human management and vegetation.

Thinning activities and their impact on forest floor vegetation have been also studied. Nagaike (2002) reviewed the cases of thinning and its impact on the species diversity of plants around the world and suggested thinning measures that correspond to the natural disturbances. The natural disturbances such as the natural falling of dead branches create micro-level variety in the environment. For example, clear-felling greatly changed the species composition and partial felling also has a large impact on species diversity depending on the felling frequency and strength. In another study, clear felling in deciduous broad-leaved forests was studied by focusing on the common species in all plots, their size, the number of individual species, and blooming as the indicators (Fukada and Kameyama, 2003). They explained that thinning the upper story trees is important because it has a large impact on the light conditions in the forest floors and this plays an important role in maintaining the species community that prefers the brighter environment (Fukada and Kameyama, 2003). Thinning activity strategies, therefore, depend on the management policy. Their impact on the species richness can be monitored by various indicators.

The various activities of thinning, mowing, and collecting fallen leaves have been studied in many areas in Japan. As for after *abandonment* of Satoyama management, Katoh and Yachi (2003) explain that fallen leaves accumulate as time passes after the last management, and this increases soil electric conductivity, which have effects on increasing the species richness of woody plants and decreasing the species richness of herbaceous plants (Katoh and Yachi, 2003). As for after *start* of Satoyama activities, Yamazaki et al (2000) showed that the significant increase in species richness was observed from research on the comparison of the vegetation *before* the human management and *after* that management. They showed that the management which mow *Pleioblastus chino* and evergreen broad-leaved shrubs such as *Eurya japonica* (Hisakaki), and grow dominant tall trees such as *Pinus densiflora* (Akamatsu) and *Quercus serrata* (Konara) was effective in maintaining and increasing the species diversity in Satoyama in Hyogo prefecture in the Kansai area of Japan. The study also showed that the appearing plant species are rich in *Cryptomeria japonica* (Sugi) and *Chamaecyparis obtusa* (Hinoki) near the villages that had been a forest area for many years.

Previous studies emphasize the importance of Satoyama management as the interaction between humans and plants. These studies suggested that the Satoyama activities were conducted based on the regionally appropriate policies for each type of forest, and they also suggested that clarifying the impact of different management on the same site can provide an idea to the appropriate management measures (Nagaike, 2002). In these past studies, however, different management styles in different regions and forest types have been reported individually. The biodiversity of plants after various Satoyama managements that are applied to different vegetation sites in the same continuous forest is not known. Thus, this study verifies the biodiversity of plants after the volunteer Satoyama activities in various dominant tall trees in the same forest. Some previous research studies some specific species selected for the conservation and indicators. This research is unique because this study surveyed all the plants with botanists in the experimental plots managed differently for each vegetation type.

1.4 Definition

Why are the management activities that were conducted in the coppice fields called Satoyama activities? *Satoyama* is called as "mountains close to villages", contrary to *Okuyama* which means "deep in the mountains" (Arioka, 2004; Tanaka, 2011). Satoyama and woodlands on plain land ('*Heichirin'*) are called as a place the coppice fields exist, whereas the 'farm-land woodlands' and 'charcoal woodlands' are called to show the functions of the coppice (Kameyama, 1996). According to Kameyama et al. (1996), the reason it is not clear whether Satoyama is the word that means "mountains" or "forests" is that productive sites are mostly covered by forests and most of them are in the mountains in Japan. This is why it is perceived that mountains and forests are often the same. Artificial planted forests are also in the Satoyama, and many of them are the coppices (Kameyama, 1996). Thus, the coppices on the plain in the Kanto Region are also called Satoyama, and their management activities are recently called Satoyama activities.

Coppice is a secondary forest that is thinned regularly. Japanese coppices have this unique name of ‘*zokibayashi*’ based on its ecological characteristics and forest culture. *Zokibayashi* is the coppice where *Quercus acutissima*, *Q. serrata*, *Carpinus tschonoskii*, *Zelkova serrata, Q. myrsinifolia*, etc. grow. According to Kameyama et al. (1996), ‘*zoki*’ means various trees, and trees that are not utilized as good timber like *Cryptomeria japonica* (Sugi) and *Chamaecyparis obtusa* (Hinoki) (Kameyama et al, 1996). *Zokibayashi* in Japan is the woodland in which these various trees are dominant (Kameyama et al, 1996).

The coppice, *zokibayashi*, have interacted with human livelihoods, and functioned as farmland woodland, and charcoal woodland (Takeuchi et al., 2001; Saito et al., 2003; Kameyama 1996). The farmland woodlands are the woodland where farmers collected the fallen leaves and litter for their fertilizer (Takeuchi et al., 2001). The charcoal woodlands are the woodlands that are utilized by cutting tree stems (‘*Jukan’*) regularly for firewood and charcoal (Takeuchi et al., 2001). In detail, farmland woodlands are classified as landowners woodlands (‘*Yashikirin’*), shelterbelt for farmland (‘*Kouchi boufurin’*), timber for farm (‘*Nougyouyouzairin’*), charcoal forests (‘*Shintanrin’*), fallen leaves collection forest (‘*Rakuyousyusyurin’*), grazing forests (‘*Houbokurin’*), special tree growing forests for fertilizer, feeding stuff, foods, materials (‘*Tokuyou Zyurin’*) (Kameyama, 1996). Thus, the word ‘coppice’ in this research means the Japanese ‘*zokibayashi’* which have had the mentioned functions and interactions with local farmers.

In general, the forest type has three categories. The *primary forests* that are in the stable climax conditions of the natural succession, and the *secondary forests* that are in the process of secondary succession after some natural or human disturbance for the agricultural production and farmers' fire resource, and the *artificial forests* that have been planted for the purpose of the production of useful timber such as *Cryptomeria japonica* (Sugi) and *Chamaecyparis obtusa* (Hinoki). Thus, the ecological feature of the coppice fields is the secondary forests. About 40 percent of the national land of Japan is this type of Satoyama, the secondary forests (The Ministry of Environment, 2006). In the Kanto plain, artificial plantations of *Cryptomeria japonica* (Sugi) and *Chamaecyparis obtusa* (Hinoki) were seen in diluvial terraces covered by the loamy layer of the Kanto Plains, and they also spread on smooth hills around them (Kameyama, 1996). These forests were generally called *lowland forests* and they were mainly coppices ('*zokibayashi'*). The other type of coppice was composed of the deciduous broad-leaved trees of *Quercus serrata* and *Quercus acutissima* (Kameyama, 1996).

The traditional Satoyama activities mean the sustainable cycle of coppicing trees in the firewood forest and collecting the forest floor litter which contains the fertile soils with fallen leaves for farmlands. The coppice cycles is considered on a few decades basis (Takeuchi et al., 2001). In the Kanto region, in early December, local farmers mowed grasses (*Imperata cylindrical*) and shrubs, thinned dense trees, and then collected the fallen leaves

(Yabu, 1996). The sustainable usage of the coppice fields let new trees grow from the stems after they coppice the tall trees (Ministry of Environment, 2009). Through these Satoyama activities, the natural succession of a forest has been maintained to a certain stage between the deciduous broad-leaved forests (*Quercus serrata* and *Q. acutissima*) and evergreen broad-leaved forests (*Q. myrsinaefolia*) (Kitoh, 2013).

The *zokibayashi* in recent situations are, however, unmanaged and have become dark coppice fields with dense bush as long as I have observed them in the suburbs of Tokyo. In the suburbs, urbanization accompanied by population increase has forced land use development to build housing (Saito et al., 2003; Takeuchi et al, 2001; Nakashizuka and Iida, 1996). Use of fossil fuel has decreased the demand for firewood and charcoal and they became unmanaged (Takeuchi et al, 2001). Recently, the isolated coppices near cities are under outside pressures to sell the forest land to develop for more profitable purposes such as consumption, labor, and commercial opportunity. The threats of the suburban coppices are that humans do not sustain the interactions with the coppices and the species inhabiting there are not sustained either. If some plant species have been threatened to decrease its number, the insects and animals that eat them would suffer in finding their foods and it is a threat for biodiversity conservation. Therefore, under such threats, humans can manage to sustain or increase the plant species (Yamazaki et al., 2000; Shimada and Fujiwara, 2002; Mason and Macdonald, 2002). Satoyama activities play a role in supporting fundamental functions of plants that are the basis of forests and ecosystem (Takeuchi et al., 2001).

1.5 Background of study site

Suburban forests have been decreasing in area as humans increase in population and develop land. As population increases, railways from cities to suburban areas are developed. The forests in suburban area must be cleared for roads, and commercial or residential buildings. The coppices have decreased or fragmented in the past 25 years in the Kanto region plain or hills (Nakashizuka and Iida, 1996).

For example, Higashi-Katsushika is within about a 20 km to 30 km radius of the capital city Tokyo and it is one of the suburbs of Tokyo (Ministry of Land, Infrastructure, Transport and Tourism, 2006). It is in the northern part of Chiba prefecture in Japan. From 2004 to 2010, the forest area in Higashi-Katsushika decreased by 119 hectare (ha) (Chiba-ken Nourinsuisanbu Shinrinka, 2012). Of all the cities in Higashi-Katsushika, Kashiwa city has the largest forest area since 2004 after merging (Chiba-ken Nourinsuisanbu Shinrinka, 2013). Kashiwa city is one of the cities whose forest area has been decreasing the most rapidly (Figure 2). One of the causes is the population increase in Kashiwa city (Figure 1) (Kashiwa City, 2012). The total population in Kashiwa city as of 2011 has increased eight times in size since in 1955 (Figure 1) (Kashiwa City, 2012).

The decrease in forest area as the population increases raises a question about the relationship between biodiversity and human activities. The relationships between biodiversity and human population density are discussed whether human settlements in the area have positive impacts on its biodiversity or not. Gary (2007) has pointed out that some consistent trends in the literature on the relationships between human population density and biodiversity are evident. Significant positive correlations were found between human population density and species richness, the richness of threatened, geographically restricted and introduced species, and extinctions. On the contrary, there is a negative correlation between human population density and protected area coverage. This implies that human settlements reduce the natural land for conservation and increase the species richness of some species including exotic species.

On the other hand, humans still need to take care of the threatened and extinct species in their locality. It is also mentioned that "species sensitive to anthropogenic change are lost or decline in abundance, while disturbance-tolerant and generalist species may prosper" (Gary, 2007). In terms of plant species richness, this statement does not clearly state what kinds of human activities are targeted, and how the humans and species have interacted over time.

What is more, among various causes, the most important is the loss and fragmentation of natural habitats (Schucking and Anderson, 1991). The forests became fragmented surrounded by cultivated farmlands, houses and building lots (Nakashizuka and Iida, 1996). It is estimated that as the forest area becomes smaller, or as these areas are further isolated by neighboring coppices, the species diversity of plants becomes lower (Nakashizuka and Iida, 1996). The socio-economic and political causes of biodiversity loss vary from region to region. The fragmented forests or the coppice fields are at risk of destruction by outside economic forces. Local communities have powers to become involved in Satoayma activity.

Since volunteer Satoyama activities' purposes have changed from the traditional purposes, volunteers and activists' own values reflect on the forest functions, and they seem to be applied to forest managements. As what kinds of plants grow after volunteer Satoyama management is not known until the scientific survey on changes in the ground flora in coppice fields, it was studied from 2011 to 2013 using the experimental plots in two coppiced woodlands and one *Pleioblastus chino* plain. The study area of this research is suburban coppice fields that are managed voluntarily by local citizens.

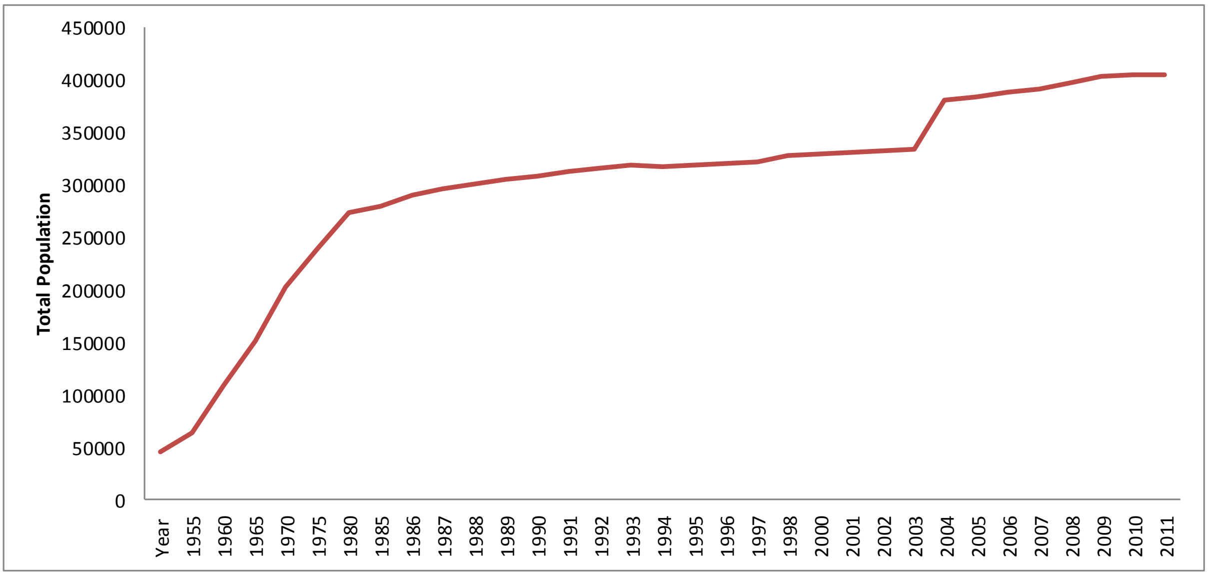


Figure 1. Total population in Kashiwa city (Source: *Kashiwa city Kokusei Chosa* [census], 2012)

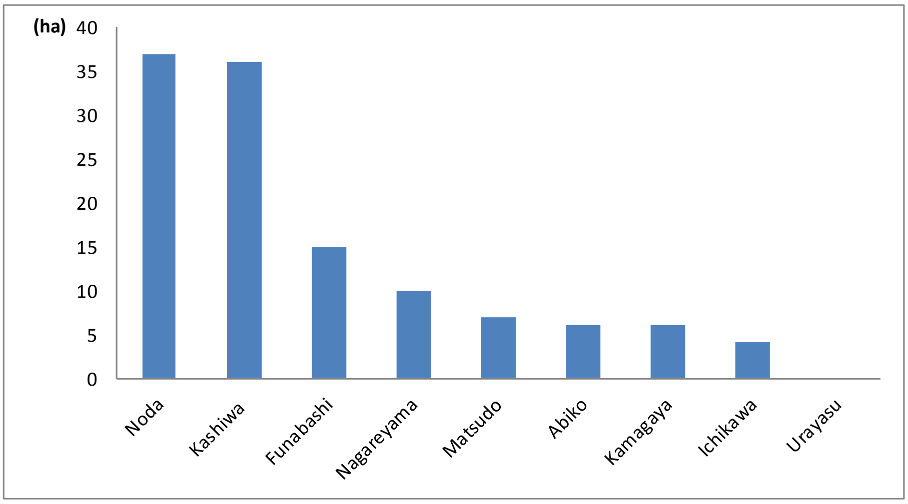


Figure 2. Forest area decrease (2004-2010) by city (Source:*Chiba ken Shinrin Ringyo Toukeisyo* [statistics])

2 METHODOLOGY

2.1 Study area

2.1.1 Study area of plant species diversity survey

This study was conducted in a coppice field of a secondary forest called Oaota forest in Kashiwa city of Chiba prefecture, the northern part of Japan’s Kanto Plain over the period 2011-2013. The forest area of the Oaota forest is about 443,500 ㎡ (Google map area calculation). The annual average temperature from 1999 to 2010 is 15.3℃; the annual precipitation for the same period is 1462.9 mm (Japan Meteorological Agency, Funabashi).

The vegetation in Kashiwa city as of 1983 (Figure 3) had little dotted evergreen broad-leaved forests of *Castanopsis sieboldi*. These forests were considered as the most natural vegetation in Kashiwa city that located beside farmlands and secondary forests. The forest area of this *Castanopsis sieboldii* forest was only 0.29% of the total forest area of Kashiwa city (Fukushima and Takahashi, 1986). On the other hand, shrub community and herbaceous plants community occupied the largest area of plant community habitat in Kashiwa city (Fukushima and Takahashi, 1986). They are the *Miscanthus sinensis* and *Pleioblastus chino* communities that grew in the fields after clear-cutting or old developments and abandoned farmlands (Fukushima and Takahashi, 1986). Contrary to these fields, Oaota forest is the largest continuous forest in Kashiwa city, and it has had a relationship with human lives.

The experimental plots were set in each site in Oaota forest, and labeled plots A, B, C and D. Plot A have been used as a garden by Satoyama volunteers. Thus, only experimental plots B, C and D were chosen for study. The experimental plots were established in 2011 on three sites: Plot B is the deciduous broad-leaved secondary forests (*Quercus serrata*, *Quercus acutissima*, *Carpinus tschonoskii*), Plot C is the mixed secondary forests of deciduous trees and conifer trees (*Cryptomeria japonica*, *Chamaecyparis obtusa*), Plot D is the dense *Pleioblastus chino* bush (Appendix A). There are two types of plots in each labeled plots: one type is the plots that are maintained by Satoyama activities (B1, C1 and D1), and the other one is the control plots that are *not* maintained by Satoyama activities (B2, C2, D2 and D3). The Satoyama activity plots and control plots were set side by side with a 10 m buffer zone around each plot. The Satoyama activity plot and control plot in each site have the close vegetation of ground flora, and the each site differs in vegetation (Appendix D). The objectives of the establishment of experimental plots were 1) comparison of ground vegetation between Satoyama activity plots and control plots, and 2) analysis of the vegetation changes from 2011-2013.

Satoyama activity has been conducted by the volunteer group NPO Chiba Satoyama Trust. According to the activity records and the hearing survey, the management history was as follows;

Plot B: Satoyama management was started from 2011. Large thinning was conducted in plot B1 in a project in cooperation with The University of Tokyo. In plot B1, only thinning was conducted, but before 2011 mushrooms were cultivated and the legacy of the accumulated cut trees and a little mowing and thinning activities were observed.

Plot C: Mowing has been conducted since 2004 when the NPO Chiba Satoyama Trust became responsible for the Satoyama management. They also cut the rhizome of *Pleioblastus chino* to improve the ground and make it easy to walk in. The large thinning activity was conducted in plot C1 in 2011 when a project with The University of Tokyo started. Thinning had been conducted before 2011, which thinned about less than 10 percent of the tall trees and this thinning activity was not as large as the one conducted in 2011.

Plot D: Mowing has been conducted since 2011 in plot D1. The growth of *Pleioblastus chino* was periodically cut to maintain the open condition. The field used to be a dense *Pleioblastus chino* bush.

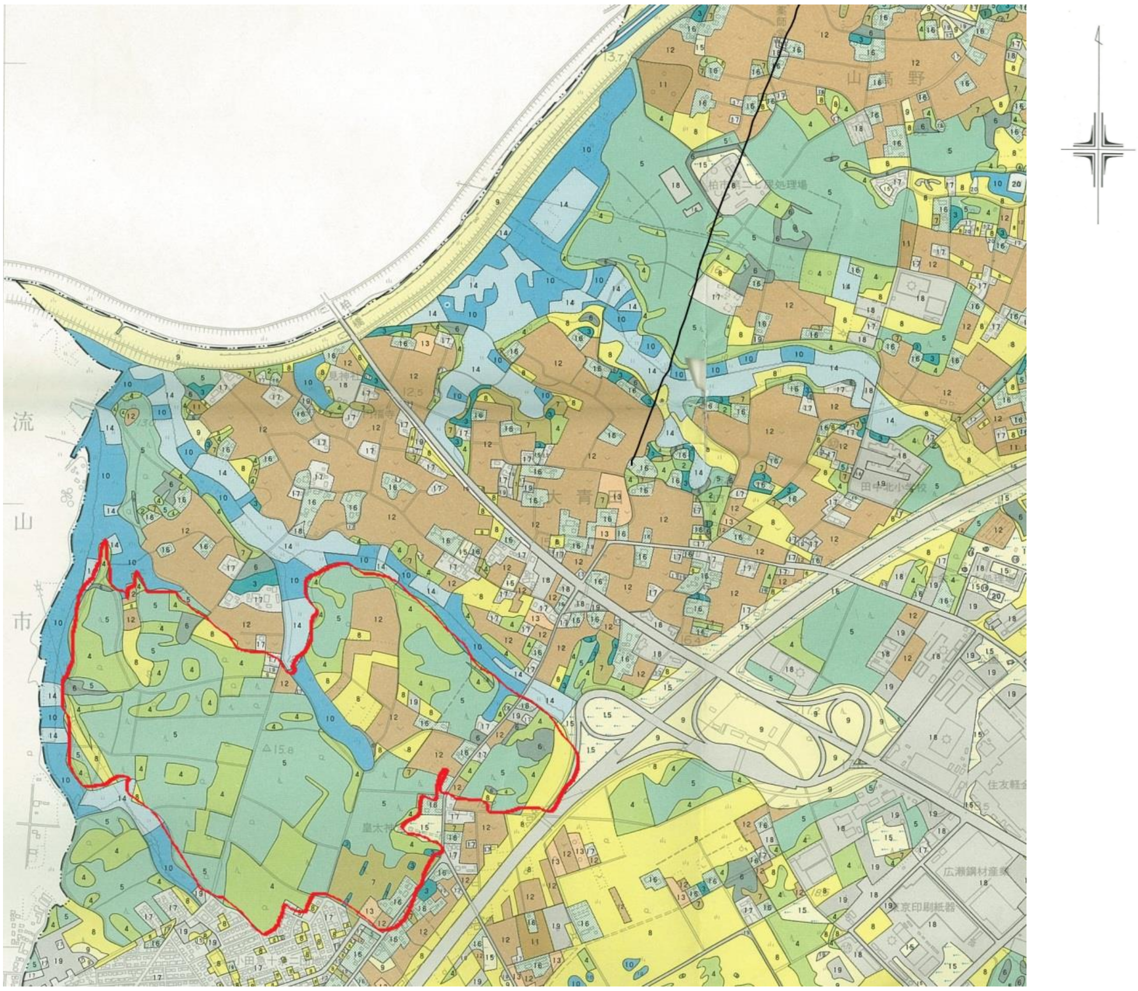
Therefore, the experimental plots have been managed by different measures. In summary, plot B is the thinning plot, plot C is the thinning and mowing plot, and plot D is the mowing plot.

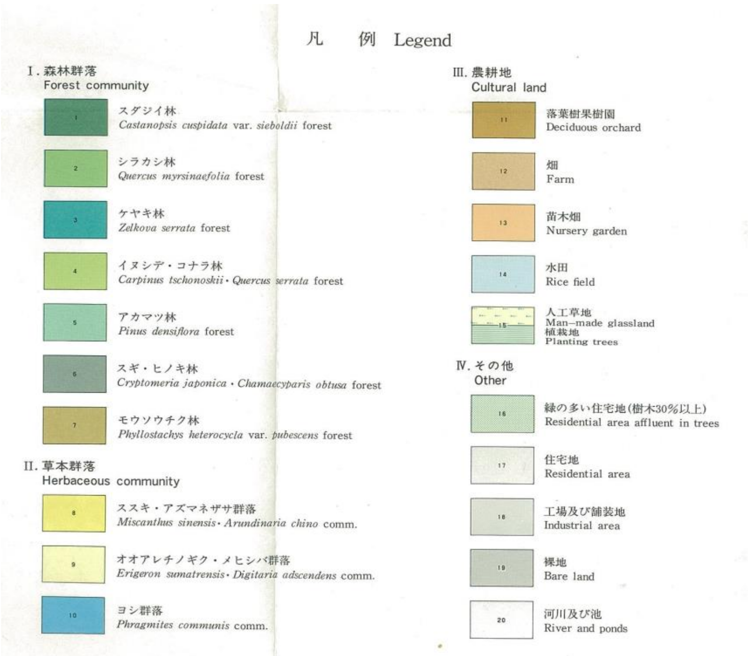
According to the "Map of Actual Vegetation in Kashiwa City" (Fukushima and Takahashi, 1986), the vegetation in Oaota forest in 1983 was *Pinus densiflora* forest, *Carpinus tschonoskii* and *Quercus serrata* forest, farmland and *Miscanthus sinensis* · *Pleioblastus chino* community. The comparison between the current experimental plots and the map of vegetation in 1983 (Figure 3) shows that the vegetation in Plot D has changed from *Pinus densiflora* forest, *Carpinus tschonoskii* and *Quercus serrata* forest to a *Pleioblastus chino* community. The vegetation in Plots B and C also has changed from *Pinus densiflora* forest to B1: *Quercus serrata* forest, B2: *Quercus acutissima* forest, C1: *Carpinus tschonoskii* and *Chamaecyparis obtusa* forest, C2: *Carpinus tschonoskii* and *Swida controversa* forest.

According to an interview with a Satoyama activists (interview conducted on 17^{th} July 2012), around 1950, some local people collected the *Pinus densiflora* branches for firewood. If three people including the interviewee collected the branches, the branches could last for three days as the fires energy source at home. Decades later around the 1960s, liberalization of importing crude oil and the fuel conversion from firewood to the crude oil occurred. The four sites became unmaintained bushes, and the *Pleioblastus chino* grew densely and highly. The forest in Oaota forest next to the experimental plot D has been maintained by an individual owner as a coppice stand where large community of *Polygonatum involcratum* inhabits.

According to another interview with the Satoyama activist, the leader of the Satoyama volunteer group took initiative and talked with the Kashiwa city municipal government after the establishment of Chiba prefecture Satoyama activity codes. The municipal government wanted to maintain the abandoned forests which had a problem of misuse as illegal wastes fields and encouraged the leader to start the volunteer Satoyama activities. The activities were started voluntarily by the local community. The participants put together a little budget to buy the boots, helmets, and gloves necessary for the Satoyama activities, and they paid three thousand yen for the entrance fee and ten thousand yen for the annual membership fee to the volunteer group. The number of members has increased since then.

The volunteer citizens have various motivations for participating in the volunteer Satoyama activities such as childhood memories of going to the mountains with his father whose job was maintaining the forests, a sense of community after retirement, creating playfields in the forest for their grandchildren, interests in the endemic plants and rare species, and attachment to the ground flora in Oaota forest. Since the forest floor of the Oaota forest had dense bushes and illegal waste, the volunteers started their activities by removing them. It is not yet known what kinds of species sprout after the voluntary Satoyama management. The objectives of this study were to examine the extent that thinning and mowing influenced species richness of the ground flora, the percentage coverage of individual species, and the maximum height of individual species.





Oaota forest Study Site

Figure 3. Map of the current vegetation of Oaota forest in 1983

Source: "Map of actual vegetation in Kashiwa city" (Fukushima and Takahashi, 1986)

Figure 4. Experimental plots in study site of Oaota forest
Source: Google map 2013 Cnes/Spot Image, Digital Earth Technology, Digital Globe Landsat.

2.1.2 Study area of *Polygonatum involcratum* habitat survey

The study sites are the *Polygonatum involcratum* habitats in Kashiwa city, Chiba prefecture. *Polygonatum involucratum* is designated as B rank importance for conservation in Chiba prefecture (Chiba prefecture, 2009). B rank importance for conservation in Chiba prefecture means that the species is experiencing severe conditions such as quite a small number of individuals, their habitat and growth environment is quite limited, or most of them are under pressure of environment alternation (Chiba prefecture, 2009). If these severe conditions are neglected, it is certain that the species will be categorized as rank A (Chiba prefecture, 2009). The effects and factors that decrease the number of individual species that are ranked B should be mitigated or eliminated as much as possible (Chiba prefecture, 2009). It is important to find out the habitat of rare species and clarify the habitat characteristics for conservation; however, *Polygonatum involcratum* has yet to be studied.

This survey aims to explain the growth environments of *Polygonatum involucratum* for conservation. The plant communities grow in specific forest floors of coppices in part of *Oaota*, shrine, homestead woodland, and environmental education field in Kashiwa city. The plant communities were found by observations, and individuals in each community were chosen randomly. The survey items include individual's height, the number of leaves and flowers, soil water content, and canopy openness. Moreover, dominant species on the 2 meter line transect (A.G. Tansley et al., 1923) were recorded to explain the plant associations and features of the *Polygonatum involcratum* communities.

There are four sites of its habitats. One is the coppice field in Oaota forest. According to the hearing interview with the NPO Chiba Satoyama Trust, the coppice field has been maintained as Satoyama, the secondary forest, and has not been changed to farmland or used for planting. Kashiwa-gakuen is the environmental education fields of Bunkyo city, Tokyo. It is established to escape from the noisy life in the city, and to conduct activities in a suburban forest. Employed gardeners take care of the coppice field in Kashiwa-gakuen regularly. In addition to *Polygonatum involcratum*, beautiful fauna such as *Salvia japonica* and *Lilium* *auratum* bloom and citizens often visit there and observe them. Hirohata-hachimangu is the shrine coppice. The shrine coppice surrounds the shrine and the approach to the shrine. The coppice in the shrine is a sacred site and the nature still remains. The ground flora is maintained by the Shinto priests and citizen volunteers. Homestead woodland is the coppice filed in the backyard. Homestead woodlands prevent strong wind and produce materials for farmers lives (Fujii, 1996). The homestead woodland in Kashiwa city used to be maintained by the landowner, and now a volunteer citizen, Mr. Sasaki mows the bush.

2.2 Plant survey

This study conducted a plant survey to examine the species diversity of plants. The permanent 20 m×20 m plots were set in four sites, Plots A, B, C and D in the Oaota forest. (Plot A came to be utilized as a garden, and was excluded from this study.)

The survey of every tree measurement was conducted in 2011 (Table 1. Fukuda et al., unpublished data). The forest physiognomy in each plot was recorded (Appendix C):

Plot B1: *Quercus serrata*, *Carpinus tschonoskii*, *Styrax japonica*, *Cryptomeria japonica*, *Celtis sinensis*. One *Quercus serrata* and one *Styrax japonica* were thinned because of death, one *Cryptomeria japonica* was coppiced because of its branches were broken, and 4 out of 17 *Quercus serrata* were coppiced.

Plot B2: *Quercus acutissima*, *Carpinus tschonoskii*, *Pinus densiflora*, *Chamaecyparis obtusa*, *Quercus serrata*, *Magnolia kobus*, *Prunus grayana*, *Prunus* *buergeriana*, and *Styrax japonica.* Plot B2 is the control plot and no trees were thinned. The most dominant tree was *Quercus acutissima* and the number of grown-up trees whose DBH was more than 30 cm were 6 out of 16. The second major species was *Carpinus tschonoskii* and 22 trees grew, but their DBH were thin, and only one tree's DBH was more than 30 cm.

Plot C1: *Carpinus tschonoskii*, *Chamaecyparis obtusa*, *Quercus serrata*, *Quercus myrsinaefolia*, *Castanoposis sieboldii*. The major type of tree is *Chamaecyparis obtusa*. Four trees of *Chamaecyparis obtusa* were thinned because of death, 8 trees were thinned to open the forest floor to light. The second dominant was *Carpinus tschonoskii*. Two trees of *Carpinus tschonoskii* were thinned to open the forest floor to light.

Plot C2: *Swida controversa*, *Cryptomeria japonica*, *Carpinus tschonoskii*, *Prunus jamasakura*, *Quercus myrsinaefolia*, and *Chamaecyparis obtusa*. The most dominant tree was *Cryptomeria japonica*. The second was *Swida controversa*. The DBH of *Cryptomeria japonica* was about 20 cm for 12 trees and that of *Swida controversa* is 9 trees. This is the control plot and no trees were thinned.

Plot D1: *Quercus myrsinaefolia*, *Prunus grayana*, *Carpinus tschonoskii*, *Celtis sinensis* were the large trees. Plots D1, D2 and D3 were densely populated by tall *Pleioblastus chino* community. Plot D1 was mowed and maintained to open its ground floor to light.

