Promotion of Practical Learning about Plantation Management Planning and System Construction II: Thinning Operations, Skidding Yarding and Volume Measurement

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Promotion of Practical Learning about Plantation Management Planning and System Construction II – Thinning Operations, Skidding Yarding and Volume Measurement –

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This research based on the practical implementation of thinning operations, skidding yarding, and volume measurement. It proposed implementing thinning intensity, patch cutting, and improvement cutting methods to thinning areas of plantation management planning. About a 3.0 ha thinning area was used as a practical operations area for "thinning, skidding yarding, and storage". Thinning planning estimated log volume and number of felled trees. Logs volume, the volume of thinned and remaining trees, and the number of trees most suitable to be remained were obtained after wood selection. 30, 40, and 50% low thinning intensities were planned. The volumes of remained trees in thinning were 218.46, 180.14, and 216.95 m^3. The total volume and number of thinned trees were 228.66 m^3 and 266, respectively. The total area of thinning in patches was 0.20 ha. The total volume of thinned trees was 110.06 m^3, and the number of thinned trees was 69. The number of trees that fell through improvement cutting was 104, with a combined volume of 80.08 m^3. The volume measurement of these logs was calculated based on the Japanese Agricultural Standard (JAS). The average diameter was about 27.16 cm, and the total volume was 147.930 m^3.

Key words: Plantation, Forest Management Plan, Thinning Operations, Skidding Yarding, Volume Measurement

INTRODUCTION

This research focused on thinning operations, skidding yarding, and volume measurement to the compartment forest in possession to promote plantation management planning and plantation management practice and strengthen professional establishment ability. It continues "Promotion of Practical Learning about Plantation Management Planning and System Construction I – Forest Management Plan, Planning of Mensuration and Thinning Operations" (Chan *et al*., 2023). The Alishan Forest Working Circle Compartment No. 141 is a state–owned forest spanning over 241.1 ha. A portion of 30 ha is provided/reserved by the Forestry and Nature Conservation Agency (FANCA) in Taiwan as the experimental area. About 3.0 ha, this experimental area was selected as the target range of practical thinning, skidding yarding, and storage operations. It can be divided into three parts based on thinning operations planning reported previously: (1) select the sample area of "low thinning intension" based on distance from roads to and adjust forest stand and row spacing, spatial allocation of forest and light perspective for landscape purpose; (2) in the sample area of "patch cutting of thinning area", build multiple layered forests and gradually create forest stand with the vertical and horizontal structure, aiming to protect biodiversity and provide small–scale "thinning in patches" as a sample of forestry education. Other planning areas adopt improvement cutting for practice teaching (Kerr and Haufe, 2011; Thompson, 2012).

Reasonable planning of plantation thinning measures is beneficial to improving the ecological environment. Disforesting unsound live–standing trees facilitates remained tree's growth. It also enhances trees' anti–hazard ability accelerates earlier removal of wood fuel, and reduces forest fire risk. A thin crown canopy can change the forest's microenvironment after thinning. It increases solar radiation flux and the temperature inside the forest, accelerating photosynthesis and the decomposition rate of dry branches and fallen leaves (Forest commission, 2007; Ker, 2008). All of these benefit the inclusion of other types of plants (especially native plant species) and the sprouting of seeds in the soil. Furthermore, the biodiversity is promoted. Thinning operation/process enhances nitrogen mineralization and nitrification rate of litter. It increases soil's fertility and porosity. It reduces the rainfall impact, enhances soil's infiltration capacity, and slows down runoff and erosion of earth's surface. Thinning can improve tree form, facilitate tree growth, increase the harvest of log volume, enhance the quality of forest trees, and create sound forest form as well (Goodbody *et al*., 2019). Forest stand after thinning, grow into trees with even crowns, round and straight trunks, and better resistance. Roots of such trees develop, enhancing wind resistance. The diversity and abundance of species and forest stand structure are

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increased. It is beneficial to the ecological system's stability. Through intensive management, the yield of usable timber can be increased. The amount of carbon dioxide absorbed and stored by the forest increases, water and soil conservation capacity is strengthened, and unit production costs are reduced (Davis, 1966). The moderate thinning of the plantation can facilitate the quality of forest trees. It positively affects the absorption and storage of carbon in the environment, biodiversity, and ecological function because it improves the ecological environment and maintains sustainable environmental resource development (Forest commission, 2010).

