Promotion of Practical Learning about Plantation Management Planning and System Construction III: Stand Management, Fauna and Flora Survey before and after Forest Thinning

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Promotion of Practical Learning about Plantation Management Planning and System Construction Ⅲ – Stand Management, Fauna and Flora Survey before and after Forest Thinning –

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This research surveyed a continuation of "Forest Management Planning" and provided ecological data for forest thinning area establishment of the plantation (Taiwan Forest Bureau, 1995 and 2016). About 30 ha area from the total 241.1 ha of Alishan Forest Working Circle Compartment No. 141 was selected as a coverage of Forest Management Planning to conduct stand survey and record ecological data about fauna and flora before and after forest thinning. It was a state-owned forest owned and provided the Forestry and Nature Conservation Agency (FANCA) in Taiwan. The forest thinning planning area was 3.0 ha sample region. Regression calculation was conducted based on varieties of trees, diameter at breast height (DBH), tree height, timber volume, crown the projection area, and other stand performance parameters from ground survey (gcpa) and air sample region data (acpa). Regression results indicated that a smaller sampling error was a better representative of the sampling population. The estimation of the timber volume of the stand showed a similar trend. Based on the flora sources, there were 2 types of bryophytes. A total of 349 species of vascular plants belonged to 252 genera and 102 families, among which there were 281 natives, 47 naturalized, and 21 cultivated species. According to the fauna survey, at least 18 wild mammal species belonged to 6 orders and 11 families, and at least 7 chiropteran animal species belong to 3 families. Forest thinning positively affected the number of birds and insect species in the forest's canopy layer. Birds foraging in the lower layer of the forest might be attracted to forage in the canopy layer due to an increase in the insect number in the ground layer after the thinning. It increased the birds' variety and the variety of insect changes was due to new habitat types formed after thinning and changes in ethnic structure among species.

Key words: Plantation, Forest Management Plan, Stand Management, Before and After Forest Thinning, Fauna and Flora Survey

INTRODUCTION

Establishing a plantation stand management database can be divided into stand management and fauna and flora surveys before and after forest thinning (ecological area survey). Stand in the stand management refers to woods with similar internal structural features such as origin, tree species composition, forest form, forest age, canopy density, site class or site index, outturn percentage, forest type, and stand condition (Hsiao, 2015). However, they are different from surrounding areas. It is an organic unity of forest phytocoenosium and site conditions and an entity of supervisor and forest management. Fauna and flora surveys include plant growth conditions and biomass before and after forest thinning, animal activities, and population changes (Kalies *et al.*, 2010; Wang, 2013).

When all sampling units in the stand present a random distribution, and system samples are equal to random samples, sampling error can be calculated with a random sampling formula (Yang and Lin, 2008). The sample size of systematic sampling is related to the area of the sample region. Fixed area of sample regions for system line area system design is adopted. The spatially useful stand density information is provided for systematic or alternative thinning design. In boundless sample regions, the probability sampling method may be changed to a rapid sampling method for calculating plantation stand density that can obtain medium accuracy (Van Laar and Akça, 2007). The density of the stand can be estimated with the sampling method by the horizontal sample point of DBH measured by horizontal angle goniometer, and an error value can be compared with the fixed area sampling method (Huseh *et al.*, 2002). A systematic sampling method is a basic double-sampling method that is commonly used to investigate forest resources. It can describe different patterns of land utilization and conditions of spatial distribution, and is generally used for forest vegetation, timber volume, and soil investigation. A simple, laminated, or double–sampling statistical analysis can be carried out based on samples (Goodbody *et al.*, 2019)

With increasing concerns about ecological system management and biodiversity conservation, the biodiver-

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sity concept is integrated into traditional management targets focused on timber production. Therefore, much of the research trends emphasize the influence of human intervention, such as forest thinning, on the composition and diversity of wild animals (Tsai *et al*., 2010; Wang, 2013). Flora survey mainly classifies land utilization and afforestation species in compartments. The major land utilization types are classified with QGIS software and high–resolution satellite images. The overview of land utilization is presented based on the land utilization classification system regulations announced by the National Land Surveying and Mapping Center, Ministry of the Interior, combining field annotation (The Red List of Vascular Plants of Taiwan–Editorial Committee, 2017). Fauna (e. g. wild animals) survey and monitoring technology refer to participating in surveys and familiarizing various investigation and monitoring technologies. The thinning for tending causes microenvironment change in the upper layer. Regarding the management and assessment of a complete forest ecological system, the environment most beneficial to forest growth and habitation of wild animals is going to be considered as the final vision of maintaining biodiversity (Pei and Chiang, 2004; Wang, 2013).

This study focused stand management, survey, and scientifically obtained other information of ecological areas by plantation management and system's strengthened professional establishment. Teaching connotation tried to be further innovated, and the foundation of practical education in forest management was able to be enhanced. The forest management planning survey established ecological data about thinning areas. The thinning planning area was in the management area of the same forest. The ground survey needed to cover varieties of trees of the stand, DBH, tree height, and timber volume. Accuracy of sampling inspection affected the volume estimation results of the stand. Fauna and flora surveys showed that variety change was associated with new types of habitats formed after thinning and a change of ethnic structure between species. This survey contained the resource census and a comparison of biodiversity before and after thinning, involving mammals, birds, amphibians, reptiles, insects and so on.

MATERIALS AND METHODS

Stand Management

The experimental site was the *Cryptomeria japonica* plantation, afforested in 1947. It was a sample region of 30 ha forest management area of Alishan Forest Working Circle Compartment No. 141 (Chan *et al*., 2023). The orthoimage was captured with an unmanned aerial vehicle (UAV) (SUPPORT FOR PHANTOM 4 PRO). The GPS accuracy was enhanced by using Pix4Dmapper photogrammetry software to combine three–dimensional point clouds and orthoimage (Goodbody *et al*., 2019). The survey grid sample regions for the thinning planning area of the *Cryptomeria japonica* plantation are drawn. The air crown projection area (acpa) was calculated using ArcGIS (Chianucci *et al*., 2016). The thinning planning area was in 3.0 ha sample region in the management area of the same forest (Chan *et al*., 2023). Regression calculation and verification were conducted based on tree variety, diameter at breast height (DBH), tree height, timber volume, the ground crown projection area (gcpa), and other stand performance parameters from ground survey, and air sample region data.

Stage 1 – UAV aerial orthoimage and setting of grid sample region.

1. Operation procedure of UAV aerial photography and orthoimage processing

UAV was used for measurement in this part of the method. Based on the mapping range of the forest management area, the flight height was planned at about 70 m, and the overlapping rate of adjacent images within an air route was 80%. The shooting time was set at 10:00 am – 11:00 am and 1:00 pm – 2:00 pm to get a clear, complete, and consistent orthoimage. For the convenience of successive analysis and application of users, the three–dimensional matching between photographic image and multiband intersection and the accuracy of GPS points was enhanced by combining a three–dimensional point cloud and an original photographic image.