<u>Plot D2 and D3</u>: *Pleioblastus chino* bush. Plots D2 and D3 are the control plots. There was a large tree of *Swida controversa* in plot D3 and thus there is a small open area under the tree. Other parts were still dense bush of *Pleioblastus chino.*

These plots were subdivided into 10ｍ×10ｍ small experimental quadrats and a plant survey of the herb layer was conducted over three years in May from 2011 to 2013. In the plant survey, plants below the chest height (under 130 cm) were the objects of this study. Firstly, the percentage of coverage of the entire vegetation coverage in the small quadrats was measured. Secondly, the percentage of coverage of each individual species and the maximum height of each species were measured for all of the appearing species. The plants that grow to higher than 130 cm in height were also surveyed as tree layer in the survey of every tree measurement in May, 2013. The point of each tree in the plots and its DBH and height were measured. The change in basal area (total cross-sectional area of tree stems at chest height) before and after thinning was shown in Figure 5. The total basal area of Satoyama activity plots (B1 and C1) decreased to about 60 to 80 percent of control plots (B2 and C2).

Table 1. Species composition of tree layer (>130 cm) in each plot in 2011 (Fukuda et al. unpublished data)

Plot name	B-1		B-2		C-1		C-2	
Total species number	5		9		5		6	
Total tree density (Number of tree/plot)	29		47		34		37	
	725		1175		850		925	
Total Basal area ($cm^2/400m^2$)	12521.752		14281.92		9930.818		13862.49	
	31.30438		35.70481		24.82704		34.65622	
Max DBH (cm)	36.3		41.5		33.7		29.5	
Max Height (m)	21.9		22.4		21.7		19.2	
Basal area (cm2/400m2), Number of Tree	BA	#Tree	BA	#Tree	BA	#Tree	BA	#Tree
Evergreen conifer tree								
Pinus densiflora Sieb. et Zucc			1182.4	1				
Cryptomeria japonica (L. fil.) D. Don	132.7	1					5591.9	14
Chamaecyparis obtusa (Sieb. Et Zucc.) Endl.			572.6	1	4514.3	19	268.8	1
Evergreen broad-leave tree								
Quercus myrsinaefolia Blume					19.6	1	346.4	1
Castanopsis sieboldii (Makino) Hatusima ex Yamazaki et Mashida					20.4	1		
Deciduous broad-leave tree								
Carpinus tschonoskii Maxim	1144.7	3	2091.0	22	5172.9	12	1119.9	4
Quercus serrata Thunb. ex Murray	10944.7	18	264.4	3	203.6	1		
Quercus acutissima Carruthers			9880.6	16				
Celtis sinensis Pers.	103.9	1						
Magnolia kobus DC.			86.6	1				
Prunus jamasakura Sieb. ex Koidz.							865.0	2
Prunus grayana Maxim.			86.6	1				
Prunus buergeriana Miq.			86.6	1				
Swida controversa (Hemsl.) Sojak.							5670.5	15
Styrax japonica Sieb. et Zucc.	195.7	6	31.2	1				

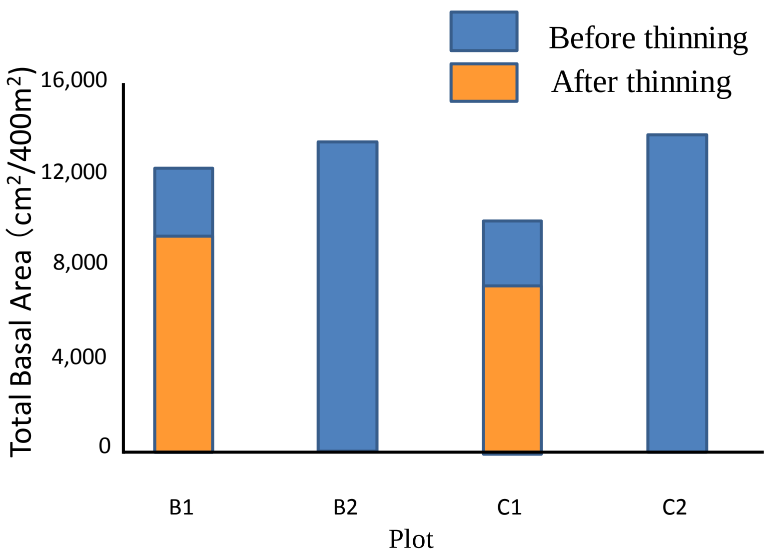


Figure 5. Total Basal Area ($cm^2/400m^2$) in each plot, changes from thinning (Shibuya et al. unpublished data)

2.3 Habitat environment survey for species diversity of plants

For each small 10 m×10 m quadrat, the percentage of soil water content and the percentage of canopy openness were measured at 9 points.

Seeds in the seed banks became able to germinate when environmental encouragements which are specific to the gap environment awake from their dormancy (Washitani, 1996). The life history of plants is categorized into two stages, one stage is the nutrition and growth stage when plants take in and accumulate organic substances in their body by photosynthesis and matter production, and the other stage is the reproduction stage when flowering plants bear fruit and seeds, sprout, grow roots into the soil, and stand (Washitani, 1996). Light and water conditions are important factors for ground flora in their growth period (Washitani, 1996).

2.3.1 Canopy openness

A fish-eye lens (Sigma 4.5mm, F2.8 EX DC Circular Fish eye HSM) was attached to the digital camera (PENTAX DIGITAL CAMERA k-7) to take hemispherical photographs. This survey was conducted in April and May during the period after trees flushed their leaves. The height of the camera was set 130 cm above the ground. The pictures were analyzed using software 'CanopOn2' (Takenaka, 2009, http://takenaka-akio.org/etc/canopon2/). The percentage of canopy openness is average porosity, the rate of sky area that is not covered by tree leaves and branches. The more porous the canopy is, the larger the mean figure of openness becomes.

Taking hemispherical photographs and calculating the percentage of sky area that is not covered by forest canopy can be indicators of ground flora's light usage (Washitani, 1996). The direct sunlight on the forest floor, sun fleck, changes over time depending on the position and amount of clouds, gaps between leave layers on the top and the position of sun (Washitani, 1996). The average time of direct sunlight on a specific point depends on the sky area that can be seen from that point. Thus, canopy openness (%) is an effective indicator for examining the degree to which forest floor plants can use light.

2.3.2 Soil water content

The percentage of soil water content was measured in plots B, C and D. The survey date was set after two or three sunny days in April and May 2013. The measurement was conducted using a TDR soil moisture meter (C-HydroSense, Campbell Scientific Australia Pty. Ltd.). The percentage of soil water content was measured at a depth of 12 cm underground at nine points. Each point was measured four times, and calculated the average of four measurements as the percentage of soil water content in the small quadrats.

2.4 Habitat environment survey for *Polygonatum involcratum*

Polygonatum involcratum communities were found by fieldwork in Oaota forest and other habitats in Kashiwa city. Individuals of *Polygonatum involcratum* were chosen randomly in each community. The survey items included their height, the number of leaves, the number of flowers and seeds, rate of soil water content, rate of canopy openness and amount of solar irradiation. The survey was conducted in July, 2012 when they bear fruits.

2.4.1 Canopy openness

North direction was marked and hemispherical photographs were taken with the fish-eye lens camera at each *Polygonatum involcratum* community. The pictures were analyzed using software 'CanopOn2' (Takenaka, 2009, http://takenaka-akio.org/etc/canopon2/).

2.4.2 Solar irradiation

Cumulative solar radiation was measured by optical type "Opt-leaf" (TAISEI E&L), which changes its color according to the sunlight dose. Paste orange Opt-leaves on the leaves of *Polygonatum involcratum* and other plants that grow at other sites where no *Polygonatum involcratum* community grows. After one week, the tapes were collected and measured for their color by "Opt-leaf meter".

2.4.3 Soil water content

The individuals were chosen randomly in each community. The measurement was conducted using the TDR soil water measurer (C-HydroSense, Campbell Scientific Australia Pty. Ltd.). The percentage of soil water content was measured at a depth of 12 cm underground.

2.4.4 Line Transect

Line transects of 2 meter were put in each *Polygonatum involcratum* community along pathways that have been naturally made by human stepping. Dominant species were recorded every 10 cm along the line transects on 19th July 2012 in habitats in Kashiwa city and 24th July 2012 in Oaota forest. The line transect is made at right angle in the direction in which the habitat factors show the maximum change, or in the direction in which invasion is proceeding (A.G. Tansley et al., 1923). In this study, the main habitat factor was pathways in the coppice fields, since *Polygonatum involcratum* community inhabit along pathways that were naturally made by human stepping. The line transect was made parallel and vertical to the pathways.

2.5 Analysis

As for plant species diversity survey, species richness, relative dominance and biodiversity indices were analyzed by the species composition list recorded from the plant survey. The appeared species were categorized by the Raunkiaer's life form, Numata (1997)'s growth forms. Their species compositions were compared among plots of different vegetation site, between Satoyama activity plots and control plots and their changes over three years. As for habitat environment survey, mean, max and minimum figure points, and standard deviation of soil water content and canopy openness were calculated.

3 RESULTS

3.1 Species richness

The number of species that was recorded at the three plots from 2011 to 2013 is shown in Figure 6. In all plots except D1 the species richness of woody plants was larger than herbaceous plants. In B1, the species richness peaked in the second year 2012 following thinning, and fell thereafter. In C1, the species richness declined from the peak in the first year 2011 following thinning and mowing, after relative stability was observed from the second year to the third year, from 2012 to 2013. Satoyama activity plots of B1 and C1 had the same change patterns with the control plots B2 and C2.

On the other hand, the marked difference in changes of species richness was observed at the *Pleioblastus chino* community site D. In D1, there was a marked increase in species richness from the first year to the second year, and then it continued increasing in the third year. In the control plots D2 and D3, species richness is much smaller than that in any other plots with no obvious changes throughout the three years.

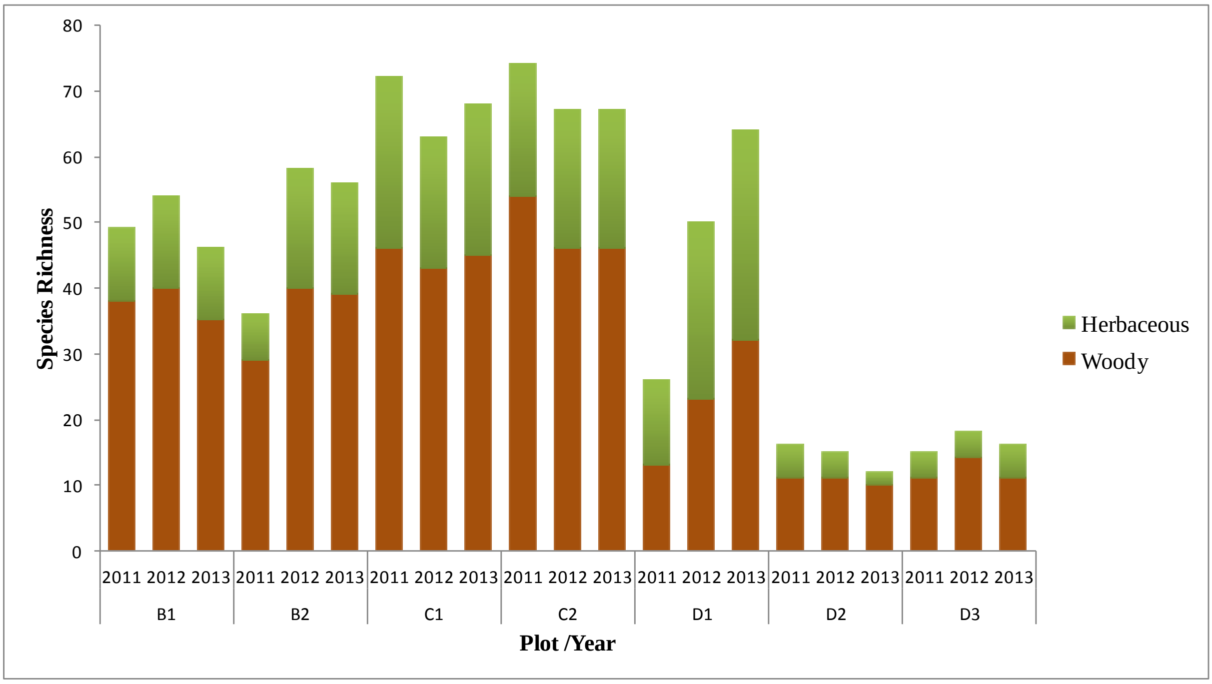


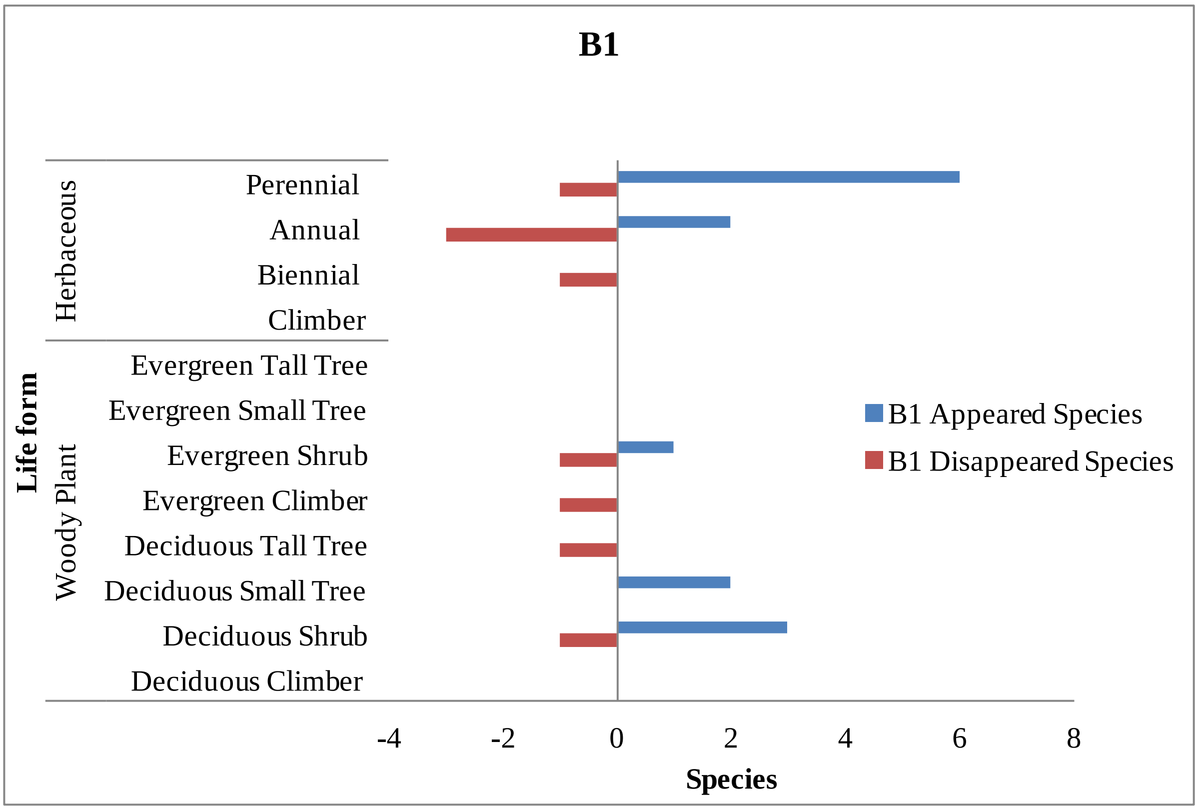
Figure 6. Species richness in each plot from 2011 to 2013

3.2 Species composition

The features of change patterns in species richness were different among plots. At the site of forest stands, the deciduous broad-leaved secondary forest (Plot B) and the mixed secondary forests of deciduous trees and conifer trees (Plot C), there are not significant differences in the total species richness between the Satoyama management plots (B1, C1) and the control plots (B2, C2). In order to look into the turnover of species, the species composition is shown in Figure 7-12.

3.2.1 Species composition from 2011 to 2012

Species composition from 2011 to 2012 is shown in Figure 7-9. Appeared and disappeared species is explained in each plot and year. In B1 at the site of deciduous broad-leaved secondary forest, perennial herbs, deciduous shrubs and deciduous small trees appeared largely, and then annual, biennial herbs, deciduous tall trees and ever-green climbers disappeared. The largest turnover was seen in perennial herbs appearance and in annual herbs disappearance. In B2, perennial herbs and deciduous shrub appeared largely, and also annual plants, climber, deciduous small trees, deciduous tall trees and deciduous climber appeared, but no disappeared species were observed. In C1, at the site of mixed secondary forests of deciduous trees and conifer trees, perennial herbs marked the most significant increase in appeared and disappeared species, and the number of disappeared species was slightly larger than that of appeared species. The ever-green small trees appeared by two species. The disappeared species are biennial herbs, deciduous small trees, deciduous climbers, and ever-green climbers. The other life forms made changes in both appearance and disappearance. In C2 (control), perennial herbs also marked the largest number of appeared and disappeared species. Ever-green small trees and deciduous small trees disappeared by one species, and deciduous climber appeared by one species. The other life forms made changes in both appearance and disappearance. In D1 at the site of *Pleioblastus chino* community, deciduous tall tree had the largest increase in appeared species, followed by perennial, biennial, and annual herbs. In spite of the increases in appearance of deciduous trees, evergreen tree species did not appear. Only evergreen climber species appeared. Evergreen small tree species disappeared. In D2 (control), there is no significant turn over. One perennial herb species disappeared and deciduous tall tree appeared and disappeared by one. In D3 (control), there is a slightly more significant turnover than D2. Deciduous tall tree species appeared by two, evergreen tall tree and climber species appeared, and then perennial plants both appeared and disappeared.



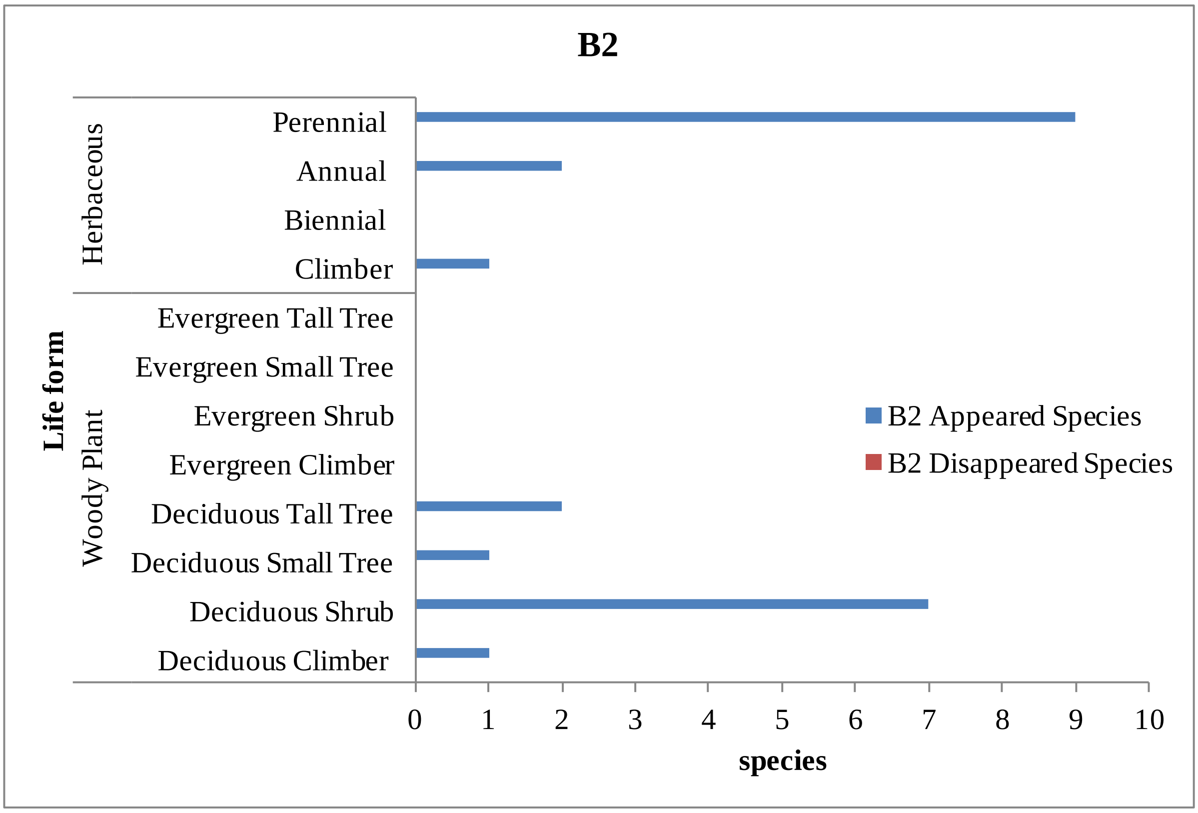
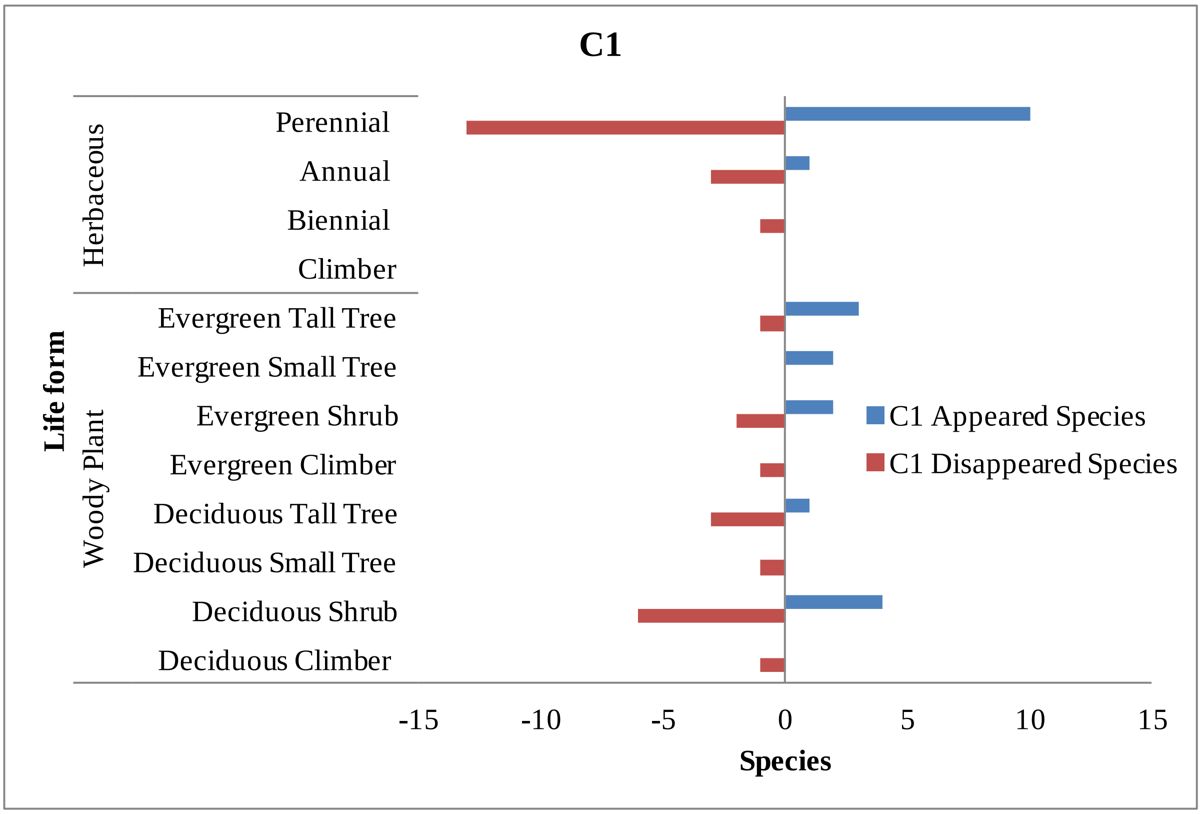


Figure 7. Species composition in Plot B from 2011-2012



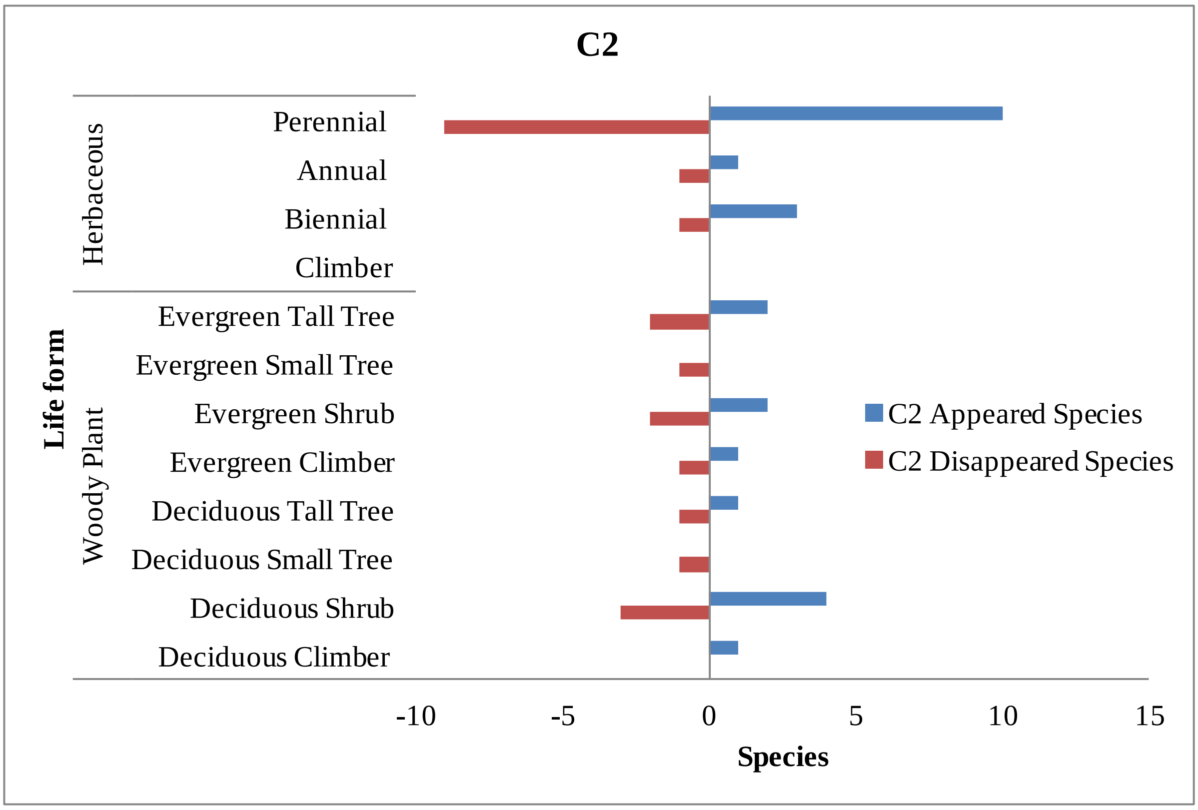
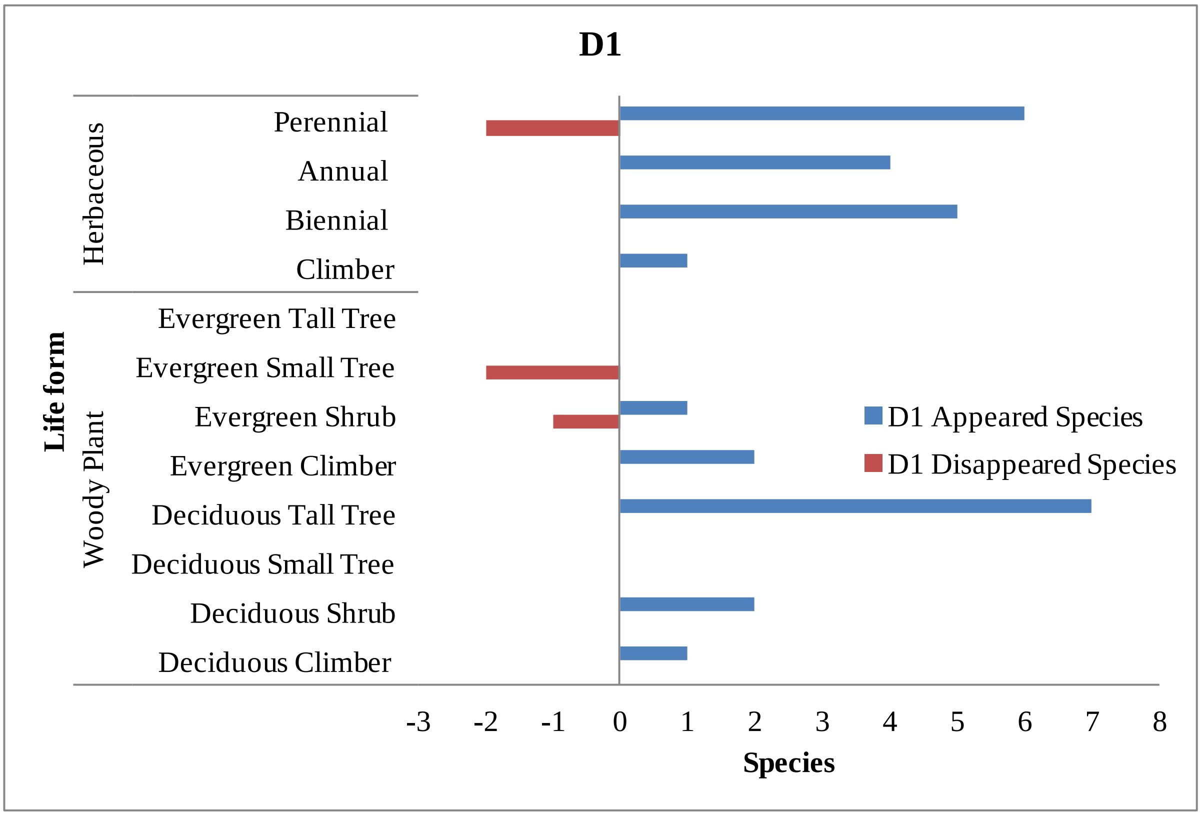
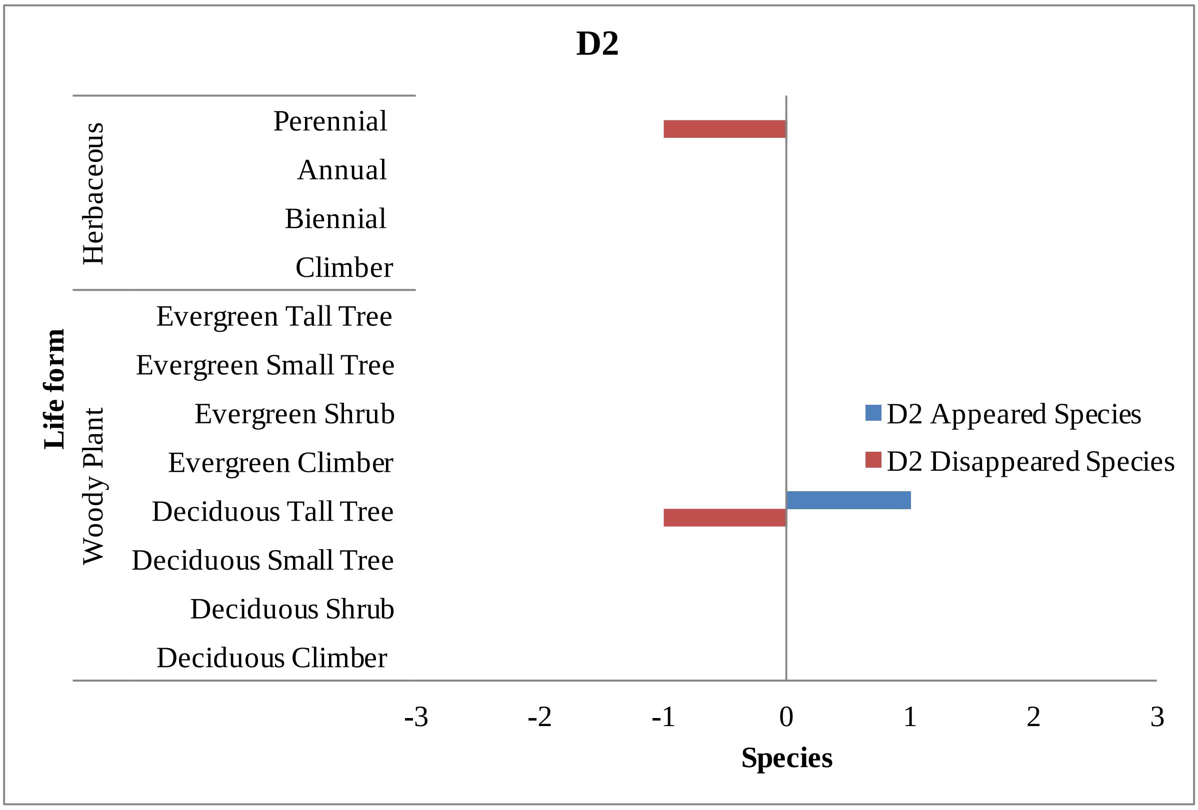