This study aimed to learn "thinning operations, skidding yarding, and volume measurement". It innovated teaching connotation through practical operations of plantation management. It established a scientific system to realize practical learning of plantation management. This helps strengthen the education foundation for logging practice of forest management. Methods for thinning operations planning, cutting, and skidding yarding technology in this study were divided as follows: (1) deduce the introduction of sustainable forest coverage and low–cost natural updating technology; (2) implement control over thinning planning and operations; (3) practical exercise of cutting and skidding yarding; (4) calculate volume combining measuring method in Chinese National Standard (CNS) and Japanese Agricultural Standard (JAS), namely practical operations of thinning, skidding yarding and storage.

MATERIALS AND METHODS

Experimental materials

Thinning operations

For forest surveyed in forest management planning, it is suggested to conduct diversified thinning for landscape demonstration and education based on field investigation and considering that there are operations roads in forest entertainment areas, geologically sensitive zones, and differences in geographic direction and other differences in the thinning area (Goodbody *et al*., 2019; Kerr and Haufe, 2011). Three diversified thinning methods were planned for a 3.0 ha forest. These were thinning from percent (%) low thinning intension, patch cutting, and improvement cutting. Skidding cableway was planned/used to distinguish boundaries of all areas and assisted thinning and skidding yarding combining operations roads. Differences in these thinning methods (Forest commission, 2007; 2011) were as follows: Percent (%) low thinning intension: its purpose was to eliminate dominated stems suppressed in the below layer. It was followed by thinning moderate trees to facilitate the growth of remained trees in the upper layer.

Patch cutting: its purpose was to create differences in the vertical and horizontal structures of the forest stand to protect biodiversity. Gap cutting or patch cutting was adopted for thinning forests. The size and diameter of gaps were about twice as large as the height of a tree.

Improvement cutting: Deforesting, pruning, or other work were implemented together. These methods varied depending upon conditions. % low thinning intension was a major adopted method. It allowed the diameter class and crown of remained trees to grow further. Closed forest stands became thin, earning positive praise for the overall landscape effect of a forest stand.

According to the Taiwan Forest Management Plan (Forest Bureau, 1997), shelter forests are built on both sides of a stream to conserve water. According to the hydrological distribution of the thinning planning area, 5 to 12.5 m wide protective green belts are kept on both sides of a stream. In this way, the planning of % low thinning intension, patch cutting is not be affected, and the potential impact on the ecological environment can be relieved (Forest commission, 2011). Thinning operations were conducted by respecting folk culture and avoiding places with auspicious geomantic omens because there were many private public cemeteries. After wood selection (Thompson, 2012), cutting work was set off in order. Fengqihu Station at the Forestry and Nature Conservation Agency (FANCA) in Taiwan was used as a storage place to conduct the measurement.

Skidding yarding

This research divided the thinning area into an area for % low thinning intension, patch cutting, and improvement cutting. The method of mechanical skidding is adopted by erecting a skidding cableway (Chan *et al*., 2023). Larger trees forming the flat part of original operation roads were selected as king posts for skidding yarding. Larger trees from the area for patch cutting were also selected as stern posts for skidding yarding. The skidding cableway was set for skidding yarding after logging. The felled trees were arranged in a head–to–tail side–by–side manner based on the bucking specification of 3.6 m. They were skidded to Fengqihu Station of FANCA for subsequent measurement after sorting and storage.

Measurement and transportation

Felled logs were all stacked in the Fengqihu timber yard. The factory in charge of operations checked the number and position of logs. The diameter class of logs is recorded. Based on the diameter of the logs, they are selected for thinning (Van Laar and Akça, 2007). For ease of transportation, the selected logs were marked and a release stamp was impressed/applied. Partial logs were selected and transported to the timber mill for processing according to teaching research and product development demands. The remaining logs were sold by FANCA in Taiwan at the marked price.