2. Setting grid sample region for orthoimage map

The blue frame range in Fig. 1 was the forest management planning area (forest compartment boundary), which was about 30 ha. The purple frame range was this thinning planning area. The black frame range was the grid sample region. There were about 600 grids, each of which was 20×25 m. The grid direction of the sample region was planned from the northeast (45°) to southwest (225°) based on topography, slope, and hydrology. These grids were numbered in order. 20–grid sample regions were sampled from the blue frame range, and 40–grid sample regions from the purple frame range, i.e., a total of 60–grid sample regions with a sampling rate of 6%. ArcGIS analysis software was used to calculate acpa based on the aerial photos.

Stage 2– Air crown breadth, ground survey, and numbering of sample region of thinning planning area.

The thinning planning area was about 3.0 ha having about 64 grids. A total of 16–grid sample regions were randomly sampled for ground survey for the purple frame range of stage 1, having a sampling rate of 25%. Trees of the thinning planning area were mostly *Cryptomeria japonica*. The DBH, tree height (Th), and other forest stand characteristics and parameters from the ground sample area (Yang and Lin, 2008). The formula (1) was as shown below:

$$\log V = -4.193148 + 0.933828 \log (DBH^2 \times Th) \quad (1)$$

where logV is the logarithm of volume; DBH is the diameter at breast height, and Th is the tree height.

Estimation of stand volume

The volume of the whole stand was estimated by setting 600–grid (20×25 m per grid) sample regions in the aerial photo of 30 ha forest compartment boundary.

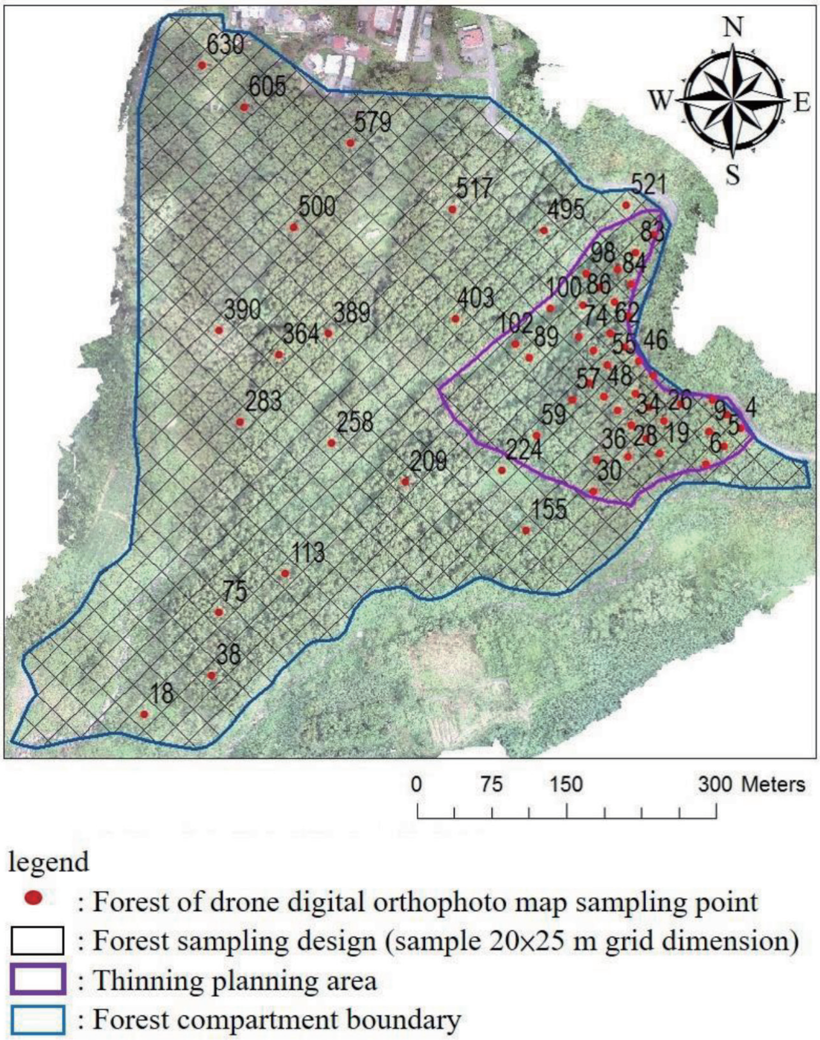

Fig. 1. Sampling on photogrammetry with plot number.

The acpa was measured and calculated by randomly sampling 60–grid sample regions. The timber volume was obtained by substituting the above acap in the final volume formula, and the volume of the whole stand was estimated.

Flora Survey

Flora Resource Census

Flora survey was conducted in the compartments within walking distance of the forest (Fig. 2 above). The species of vascular plants were listed/categorized based on land utilization. For identification and endemism of flora species, refer to the second edition of Flora of Taiwan and Formosan Trees (2017). For the threatened species categories, refer to the 2017 Bibliography of National Red Lists for Vascular Plants evaluation standard. Independent surveys were conducted in October 2019, March 2020, August 2020, and November 2020.

Biodiversity Comparison before and after Thinning of Cryptomeria japonica Stand

Eight 10×10 m quadrats were set in the thinning area and its sample number was marked in the southwest corner. The size of xylophyta with DBH ≧ 1 cm was measured. A Braun Blanquet stratified quadrat survey was conducted on/for the remaining plants. This survey covered the dominance hierarchy of all higher plants, other herbaceous plants, and ferns in quadrats. Monitoring was carried out once every half year after thinning to learn about the influence of thinning on variety, composition, and successive updating of plants in quadrats. The method was as follows:

1. Dominance analysis

Xylophyta with DBH ≧ 1 cm: three kinds of dominance analysis were used to analyze trees with large diameters featuring a low number in the forest but a large basal area. (1) Number of trees: it can be indicated with the number of trees directly because the size of the eight sample regions is the same, and the number of trees is less; (2) Basal area: it stands for the dominance of plants in the forest. Measured diameter was converted into area. For trees with branches below 1.3 m, the diameters of all branches was able to be converted into areas, and then these areas were added up as the base area of the same tree.