Figure 8. Species composition in Plot C from 2011-2012


D1
Life form
Herbaceous
Woody Plant
Perennial
Annual
Biennial
Climber
Evergreen Tall Tree
Evergreen Small Tree
Evergreen Shrub
Evergreen Climber
Deciduous Tall Tree
Deciduous Small Tree
Deciduous Shrub
Deciduous Climber
D1 Appeared Species
D1 Disappeared Species
-3 -2 -1 0 1 2 3 4 5 6 7 8
Species


D2
Life form
Herbaceous
Woody Plant
Perennial
Annual
Biennial
Climber
Evergreen Tall Tree
Evergreen Small Tree
Evergreen Shrub
Evergreen Climber
Deciduous Tall Tree
Deciduous Small Tree
Deciduous Shrub
Deciduous Climber
D2 Appeared Species
D2 Disappeared Species
-3 -2 -1 0 1 2 3
Species

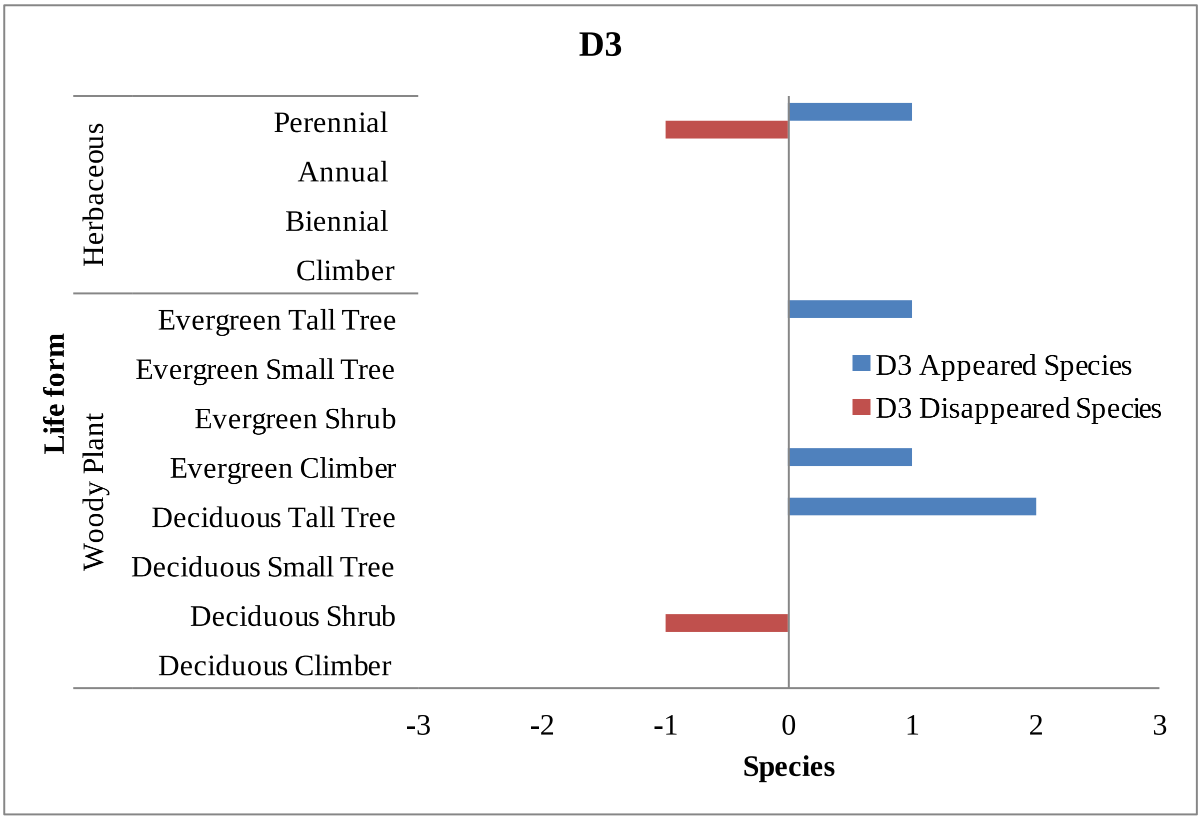


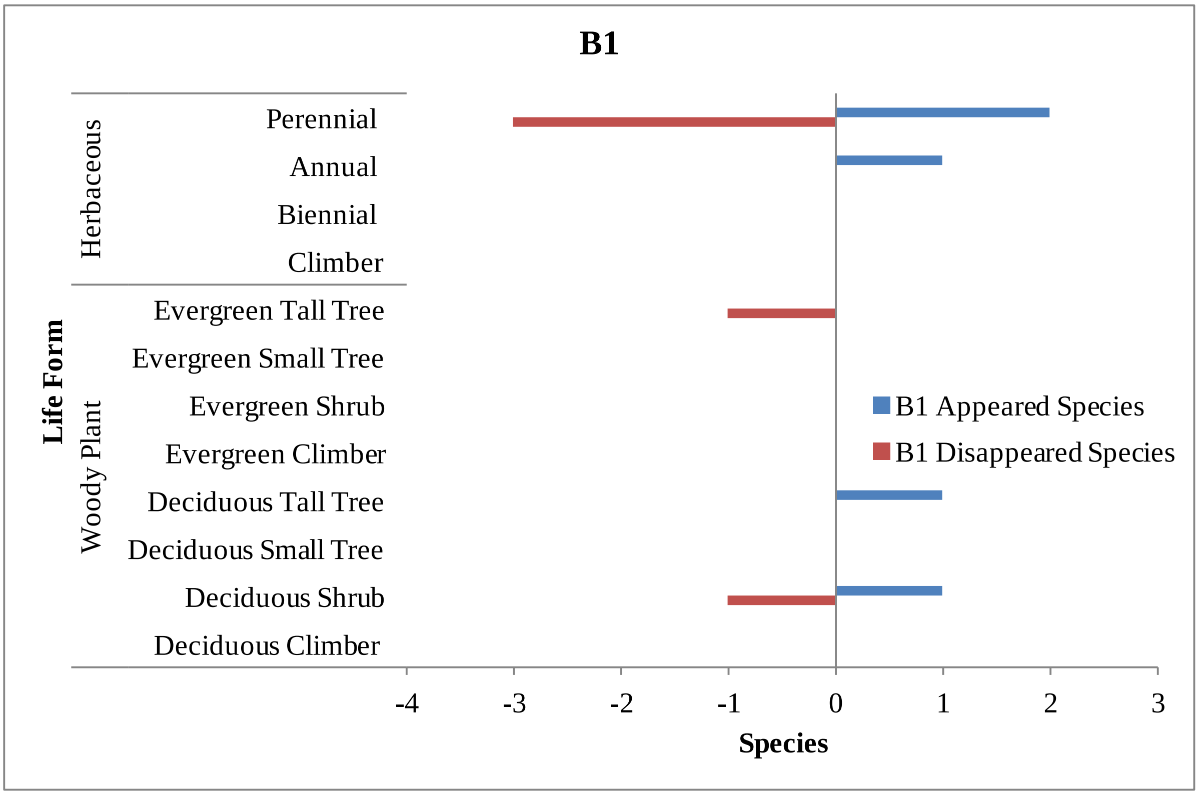
Figure 9. Species composition in Plot D from 2011-2012

3.2.2 Species composition from 2011 to 2013

Species composition from 2011 to 2013 is shown in figure 10 to12. At the site of deciduous broad-leaved secondary forest, perennial herbs increase the most in appeared species, but the number of disappeared species was larger than it. Only one deciduous tall tree and annual plant appeared, and one evergreen tall tree species disappeared. Deciduous shrub turned over with one appeared species and disappeared species. In B2 (control), perennial herbs and deciduous tall tree species appeared the largest, but perennial herbs also disappeared. Annual herbs appeared by one and evergreen small tree and deciduous small tree disappeared by one. Evergreen shrub turned over by one appeared and disappeared species. The comparison between B1 and B2 shows that turning over of perennial herbs is significant and their number of appeared species is the largest. The comparison of species composition changes between the first period (year 2011-2012) and the second period (year 2012-2013) shows that more diverse life forms turned over in the first period than in the second period.

In C1 at the site of mixed secondary forests of deciduous trees and conifer trees, deciduous shrub increased in appeared species the most. Annual herb and deciduous small tree appeared by one. Perennial herbs and evergreen shrubs made turn over by appeared and disappeared species. In C2, perennial herbs appeared the largest, followed by deciduous tall trees and evergreen climbers. Deciduous shrub made turn over by appeared and disappeared species. The comparison between C1 and C2 shows that more variety of life forms disappeared in C1. They were perennial herb, evergreen shrubs and deciduous shrub. The comparison between the first and the second period, again, the number of species that appeared and disappeared was significantly larger in the first period than the second period.

At the site of *Pleioblastus chino* community plain, in D1, perennial herb increased in appeared species significantly. Deciduous shrubs, biennial herbs, deciduous climber and annual herbs appeared with no disappearance. In D2 (control), perennial herbs and deciduous tall tree disappeared. Evergreen climber grew over the tall *Pleioblastus chino* and made its roof. Deciduous shrub appeared by only one species. In D3 (control), there is not significant changes. One perennial herb appeared, but one deciduous tall tree disappeared. The comparison between D1 (Mow) and D2, 3 (Control) shows that much more diverse life forms appeared in D1 than in control plots. In common with other plots, the number of species that appeared and disappeared was significantly larger in the first period than the second period.



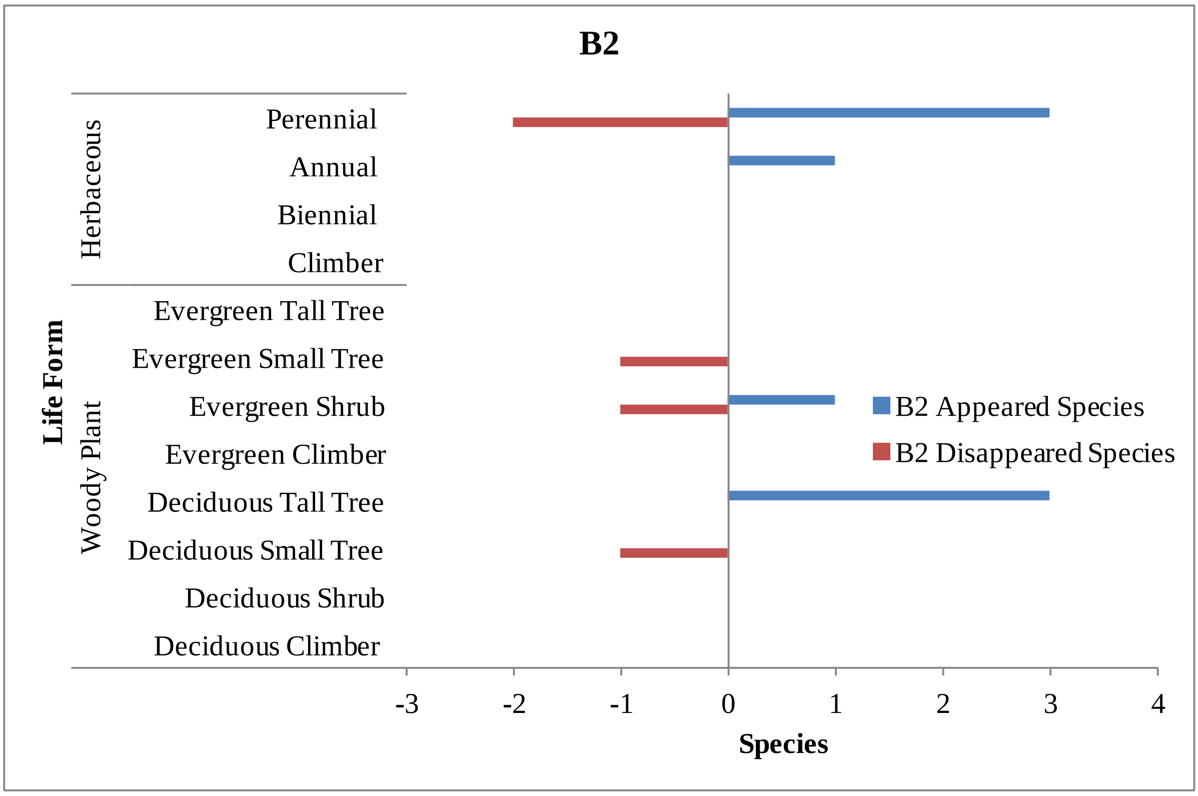
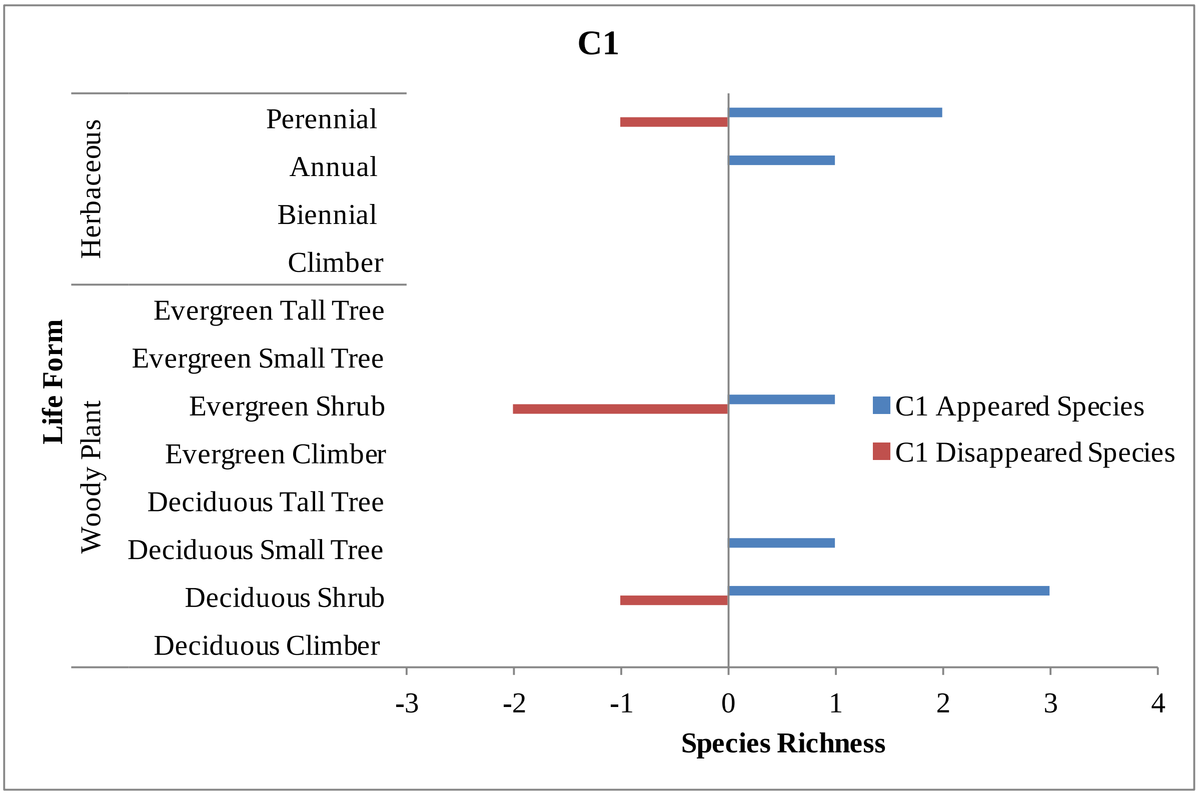


Figure 10. Species composition in Plot B from 2011-2013



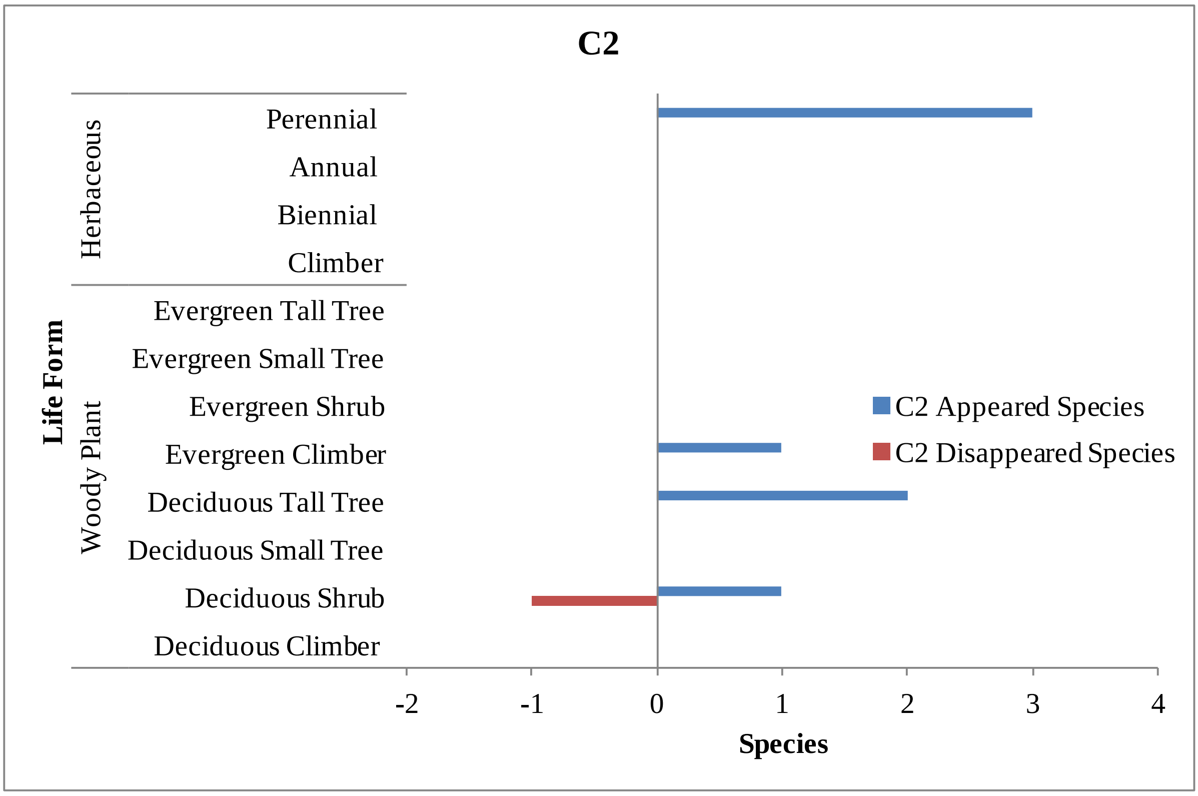
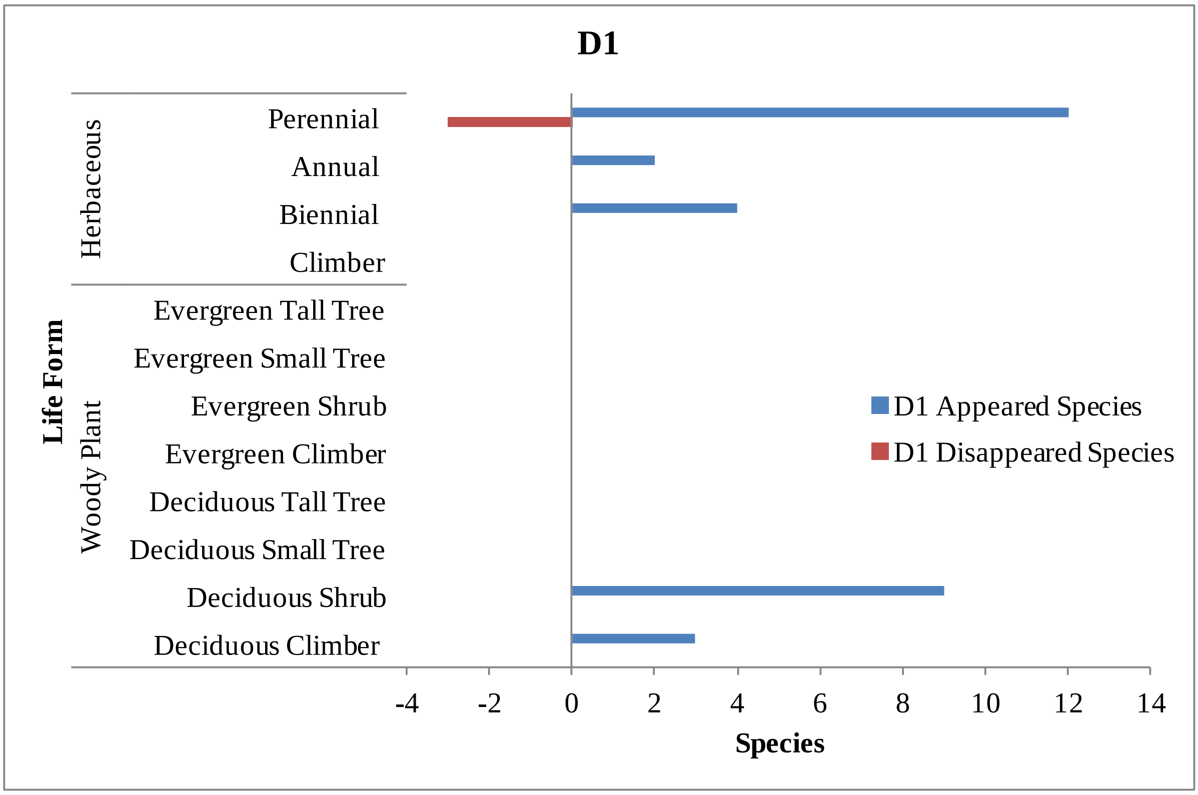
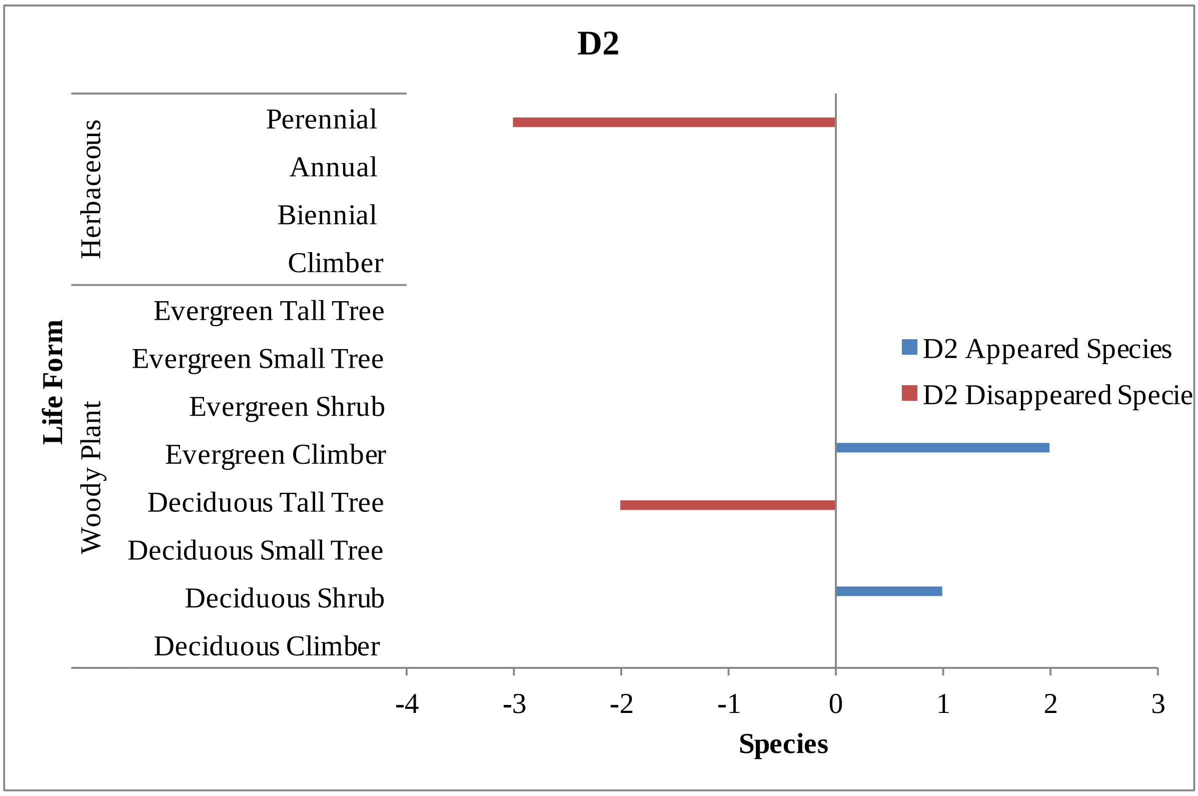


Figure 11. Species composition in Plot C from 2011-2013


D1
Life Form
Herbaceous
Perennial
Annual
Biennial
Climber
Woody Plant
Evergreen Tall Tree
Evergreen Small Tree
Evergreen Shrub
Evergreen Climber
Deciduous Tall Tree
Deciduous Small Tree
Deciduous Shrub
Deciduous Climber
D1 Appeared Species
D1 Disappeared Species
-4 -2 0 2 4 6 8 10 12 14
Species


D2
Life Form
Herbaceous
Perennial
Annual
Biennial
Climber
Woody Plant
Evergreen Tall Tree
Evergreen Small Tree
Evergreen Shrub
Evergreen Climber
Deciduous Tall Tree
Deciduous Small Tree
Deciduous Shrub
Deciduous Climber
D2 Appeared Species
D2 Disappeared Specie
-4 -3 -2 -1 0 1 2 3
Species

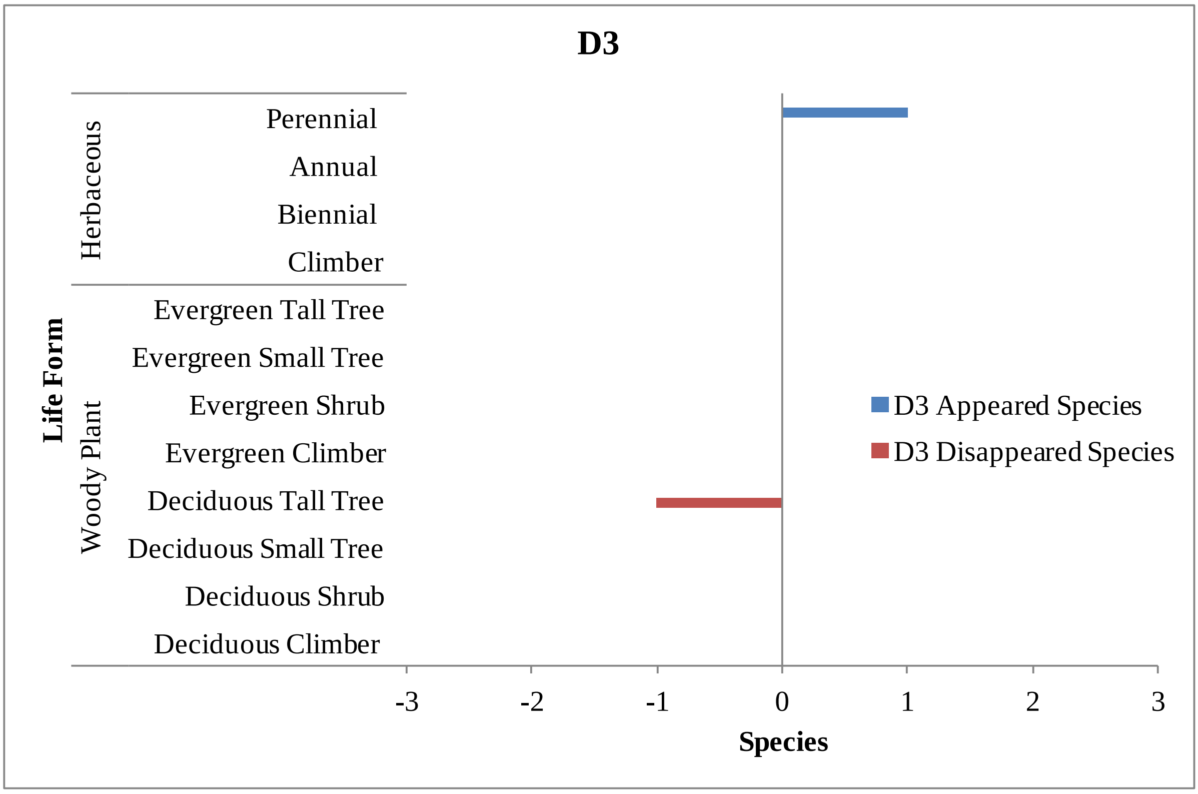


Figure 12. Species composition in Plot D from 2011-2013

3.2.3 Species composition –Rare species

The features of the species composition change patterns differ among plots. It is important to see the species closely in each plot. The lists 2-7 show the lists of species that appeared, disappeared and remained constant.

According to the species composition table 2-4 in the first period from 2011 to 2012, *Cephalanthera falcata*, the D rank important species for conservation in Chiba prefecture appeared in B1 and B2. In C2 (Control), *Cephalanthera falcata* disappeared. What is more, *Tricyrtis affinis*, the B rank important species for conservation in Chiba prefecture disappeared in C2 (Control). The most common species in all plots except D3 are constant. They are *Aucuba japonica* (evergreen shrub), *Pleioblastus chino* (grow in the abandoned coppice fields), *Ophiopogon japonicus* (evergreen annual plant that grows on the dark forest floor), *Neolitsea sericea* (evergreen small trees), *Wisteria floribunda* (deciduous climber tree), *Arisaema serratum* (annual plant that grows in the shade, along the ride in the coppice fields), *and Akebia trifoliata* (deciduous climber tree that grows in the shade).

According to the species composition list 5-7 in the second period from 2011-2013, *Ajuga nipponensis* (annual plant that grows on sunny forest floors), the D rank important conservation species in Chiba prefecture, appeared in D1 (Mow). *Cephalanthera falcata* appeared in C1. No rare species disappeared in the second year. The common species in all plots in the second period were *Akebia trifoliata*, *Aucuba japonica*, *Neolitsea sericea*, *Ophiopogon japonicus*, *Pleiblastus chino*, *Wisteria floribunda*. They were the constant species over the two years.

Satoyama activities, thinning and mowing improved the light conditions on the forest floor. In Satoyama activity plots, the rare species appeared, but they disappeared in the control plots.