RESULTS AND DISCUSSION

Thinning operations

For preparations of thinning operation, people prepare offerings and worship according to folk customs,

beliefs, and habits for a smooth commencement in Taiwan. Chainsaws are adopted for logging, and timber wedges are adopted for controlling the falling direction during felling operations. Based on forest farm safe and sanitary rules, relevant firefighting apparatus and safety equipment are prepared to prevent fire. This is because there is a certain risk in thinning operations. Chainsaws used for thinning are trimmed and sharpened. Public notice boards are set up.

Obstacles like weeds and shrubs during the felling operation were needed to clear away firstly. A proper falling direction was selected to lessen harm to the forest. Size and growth status of trees were different, and the butt swell; therefore, was removed before successful felling for trees with butt swell. For the convenience of checking, the felling point was set at the tree base (buttress), 30 cm from the ground. The opening for the felling direction was cut out before the felling. The direction of the opening was consistent with the felling direction, and the sawing angle was about 35–40°. After this opening was cut, the opening for cutting was sawn on the opposite side. The felling direction was controlled with a wood wedge. Excavators was to be applied/used above the felling trees to get an accurate falling direction.

Wood selection operations for thinning intensity

The size of each unit sample area was 25×20 m (area was 500 m^2) (Chan *et al*., 2023). The 3 ha thinning planning area was divided into 2 regions containing 60 grids in total. The two methods of thinning from below and thinning in patches were adopted for thinning planning. For remaining forest stands not involved in thinning planning, dead trees were deforested with improving cutting methods to decrease the felling impact. Thinning from below was dominated by the harvesting volume of thinned trees. It was supplemented by adjusting the density of trees. Three kinds of thinning intensities were planned based on the number of sample areas, i.e., 50, 40, and 30%, as shown in Fig. 1. The thinning intensity of the dark brown area of 0.8 ha was 50% (Fig. 1 above). Its log volume was 330.12 m^3, and the number was 262 after wood selection (Table 1). The thinning intensity of the brown area was 40% (Fig. 1 middle), the area of which was 0.71 ha. Its actual log volume was 239.40 m^3, and the number was 190. The thinning intensity of the skin color area having 0.61 ha was 30% (Fig. 1 below). Its logs volume and number were 274.68 m^3 and 218, respectively.

Patch cutting

The "patch cutting of thinning area" means clear–cutting in a small area (as shown in Fig. 2 above) utilizing mosaic within a range multiple of the planned tree height. In the thinning planning area, the patch cutting (area 50×40 m) was planned with twice the average tree height (22 m) surveyed on the ground as the diameter. The red range was planned as the thinning range. The total area of patch cutting was 0.20 ha. The volume of selected trees was 110.06 m^3, the total number of trees was 69, and the actual thinning intensity was 100% (Table 1).

Improvement cutting operations

Trees to be deforested in improvement cutting areas were dead, oppressed, and cull trees. Improvement cutting of forest stand in green patch areas was carried out after deducting sample areas for patch cutting (as shown in Fig. 2 below), the range of which was 1.10 ha. The total volume estimated based on the final volume formula was 485.45 m^3, and the number of trees that felled in this area was 385. The total volume and the number of trees that fell in the improvement cutting area were not calculated because dead, oppressed, and culled trees were deforested. The actual thinning intensity of the area was 27%. The area's total volume of deforested trees was 80.08 m^3, and the number of deforested trees was 104. The estimated volume and the number of retained trees in the area were 405.37 m^3 and 281, respectively (Table 1).

Tree selection, volume and number of logs and thinning intensity

The volume and number of logs are estimated by substituting the results of all thinning planning sample areas into the final volume formula (Thompson, 2012). Logs in stock, volume of thinned and retained trees, and other results were obtained after wood selection, as shown in Table 1. Real thinning from below intensities were 50, 40, and 30%. The volume of trees thinned were 111.66, 59.26, and 57.73 m^3, 47, 38, and 31% of tree number thinning intensity. Total number of trees thinned was 266. The volume of trees remained was 615.54 m^3. The total area of thinning in patches was 0.20 ha. The total volume of thinned trees was 110.06 m^3, and the number of thinned trees was 69, 100% of tree number thinning intensity. The estimated number of remained trees after improvement cutting was 281, and the estimated volume of remained trees was 405.37 m^3, 27% of real thinning intensity.