2. Herbaceous plants, ferns, and seedlings with DBH less than 1 cm

Seedlings were only assessed by dominance and

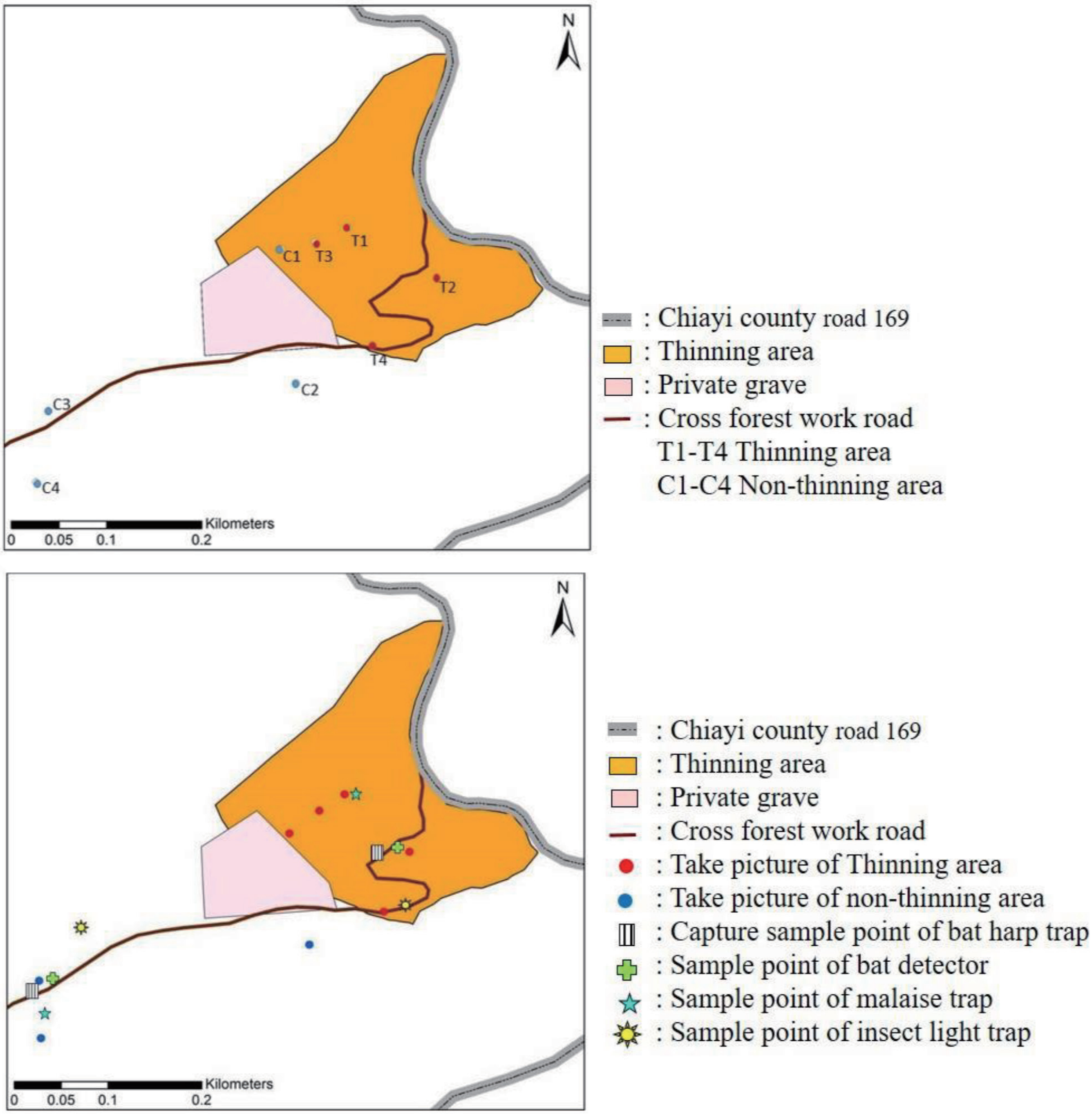

Fig. 2. Plot position of fauna (below) and flora (above) in thinning area.

then classified based on Braun Blanquet survey methods. There are six grades, +: < 1%; 1: 1–5%; 2: 6–25%; 3: 26–50%; 4: 51–75%; 5: 76–100%.

3. Biodiversity index analysis

The number of species were surveyed, and Shannon's and Simpson's diversity indexes and Chao1 index were used to analyze the number of species in every quadrat. All biodiversity index analysis was calculated by adopting PAST3.25 version shared software, including the Number of species (S): Directly list the number of species that appeared in all quadrats. Simpson's diversity index (1–D): it is between 0–1. A higher 1–D value indicates a higher the Simpson's diversity. In it D is the dominance, ni is the number of all species or relative dominance, and n is the total number of plants or total dominance. Shannon's diversity index (H): is a diversity index obtained based on comprehensive consideration of several individual species and many species. Ⅳ. Chao1: is an index used to estimate the total number of species in ecology. The higher the Chao1 value, the more the total number of species.

4. Principal component analysis

Principal component analysis (PCA) reduced data dimension. The problem of collinearity can be avoided using PCA. However, the most prominent characteristic of data can be retained.

Fauna survey

Survey Time and Place

Sample survey points were separately selected in the thinning area and adjacent non–thinning area to survey mammals, birds, amphibians, reptiles, and insects from October 2019 to November 2020. The sample region map and sample survey points of all classes were shown in Fig. 2 (below). Thinning was conducted in the thinning area from May to July 2020.

Survey Methods

1. Mammals

Survey methods included the transect, infrared camera automatic shooting, net trapping, and bat ultrasonic detector methods (Tsai *et al.*, 2010). These were described as follows:

(1) Transect method: taking an existing forest road as the transect, investigators record individuals, footprints, egestion, corpses, digging traces, nests and dens, animal sounds, and other activity signs of animals witnessed along the transect. These recordings were taken at least twice during the day and twice during the night in every season.

(2) Infrared camera automatic shooting method: set five sampling points of an automatic infrared camera in the thinning area and three sampling points of an automatic infrared camera in the non–thinning area to survey animals that move on the ground. A camera for every sampling point was fixed to a tree trunk at a height of about 60 cm with a lens facing downward and a shooting angle of about 30–45°. The appearance frequency (OI) of species was analyzed according to shooting data from automatic cameras to compare changes in the relative abundance of mammals before and after thinning. The OI value was calculated based on the formula of Pei and Chiang (2004): OI = (number of valid photos of a species at a sampling point/total working hours at this sampling point) ×1000 h

(3) Net trapping method: separately select 1 sampling point for chiropterans in the thinning and non–thinning areas and set a harp net to trap them. Trapping time was from 1 h before sunset to sunrise of the next day. Trap was for 1 to 2 nights at each sampling point every season.

(4) Bat ultrasonic detector method: insectivorous bats mainly located and assisted foraging with ultrasonic waves and identified species by analyzing ultrasonic frequency and structure. Set a set of Anabat SD2 bat ultrasonic detectors in the thinning and non–thinning areas, respectively to record the ultrasonic wave of bats. The recording time from 1.0 h before sunset to sunrise of the next day was set. Record was for 1–2 nights at each sampling point every season. Compare the relative abundance of all species based on number of recorded sounds.