Table 2. Species composition of plants in Oaota forest's each plot

Year 2011-2012 (Appeared species : +)

	Appeared Plant Species	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**D3**
	Achyrantje longifolia	+	+		+			
D	*Cephalanthera falcata*	+	+					
	Euscaphis japonica	+						
	Symplocos chinensis	+						
	Viola mandshurica	+						
	Viola grypoceras	+						
	Persicaria nepalensis	+						
	Aralia elata	+			+			
	Euonymus oxyphyllus	+	+					
	Polygonatum falcatum	+						
	Elaeagnus pungens	+						
	Albizia julibrissin	+						
	Disporum sessile	+	+	+				
	Dioscorea japonica	+						
	Gynostemma pentaphyllum		+					
	Polygonatum odoratum		+					
	Ligustrum obtusifolium		+	+				
	Ilex serrata		+	+				
	Celtis sinensis		+			+		
	Dioscorea tokoro		+					+
	Quercus serrata		+					
	Stephanandra incisa		+					
	Cremastra appendiculata		+		+			
	Cephalanthera longibracteata		+	+				
	Smilax china		+					
	Scutellaria indica		+					
	Celastrus orbiculatus		+			+		
	Parthenocissus tricuspidata		+					
	Rosa multiflora		+					
	Paederia scandens		+	+	+			
	Lindera glauca		+			+		
	Rabdosia inflexa		+					
	Kerria japonica		+					
	Cephalotaxus harringtonia			+				
	Cimicifuga japonica			+				
	Lonicera gracilipes			+				
	Rohdea japonica			+				
	Viburnum dilatatum			+				
	Taxus nucifera			+				
	Castanea crenata			+	+			
	Lysimachia japonica			+				
	Thelypteris japonica			+				
	Trachycarpus fortunei			+				+
	Nandina domestica			+				
	Phryma leptostachya			+	+	+		
	Osmanthus heterophyllus			+				
	Mahonia japonica			+				

Dryopteris erythrosora	+				
Cayratia japonica	+				
Tricyrtis affinis	+				
Daphniphyllum macropodum	+				
Youngia japonica		+	+		
Actinidia chinensis		+			
D grandiflorum		+	+		
Cryptomeria japonica		+			
Camellia sinensis		+			
Commelina communis		+			
Euonymus fortunei		+	+		
Sambucus sieboldiana		+			
Viola yedoensis		+			
Thelypteris japonica		+			
Stenactis annuus		+			
Erigeron canadensis		+			
Solanum lyratum		+			
Duchesnea chrysantha		+			
Ardisia crenata		+			
Polygonum filiforme		+			
Ilex integra		+			
Rubus palmatus		+			
Rhus trichocarpa		+			
Mallotus japonicus			+		
Sicyos angulatus			+		
Carpinus tschonoskii			+		+
Clerodendrum trichotomum			+		
Pueraria lobata			+		
Zelkova serrata			+		
Picris hieracioides			+		
Smilax riparia			+		
Aster scaber			+		
Alopecurus aequalis			+		
Taraxacum officinale			+		
Melia azedarach			+		
Cocculus trilobus			+		
Trachelospermum asiaticum			+		
Ixeris polycephala			+		
Stellaria media			+		
Euonymus japonicus			+		
Aphananthe aspera			+	+	
Corydalis incisa			+		
Galium spurium			+		
Torilis japonica			+		
Phytolacca americana			+		
Prunus grayana					+
Hedera rhombea					+

Table 3. Species composition of plants in Oaota forest's each plot

Year 2011-2012 (Disappeared species : +)

	Disappeared Plant Species	B1	B2	C1	C2	D1	D2	D3
	Mosla punctulata	+						
	Youngia japonica	+		+				
	Cymbidium goeringii	+						
	Lonicera japonica	+						
	Sambucus sieboldiana	+		+				
	Galinsoga ciliata	+						
	Stellaria media	+						
	Fatsia japonica	+		+	+			
	Prunus jamasakura	+						
	Mallotus japonicus			+				
	Celtis sinensis			+				
	Actinidia chinensis			+				
	Helianthus tuberosus			+				
	Potentilla fragarioides			+				
	Quercus acutissima			+				
	Cryptomeria japonica			+				
	Taraxacum officinale			+				
	Aralia elata			+				
	Disporum smilacinum			+				
	Camellia sinensis			+		+		
	Euonymus oxyphyllus			+	+			
	Celastrus orbiculatus			+				
	Tetragonia tetragonioides			+				
	Euonymus fortunei			+				
	Elsholtzia ciliata			+				
	Viola yedoensis			+				
	Thelypteris japonica			+				
	Erigeron philadelphicus			+				
	Broussonetia kazinoki			+				
	Mosla dianthera			+				
	Solanum lyratum			+				
	Chloranthus serratus			+	+	+		
	Duchesnea chrysantha			+				
	Polygonum filiforme			+				
	Siegesbeckia pubescens			+				
	Rubus palmatus			+				
	Rhus trichocarpa			+				
	Dioscorea japonica			+				
	Hydrangea macrophylla				+			
	Polygonatum odoratum				+			
	Lonicera gracilipes				+			
	Styrax japonica				+		+	
	Dioscorea tokoro				+			
	Rohdea japonica				+			
	Viburnum dilatatum				+			
D	*Cephalanthera falcata*				+			
	Symplocos chinensis				+			+
	Smilax riparia				+			
	Trachycarpus fortunei				+			

	Astilbe microphylla	+			
	Elaeagnus glabra	+			
	Osmanthus heterophyllus	+			
	Mahonia japonica	+			
	Thelypteris palustris	+			
	Dryopteris erythrosora	+			
	Disporum sessile	+			
	Corydalis incisa	+			
B	*Tricyrtis affinis*	+			
	Daphniphyllum macropodum	+			
	Ligustrum japonicum		+		
	Paederia scandens		+	+	
	Ardisia crenata		+		
	Viola grypoceras				+

Table 4. Species composition of plants in Oaota forest's each plot

Year 2011-2012 (Constant species : +)

Constant Plant Species	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**D3**
Aucuba japonica	+	+	+	+	+	+	
Mallotus japonicus	+						
Akebia quinata	+	+	+	+			
Pleioblastus chino	+	+	+	+	+	+	
Gynostemma pentaphyllum	+		+	+			
Carpinus tschonoskii	+	+	+	+		+	
Ilex crenata	+	+	+	+			
Ligustrum obtusifolium	+			+			
Lonicera gracilipes	+	+					
Prunus grayana	+	+	+	+	+		
Styrax japonica	+						
Celtis sinensis	+			+			
Rohdea japonica	+						
Viburnum dilatatum	+	+					
Pourthiaea villosa	+	+					
Hedera rhombea	+	+	+	+	+		
Rhamnus japonica	+						
Morus australis	+						
Quercus serrata	+		+	+	+	+	
Magnolia praecocissima	+	+	+	+			
f striatus	+	+					
Zanthoxylum piperitum	+		+	+			
Ophiopogon japonicus	+	+	+	+	+	+	
Neolitsea sericea	+	+	+	+	+	+	
Parthenocissus tricuspidata	+		+	+	+	+	
Ligustrum japonicum	+	+	+	+			
Rosa multiflora	+		+	+			
Helwingia japonica	+	+					
Osmanthus heterophyllus	+	+			+		
Solanum lyratum	+						
Wisteria floribunda	+	+	+	+	+	+	
Arisaema serratum	+	+	+	+	+	+	
Euonymus sieboldianus	+	+	+	+			
Ardisia crenata	+	+	+				
Swida controversa	+	+	+	+			
Akebia trifoliata	+	+	+	+	+	+	
Potentilla freyniana	+						
Aphananthe aspera	+	+	+	+			
Callicarpa japonica	+	+	+	+			
Cinnamomum japonicum	+						
Lindera glauca	+						
Calanthe discolor		+					
Symplocos chinensis		+					
Quercus myrsinaefolia		+	+	+	+	+	
Lonicera japonica		+	+	+			
Viola grypoceras		+	+	+			
Ligstrum lucidum		+					
Polygonatum falcatum		+	+	+	+		

Elaeagnus pungens	+				
Fatsia japonica	+				
Acanthopanax spinosus	+				
Orchidaceae sp	+				
Achyrantje longifolia		+			
Acer palmatum		+	+		
Acanthopanax japonicus		+	+		
Dioscorea tokoro		+		+	+
Zelkova serrata		+	+		
Smilax china		+	+		
Castanopsis sieboldii		+	+		
Oplismenus undulatifolius		+	+		
Oplopanax japonicus		+	+		
Eurya japonica		+	+		
Ardisia pusilla		+	+		
Liriope platyphylla		+	+		
Morus bombycis		+	+		
Ilex serrata			+		
Euscaphis japonica			+		
Celastrus orbiculatus			+		
Polygonatum odoratum				+	
Arisaema urashima				+	
Cymbidium goeringii				+	+
Disporum smilacinum				+	
Disporum sessile				+	
Cayratia japonica				+	
Dioscorea japonica				+	
Cocculus trilobus					+
Euonymus oxyphyllus					+

Table 5. Species composition of plants in Oaota forest's each plot, Year 2011-2013 (Appeared species : +)

	Appeared plant species	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**D3**
	Acanthopanax spinosus			+	+			
	Achyrantje longifolia					+		
	Ailanthus altissima				+			
D	*Ajuga nipponensis*					+		
	Akebia quinata					+		
	Aralia elata					+		
	Callicarpa japonica					+		
	Carex breviculmis				+	+		
	Celastrus orbiculatus	+						
D	*Cephalanthera falcata*			+				
	Cirsium japonicum					+		
	Cocculus orbiculatus					+		
	Duchesnea chrysantha	+						
	Elsholtzia ciliata	+	+					
	Erigeron canadensis			+		+		
	Euscaphis japonica			+				
	Fatsia japonica			+				
	Ilex rotunda					+		
	Lactuca indica					+		
	Lamium purpureum					+		
	Lindera glauca			+				
	Lonicera gracilipes					+		
	Lonicera japonica						+	
	Lysimachia japonica		+		+	+		
	Mahonia japonica		+					
	Mallotus japonicus				+			
	Oplismenus undulatifolius		+			+		+
	Oplopanax japonicus					+		
	Paederia scandens	+						
	Poa annua					+		
	Potentilla freyniana					+		
	Pourthiaea villosa			+				
	Prunus jamasakura		+			+		
	Pueraria lobata						+	
	Quercus acutissima		+					
	Rumex acetosa					+		
	Sambucus sieboldiana					+	+	
	Smilax china					+		
	Smilax riparia		+					
	Solanum carolinense					+		
	Solanum lyratum					+		
	Solidago altissima			+	+	+		
	Stellaria aquatica					+		
	Stenactis annuus					+		
	Styrax japonica		+					
	Swida controversa					+		
	Trachelospermum asiaticum				+			
	Viburnum dilatatum					+		
	Viola grypoceras					+		
	Zanthoxylum piperitum					+		
	Zelkova serrata	+						

Table 6. Species composition of plants in Oaota forest's each plot

Year 2011-2013 (Disappeared species : +)

Disappeared plant species	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**D3**
Rhamnus japonica	+						
Rohdea japonica	+						
Solanum lyratum	+						
Potentilla freyniana	+						
Cinnamomum japonicum	+						
Osmanthus heterophyllus		+					
Pourthiaea villosa		+					
Elaeagnus pungens		+					
Orchidaceae sp		+					
Calanthe discolor		+					
Eurya japonica			+				
Acanthopanax japonicus			+				
Liriope platyphylla			+				
Ardisia crenata			+				
Ligustrum obtusifolium				+			
Dioscorea tokoro					+		
Polygonatum odoratum					+		
Disporum smilacinum					+		
Pueraria lobata						+	
Lonicera japonica						+	
Sambucus sieboldiana						+	
Aphananthe aspera							+

Table 7. Species composition of plants in Oaota forest's each plot

Year 2011-2013 (Constant species : +)

Constant Plant Species	**B1**	**B2**	**C1**	**C2**	**D1**	**D2**	**D3**
Acanthopanax spinosus		+					
Acer palmatum			+	+			
Achyrantje longifolia			+				
Actinidia chinensis				+			
Akebia quinata	+	+	+	+			
Akebia trifoliata	+	+	+	+	+	+	+
Aphananthe aspera	+	+	+	+			
Aralia elata				+			
Ardisia crenata	+	+		+			
Ardisia pusilla			+	+			
Arisaema serratum	+	+	+	+	+		+
Arisaema urashima					+		+
Aucuba japonica	+	+	+	+	+	+	+
Callicarpa japonica	+	+	+	+			
Carpinus tschonoskii	+	+	+	+			
Castanopsis sieboldii				+			
Cayratia japonica					+		
Celastrus orbiculatus				+			
Celtis sinensis	+			+			
Cocculus trilobus						+	+
Cryptomeria japonica				+			
Dioscorea japonica					+		
Dioscorea tokoro			+				
Disporum sessile		+			+		
Euonymus oxyphyllus						+	
Euonymus sieboldianus	+	+	+	+			
Eurya japonica				+			
Euscaphis japonica				+			
f striatus	+	+					
Fatsia japonica		+					
Gynostemma pentaphyllum	+		+	+			
Hedera rhombea	+	+	+	+	+		
Helwingia japonica	+	+					
Ilex crenata	+	+	+	+			
Ilex serrata				+			
Ligstrum lucidum		+					
Ligustrum japonicum	+	+	+	+			
Ligustrum obtusifolium	+		+				
Lindera glauca	+						
Liriope platyphylla				+	+		
Lonicera gracilipes	+	+					
Lonicera japonica		+	+	+			
Lysimachia japonica			+				
Magnolia praecocissima	+	+	+	+			
Mallotus japonicus	+						

Morus australis	+						
Morus bombycis			+	+			
Neolitsea sericea	+	+	+	+	+	+	+
Ophiopogon japonicus	.+	+	+	+	+	+	+
Oplismenus undulatifolius			+	+			
Oplopanax japonicus			+	+			
Osmanthus heterophyllus	+				+		
Parthenocissus tricuspidata	+		+	+	+	+	+
Pleioblastus chino	+	+	+	+	+	+	+
Polygonatum falcatum		+	+	+	+		
Pourthiaea villosa	+						
Prunus grayana	+	+	+	+	+		
Quercus myrsinaefolia		+	+	+	+	+	+
Quercus serrata	+		+	+	+		+
Rhus trichocarpa				+			
Rosa multiflora	+		+	+			
Rubus palmatus				+			
Smilax china			+	+			
Styrax japonica	+						+
Swida controversa	+	+	+	+			
Symplocos chinensis		+					
Thelypteris japonica			+				
Trachycarpus fortunei			+				
Viburnum dilatatum		+	+				
Viola grypoceras		+	+	+			
Wisteria floribunda	+	+	+	+	+	+	+
Zanthoxylum piperitum	+		+	+			
Zelkova serrata			+	+			

3.3 Life form analysis

Figure 13-14 show the species abundance of appeared woody plants by life form in the first period and the second period from 2011. The comparison between the first period and second period found that more diverse life forms appeared in the first period than that in the second period. In plot B, deciduous trees increased the largest. The deciduous trees increased the most in the first period, and then the deciduous tall trees increased the most in the second period. In plot C, both evergreen trees and deciduous trees increased in the first period, and then in the second period the increase in evergreen tree became smaller. In plot D, the deciduous trees increased the largest and evergreen trees also increased, but in the second period, only evergreen climber appeared.

Figure 15-16 show the species abundance of herbaceous plants in the first period and the second period. Perennial plants increased the most in both first period and the second period. The increase in appeared species was larger in the first period than that in the second period, again the same pattern as woody plants. In plot D, however, D1 observed the larger increase in appeared species of perennial plants in the second year than in the first year. In plot B, perennial and annual plants appeared. In plot C, perennial and annual plants appeared and biennial plants appeared in C2 in the first period. In plot D, the most diverse life forms of herbaceous plants appeared in D1 where mowing was conducted. Whereas D2 (control) did not have any herbaceous plants that appeared in both the first and the second period. In D3 (control), only one perennial plant appeared.

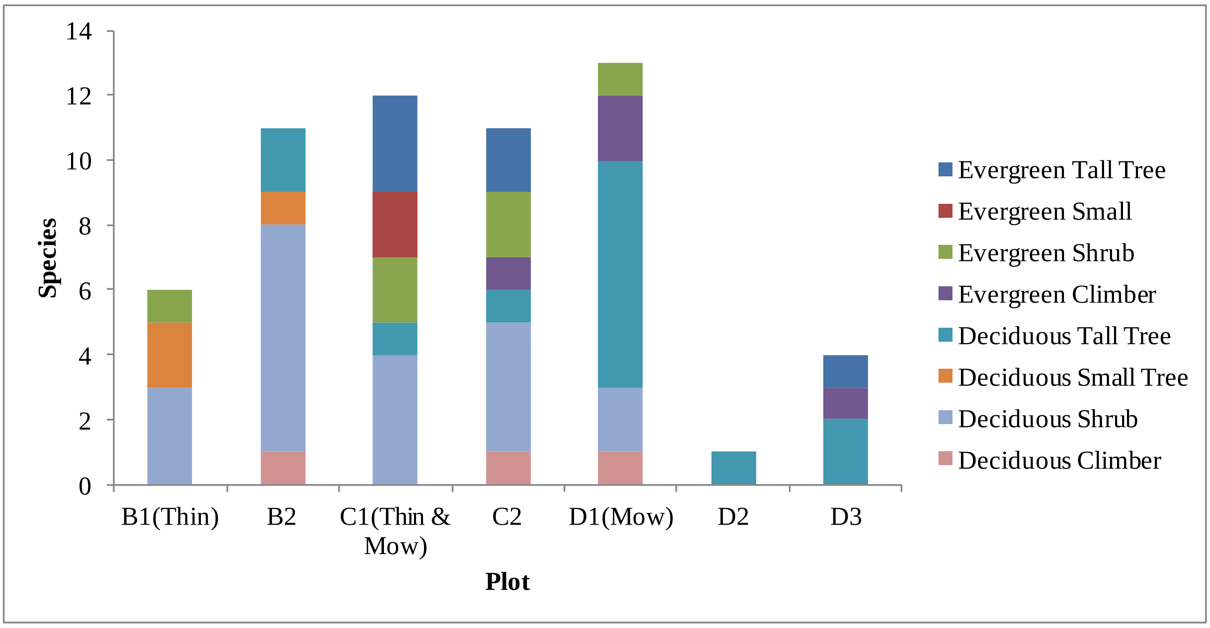


Figure 13. Species abundance of woody plants by life forms, appeared species in the first period

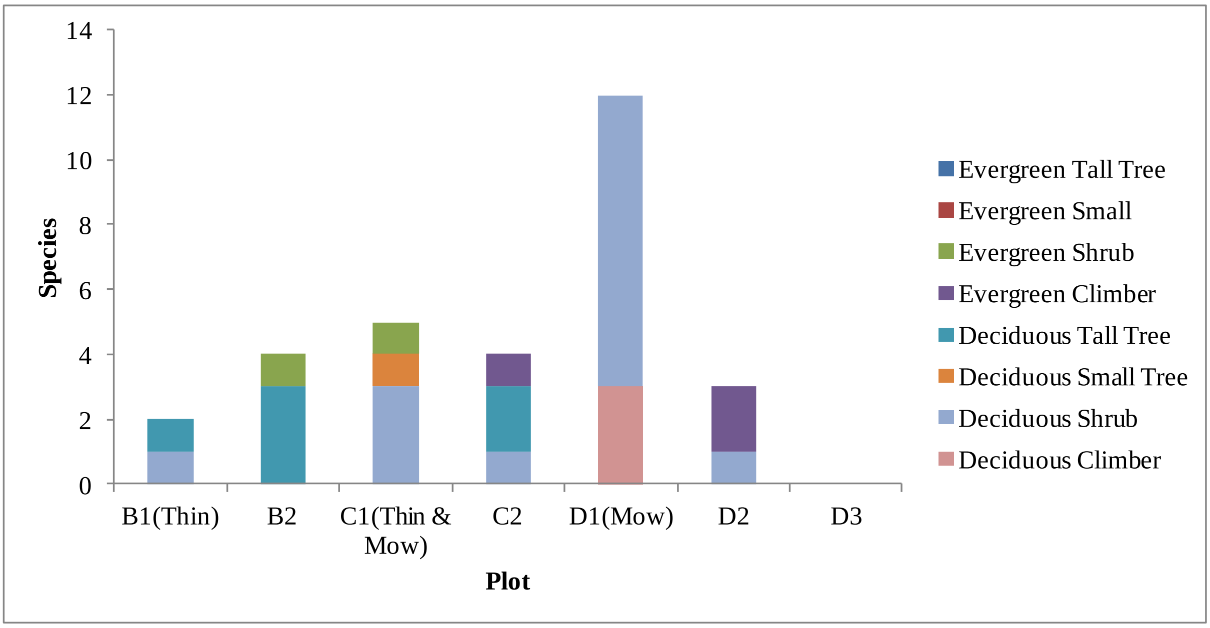


Figure 14. Species abundance of woody plants by life forms, appeared species in the second period

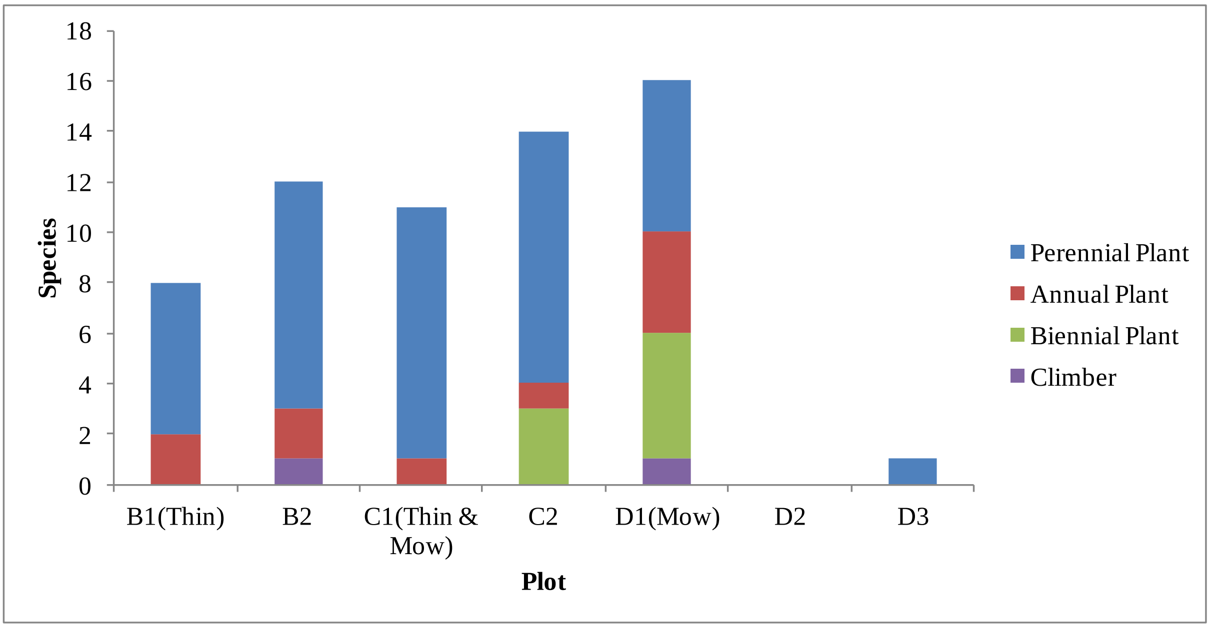


Figure 15. Species abundance of herbaceous plants by life forms, appeared species in the first period

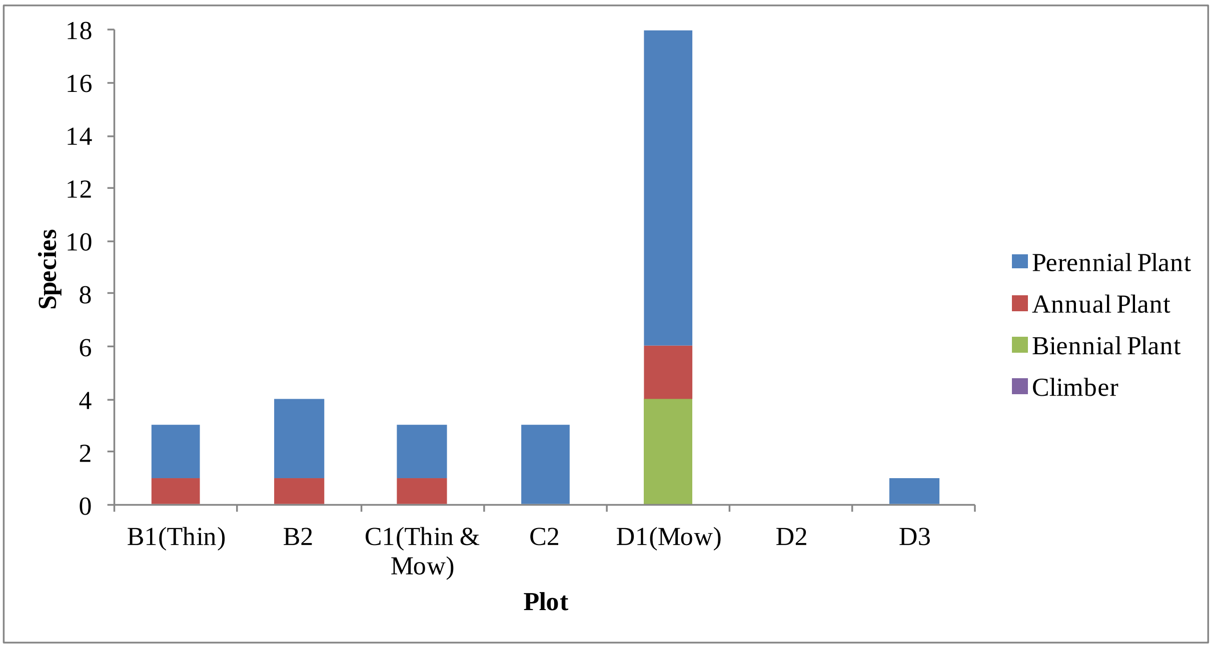


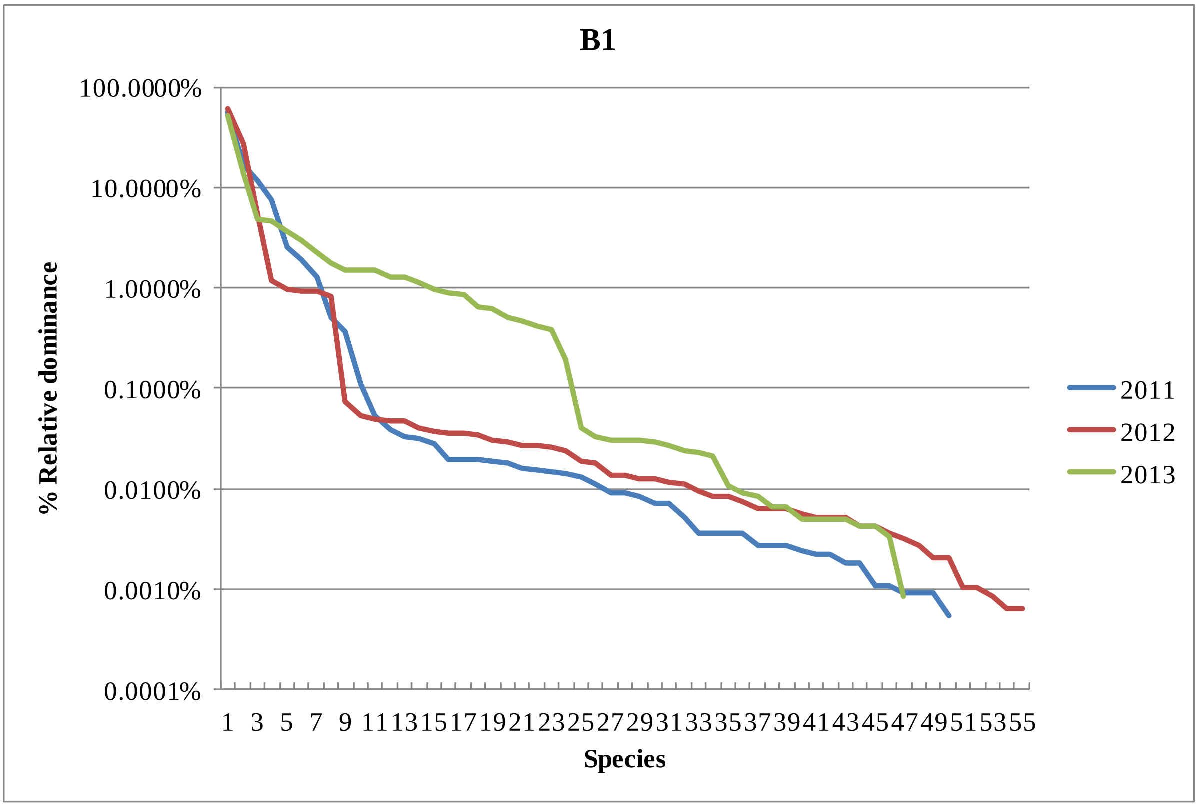
Figure 16. Species abundance of herbaceous plants by life forms, appeared species in the second period

3.4 Relative dominance

The figures 17- 19 show the relative dominance over the three years in each plot. In plot B, the relative dominance curve in 2013 shows more moderate curve than the previous two years. The ground flora became more diverse as thinning was conducted in B1. In B1, the number of species more than 0.1 percent relative dominance increased significantly in 2013. The results showed that evenness was lower in the previous years than in 2013. It increased from 9 to 26 in three years in B1 (Thin), and it increased 9 to 20 in B2 (Control).

In plot C, the relative dominance curves in each year draw similar shapes. In C1 (Thin and Mow), the relative dominance curve in 2013 shows more moderate curve than the previous two years. On the other hand, in C2 (Control), it draws almost the same curve as that in 2012, and its evenness is lower than that in 2011. The number of species more than 0.1 percent relative dominance kept increasing over the three years from 16 to 30 in C1. On the other hand, it does not change and remained 20 in C2 (Control).

In plot D, the relative dominance curve in 2013 became much more moderate than those in the previous years. In D1 (Mow), the relative dominance of species became more even and diverse in 2013. The number of species more than 0.1 percent relative dominance kept increasing over the three years from 5 to 31 in D1. On the other hand, it does not change significantly in D2 (Control), and it decreased from 6 to 2 in D3 (Control).