Bucking operations

Bucking dimensions were selected based on different market specifications and usage requirements. This study selected 3.6 m was selected as the bucking dimension ((Forest commission, 2007; 2011). The central part of trees might rot due to growth conditions, affecting the outturn. The depth of the rotten part; therefore, was needed to confirmed, and the rotten part was cut away before bucking. To accelerate bucking speed, 3.6 m bamboo poles from the thinning area were selected and used for measurement (Yang and Lin, 2008). Upon bucking, the required length was measured and cut with the bamboo pole as a ruler. Many twigs were near the treetop, and they all require trimming for subsequent bucking. Saw cutting was performed after confirming dimensions and trimming of twigs. Trees felled were crosscut for bucking in order and placed on woodland for skidding yarding. Trees with smaller diameter class and lops and tops were cut into 1.8 m long (logs/sections) and placed on timbers in woodland orderly.

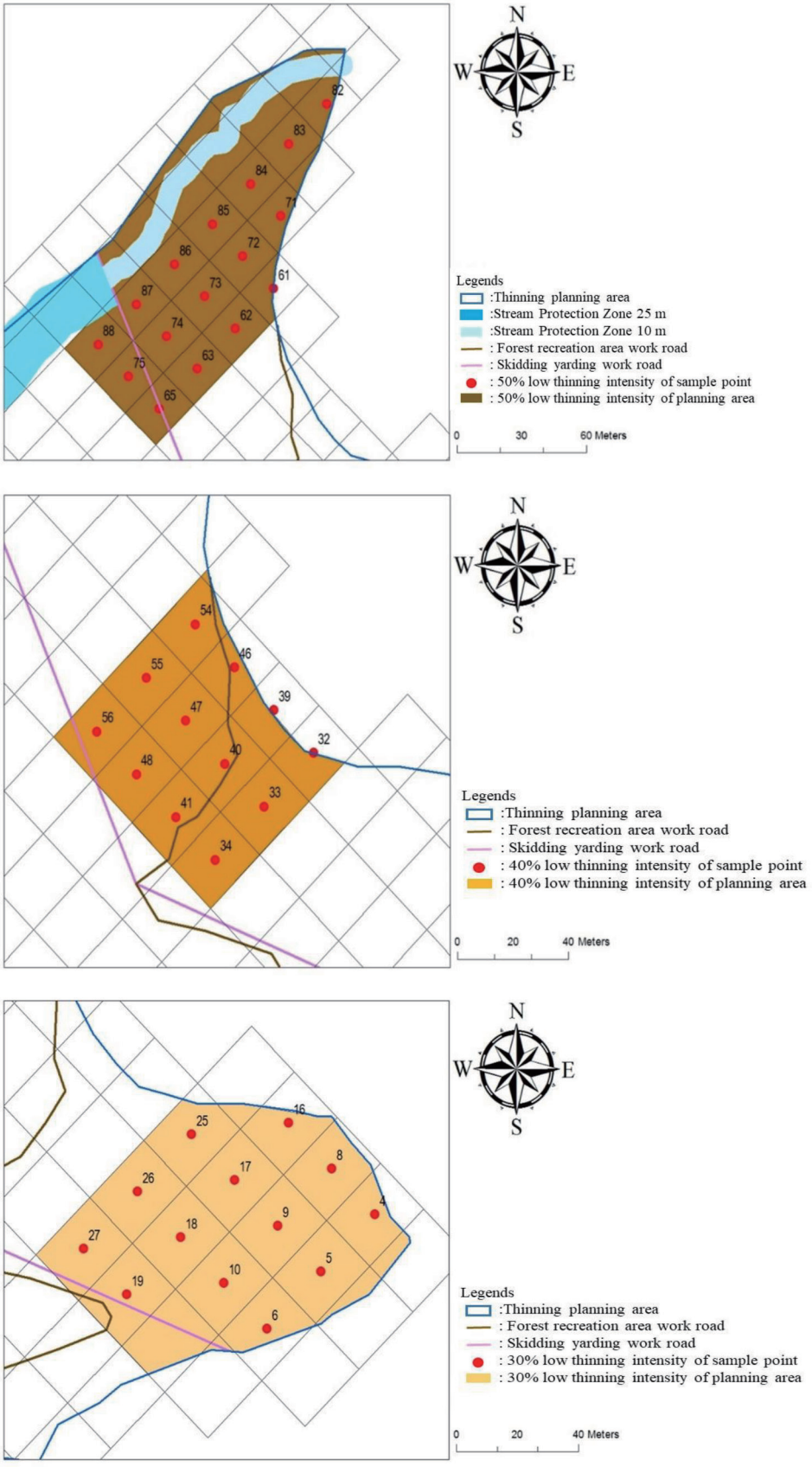