2. Birds

The automatic camera and the fixed–point survey methods (Kalies *et al*., 2010; Wang, 2013) were used to survey birds. The sampling points of the fixed point survey were the same as the automatic infrared camera survey. Five sampling points were in the thinning area, and 3 sampling points were in the non–thinning area. The survey frequency was twice at each sampling point every season at least. Survey was completed within 4 hours after sunrise, retaining 6 min for each sampling point. Recording content included the type of birds observed and the number of bird sounds heard around sampling points. A mobile phone was used to record sound to assist in discriminating species. The data analysis and Shannon–Wiener diversity index analysis were used to compare changes in the thinning and non–thinning areas before and after thinning. The Shannon–Wiener diversity index (*H*') formula (2) was as follows:

$$H' = -\sum_{i=1}^{s}(pi * \ln pi) \quad \text{.......} \quad (2)$$

S is the total the number of species, pi is the proportion of ith species to total number of (number of ith species/Total number of species); When only one species exists in this community, *H*' reaches its minimum value 0

3. Amphibians and reptiles

Taking the forest road as a transect and conducted at least twice a night survey every season. Advance slowly along the transect and record amphibians and reptiles that were observed or sounds that were heard. Compare changes in the thinning and non–thinning areas before and after thinning based on the average number of surveys every time and the Shannon–Wiener diversity index (Kalies *et al*., 2010; Tsai *et al*., 2010). Shannon–Wiener diversity index (*H*') formula (2) was the same as the above.

4. Insects

Separately set a malaise trap sampling point in the thinning and non-thinning areas to trap insects. If sunny, sweeping nets, rotten fruit traps, and night lights were adopted along the transect to trap insects. Insect species were only identified by the "Order hierarchy". The Shannon–Wiener diversity index was analyzed to compare changes in the thinning and non–thinning areas before and after thinning. The Shannon–Wiener diversity index (*H*') formula (2) was the same as the above.

RESULTS AND DISCUSSION

Stand management

Air crown breadth, ground survey, and sample region of thinning planning area

The thinning planning area was about 3.0 ha and there were about 64 grids in total. A total of 16–grid sample regions were randomly sampled for the ground survey (Chan *et. al*., 2023), based on the sampling points in the purple frame range of stage 1 with a sampling rate of 25%. Parameters such as diameter at DBH, tree height, timber volume, and other condition parameters of the stand were randomly surveyed in the ground sampling area. Tree varieties, diameter at DBH, tree height, timber volume, and gcpa of thinning ground sample region within a 16–grid sample region were surveyed. According to statistics, the total number of trees in a 16–grid sample region was 274 trees, with an average DBH, tree height, and timber volume of 40.26±9.04, 21.98 ±3.30 m, 1.26±0.59 m^3, respectively.

Establishment of timber volume formula

To establish the timber volume formula, the relation between gcpa and acpa of the 16–grid ground sample region needed to be verified. According to the ground survey, forest species in No. 5 sample region were all *Cunninghamia lanceolata*. Considering that it affected the follow–up establishment of timber volume for *Cryptomeria japonica*, this sample region was removed. The data on gcpa and acpa obtained from the ground survey of a 15–grid sample region were compared. The estimation formula of acpa and timber vol-

Table 1. Pearson correlation coefficient matrix

Item	acpa[1)]	gcpa	Volume
acpa	1	–	–
gcpa	0.84 (t= 5.616; df=13; p–value= 0.0000839)	1	–
Volume	0.90 (t= 7.470; df=13; p–value= 0.0000047)	0.94 (t= 10.243; df=13; p–value= 0.000000136)	1

[1)] acap: aerial crown area of photogrammetry; gcpa: ground crown projection area

Table 2. Established regression mode l (y=volume, x=gcpa) by ground plot data

	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	–9.432766	2.996609	–3.148	0.0077 **
gcpa [1)]	0.083405	0.008143	10.243	0.000000136 ***

[1)] See Table 1
Signif. code): 0 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' '
Residual standard error: 2.056 on 13 degrees of freedom
Multiple R–squared: 0.8898, Adjusted R–squared: 0.8813
F–statistic: 104.9 on 1 and 13 DF, p–value: 0.0000001361
y (volume) = –9.4 + 0.0834 gcpa

Table 3. Established regression model (y=volume, x= crown area of photogrammetry) statistic summary

Item	Estimate	Std. Error	t value	Pr (>|t|)
Intercept	–9.93182	4.16898	–2.382	0.0332 *
acpa [1)]	0.09536	0.01276	7.470	0.0000047 ***

[1)] See Table 1
Signif. Codes: 0 '***', 0.001 '**', 0.01 '*', 0.05 '.', 0.1 ' '
Residual standard error: 2.691 on 13 degrees of freedom
Multiple R–squared: 0.8111, Adjusted R–squared: 0.7965
F–statistic: 55.8 on 1 and 13 DF, p–value: 0.000004695
y (volume)= –9.931 + 0.09536 acpa

ume and pertinence of the three formulas were established with a verification formula, as shown in Table 1.

(1) Ground timber volume formula: Sample from the ground data of 15–grid tally sample region, and ground timber volume formula (3) with the ground survey's crown area and ground timber volume is shown in Table 2.
Ground timber volume (V, m^3)
=140.56+10.668×gcpa (m^2)..............................(3)

(2) Aerial timber volume formula: Sample from aerial data of 15–grid sample region, and establish aerial timber volume formula (4) with crown area of aerial photo survey, as shown in Table 3.
Aerial timber volume (V, m^3)
=0.09536×(acpa, m^2)–9.93182..........................(4)

(3) Establish final timber volume formula: There is a significant relationship between timber volume and linear relation intercept of acpa (Pr>|t|=0.0332). Calculating the timber volume of the ground sample region via Eq. (5) after calculating acpa and then calculating the confidence interval and error rate is planned.
Final timber volume formula (V, m^3)
=(0.09536×(acpa, m^2)–9.93182).......................(5)

(4) Calculating confidence interval and error rate of sample region timber volume
n: Number of aerial sample regions, n = 40
m: Number of ground sample regions, m = 15
$\bar{Y}_m$: Estimated mean of Y of ground 15–grid sample region, $\bar{Y}_m$= 20.78 m^3
$\bar{X}_n$: Estimated mean of auxiliary variable X of aerial 40–grid sample region, $\bar{X}_n$=316.08 m^2
$\bar{X}_m$: Estimated mean of X of ground 15–grid sample region, $\bar{X}_m$= 322.04 m^2

a. Confidence interval of thinning area

Estimated value of major variable regression $\bar{Y}_{reg}$

$$=\bar{Y}_m+b(\bar{X}_n-\bar{X}_m)$$
$$=20.78+0.09536\ (316.08–322.04)$$
$$=20.21$$

Estimated value of variance $s^2_{\bar{Y}reg}$

$$=7.24\left[\frac{1}{15}+\frac{(316.08–322.04)^2}{44442.77}\right]+\frac{33.22–7.4}{40}-\frac{33.22}{60}$$
$$=2.34$$
$$s_{\bar{Y}reg}=1.53$$

Degree of freedom 15 – 2 = 13 and α=0.05, t =1.77.
95% confidence interval of average timber volume of sample region: 20.21±2.70 m^3