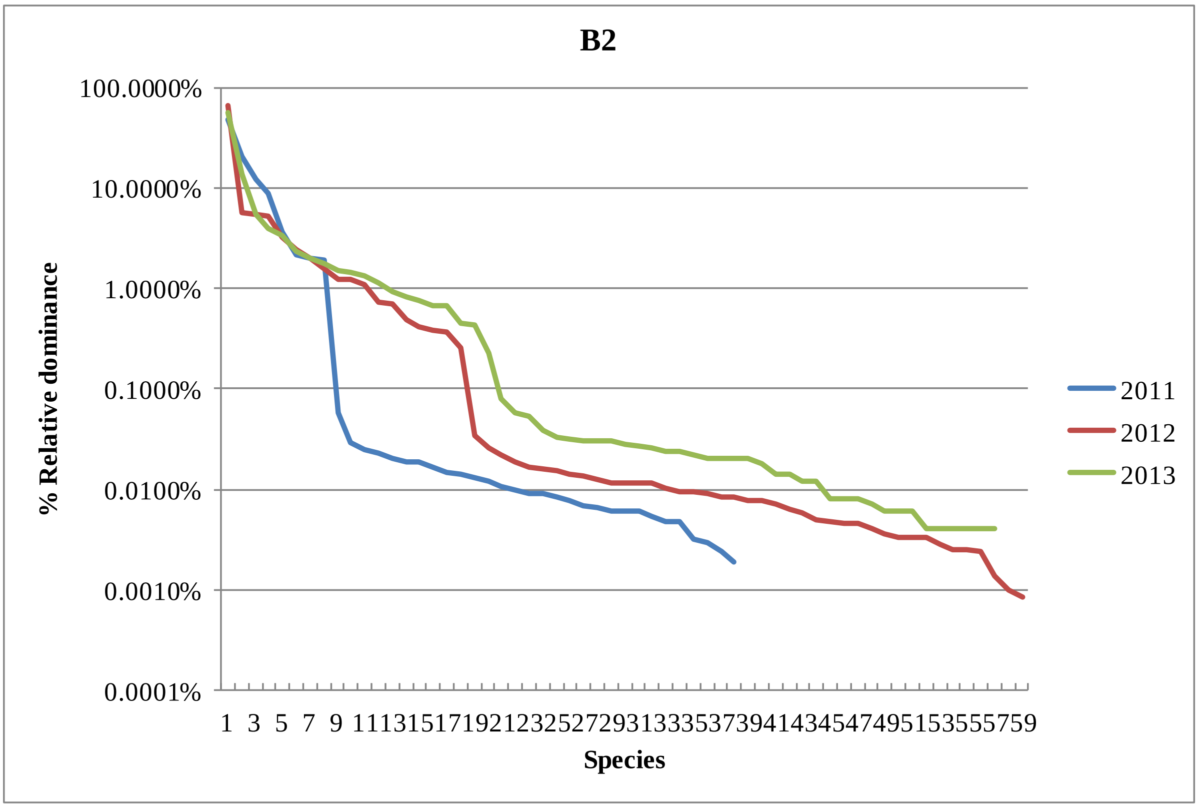
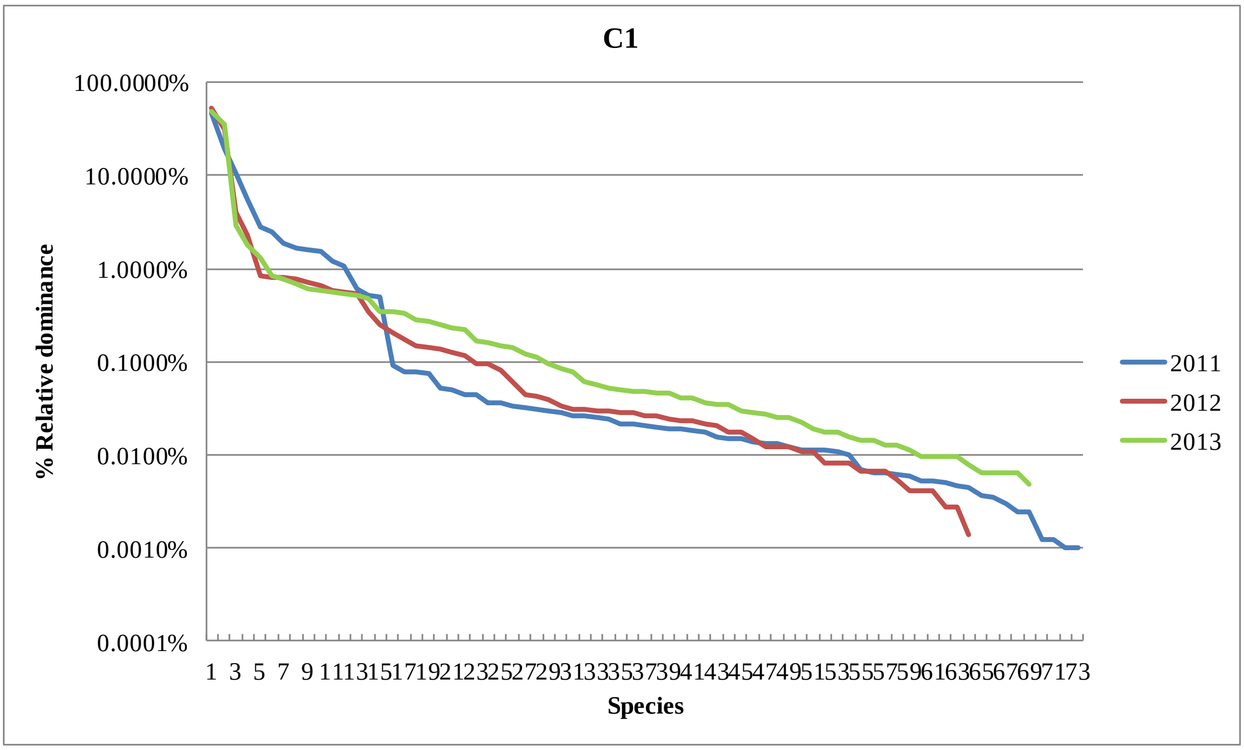


Figure 17. Relative dominance curves in plot B from 2011 to 2013



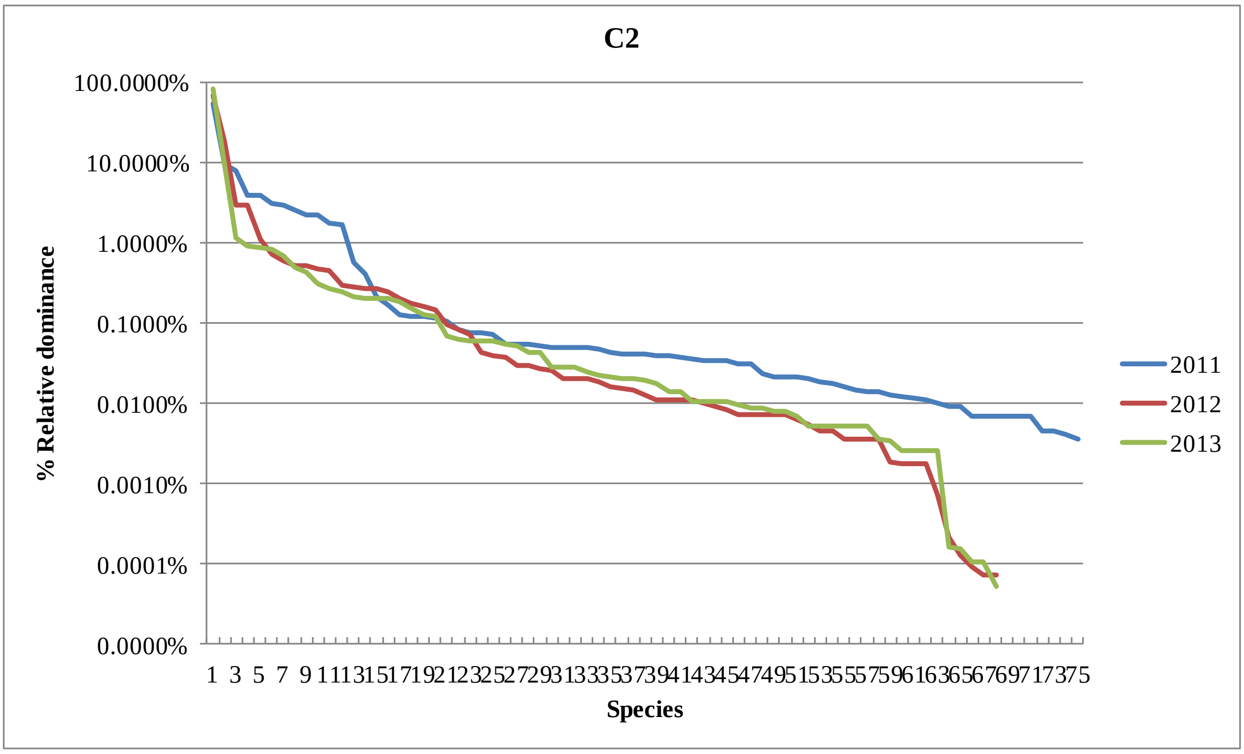
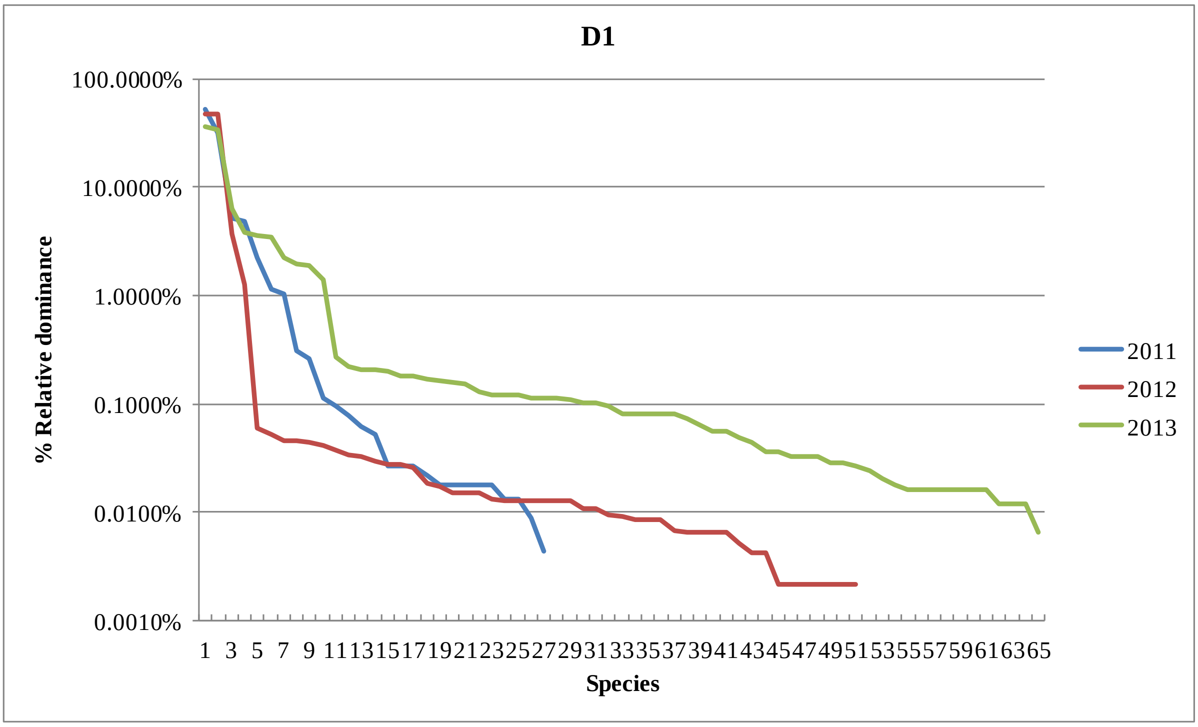
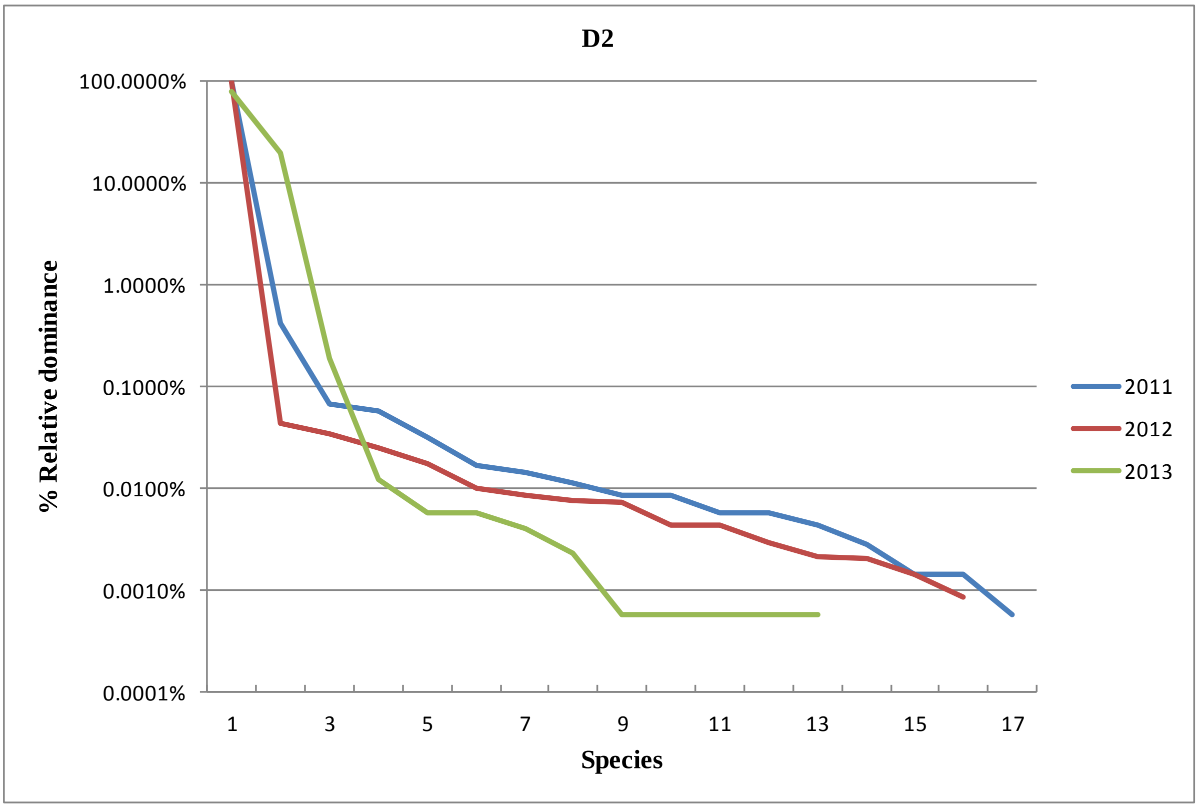


Figure 18. Relative dominance curves in plot C from 2011 to 2013


D1
100.0000%
10.0000%
1.0000%
0.1000%
0.0100%
0.0010%
% Relative dominance
1 3 5 7 9 11131517192123252729313335373941434547495153555759616365
Species
2011
2012
2013


D2
100.0000%
10.0000%
1.0000%
0.1000%
0.0100%
0.0010%
0.0001%
% Relative dominance
1 3 5 7 9 11 13 15 17
Species
2011
2012
2013

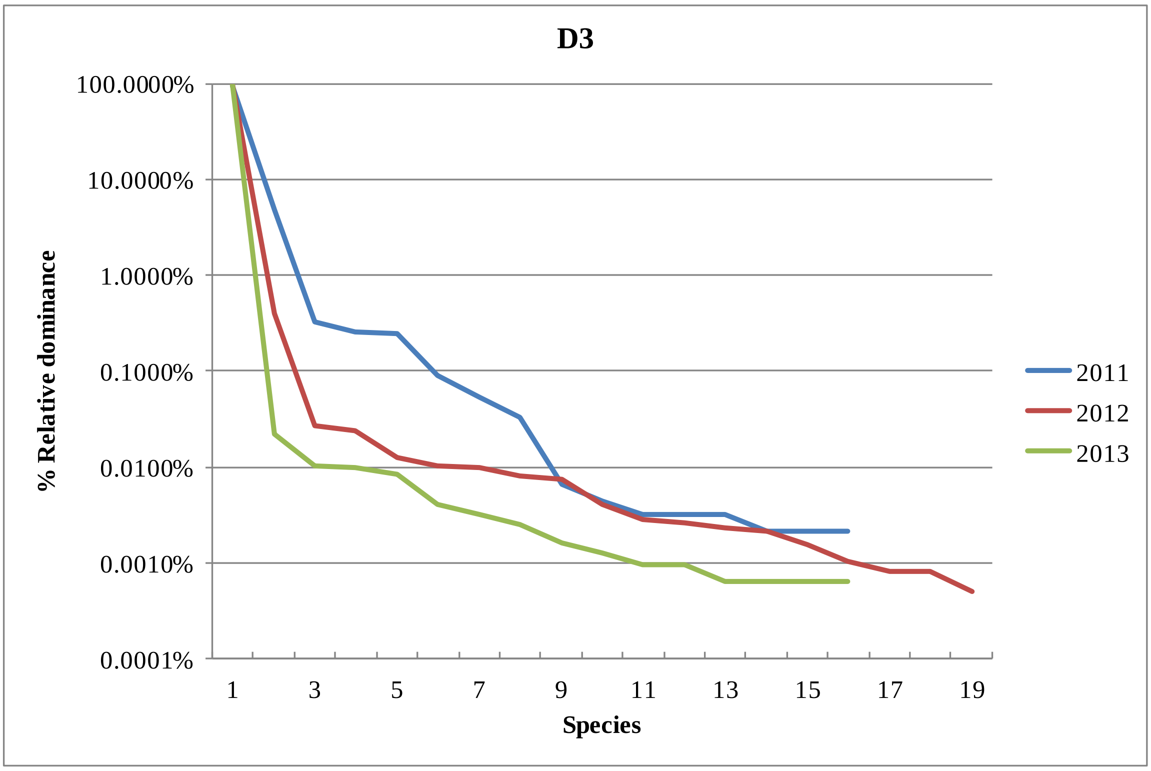


Figure 19. Relative dominance curves in plot D from 2011 to 2013

3.5 Biodiversity index

Biodiversity index shows a community's diversity. Species richness is the most common biodiversity index. The other common indices are Shannon's diversity index *H'* and Simpson's 1/D (Zaal and Fukuda, 2011). Shannon's *H'* is calculated the following equation;

$$H' = -\sum P_i log_2(P_i)$$

Simpson's 1/D is calculated as follows;

$$\mathrm{D} = \sum_{i=1}^{N} P_i^2$$

If the total number of N species are equal in abundance,

$$P_i = \frac{1}{N}$$

$$P_i^2 = \frac{1}{N^2}$$

$$\sum_{i=1}^{N} P_i^2 = \sum_{i=1}^{N} \frac{1}{N^2} = N \frac{1}{N^2}$$

$$\text{Simpson D} = \frac{1}{N}$$

$$\frac{1}{D} = N$$

Therefore, if the Shannon's index is larger, either species richness or the abundance evenness is greater, or both of them are greater. If the abundance evenness is equal, Simpson's 1/D is the same figure as the number of species. If the Simpson's 1/D is larger, then dominance of a specific species is less and abundance evenness is larger.

Figure 20 shows the Shannon's *H'* index figures in each plot over the three years. These indices can change seasonally and their values were compared among plots in the same years. In both plots B (Thin) and C (Thin & Mow), the index figure is smaller in the Satoyama activity plots B1 and C1 than in control plots B2 and C2 in 2011. This pattern, however, changed. The index figures in Satoyama activity plots exceeded that in control plots in 2013. In plot D, the index figure was larger in Satoyama activity plot D1 than that in control plots D2 and D3 from 2011 to 2013. It was 0.91 times greater in B1 (Thin) than that in B2 (Control) in 2011, but after that it became 1.11 times greater in B1 (Thin) than that in B2 (Control). In Plot C, also, it was 0.97 times larger in C1 (Thin & Mow) than that in C2

(Control) in 2011, but later it became 1.77 times larger in C1 (Thin & Mow) than that in C2 (Control) in 2013.

Figure 21 shows the Simpson's 1/D index for each plot over the three years. In plot B, the index figure was larger in B2 (Control) than in B1 (Thin) in 2011. In 2012, however, they became even in 2012. And it became larger in plot B1 (Thin) than in plot B2 (Control) in 2013. It was 0.81 times larger in B1 (Thin) than that in B2 (Control) in 2011, but after that it became 1.16 times larger in B1 than that in B2 in 2013. In plot C, the index figure point was larger in C1 (Thin & Mow) than in C2 (Control) over the three years. In plot D, also it was larger in D1 (Mow) than that in D2 and D3 (Control) over the three years.

Therefore, Shannon's *H'* in Satoyama activity plots increased more in the third year in plots B and C. This means that the Satoyama activity plot came to have greater biodiversity in abundance evenness, even though the species richness decreased in plot B and it did not change significantly in plot C from 2012 to 2013. The Simpson's 1/D index became much larger in Satoyama activity plots after three years, proving that the specific species came to have less dominance, and relative dominance of each species became more even in Satoyama activity plots that those in control plots.

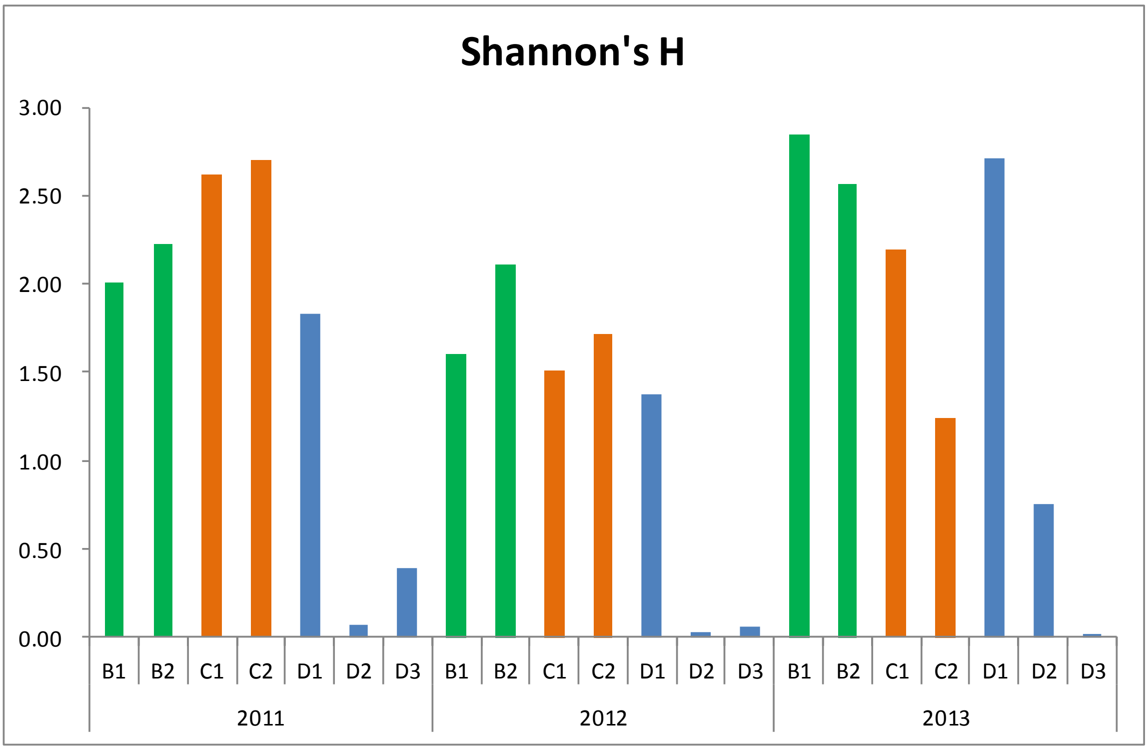


Figure 20. Shannon's *H*' index in each year by plot

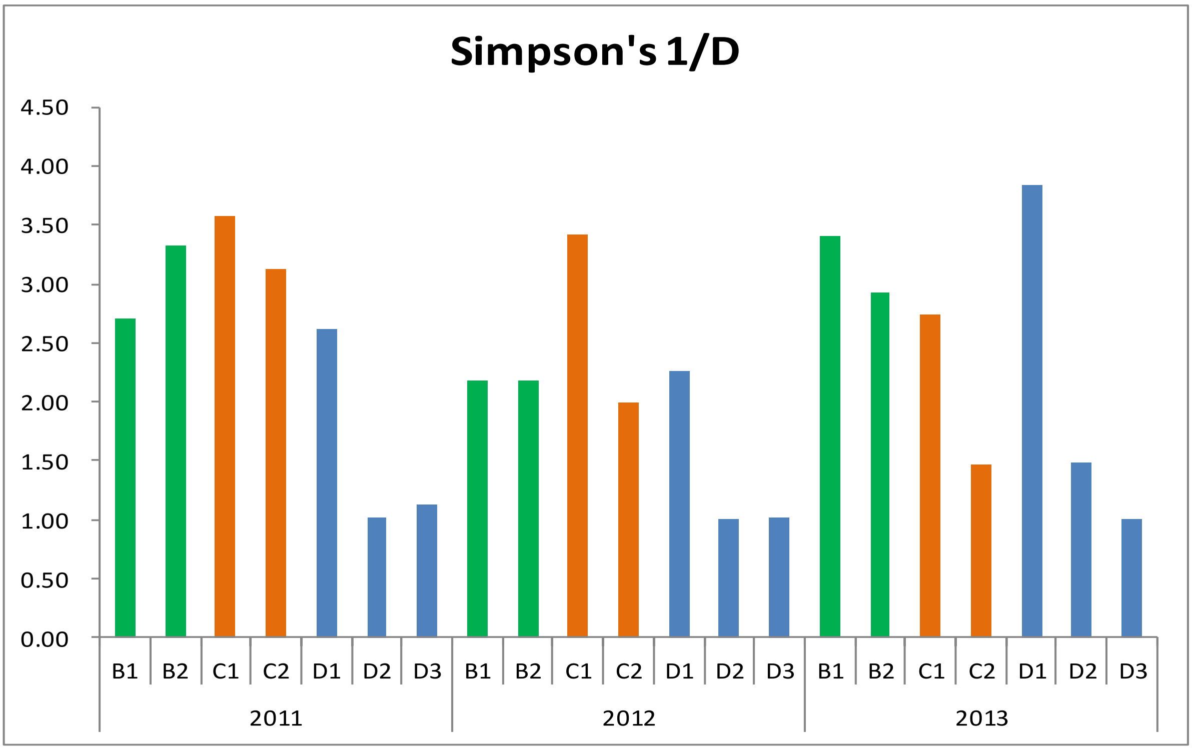


Figure 21. Simpson's 1/D index in each year by plot

3.6 Habitat environment survey for species diversity of plants

3.6.1 Soil water content

Figures 22-23 show the percentage of soil water content for each plot. The plots were surveyed in April 15th, 16th and 25th and May 13th and 15th 2013, in spring when the leaves of canopy open. In plot B, the percentage of soil water content was higher in both April and May. In plot C, there was not a significant difference between C1 and C2 in April. In May, C1 had slightly higher soil water content than that in C2. In plot D, the percentage of soil water content was slightly higher in D2 and D3 than that in D1 in April, and there was no significant difference among them in May.

Figures 24-25 show the maximum, minimum, and mean figures of the soil water content in each plot. The comparison of all plots in the Figures 26-27 shows that soil water content was higher in B1 (Thin) than in B2 (Control) in April, and it was higher in C1 (Thin and Mow) than in C2 (Control) in May.

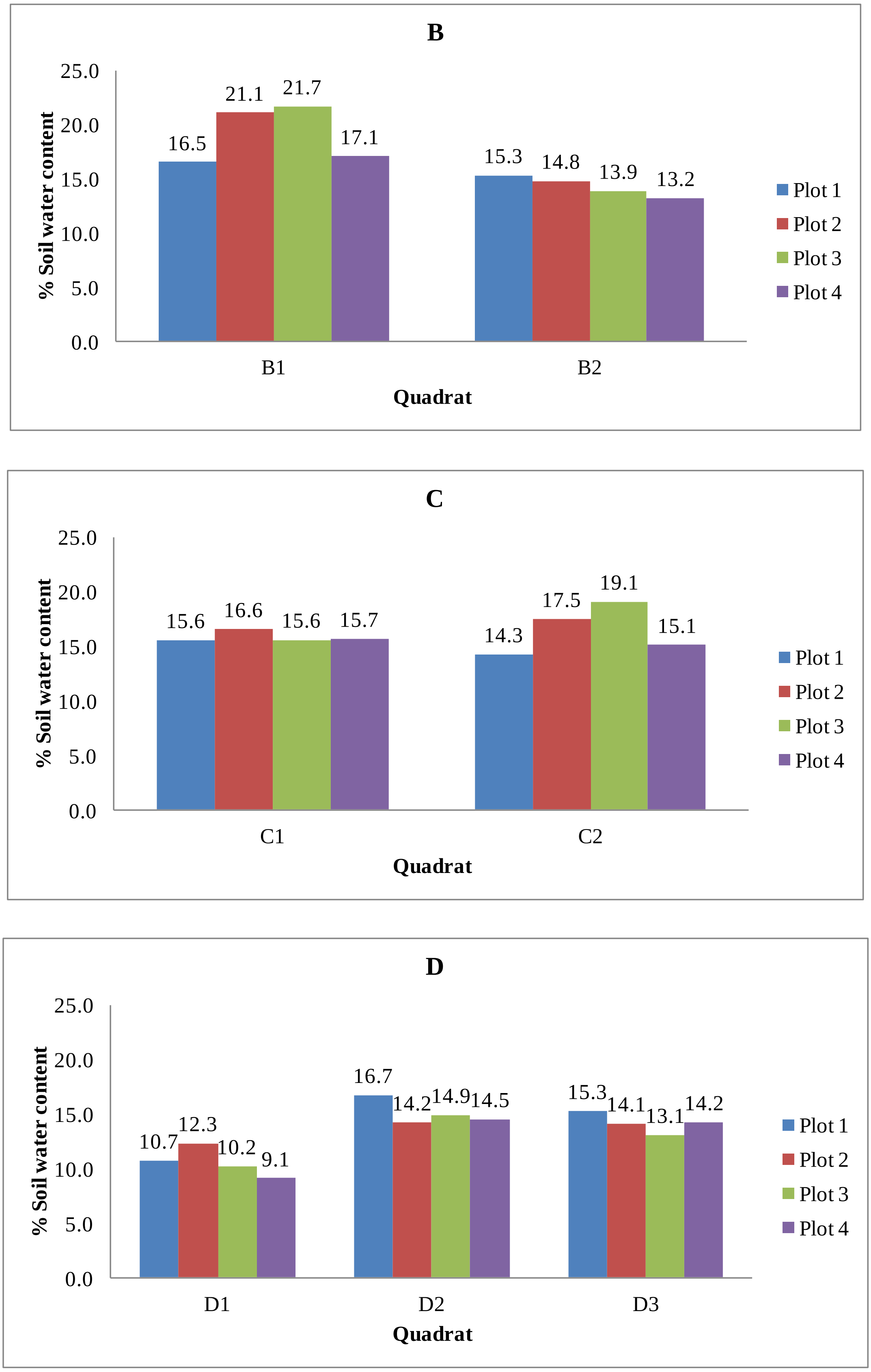


Figure 22. Soil water content, Mean in each quadrat, April 2013

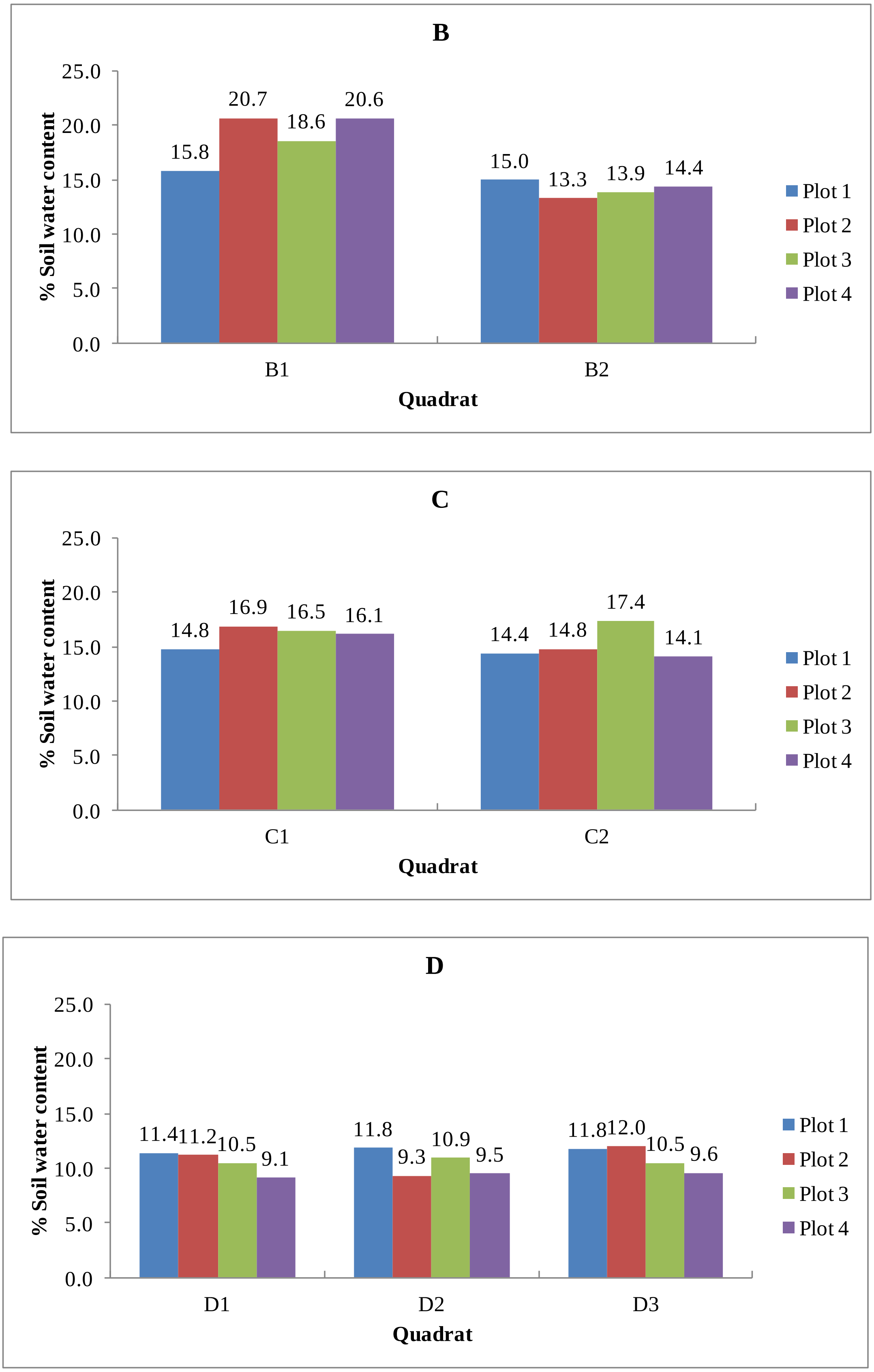
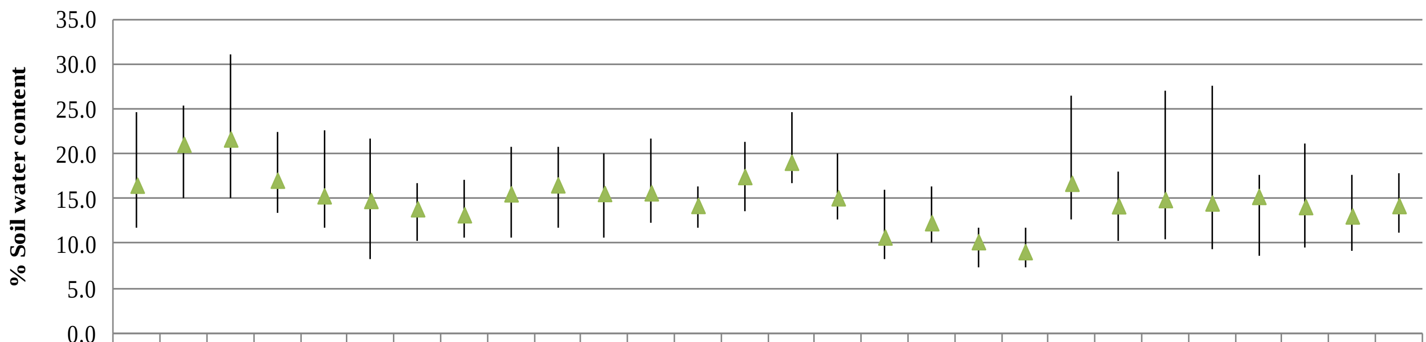