Fig. 1. 50% (above, 0.80 ha), 40% (middle, 0.71 ha) and 30% (below, 0.61 ha) low thinning intensity of plot distribution on thinning planning area.

Table 1. Volume, tree number, different thinning intensity of thinning planning area

Thinning intensity of thinning planning area	Grid number/ha	Real selection tree		Thinning planning						
				Real Thinning		Real remaining tree		Real thinning intensity (%)	Tree number thinning intensity (%)	Tree distance (m)
		Real volume (m^3)	Real number	Volume (m^3)	Tree number	Volume (m^3)	Tree number			
50%	16/0.80	330.12	262	111.66	125	218.46	137	50	47	7.69×7.69
40%	12/0.71	239.40	190	59.26	73	180.14	117	40	38	7.03×7.03
30%	13/0.61	274.68	218	57.73	68	216.95	150	30	31	6.37×6.37
Total	41/2.12	844.20	670	228.66	266	615.54	404	–	–	–
Patch cutting of planning area (2× tree height length square of patch cutting)	4.0/0.20	110.06	69	110.06	69	–	–	–	100	–
Improvement cutting of planning area	22/1.10	Final volume estimation		Real Thinning		Remaining tree estimation		–	Real thinning intensity (%)	–
		VM (m^3)	Tree number	Volume (m^3)	Tree number	Volume (m^3)	Tree number			
		485.45	385	80.08	104	405.37	281	–	27	–