The estimated value of all forest timber volume of thinning area and confidence interval: 1212.51±162.44 m^3

b. Sampling error rate

Sampling error rate is an index to measure the accuracy of a sample survey. A smaller sampling error rate indicates a more accurate and reliable result.

$$\text{Sampling error rate (E)} = \frac{t \times s_{\bar{Y}reg}}{\bar{Y}reg} = \frac{2.70}{20.21} \times 100$$
$$=13.40\%$$

Estimation of stand timber volume

The volume of the whole stand was estimated by setting 600–grid (20×25 m per grid) sample regions in the aerial photo of 30 ha forest management area. The acpa was measured and calculated by sampling 60–grid sample regions by random sampling, the timber volume was obtained by substituting the above acpa in the final volume formula (5), and the volume of the whole stand was estimated.

a. Confidence interval of timber volume of the whole stand in the forest management area

n: Number of aerial sample regions, n = 60

m: Number of ground sample regions, m = 15

$\bar{Y}_m$: Estimated mean of Y of ground 15–grid sample region, $\bar{Y}_m$= 20.78 m^3

$\bar{X}_n$: Estimated mean of auxiliary variable X of aerial 60–grid sample region, $\bar{X}_n$=293.49 m^2

$\bar{X}_m$: Estimated mean of X of ground 15–grid sample region, $\bar{X}_m$= 322.04 m^2

Estimated value of major variable regression

$$\bar{Y}_{reg} = \bar{Y}_m + b(\bar{X}_n - \bar{X}_m)$$
$$=20.78+0.09536\ (293.49\text{-}322.04)=18.05$$

Estimated value of variance $s^2_{\bar{Y}reg}$

$$=7.24\left[\frac{1}{15}+\frac{(293.49–322.04)^2}{44442.77}\right]+\frac{35.59–7.24}{60}-\frac{35.59}{600}$$
$$=3.44$$

$s_{\bar{Y}reg}$ =1.85

Degree of freedom 15 – 2 = 13 and α=0.05, t =1.77.

95% confidence interval of average timber volume of sample region: 18.05±3.28 m^3

Estimated timber volume of the whole stand in thinning area and confidence interval: 10832.18±1970.43 m^3

b. Sampling error rate

Sampling error rate is an index to measure the accuracy of a sample survey. The smaller the sampling error rate, the more representative the sampling population is to the universal set population.

$$\text{Sampling error rate (E)} = \frac{t \times s_{\bar{Y}reg}}{\bar{Y}reg} = \frac{3.28}{18.05} \times 100$$
$$=18.19\%$$

Flora Resource Survey

Flora resources in the sample region

This survey project contains a composition of surveyed floras in sample regions and types of floras collected and recorded during the survey along the practicable route in compartments. Two species of bryophytes were found. These were *Dumortiera hirsute* and *Rhodobryum giganteum*. A total of 349 species of vascular floras belong to 102 families and 252 genera were surveyed, including two club mosses, 72 species of ferns, 9 species of gymnosperms, and 266 species of angiosperms. Among these vascular floras, 281 were native, 47 were naturalized, and 21 were cultivated species.

Among all species, club mosses surveyed were only *Selaginella delicatula* and *S. doederleini* of *selaginellaceae*, the rarity class of which was the Least Concern (LC) class. A total of 72 species of ferns belonging to 20 families were surveyed, all of which are initial species of Taiwan. Among them, 4 species were special species of Taiwan: *Diplazium pseudodoederleinii*, *Microlepia trichocarpa*, *Lepisorus monilisorus*, and *Pteris aspericaulis*. Regarding categories of threatened species, only *Antrophyum henryi* was Vulnerable (VU) class. *Microlepia trichocarpa*, a special species of Taiwan, is Near Threatened (NT) class. All other 70 species are all LC class.

A total of 9 species of gymnosperms belonging to five families and eight genera were surveyed. Many of them were afforestation species in this compartment. Although only seven initial species and two cultivated species were listed in the Bibliography, almost all species in this compartment are afforestation species, except *Pinus taiwanensis* and *P. morrisonicola*. These species was to be initial species that grow out by themselves. The *Podocarpus costalis* was Critically Endangered (CR) class, *Taiwania cryptomerioides* was Endangered (EN) class, *Cephalotaxus wilsoniana*, *Calocedrus macrolepis* and *Cunninghamia lanceolata* were VU class and were listed in the Bibliography. All of them were not initial species, and it was not necessary to conduct conservation of them.

A total of 266 species of angiosperms belonging to 75 families were surveyed, of which 200 species were initial species, 47 were naturalized species, and 21 were cultivated species. Among these initial species, 51 species were special species of Taiwan, including ligneous floras such as *Acer albopurpurascens*, *A. serrulatum*, *Sloanea formosana* and *Rhododendron rubropilosum*, *Rhynchoglossum obliquum*, *Paraphlomis tomentosocapitata*, *Aspidistra elatior*, *Pachycentria formosana*, and *Ardisia cornudentata*. Regarding categories of threatened species, a species of angiosperms was critically endangered. It was called *Phalaenopsis aphrodite*. Three species are VU species: *Livistona chinensis*, *Aristolochia cucurbitifolia*, and *Begonia lukuana*. Two species were NT species: *Cinnamomum osmophloeum* and *Taeniophyllum glandulosum*. The threatened degree of the remaining 193 species was not discriminated.

Sample Region Survey

This experimental site was surveyed by setting 8 sample regions (10×10 m per sample region). Sample regions in the thinning area were named T1, T2, T3, and T4. The non–thinning sample regions were named C1, C2, C3, and C4. The position of sample regions is shown in Fig. 2 (above). To obtain a sample region with *Cryptomeria japonica* being upper layer tree species, C3 and C4 sample regions were distributed at relatively far places, while the C1 sample region was near the junction of the thinning and non–thinning areas.

In data from previous sample region surveys, there was a significant difference in the number of species in different sample regions. There were 1–10 different species at the preliminary stage of the survey. Except for the T3 clear–cutting sample region, there was only a little difference in the number of species among most sample regions with or without felling. In the entire survey, the T2 sample region had much more varieties of trees, which was about 10–12 species. It includes *Itea parviflora*, *Morus australi*, *Schefflera octophylla*, *Callicarpa formosana*, and *Litsea akoensis* (The Red List of Vascular Plants of Taiwan–Editorial Committee, 2017). Other sample regions had 2–5 varieties of trees. The number of species in the T1 region was the least, and no other tree species with DBH ≧ 1 cm existed except for *Cryptomeria japonica*. These results were related to its growing environment, which made multiple initial species spread seeds and grow.

In summary of survey data about trees with DBH ≧ 1 cm of 8 sample regions, 23 species of floras were surveyed. The floras such as *Schefflera octophylla* and *Machilus japonica* were relatively stable. Based on the basal area data, *Castanopsis kusanoi* had a DBH of 92.6 cm in the T4 sample region. Though its DBH was high/significant/ample, there was a wide range of splitting on its basal trunk, which appeared hollow. Other floras were mostly trees with small diameters.