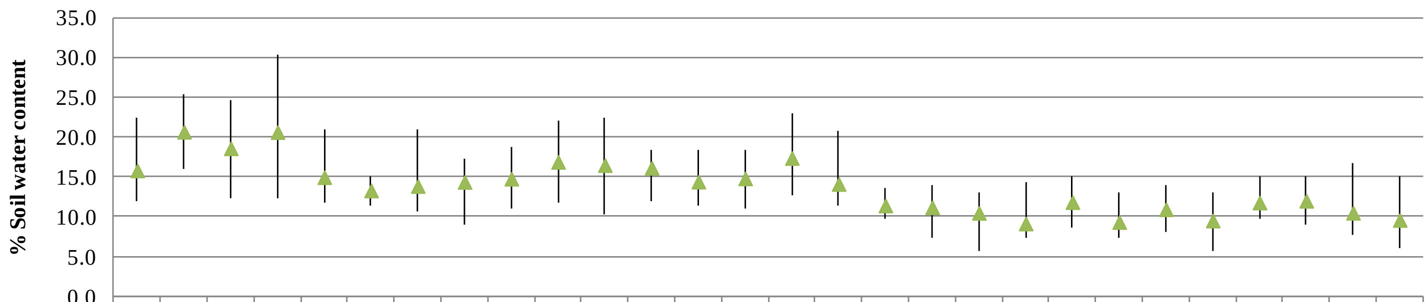
Figure 23. Soil water content, Mean in each quadrat, May 2013



	B-1-1	B-1-2	B-1-3	B-1-4	B-2-1	B-2-2	B-2-3	B-2-4	C-1-1	C-1-2	C-1-3	C-1-4	C-2-1	C-2-2	C-2-3	C-2-4	D-1-1	D-1-2	D-1-3	D-1-4	D-2-1	D-2-2	D-2-3	D-2-4	D-3-1	D-3-2	D-3-3	D-3-4
Min	11.7	15.0	15.0	13.3	11.7	8.3	10.3	10.7	10.7	11.7	10.7	12.3	11.7	13.7	16.7	12.7	8.3	10.0	7.3	7.3	12.6	10.2	10.4	9.4	8.6	9.6	9.2	11.2
Max	24.7	25.3	31.0	22.3	22.7	21.7	16.7	17.0	20.7	20.7	20.0	21.7	16.3	21.3	24.7	20.0	16.0	16.3	11.7	11.7	26.4	18.0	27.0	27.6	17.6	21.2	17.6	17.8
▲Average	16.5	21.1	21.7	17.1	15.3	14.8	13.9	13.2	15.6	16.6	15.6	15.7	14.3	17.5	19.1	15.1	10.7	12.3	10.2	9.1	16.7	14.2	14.9	14.5	15.3	14.1	13.1	14.2

Small plot

Figure 24. Soil water content, Max, Min, Mean in each quadrat, April 2013



	B-1-1	B-1-2	B-1-3	B-1-4	B-2-1	B-2-2	B-2-3	B-2-4	C-1-1	C-1-2	C-1-3	C-1-4	C-2-1	C-2-2	C-2-3	C-2-4	D-1-1	D-1-2	D-1-3	D-1-4	D-2-1	D-2-2	D-2-3	D-2-4	D-3-1	D-3-2	D-3-3	D-3-4
Min	12.0	16.0	12.3	12.3	11.7	11.3	10.7	9.0	11.0	11.7	10.3	12.0	11.3	11.0	12.7	11.3	9.7	7.3	5.7	7.3	8.7	7.3	8.0	5.7	9.7	9.0	7.7	6.0
Max	22.3	25.3	24.7	30.3	21.0	15.0	21.0	17.3	18.7	22.0	22.3	18.3	18.3	18.3	23.0	20.7	13.7	14.0	13.0	14.3	15.0	13.0	14.0	13.0	15.0	15.0	16.7	15.0
▲Average	15.8	20.7	18.6	20.6	15.0	13.3	13.9	14.4	14.8	16.9	16.5	16.1	14.4	14.8	17.4	14.1	11.4	11.2	10.5	9.1	11.8	9.3	10.9	9.5	11.8	12.0	10.5	9.6

Small plot

Figure 25. Soil water content, Max, Min, Mean in each quadrat, May 2013

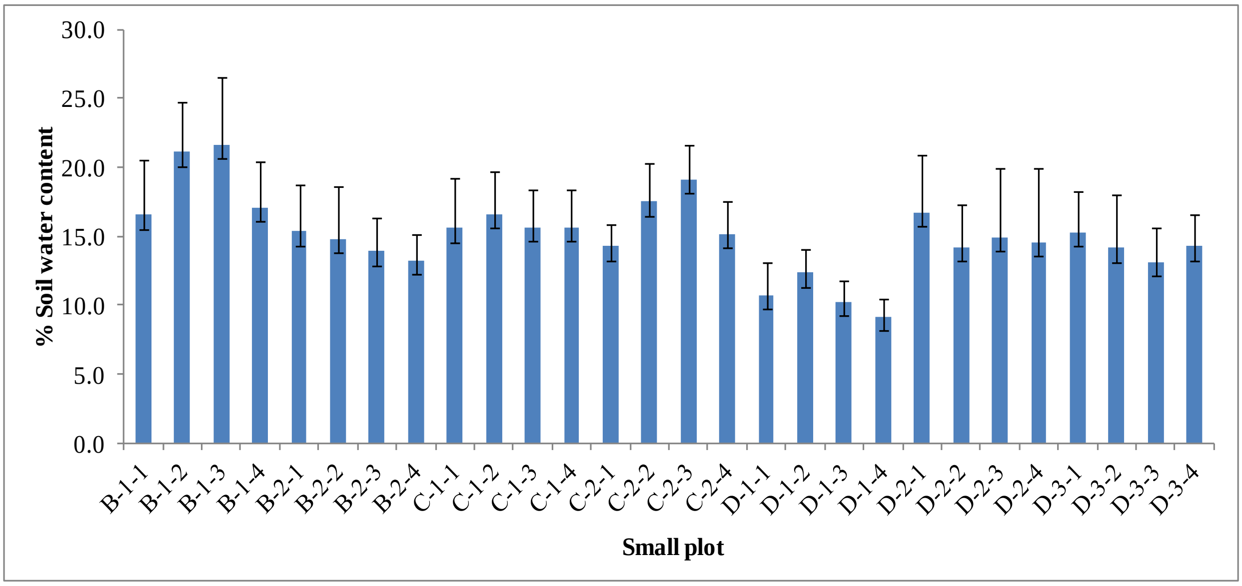


Figure 26. Soil water content, Mean and Standard Deviation in each quadrat, April 2013

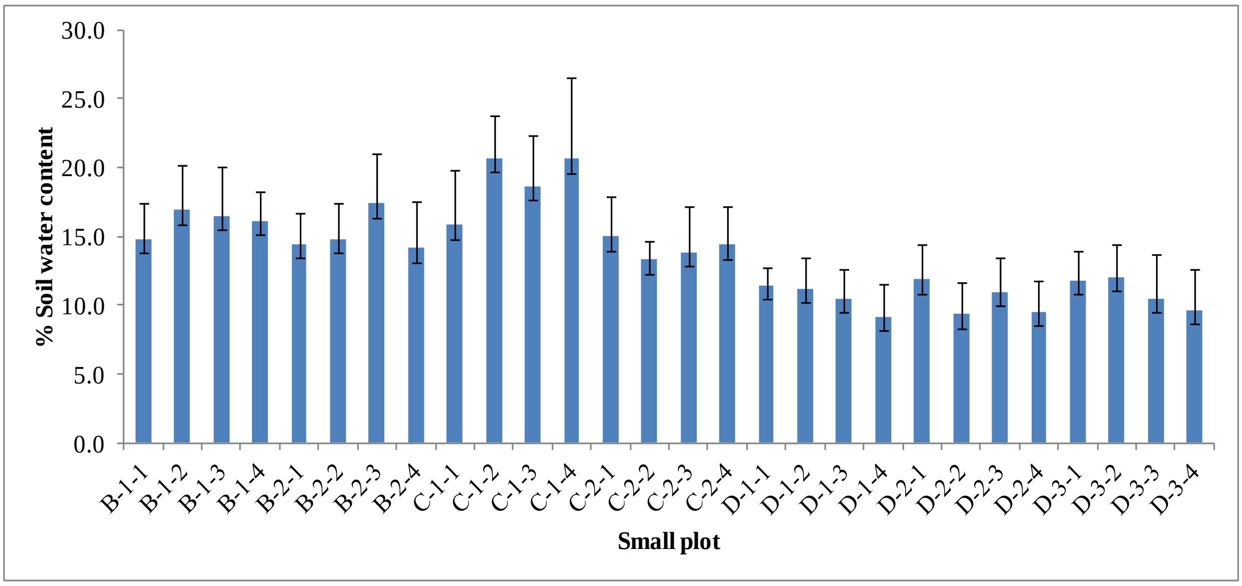


Figure 27. Soil water content, Mean and Standard Deviation in each quadrat, May 2013

3.6.2 Light condition

Figures 28-29 show the mean canopy openness in each plot. The surveys were conducted on April 15th and 16th, and May 13th, 14th and 15th 2013.

In April, the maximum figure point of mean canopy openness in all plots was 31 percent in D1. B (Thin) has much larger mean canopy openness than B2 (Control). D1 (Mow) also had much larger mean canopy openness than D2 and D3 (Control). On the other hand, C1 (Thin and Mow) has about the same figure point of mean canopy openness as C2 (Control).

In May, the maximum figure point of mean canopy openness in all plots was 19 percent in D1. It decreased from April by 12 percent. The tree leaves started to sprout from April to May. The difference of the mean canopy openness between Satoyama activity plot and control plots became smaller than that in April. In all Satoyama activity plots, the mean canopy openness turned out to be larger than those of the control plots.

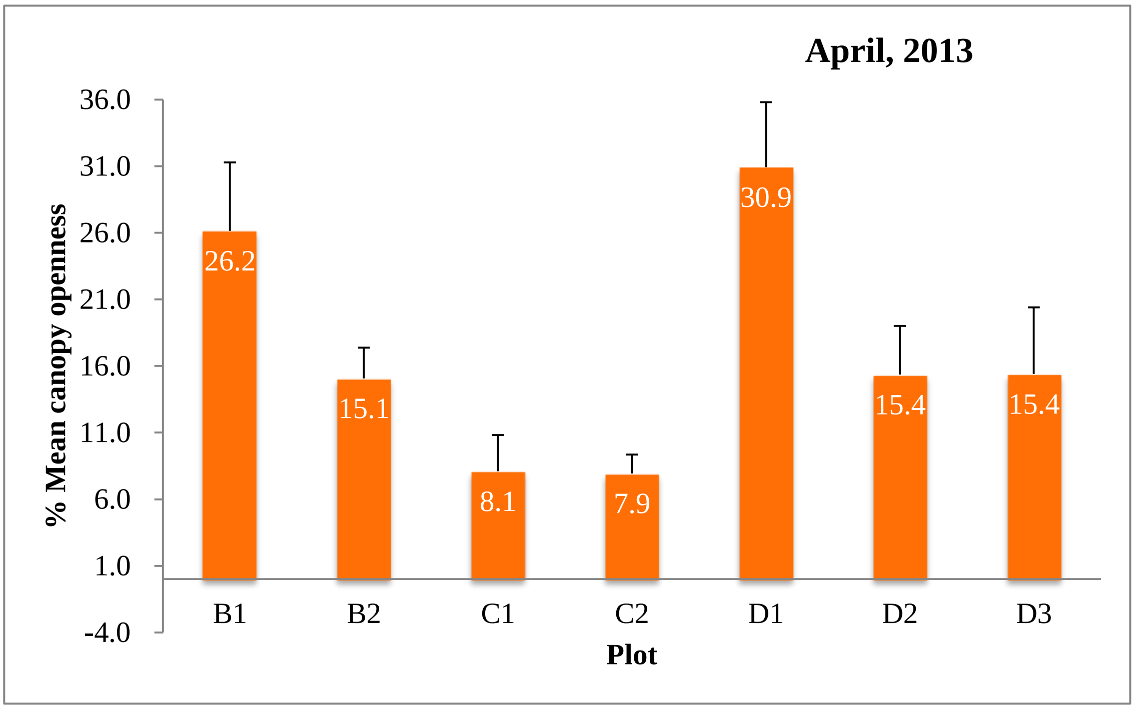


Figure 28. Canopy openness, Mean and Standard Deviation in each plot, April 2013

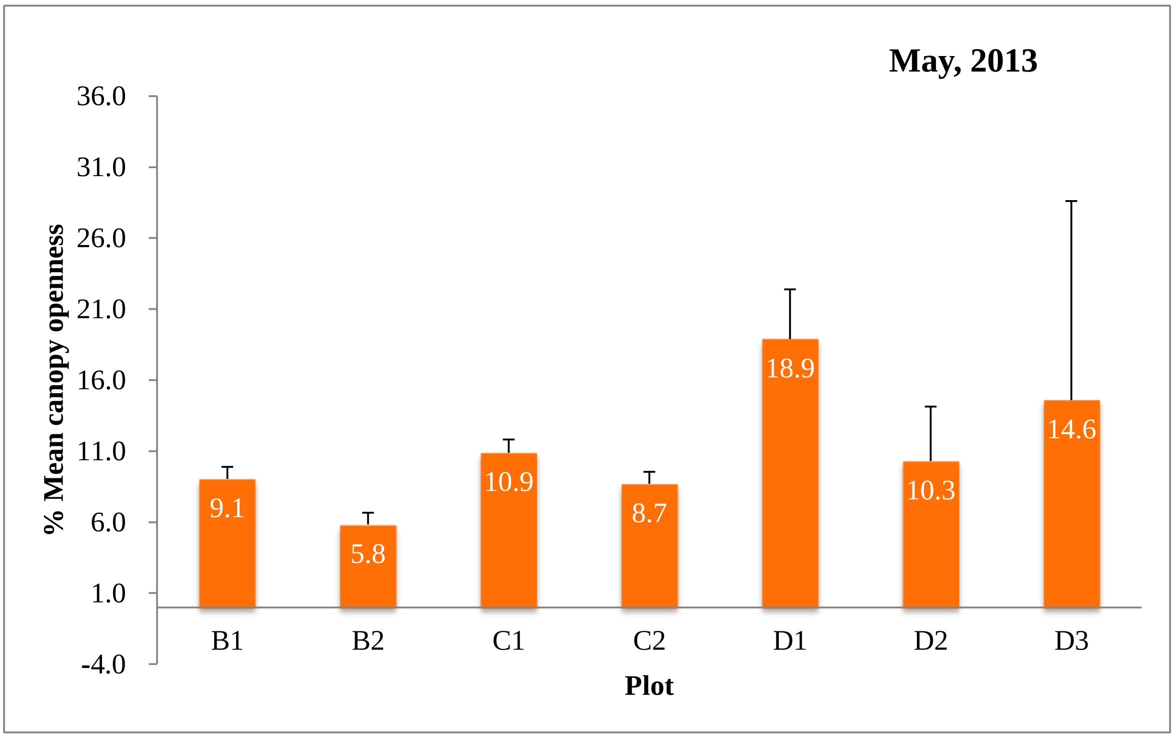


Figure 29. Canopy openness, Mean and Standard Deviation in each plot, May 2013

3.7 Habitat environment survey for *Polygonatum involcratum*

3.7.1 Light condition

Figure 30 shows the percentage of mean openness in each community site in Oaota forest on July, 9th 2012. The total average is 9.7 percent. The percentage of mean openness in each community site in Oaota forest ranges from 8.7 to 11.1. In the site of community Ⅲ (Oaota Ⅲ in the Figure 30), the percentage of mean openness was the highest. The Oaota Ⅰ, Ⅱ, and Ⅳ community sites lies along the pathways in the coppice field (Picture 1,2,4). The Oaota Ⅲ community, however, lies in a gap of fallen branches (Picture 3), and it is not along the pathway.

Figure 31 shows the percentage of mean openness in three community sites in Kashiwa city, which was surveyed on July 13th, 2012. The total average of community sites is 8.9 percent. The percentage of mean openness in the three community sites ranged from 6.3 to 12.6 percent.

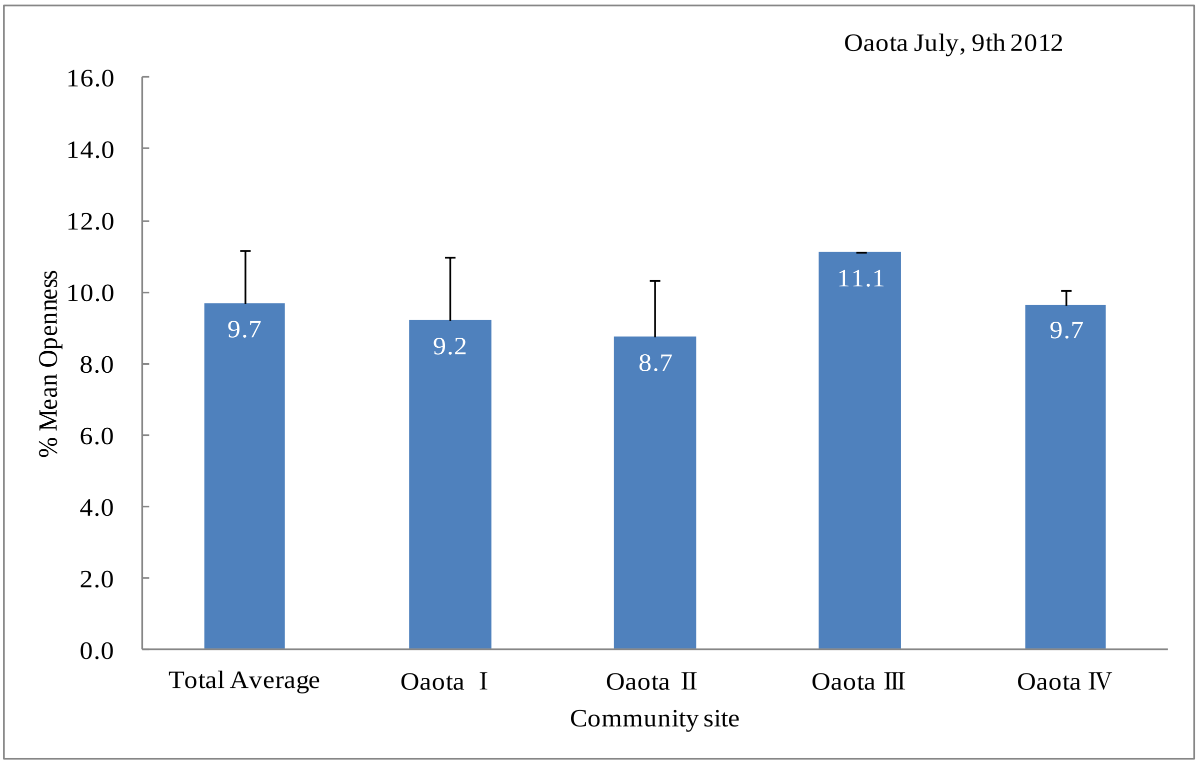


Figure 30. Canopy openness, Mean openness (%) in each community site in 2012

Oaota forest, surveyed on 9th July 2012

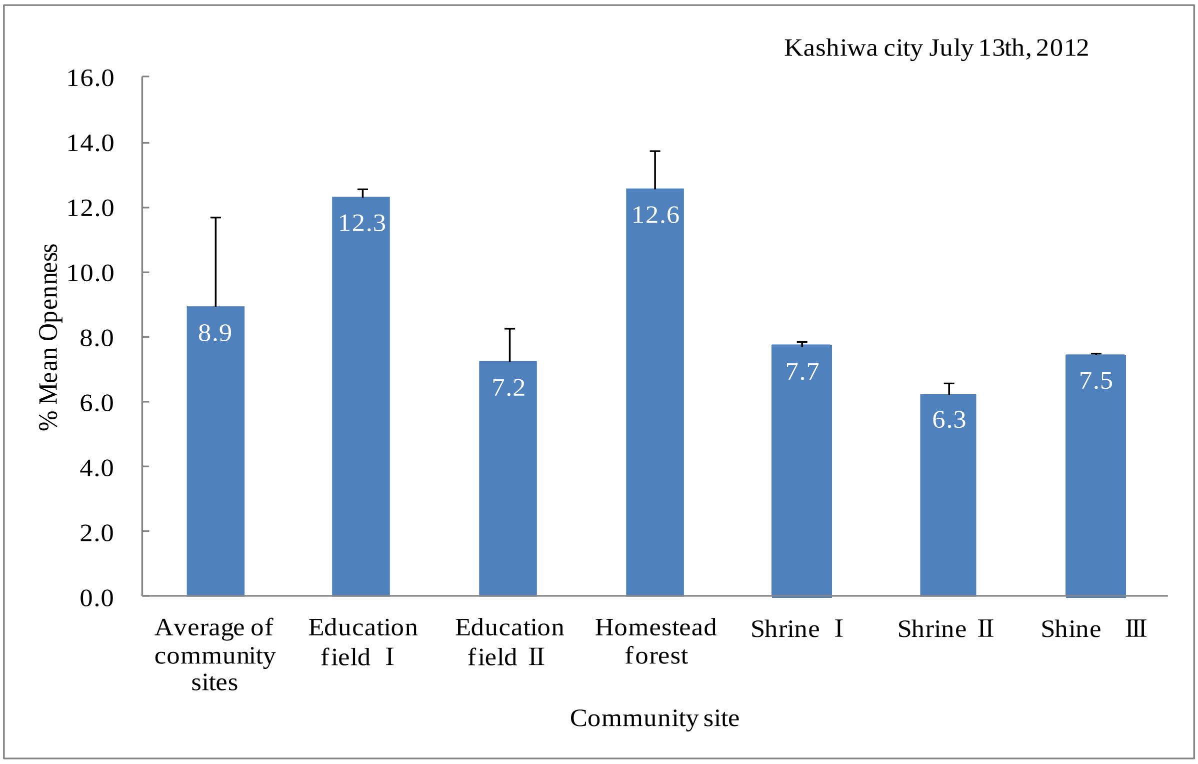


Figure 31. Canopy openness, Mean openness (%) in each community site in 2012

Kashiwa city, surveyed on 13th July 2012

Picture 1. Oaota I

Picture 2. Oaota II

Picture 3. OaotaⅢ

Picture 4. Oaota Ⅳ

3.7.2 Soil water content

Figure 32 shows mean and standard deviation percentage of soil water content in each community site. It was surveyed on July 9th in Oaota forest, and July 13th in the three sites in Kashiwa city. Mean value of soil water content in the community habitats of *Polygonatum involcratum* ranged from 13.1 to 16.4 percent in Oaota forest on July, 9th, 2012. In the other three sites in Kashiwa city, mean value of soil water content ranged from 13.8 to 20.7 percent on July 13th, 2012.

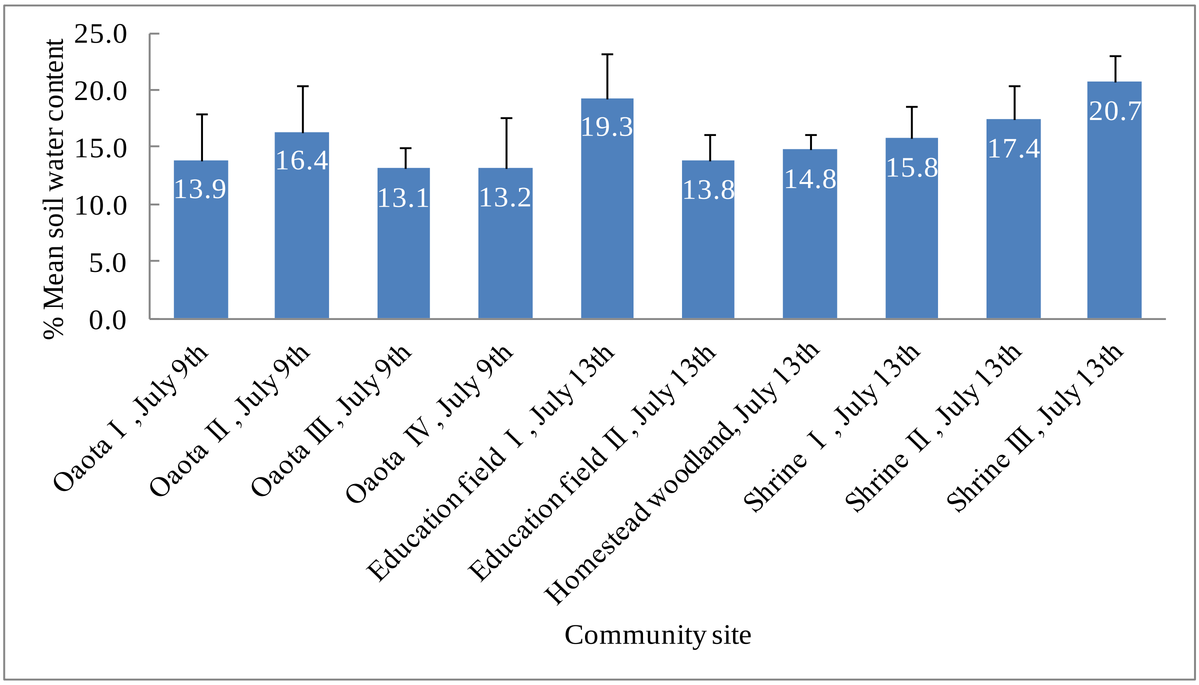


Figure 32. Percentage of mean soil water content, Mean and Standard Deviation in each community site in 2012 (Surveyed on 9th July 2012 in Oaota, and 13th July 2012 in Education field, Homestead woodland, and Shrine)

3.7.3 Height and the number of leaves

Figure 33 shows the average height of *Polygonatum involcratum* in each community, and it ranged from 7 to 29 cm. Individuals that are around 15 cm height were frequently observed. Figure 34 shows the average number of leaves in each community, and it ranged from 3 to 6. The individuals that had 4 to 6 leaves were observed frequently.

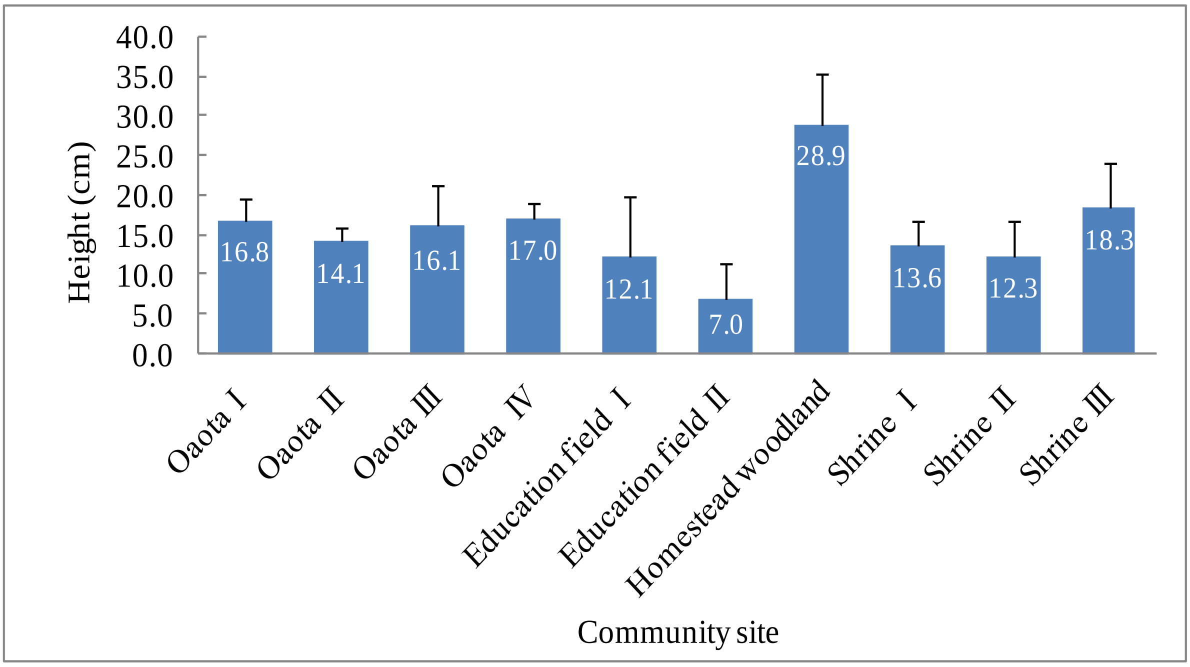


Figure 33. Average height of *Polygonatum involcratum* in each community site
(Surveyed on 9th July 2012 in Oaota, and 13th July 2012 in Education field, Homestead woodland, and Shrine)

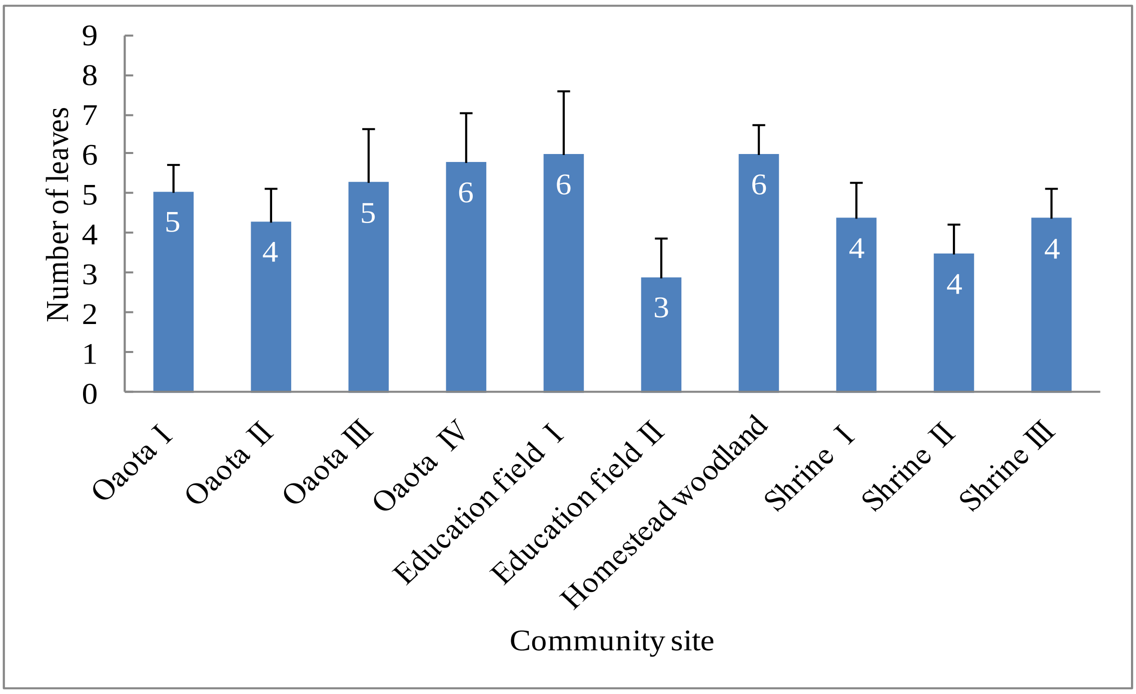


Figure 34. Average number of leaves of *Polygonatum involcratum* in each community site (Surveyed on 9th July 2012 in Oaota, and July 13th in Education field, Homestead woodland, and Shrine)

3.7.4 Comparison between habitat and non-habitat

Figure 35 shows the comparison between habitat and non-habitat of *Polygonatum involcratum* in relation to the percentage of soil water content and the percentage of mean openness. The figure points of *Polygonatum involcratum* community lie in the smaller range than the more scattered figure points of No *Polygonatum involcratum* community.

Figure 36 shows the relationship between the soil water content (%) and solar irradiation (MJ/m^2/day). The soil water content and solar irradiation were measured for the *Polygonatum involcratum* community and the other rare species community sites on 19th July, 2012 in Kashiwa city. The Figure 36 shows that there is not such a significant difference in soil water and light condition between the other species and the *Polygonatum* *involcratum* on that day in Kashiwa city. There were other species community sites in the coppices in Kashiwa city. *Cymbidium macrorrhizon* is a C rank species and *Cephalanthera falcata* is a D rank species on the red data list of Chiba prefecture, and it is necessary to conserve in-situ habitats of the rare species (Takishita, 2012; Shirakawa, 2011). These rare species that should be conserved grow in the same coppice fields as *Polygonatum involcratum* habitat and the light and soil water conditions in their habitats were similar to each other as of 19th July, 2012.

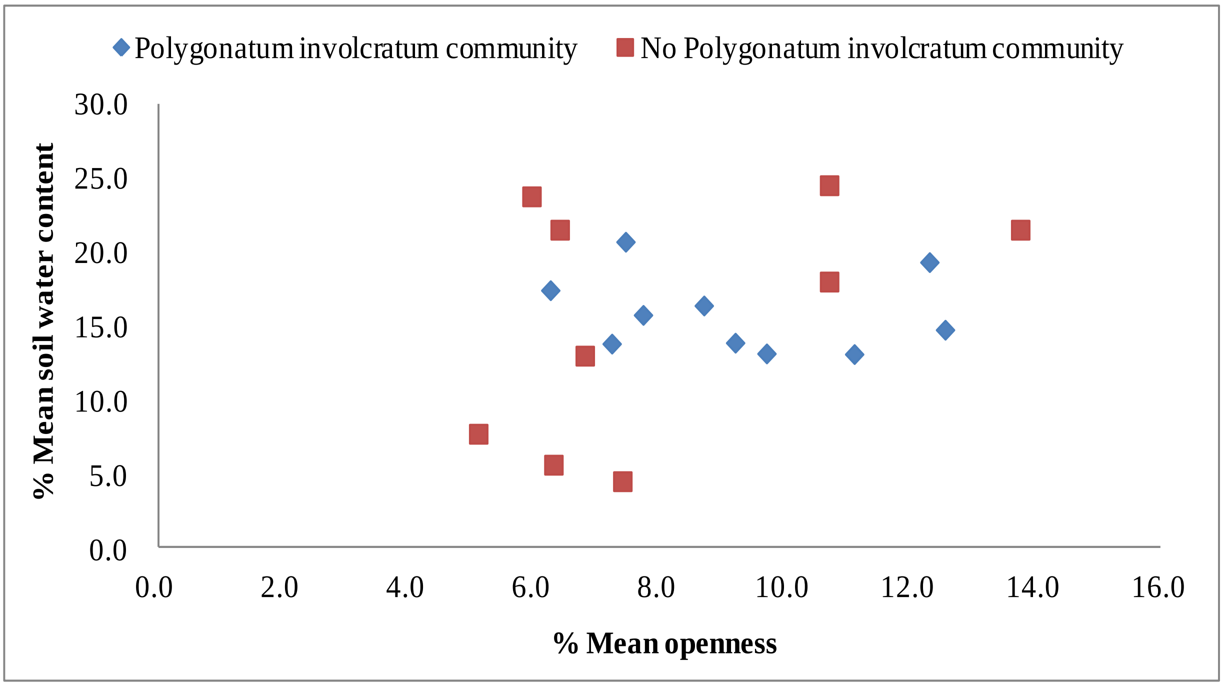


Figure 35. Mean soil water content (%) and mean openness (%) in 2012- Comparison between habitat of *Polygonatum involcratum* and non-habitat, surveyed on 9th and 13th July 2012

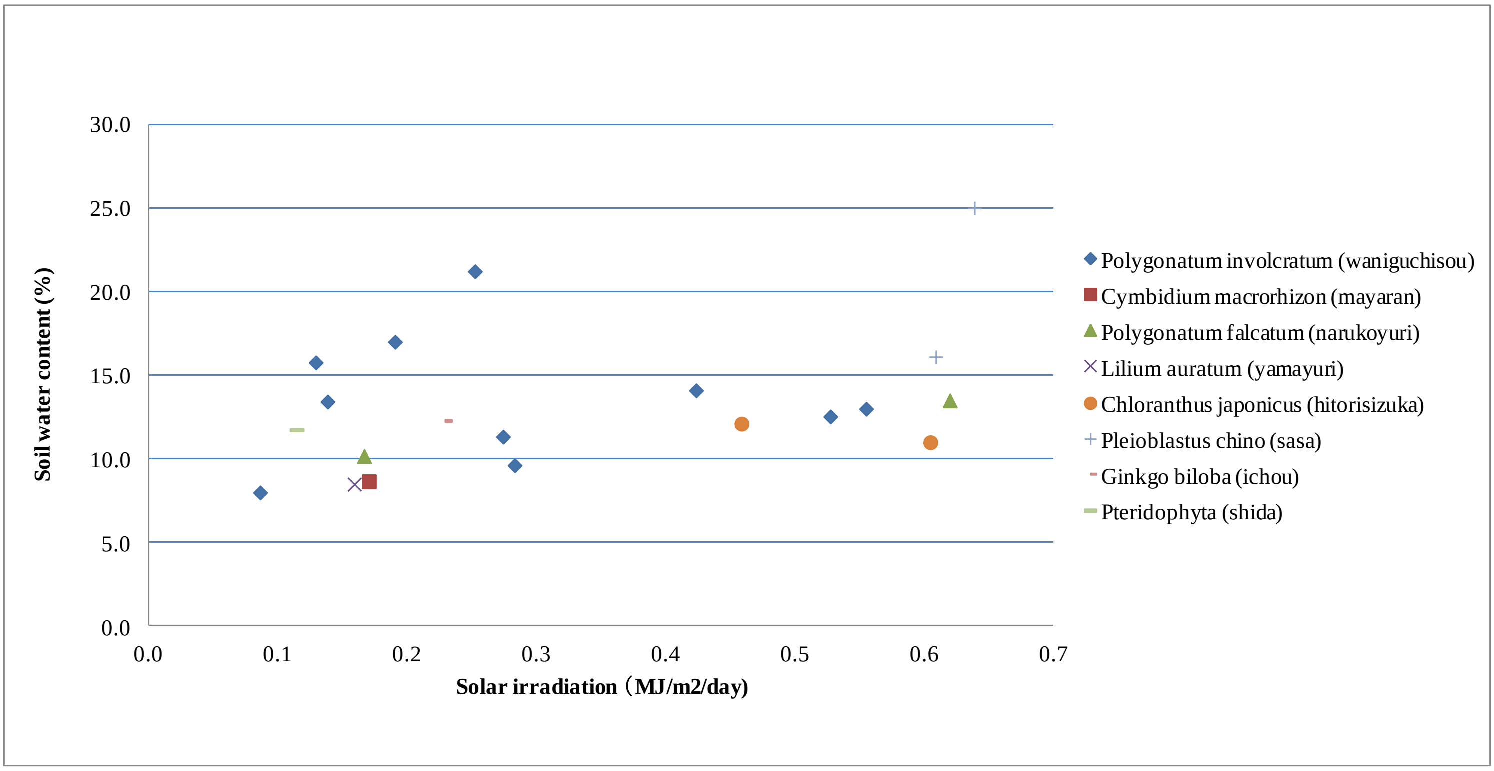


Figure 36. Soil water content and solar irradiation in 2012 – Comparison between habitat of *Polygonatum involcratum* and non-habitat (Surveyed on 19th of July, 2012 in Kashiwa city)

3.7.5 Relationship between height and canopy openness

Figure 37 shows the relationship between the heights (cm) and mean openness, the rate of canopy openness (%). Height (cm) is the average height of individuals chosen randomly in each community. Mean openness (%) is the average of the rate of canopy openness in each community. The regression formula, Height (cm) =1.4371×(Mean openness) +2.3616 has the reliability of 30%.

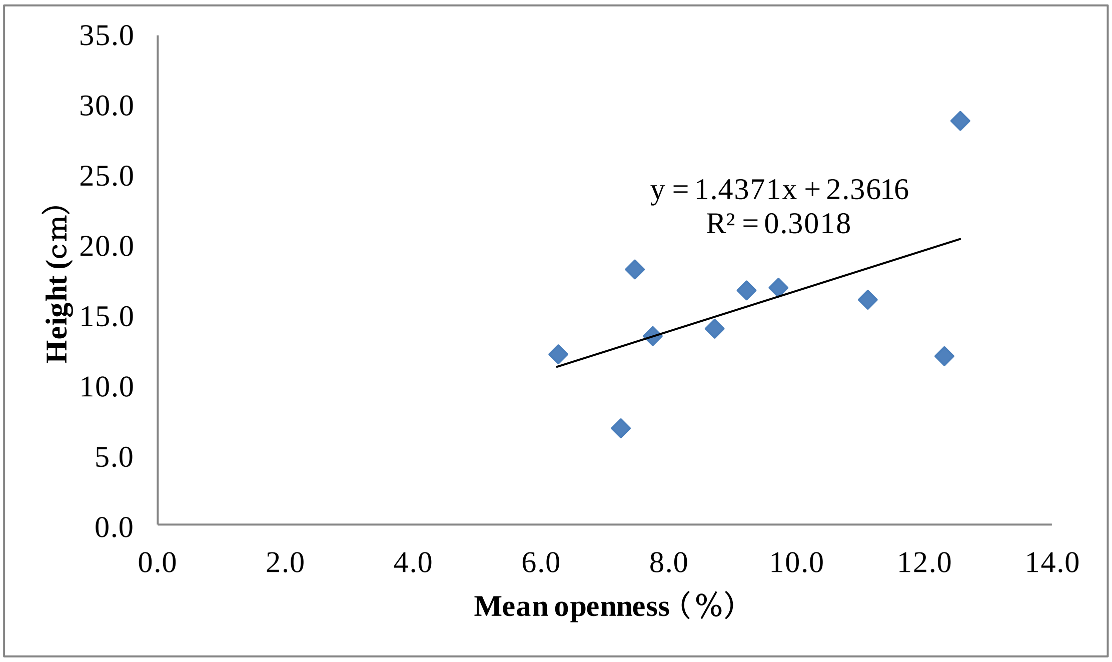


Figure 37. Height (cm) and mean openness (%) in 2012

3.7.6 Line transect

Figures 38-41 show a definite range of vegetation in *Polygonatum involcratum* communities in Kashiwa city. In Oaota forest community Ⅰ, *Polygonatum involcratum* inhabit on the pathway. *Pleioblastus chino* and *Oplismenus undulatifolius* were often observed. In Oaota forest community Ⅱ, *Polygonatum involcratum* grew along the pathway, the line transect that was put parallel to the pathway recorded its larger community than vertical transect line. *Viola grypoceras* and *Hedera rombea* inhabited nearby. In Oaota forest community Ⅲ, the habitat was densely covered by tall *Pleioblastus chino*. *Polygonatum involcratum* inhabit near the gap of fallen tree, where they can still gain some sunlight. In Oaota forest community Ⅳ, *Polygonatum involcratum* inhabit next to pathways, and grew with *Parthenocissus tricuspidata* and closely related plant of *Polygonatum falcatum.*

In Education field, *Polygonatum involcratum* habitat was on the hill and that various plant species were observed. The observed frequency of *Pleioblastus chino* was less than in other habitats. Beautiful blooming plants such as *Galium kinuta*, *Rubus illecebrosus*, *Salvia japonica*, *Chloranthus japonicus*, *Kerria japonica* were observed. Especially, *Galium kinuta*, *Rubus illecebrosus* are B rank important species for conservation in Chiba prefecture (Chiba prefecture, 2009). This habitat is near the entrance of the education field, and that the gardeners and citizen volunteers take care of the tree branches to help plants bloom.

In homestead woodland, *Polygonatum involcratum* habitat was surrounded by a large

Polygonatum falcatum community. It was also covered by *Pleioblastus chino* and climbers of *Pueraria lobata* and *Parthenocissus tricuspidata*.

In Shrine community Ⅰ, large *Pleioblastus chino* bush grew, but still a closely related plant species of *Polygonatum falcatum* inhabit near *Polygonatum involcratum* community. In Shrine community Ⅱ, where the canopy openness was the smallest, a closely related plant species of *Disporum sessile* community was observed, and *Polygonum filiforme* which prefer darker ground grew with *Polygonatum involcratum*. In Shrine community Ⅲ, closely related plant species *Disporum sessile* community grew with *Polygonatum involcratum*. *Thelypteris japonica* which prefers darker and humid ground was also observed.

Therefore, *Polygonatum involcratum*'s habitat characteristics are that they inhabit in the coppice fields of relatively dark area and along pathways where sunlight can still reach. *Polygonatum involcratum* grew next to each other with closely related plant species such as *Polygonatum falcatum* and *Disporum sessile.* Near its habitat, variety of endemic plants such as *Galium kinuta*, *Rubus illecebrosus*, *Salvia japonica*, *Chloranthus japonicus*, and *Kerria japonica* grow. Some rare species, *Galium kinuta* and *Rubus illecebrosus*, also grow in the habitat. *Pleioblastus chino* and climbers were less frequently observed in such habitat of diverse plant species.

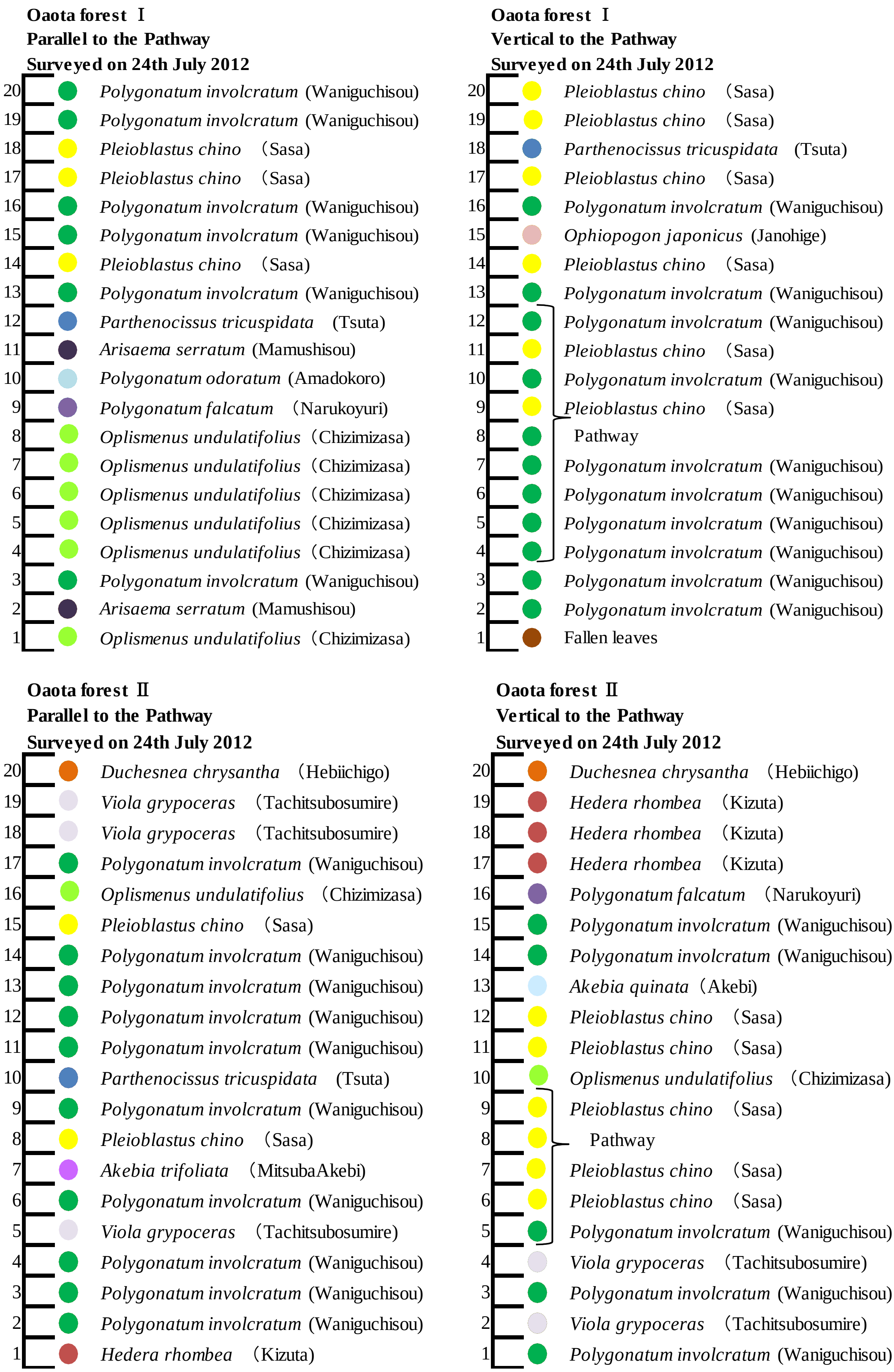


Figure 38. Line transect of *Polygonatum involcratum* community Ⅰ-Ⅱ in Oatao forest

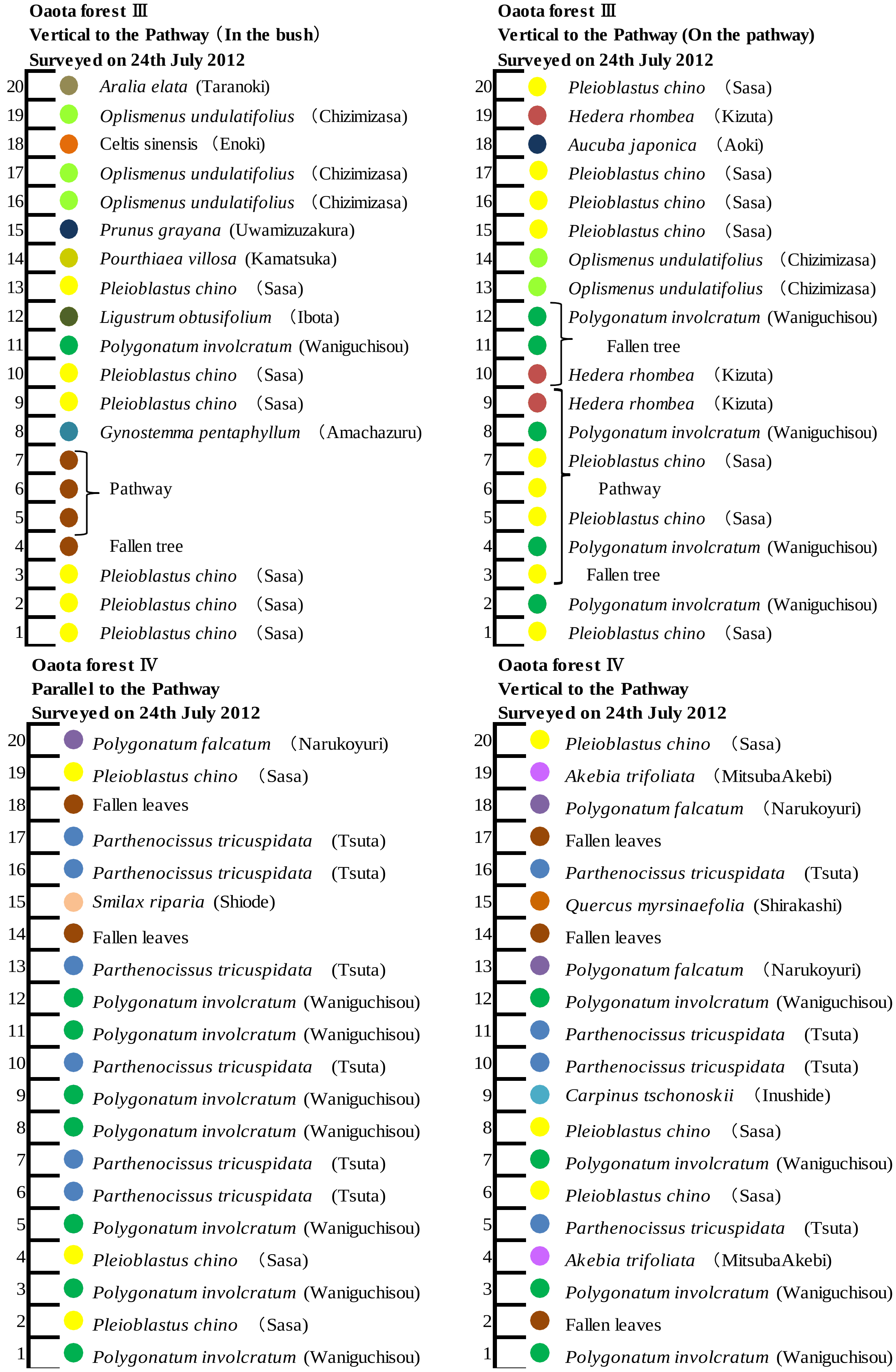


Figure 39. Line transect of *Polygonatum involcratum* community Ⅲ-Ⅳ in Oatao forest

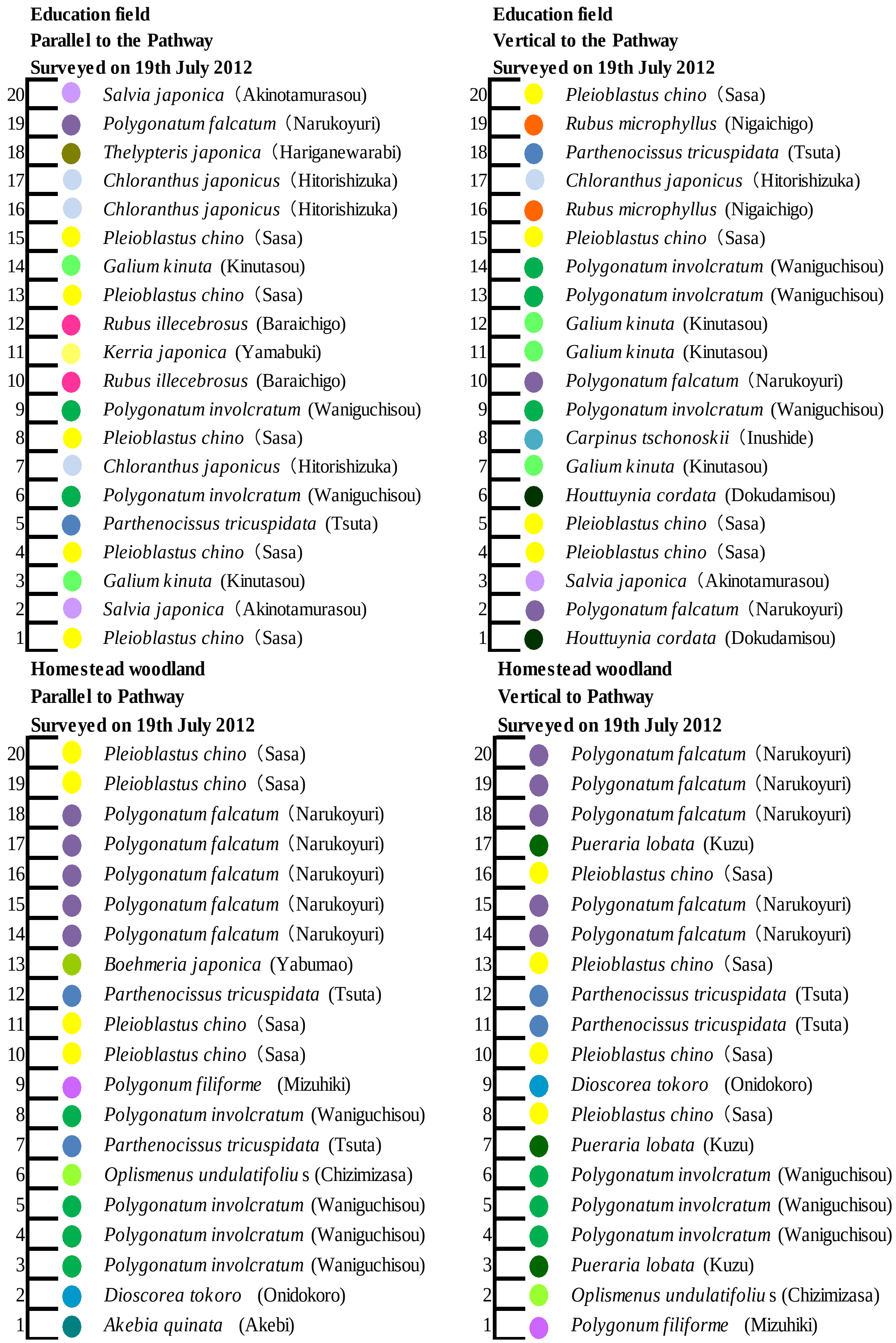


Figure 40. Line transect of *Polygonatum involcratum* community in Education field and Homestead woodland

Figure 41. Line transect of *Polygonatum involcratum* community Ⅰ toⅢ in Shrine

4 DISCUSSION

This study analyzed the biodiversity of plants in Oaota forest where volunteer Satoyama activities have been conducted. The species richness was firstly analyzed to observe its changes. It was hypothesized that species diversity of plants would increase after Satoyama management (Nakashizuka and Iida, 1996). The main factors are removal of dominant species and improvement of light condition on the forest floor. Previous studies revealed that species richness decreases when *Pleioblastus chino* dominates (Nakashizuka and Iida, 1996; Azuma et al., 2003). The previous study also found a negative correlation between the heights of *Pleioblastus chino* and species richness of other plants (Nakashizuka and Iida, 1996). Species richness increased largely in plot D where volunteers mowed *Pleioblastus chino*, which agree with the past study. The number of woody plants below 130 cm height was less than that of herbaceous plants only in Plot D. It can be considered that this is partly because this area used to be utilized as a farmland (hearing interview with NPO Chiba Satoyama Trust) and the site is an area where only several tall trees cover the forest floor.

The other result showed that the patterns of changes in species richness over the three years were the same between Satoyama management plots and control plots. The patterns of changes showed peaking in the second year and decreased afterward in plot B; it decreased slightly in the second year and did not change significantly in plot C; and it increased largely in the second year and the third year in plot D1. There is also a report that species richness has changed over the 11 years after the management (Mason and Macdonald, 2002). The change patterns in the study showed that the species richness peaked two and three years after coppicing (Mason and Macdonald, 2002). The change patterns in species richness were similar with the past study of the coppice fields in England.

Nagaike (2012) reported that there were cases of species richness increase, decrease, and constant after the Satoyama management. It was proposed that the management frequency and strength should not exceed the extent of natural disturbances (Nagaike 2012; Mori 2010). Since the "non-equilibrium status" of forest ecosystems is raised as an important factor that should be considered for forest management and restoration, and it is directly related to natural disturbances that create micro-level environment such as gaps created by old fallen branches (Mori, 2010). Therefore, the same change patterns in species richness of Satoyama activity plots and control plots showed that the management frequency and strength corresponded to the extent of natural disturbances in control plots.

Since a significant difference in species richness between the Satoyama activity plots and control plots in the woodland plot B and C was not found, this study analyzed the turnover of species in each plot over the three years. A previous study reported that in an unmanaged plot where deciduous fallen leaves had accumulated on the forest floor, the species richness of woody plants increased and that of herbaceous plants decreased (Katoh and Yachi, 2003). This tendency in the past study was observed in the broad-leaved deciduous secondary forests of *Quercus serrata*, and the tendency was not observed in the conifer secondary forests of *Chamaecyparis obtusa* in Tochigi prefecture. From the result of this study, in plot B, the deciduous broad-leaved secondary forests (*Quercus serrata*, *Quercus acutissima*, *Carpinus tschonoskii*) site, woody plants increased and herbaceous plants did not increase or decrease largely, which agrees with the tendency in the study.

What is more, this study revealed that the turnover of appeared and disappeared species varies depending on the woodlands and Satoyama management styles. For example, the common result from 2011 to 2012 was that perennial plants and deciduous shrubs appeared in plots B, C and D1, and deciduous tall tree appeared largely in D1. Also from 2012 to 2013, perennial plants appeared in plots B, C and D1, deciduous tall trees appeared in plot B and C2, and deciduous shrub appeared in B1, C, D1 and D2. Thus, this study found a tendency that perennial plants and deciduous trees appeared. In the unmanaged control plots, deciduous trees also appeared.

According to Yabu (1996), coppice fields of *Quercus serrata* and *Quercus acutissima* that were managed with weak strength by mowing and gathering fallen leaves, the *Pleioblastus chino* did not populate densely. In such secondary coppices, *Styrax japonica* (Egonoki, deciduous tall tree), *Viburnum dilatatum* (Gamazumi, deciduous shrub), *Stephanandra incise* (Kogomeutsugi, deciduous shrub), the unique trees in secondary forests grow, and gradually the evergreen trees such as *Quercus myrsinaefolia* (Shirakashi, evergreen tall tree), *Castanopsis sieboldii* (Sudajii, evergreen tall tree), *Neolitsea sericea* (Shirodamo, evergreen small tree), *Ligustrum japonicum* (Nezumimochi, evergreen small tree), *Aucuba japonica* (Aoki, evergreen shrub), *Trachycarpus fortune* (Syuro, evergreen tall tree) populate densely (Yabu, 1996).