In previous surveys of ground cover composition, as shown in Fig. 3, the number of ground covers in previous surveys of most sample regions was increasing, especially species in thinning areas. This was probably because of human intervention before thinning and sunshine to the ground after thinning. Thus, many heliads grow rapidly after the invasion, increasing the number of species in all sample regions. However, the biodiversity does not necessarily rise (Fig. 3 below).

The previous ground cover surveys in sample regions indicate that *Elatostema lineolatum* and *Monachosorum henryi* were the most important species of ground cover composition in this area, and only the C3 sample region was featured with *Elatostema lineolatum* and *Strobilanthes flexicaulis* as major dominant species. The dominance of other ground covered of partial sample regions only reaches grade 2 (6%–25%) because the ground was not fully covered with ground covers. There was a difference in flora composition due to the climate influence. For example, the original major composition of C2, C3, and T2 sample regions was

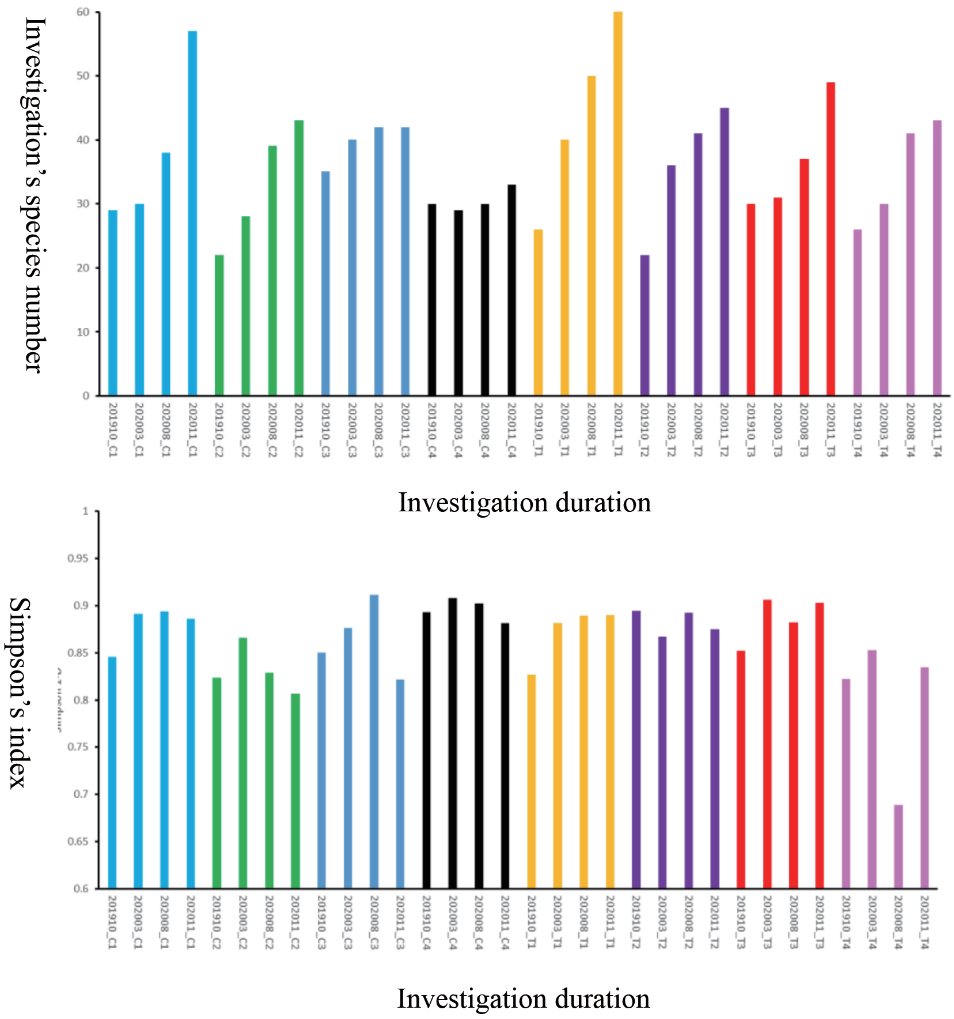

Fig. 3. Investigation's species number (above) and simpson's index (below) of understory vegetation in 3.0 ha thinning area for 2019–2020 per month's monitoring.

Elatostema lineolatum, and only the C2 sample region changes slightly (Fig. 4) in the March of the following year.

However, the dominance of C3 and T2 sample regions decreased with a significant change in their composition (Table 4), there was much obvious difference in points of the two sample regions on the PCA axis. Change of dominance was probably a composition change due to seasons or human intervention, like weeding upon tomb sweeping and soil preparation.

Fauna survey

Mammals

By transect method, six surveys were conducted respectively in daylight and at night before and after thinning. Only 28 *Petaurista philippensis grandis* and *Petaurista alborufus lenas* were surveyed and recorded along a transect survey at night. There were no individuals or signs of mammals in the daylight.

By infrared camera automatic shooting method, thinning was conducted in the thinning area from May 2020 to July 2020. The cameras were set in the thinning area and were removed temporarily during this period. For October 2019 to October 2010, the total working hours of automatic cameras was 34,642.2 h in the thinning area (22,449.1 h before thinning and 12193.1 h after thinning) and 22,242.8 h in the non–thinning area. Four wild animal species were recorded in the thinning area before thinning. Seven wild animal species were recorded in the non–thinning area. *Urva urva* and *Melogale moschata* had a higher relative abundance (OI value), but the OI value of mammals in sample regions