During this study period, deciduous trees turned over the largest. Such evergreen trees inhabited constantly and grew higher than 130 cm. In the future, there is a possibility that evergreen broad-leaved trees will appear.

To investigate each species that changed revealed what kinds of rare species reappeared after the volunteer Satoyama activity. For example, *Cephalanthera falcata* is the rare species for conservation in Chiba prefecture (Chiba, 2009), and it grows on the forest floor of the natural forest around the Lake Konbukuro in Kashiwa city (Shirakawa, 2010). Its habitat in the secondary forest area is in the area with a light forest floor and fewer herbaceous plants (Shirakawa, 2009). Its growth requires a mycorrhizal association with *Quercus serrata* as a host tree (Takishita, 2012). The characteristics of its habitat type in Kashiwa city were revealed that *Cephalanthera falcata* type species were associated with the maintained deciduous forest and abandoned vegetation management with minimum level of human disturbance (Takishita, 2012). In the study, it was suggested that restarting the vegetation management would be preferable for its conservation (Takishita, 2012).

The results of this study support the past studies. *Cephalanthera falcata* appeared in the deciduous broad-leaved forest, in both thinning plot (B1) and control plot (B2), and disappeared in the unmanaged control plot in mixed forest (C2) in the first period. In the second period, *Cephalanthera falcata* appeared in the thinning and mowing plot in mixed forest (C1). Thus, this study also revealed that *Cephalanthera falcata* appeared in the forest floor of *Quercus serrata* and mixed forest in the Satoyama management plots. It also appeared in the unmanaged plot in the first period. The possible consideration is that it could still access the light in the relatively dense forest, as this is also explained in Takishita (2012).

The other rare species are *Tricyrtis affinis* and *Ajuga nipponensis*. *Tricyrtis affinis* grows in a mixed forest with grass mowing (Takishita, 2012). It had grown but disappeared in the unmanaged mixed forest plot (C2) in the first period, which agrees with the past study. *Ajuga nipponensis* grows on the light forest floor in secondary forests such as *P. densiflora, C. japonica* forest, orchard, mixed forest, broad-leaved evergreen forest, bamboo forest, and deciduous forest (Takishita, 2012). *Ajuga nipponensis* appeared in the mowing plot in *Pleioblastus chino* community (D1) in the second period. Therefore, some rare species appeared in the Satoyama activity plots, and disappeared in the unmanaged control plot. It is possible to explain that the light conditions were improved through the Satoyama activities, and the rare species which prefer the light forest floor in the secondary forests appeared.

In order to consider what kinds of secondary forest the Oaota forest will grow in the future, this study investigated what kinds of life forms appeared in which year. Diverse life forms appeared in mix from shrubs to tall trees in the early stage of secondary succession in Japan (Shizu and Sode, 2012). This is because the dominant species changes quickly. The past study surveyed the ground flora seven years after clear-cutting, and found that the share of tall trees had become larger than the share of shrubs and small trees as times passed (Shizu and Sode, 2012). The results showed that more diverse life forms appeared in the first period than that in the second period, which agrees with the past study.

The frequency of tall trees, deciduous tall trees, was relatively large in the mowing plot D1 in the *Pleioblastus chino* community in the first period, which supports the past study. On the other hand, the frequency of shrubs was relatively high in plots B and C in the first period, which disagrees with the past study. In the second period, however, the result in the first period became opposite. The frequency of deciduous shrubs was the largest in D1. On the other hand, the frequency of deciduous tall trees was the largest in B2 and C2 where Satoyama management was not conducted. This can be explained that the thinning activities were different between the past study and this study. In this study only too dense tall trees and dead trees were thinned.

On the forest floor of unmanaged sites, shrubs, evergreen broad-leaved trees, and shade-tolerant trees increased (Tsuji and Hoshino, 1992). The result of this study showed that in the control plots of B2 and C2, shrubs increased the largest in the first period. The shrubs in B2 were deciduous shrub, and those in C2 were deciduous shrub and evergreen shrub. Therefore, regular mowing management is preferable, because the shrubs became densely populated and cover the forest floor. The frequency of deciduous tall trees was the largest in plot D1, if they were marked and conserved, the *Pleioblastus chino* community plain would grow into the deciduous tree coppice.

It is important to see the relative dominance of each species to find whether a specific species dominate or diverse species grow evenly. The comparison of it between Satoayma management plots and control plots revealed the changes in dominant species and evenness in each species. It is considered that more diverse species inhabit when a specific dominant species is removed by mowing and the improvement of light condition (Kameyama, 1996). The result showed that the relative dominance curves in Satoyama activity plots in 2013 were more moderate than that in 2011 and 2012. This means that the relative dominance of diverse species increased. More diverse species that were more dominant than 0.1 percent grew in Satoyama management plots than those in control plots. Therefore, the Satoyama management supports diverse species to recover and inhabit as time passes.

The biodiversity indices explain the tendencies that only species richness could not explain. In order to explain the various aspects of biodiversity, the Shannon's *H*' and Simpson's 1/D index were calculated. The comparison of those values in each plot over the three years reveals the changes in biodiversity with different index. It is considered in a past study that Satoyama activity has contributed to maintaining the species diversity of ground flora (Nakashizuka and Iida, 1996). The results of Shannon's *H'* index shows that the biodiversity was higher in control plots than in Satoyama management plots from 2011 to 2012, but Satoyama management plots came to have a higher biodiversity index in 2013, as for the woodland sites of plots B and C. It remained higher in the Satoayama management plot in *Pleioblastus chino* community in plot D over the three years. This result can be explained by abundance evenness having increased in 2013, and Satoyama management plots came to have higher biodiversity indicator, even though the species richness did not increase significantly. The Simpson's 1/D index also showed the similar tendency. The abundance evenness was far from equal in all plots, but Satoyama activity plots came to have higher indicators in 2013. These results demonstrate that biodiversity can decrease right after the Satoyama management. For example, thinning can lead to the activity of stepping on the ground flora and pulling the huge fallen tall trees on the forest floor. These activities damage some part of the ground flora and it takes time to recover from the disturbances.

To determine the impacts of light and water conditions on the biodiversity of plants, the habitat environment survey was conducted. It was revealed that light condition is important for the ground flora to sprout and grow (Shirakawa, 2009; Takishita, 2012; Kameyama, 1996; Shigematsu; 1983). The amount of light in the forest is a factor that determines the increase and decrease of the total amount of ground vegetation and coverage (Shigematsu, 1983). The access to water is a crucial factor for plants to sustain their lives. The results showed that Satoyama management plots had a higher percentage of soil water content in plot B in April and in plot C in May.

As for the light condition, a significant change was observed in April and May. In April, the mean canopy openness was larger in Satoyama activity plots than that in control plots in Plots B and D, but a significant change was not observed in plot C. In May, it decreased overall, and Satoyama activity plots had better light condition than the control plots. This explains that even after leaves sprout from April to May, Satoyama management site can maintain the sunlight that can reach the forest floors.

The habitat environmental survey for *Polygonatum involcratum* was conducted in July, 2012 in Kashiwa city to clarify its habitat characteristics. The survey result showed that the total average of the percentage of mean openness in each community site in Oaota forest was 9.7 percent, ranging from 8.7 percent to 11.1 percent. Its average was 8.9 percent, ranging from 6.3 to 12.6 percent in the habitat in the education field, the homestead woodland and the shrine in Kashiwa city on July 13^{th}, 2012. The soil water content in the community habitats was from 13.1 to 16.4 percent in Oaota forest on July 9^{th}, 2012, and 13.8 to 20.7 percent in the habitat in the education field, the homestead woodland and the shrine in Kashiwa city on July 13^{th}, 2012. Shirakawa (2010) surveyed on the habitat environment of the rare species in the natual forest around Lake Konbukuro in Kashiwa city. The rare species were *Hosta albo-marginata (Hook.) Ohwi* in wetland and *Cephalanthera falcata (Thunb.) Blume* in forest (Shirakawa, 2010). The habitat of *Cephalanthera falcata* ranged from 10 to 40 percent in soil water content, and from 15 to 30 percent in canopy openness. The habitat of *Hosta albo-marginata* ranged from 30 to 90 percent in soil water content, and from 20 to 30 percent in canopy openness. Thus, the habitat of *Polygonatum involcratum* was relatively dark and tree-shaded, and lower soil water content around 10 to 20 percent.

The average height ranged from 7 to 29 cm, and most of the individuals had a height around 15 cm. The average number of leaves ranged from 3 to 6. The relationship between the light and height showed that there is a slight tendency that the height increases as mean openness increases. The reliability of this tendency was low with 30 percent of determination coefficient, and the amount of light that the individual takes in changes as time or weather passes in reality.

The *Polygonatum involcratum* community has to survive in the coppice fields where *Pleioblastus chino* dominates. The field observation and transect line study found that *Polygonatum involcratum* community grows along the pathway with various species next to each other. In Oaota forest, there were the pathways that were naturally made by human stepping and the growth of *Pleioblastus chino* was suppressed. For example, in Shrine community Ⅲ where canopy openness was the smallest and dark, *Pleioblastus chino* was not frequently observed. Light condition is one of the main factors of the existing amount of *Pleioblastus chino* (Azuma and Kobayashi, 2003), and that it does not grow highly, which enable other plant species to gain sunlight. Therefore, the *Polygonatum involcratum* can survive in the habitat on a coppice field, which is relatively dark and *Pleioblastus chino* growth is suppressed by pathways and darkness.

More importantly, *Polygonatum involcratum* inhabit in the coppice fields where humans take care and pass, and diverse plant species can inhabit such as closely related plant species of *Polygonatum falcatum* and *Disporum sessile*, and rare species of *Galium kinuta* and *Rubus illecebrosus*. Therefore, there is an interaction between humans' care and vegetation for the conservation of diverse plant species.

5 CONCLUSION

This study conducted a survey on plant species diversity in Oaota forest and rare species, *Polygonatum involcratum* survey in Kashiwa city. As a result of the verification of species diversity after the volunteer Satoyama management, the diversity indices increased in all plots of different vegetation types, broad-leaved deciduous forest, mixed forest, and *Pleioblastus chino* bush. Especially in woodland plots, it increased in the third year after the Satoyama management. The species richness in *Pleioblastus chino* bush where mowing was conducted increased largely since 2011, but the control plots in the area remained the smallest diversity of plants.

The biodiversity, the species diversity of plants in this study, has various scientific approaches. From the aspect of species richness, this survey found that both Satoyama management and non-managed plots had the same change pattern of species richness. What is more, the species richness does not necessarily increase over time after Satoyama management. Its changes corresponded to the one with natural disturbances in control plots.

The reason that only species richness cannot measure the biodiversity was the turnover of species. Analysis showed that the turnover of species was larger in the first period than the second period. What is more, the share of life forms for appeared species showed that more variety of life forms appeared in the first period than in the second period. Especially, perennial plants and deciduous trees appeared and disappeared largely in common in all plots.

In the future, the Oaota forest around the study sites will become the deciduous tree forest which is unique in the secondary coppices in Kanto region (Chibaken shiryou kenkyu zaidan, 1996).

Moreover, Shannon's diversity *H'* index showed that it was lower in the Satoyama management plots than that in non-management plots until the second year after thinning and mowing. This tells that it takes about two years for various species to grow their community habitat evenly in the study plots. The indicator was determined by two factors, the species richness and evenness of relative dominance. And even though the species richness did not increase significantly, the relative dominance increased more in 2013 than in 2011 as shown by the relative dominance curve.

The most rewarding result was that some rare species appeared after Satoyama management. *Cephalanthera falcata* appeared in the Satoyama management plots and disappeared in the unmanaged plots. *Ajuga nipponensis* appeared in the Satoyama management plot after *Pleioblastus chino* was mowed. This proves that the volunteer Satoyama management improved the forest floor environment of rare species habitats.

What is more, Oaota forest is a habitat of the rare species, *Polygonatum involcratum*, which is now difficult to find such large communities in Kashiwa city. Thus, the habitat environmental survey was conducted. The survey found the characteristics of *Polygonatum involcratum* habitat that mean openness range from 8.7 - 11.1 % in Oaota forest, and 6.3 -

12.6 % in other three sites in Kashiwa city. The soil water content ranged from 13.1 - 16.4 % in Oaota forest and 13.8 - 20.7 % in the education field, the homestead woodland, and the Shrine in Kashiwa city. This survey clarified that they inhabit on the coppice fields of relatively dark, tree-shaded area.

The observations showed that the association with other plants is one factor. *Polygonatum involcratum* community grows along the pathways and in the dark tree-shaded coppice fields where the growth of *Pleioblastus chino* is suppressed. More importantly, other rare species also grow around the habitat of *Polygonatum involcratum*. *Polygonatum falcata* and *Disporum sessile*, closely related species of *Polygonatum involcratum*, and *Galium Kinuta* and *Rubus illecebrosus*, rare species, were observed on transect line in *Polygonatum involcratum* community.

Therefore, I believe that volunteer Satoyama management plays an important role in maintaining ground flora species diversity and conservation of rare species. Even though the purpose of Satoyama management has become various in recent suburban isolated coppices, the traditional coppicing techniques in Satoyama have been still inherited. We contribute to the biodiversity and conservation of rare species.

Attachments to local plants move citizens. In the coppice fields where humans take care and passes, diverse plant species including the rare species *Polygonatum involcratum* inhabit. The plants expect to see us in coming next season.

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APPENDICIES

Appendix A　Picture of experimental plots in Oaota forest

1. Deciduous broad-leaved secondary forest

Plot B1 (Thin)

Plot B2 (Control)

2. Mixed secondary forest of deciduous and conifer trees

Plot C1 (Thin and Mow)

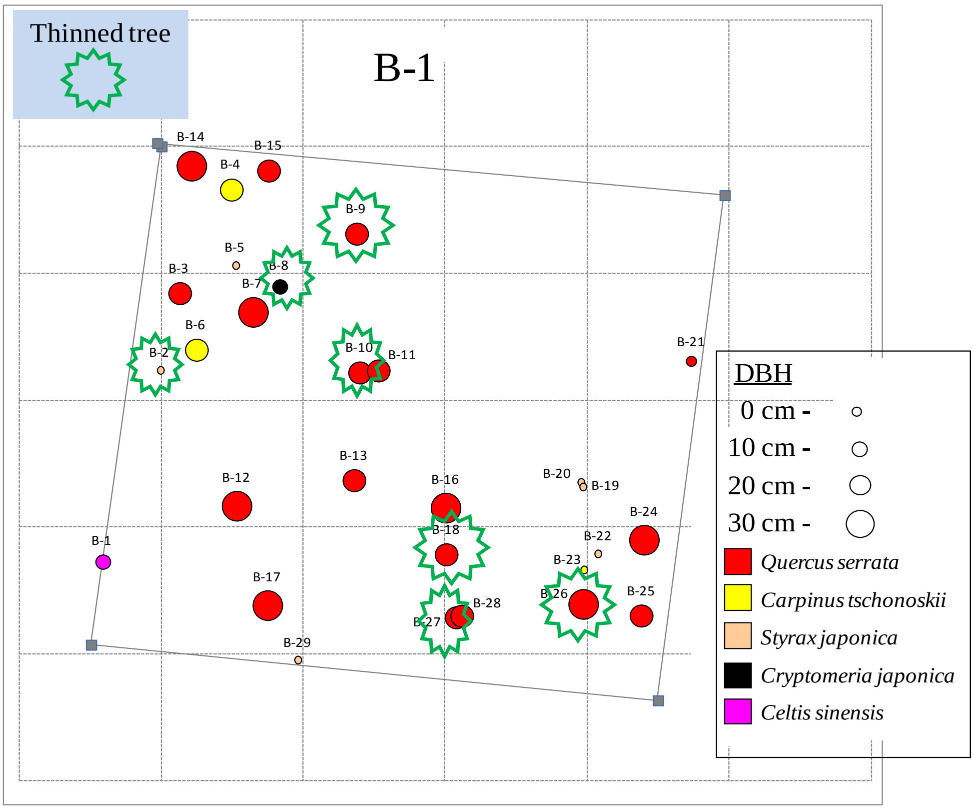
Plot C2 (Control)

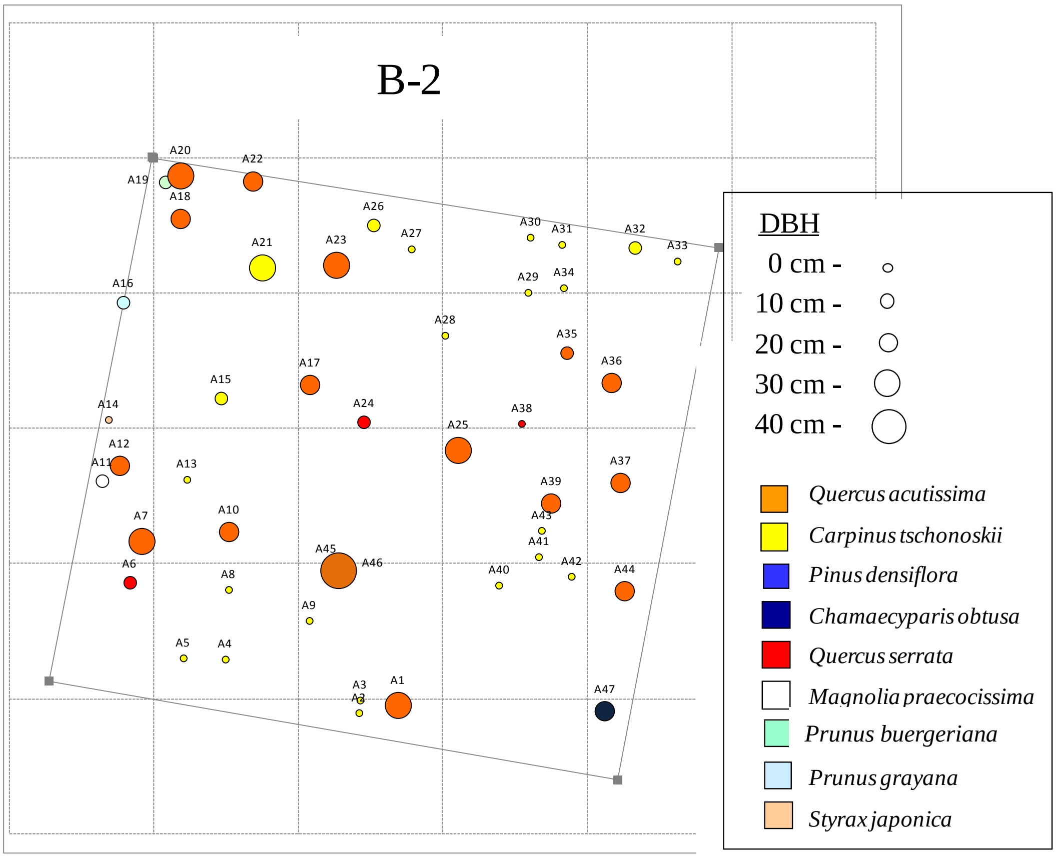
3. *Pleioblastus chino* plain

Plot D1 (Mow)

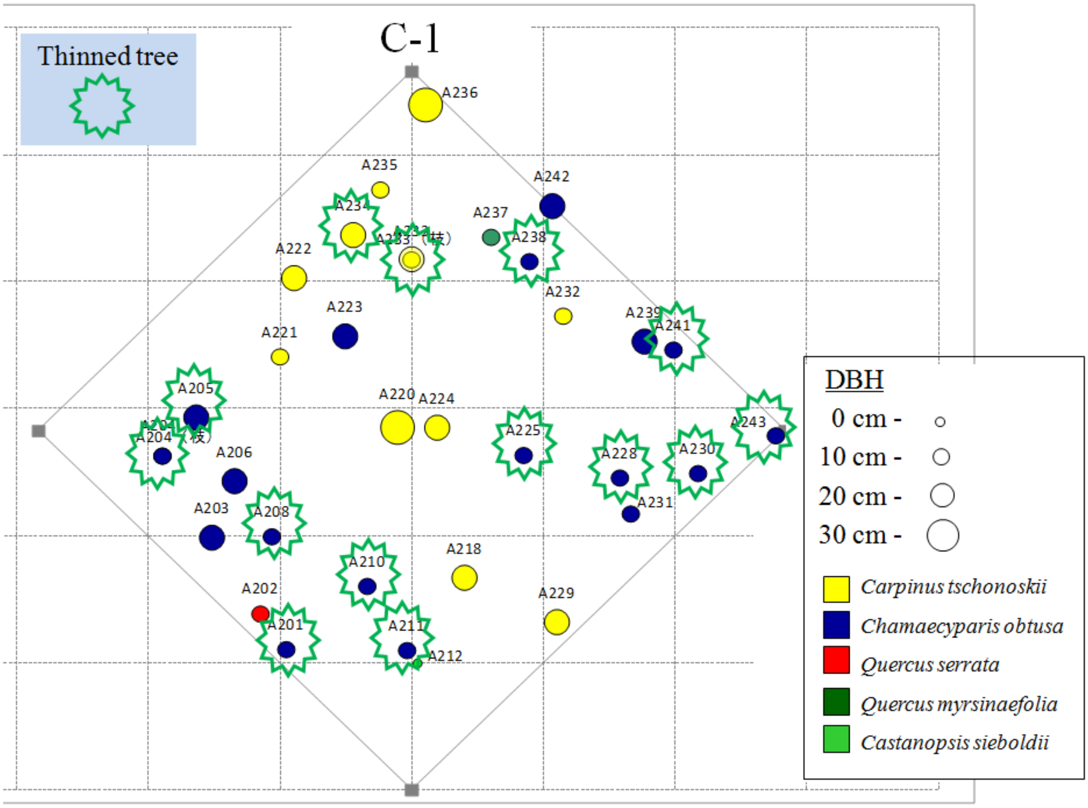
Plot D2 and D3 (Control)

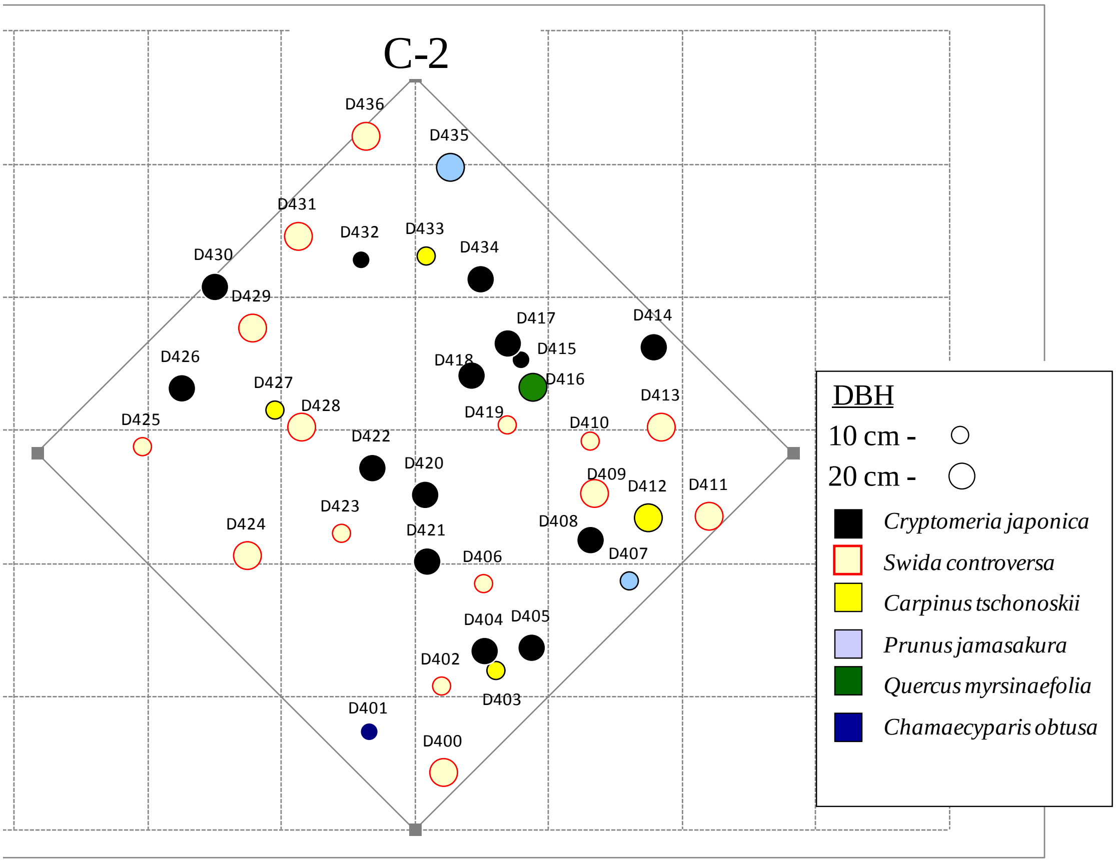
Appendix B   Picture of *Polygonatum involcratum*





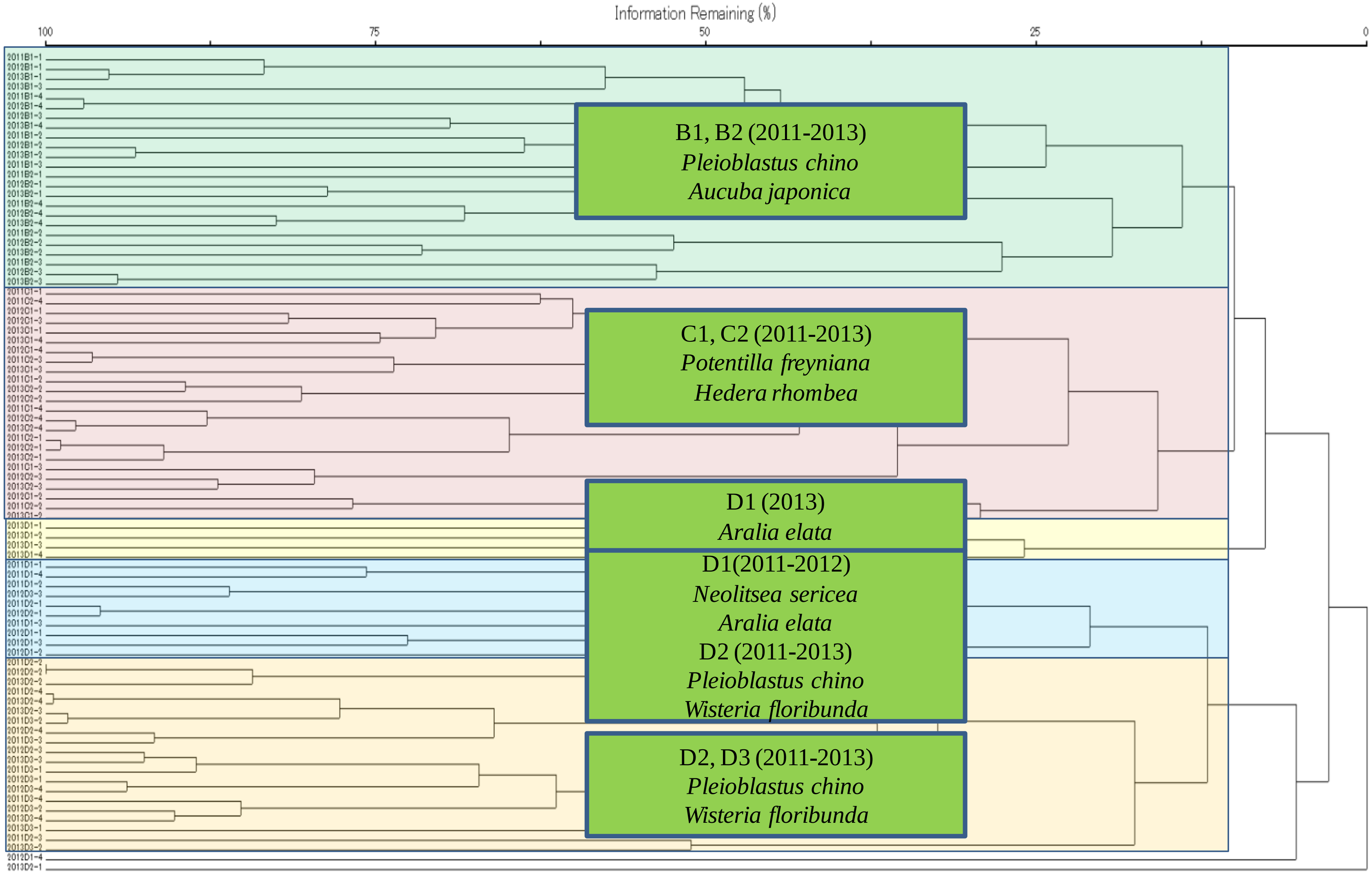
(Shibuya et al., unpubl)





(Shibuya et al., unpubl)

Appendix D Cluster Analysis



Dominant species list for the cluster analysis

Year	Quadrat	Species name	Relative dominance
2011	B1	*Pleioblastus chino*	56.62%
		Aucuba japonica	16.85%
		Lonicera gracilipes	11.76%
	B2	*Pleioblastus chino*	48.21%
		Aucuba japonica	20.92%
		Ligstrum lucidum	12.03%
	C1	*Hedera rhombea*	47.47%
		Pleioblastus chino	19.64%
		Aucuba japonica	10.39%
	C2	*Pleioblastus chino*	54.49%
		Aucuba japonica	9.60%
		Potentilla fragarioides	7.96%
	D1	*Neolitsea sericea*	52.48%
		Wisteria floribunda	31.91%
		Potentilla fragarioides	5.11%
	D2	*Wisteria floribunda*	99.35%
		Pleioblastus chino	0.41%
		Aucuba japonica	0.07%
	D3	*Wisteria floribunda*	94.16%
		Akebia trifoliata	4.81%
		Pleioblastus chino	0.32%
2012	B1	*Pleioblastus chino*	61.86%
		Aucuba japonica	26.94%
		Lonicera gracilipes	5.54%
	B2	*Pleioblastus chino*	66.88%
		Hedera rhombea	5.72%
		Lonicera gracilipes	5.57%
	C1	*Hedera rhombea*	53.83%
		Pleioblastus chino	30.86%
		Ophiopogon japonicus	4.08%
	C2	*Lonicera gracilipes*	0.51%
		Pleioblastus chino	0.27%
		Aucuba japonica	0.20%
	D1	*Pleioblastus chino*	0.03%
		Wisteria floribunda	0.01%
		Hedera rhombea	0.00%
	D2	*Pleioblastus chino*	20.08%
		Akebia trifoliata	20.08%
		Wisteria floribunda	16.20%
	D3	*Wisteria floribunda*	72.72%
		Pleioblastus chino	5.96%
		Parthenocissus tricuspidata	4.84%

Year	Quadrat	Species name	Relative dominance
2013	B1	*Pleioblastus chino*	51.64%
		Aucuba japonica	13.61%
		Neolitsea sericea	4.80%
	B2	*Pleioblastus chino*	56.15%
		Aucuba japonica	13.86%
		Ilex crenata	5.40%
	C1	*Pleioblastus chino*	49.12%
		Potentilla freyniana	35.06%
		Swida controversa	2.87%
	C2	*Potentilla freyniana*	82.01%
		Pleioblastus chino	9.46%
		Viola grypoceras	1.13%
	D1	*Aralia elata*	36.87%
		Sambucus sieboldiana	33.94%
		Ilex rotunda	6.25%
	D2	*Pleioblastus chino*	79.80%
		Wisteria floribunda	19.98%
		Aucuba japonica	0.19%
	D3	*Pleioblastus chino*	99.93%
		Wisteria floribunda	0.02%
		Neolitsea sericea	0.01%