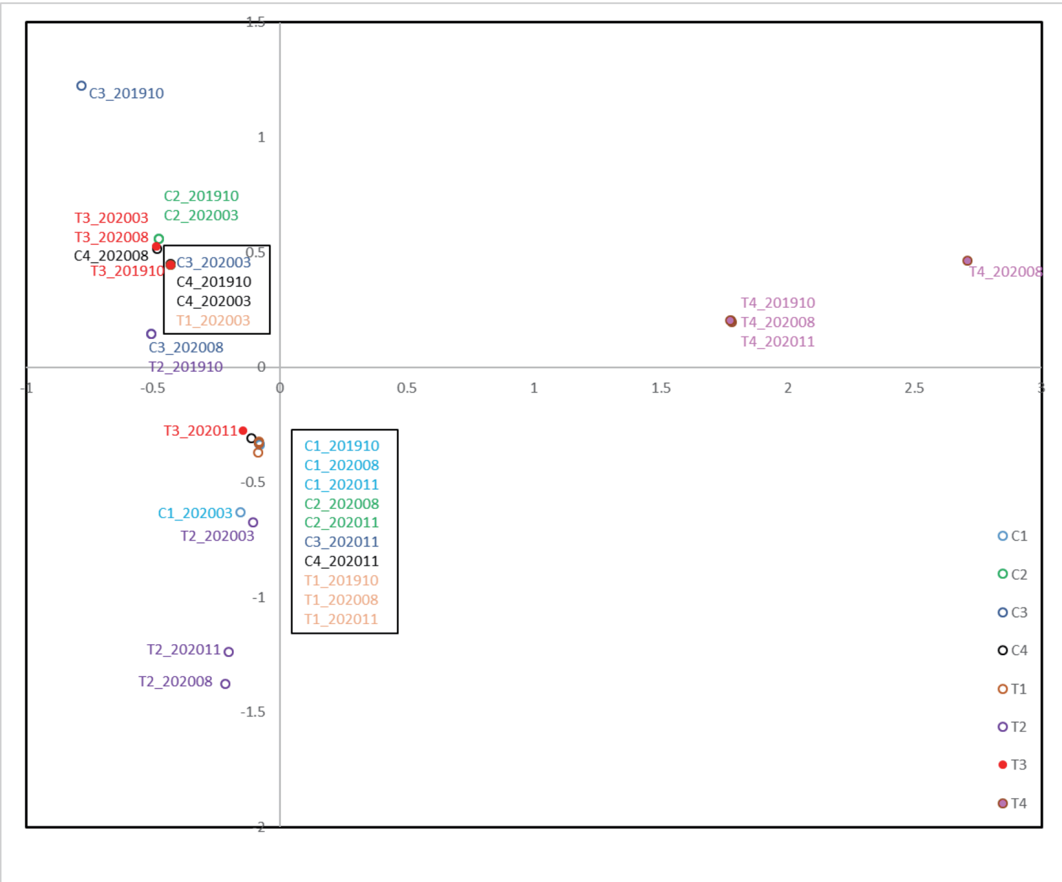

Fig. 4. Alishan working circle 141 compartment of understory vegetation's Principal Component Analysis (PCA).

Table 4. Alishan working circle 141 compartment of understory vegetation species richness (Taxa S) and vegetation diversity

Date	October 2019								March 2020								August 2020								November 2020							
Sample area	C1	C2	C3	C4	T1	T2	T3	T4	C1	C2	C3	C4	T1	T2	T3	T4	C1	C2	C3	C4	T1	T2	T3	T4	C1	C2	C3	C4	T1	T2	T3	T4
Taxa S	29	22	35	30	26	22	30	26	30	28	40	29	40	36	31	30	38	39	42	30	50	41	37	41	57	43	42	33	61	45	49	43
Simpso 1-D	0.85	0.82	0.85	0.89	0.83	0.89	0.85	0.82	0.89	0.87	0.88	0.91	0.88	0.87	0.91	0.85	0.89	0.83	0.91	0.90	0.89	0.89	0.88	0.69	0.89	0.81	0.82	0.88	0.89	0.87	0.90	0.83
Shan-non H	2.05	1.98	2.11	2.38	1.91	2.49	2.07	1.91	2.34	2.23	2.30	2.54	2.29	2.23	2.46	2.09	2.39	2.06	2.61	2.44	2.39	2.43	2.29	1.49	2.39	1.97	1.99	2.27	2.43	2.27	2.49	2.04
Chao1	34.0	29.5	40.0	35.3	31.0	33.3	37.5	26.8	35.3	35.0	50.5	56.5	43.8	46.5	53.5	33.3	47.3	46.5	69.5	42.0	64.0	59.0	44.0	41.0	64.0	48.0	52.0	40.0	89.0	55.5	53.2	48.0

Notes: Dark color: Clear felling; light color: thinning region; white color: non–thinning region was not high. Both of them was not shot again in the thinning area after thinning. The OI value of the thinning area after thinning had a decreasing trend (upper part of Fig. 5 right). The number of species also decreases after thinning (Fig. 5 left).

By net trap, a harp net was adopted to trap animals for 7 nights before thinning and 6 nights after thinning. One *Murina recondita* was trapped in thinning area before thinning, and 1 *Miniopterus fuliginosus* was trapped in the non–thinning area before thinning. One *Murina recondita* was trapped in thinning area after thinning, and seven *Miniopterus fuliginosus* and two *Murina recondita* were trapped in the non–thinning area after thinning. Two types, totaling 12 bats, were trapped.

By bat ultrasonic detector, a bat ultrasonic detector was used to record sounds for 6 nights in the thinning and non-thinning areas. Before thinning, six types, totaling 183 pieces, of valid audio were recorded in the thinning area, and 4 types of 159 pieces of valid audio were recorded in the non–thinning area. After thinning, five types of 373 pieces of valid audio were recorded in the thinning area, and four types of 344 pieces of valid audio were recorded in the non–thinning area. The number of *myotises* in July and the number of *murinas* in September increased. It could be because season change affects the activities of bats.

By mammals, at least 18 species of animals belonging to six orders and 11 families were surveyed. They included two species of *artiodactyla* belonging to two families, three species of carnivore belonging to three families, one species of *pholidota* belonging to one family, one species of primates belonging to one family, four species of *rodentia* belonging to one family (*muroid* surveyed by the automatic camera includes *muridae* of *rodentia* and *soricomorpha*), and at least seven species of *chiroptera* belonging to three families (*Myotis*, *murina*, and *pipistrellus* cannot be discriminated to species, only *Murina recondita* were identified as trapped species). In addition, domestic cats and dogs were recorded. Among wild animals, five species were special, and nine species were special subspecies. The *Manidae* was a Class Ⅱ Preserved Rare Animal. *Naemorhedus swinhoei*, *Urva urva*, and other two species are Class Ⅲ Other to be Preserved Wild Animals.

Birds

Only *Lophura swinhoii* shot by automatic infrared camera from October 2019 to October 2010 were identifiable. Fixed point survey recorded 35 species of birds belonging to 5 orders and 23 families. Relative abundance of scrub birds was higher, and that of a red–headed babbler and crested thrush was lower. Among 35 species of birds, 13 were special, and 13 species were special subspecies. Two species were Class Ⅱ Preserved Rare Wild Animals. Seven species are Class Ⅲ Other to be Preserved Wild Animals. 395 birds belonging to 31 species were recorded in thinning areas, and 307 birds

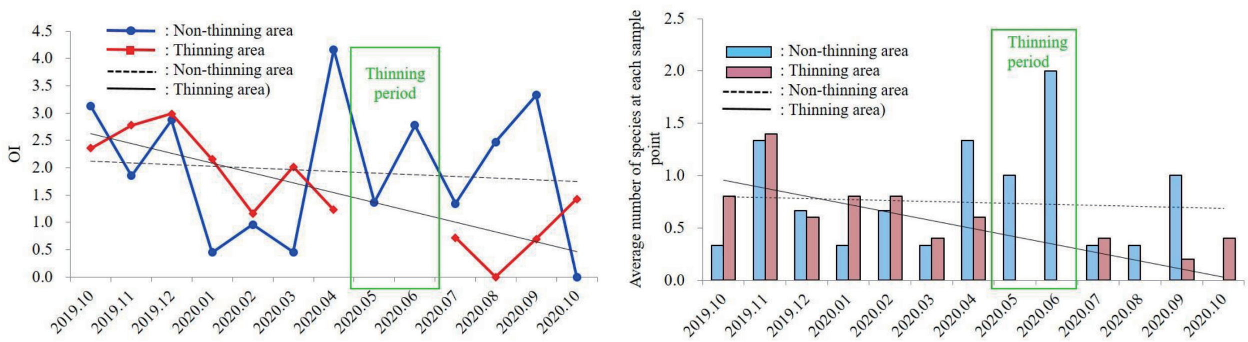

Fig. 5. Mammal's OI (right) and species number change (left) of plot for 2019–2020 per month monitoring.

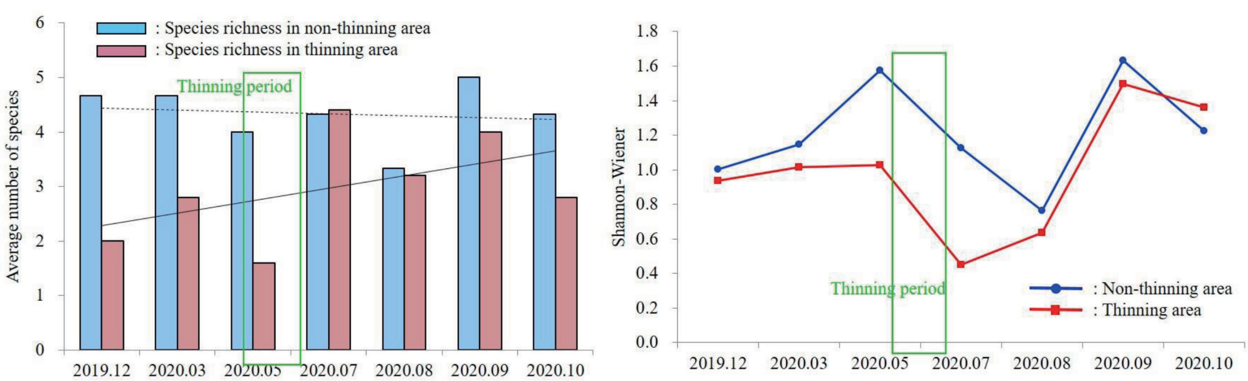

Fig. 6. Bird means species richness (right) for per month monitoring and Amphibian's shannon–wiener index (left) for every month monitoring.

belonging to 26 species were recorded in non–thinning area. The number of species in July 2020, just after thinning, increased obviously (Fig. 6 right). Results of the Shannon–Wiener diversity index showed that the diversity index of the non-thinning area slightly reduced to 2.14±0.44 from 2.29±0.12 before thinning, while that of thinning area increased from 2.07±0.15 to 2.50±0.10. This results showed that bird diversity increased in the short term after thinning. Results of bird diversity in all months showed similar results/trend. Studies have found that thinning neutrally or positively influences birds in the forest canopy (Kalies *et al.*, 2010). Birds foraging in the lower layer of the forest may be attracted to forage in the canopy layer due to increase insect number in the ground layer after thinning operation, increasing bird variety (Tsai *et al.*, 2010).

Amphibians and reptiles

Six–night surveys were conducted before and after thinning, totaling 12–night surveys. Two species of reptiles belonging to two families (*Pareas formosensis* and *Diploderma makii*) are recorded in thinning areas. The *Diploderma makii* was a special specie of Taiwan and belongs to Class II Preserved Rare Wild Animals. Seven species of amphibians belonging to three families were recorded, and 47 individual amphibians were witnessed. Five species of amphibians were special to Taiwan, and there are no preserved amphibians.

There was no obvious difference in the average number of animals and animal species in each survey before and after thinning. This indicated that thinning had less influence on amphibians. The results of the Shannon–Wiener diversity index were similar. Overall, the diversity index of the thinning area before and after thinning were 0.99±0.05 and 0.99±0.52, respectively. The diversity index of the non–thinning area before thinning was 1.24±0.30, and that after thinning was 1.19±0.36. However, looking at the diversity index change every month, the diversity decreased significantly in July after thinning in May 2020, while it rapidly increased after this time (Fig. 6 left). It is estimated that thinning does not effect on batrachian. Only frequent entrance and exit of human beings during the thinning period or just after thinning caused a temporary decrease of relative quantity of batrachian or reduction of croak.

Insects

From December 2019 to October 2020, among all insect survey methods, 10 orders of insects were trapped seven times for the malaise trap survey, 10 orders of insects were surveyed three times for the sweeping net survey, four orders of insects were surveyed one time for the rotten fruit trap survey, and nine orders of insects were surveyed for two times of night light survey. In total, 12 orders of insects were surveyed. They were *Blattaria*, *Coleopteran*, *Collembolan*, *Dermapteran*, *Diptera*, *Ephemeroptera*, *Hemiptera*, *Homoptera*, *Hymenoptera*, *Lepidoptera*, *Neuropteran*, and *Orthoptera*. It suggests that thinning positively affects partial insect species. It can be related to new habitats formed after thinning and change of ethnic structure between species (Wang, 2013). The thinning of the plantation shows that the openness degree of the canopy and the number of insects is of positive relevance (Hsiao, 2015).

CONCLUSION

This research surveyed a continuation of previous “Forest Management Planning”. The forest stand, fauna and flora, and other ecological data before and after thinning were investigated. Establishing timber volume formula was based on the acap obtained by aerial photo calculated through verification and estimation formulas of timber volume. According to the Pearson matrix, the correlation coefficient was 0.84–0.94–0.81. The three formulas were correlative to one another. It was observed through the flora survey that the number of trees and basal area after thinning reduced since thinned species were deforested directly. Although partial species were not the target of thinning, they would be deforested and affected by path cutting, weeding, and soil preparation during the thinning process. Moreover, there was very little change. The fauna survey showed that thinning positively affected the number of birds and insects in the forest canopy. Five species of wild animals were special species, and nine species were special subspecies. The *Manidae* was a Class II Preserved Rare Animal. *Naemorhedus swinhoei*, *Urva urva*, and other two species were Class III Other to be Preserved Wild Animals. Through proper and reasonable planning, thinning measures for plantations were beneficial to the improvement of the ecological environment and was able to facilitate the growing quality of forest trees. It is suggested that the absorption and storage of carbon are in the environment, biodiversity, and ecological functions positively, and can maintain sustainable development of environmental resources.

AUTHOR CONTRIBUTION

Wan–Ting Xie carried out the experimental study and performed the experimental data. Ming–Hsun Chan, Wei–Chun Chao and Jian–Nan Liu provided the equipment and performed the course/experimental data with the statistical analysis. Noboru Fujimoto supervised the work. Han Chien Lin designed the study and wrote this paper. The authors assisted in editing of the manuscript and approved the final version.

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