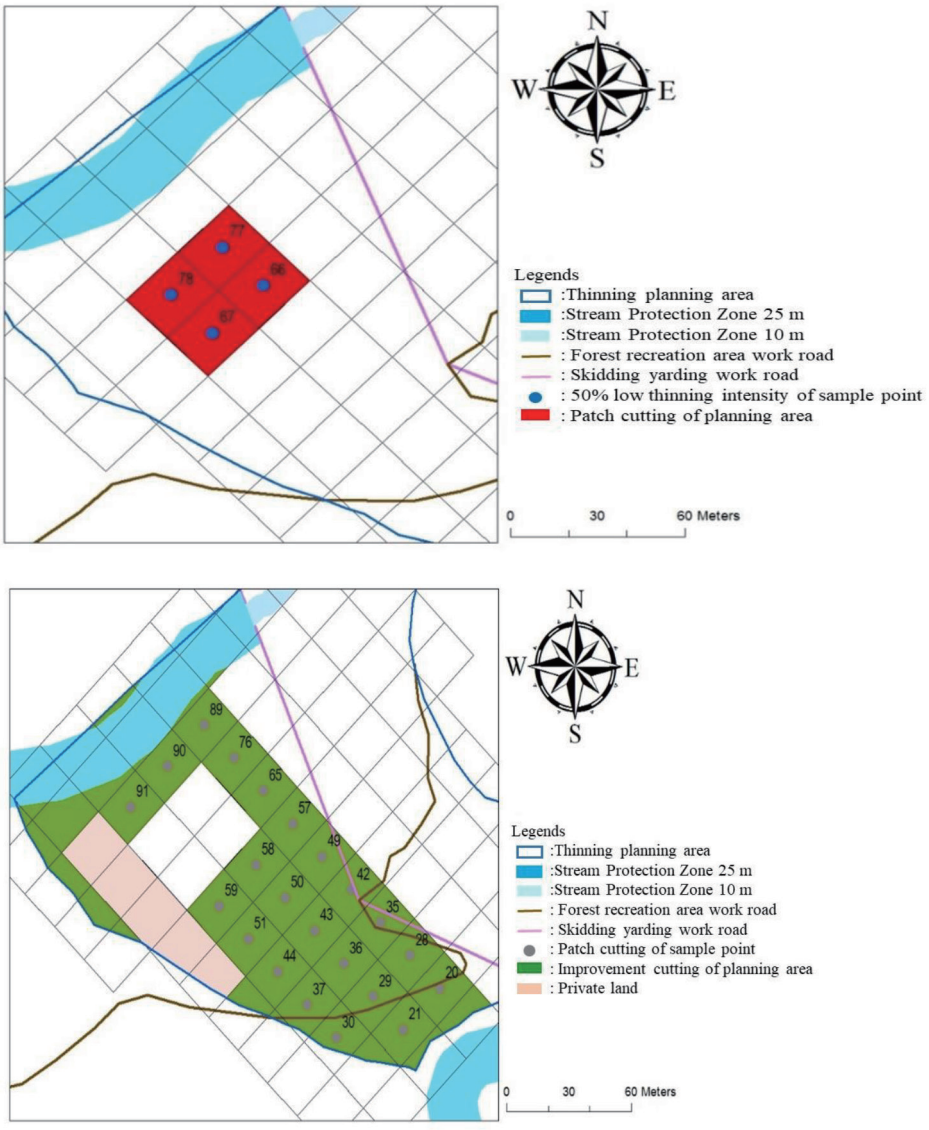

Fig. 2. Range of patch cutting (above, 0.20 ha) and Improvement cutting (below, 1.10 ha) of thinning planning area.

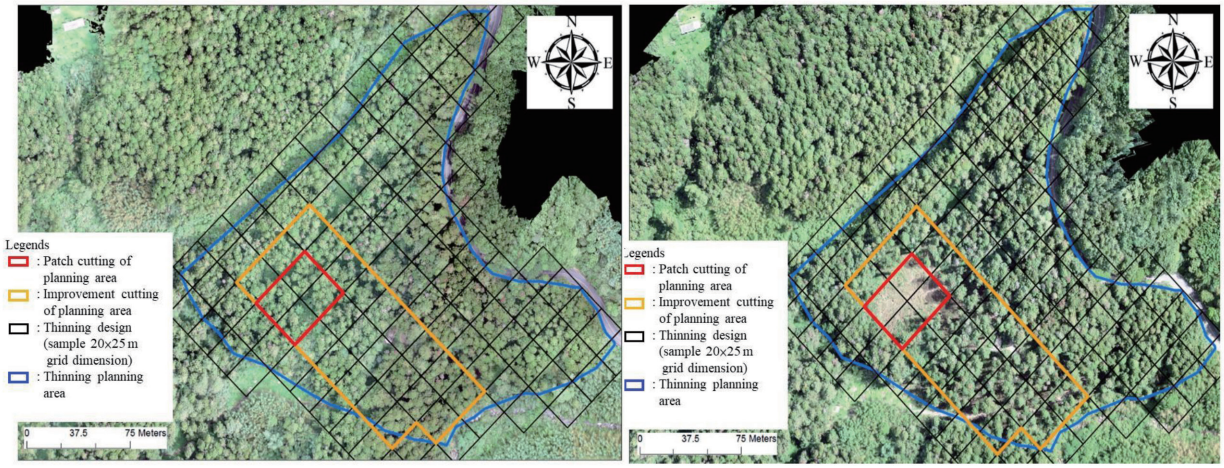

Fig. 3. Thinning planning area (3.0 ha) of photogrammetry (right: before thinning; left: after thinning).

Skidding yarding

Skidding yarding operations were carried out by adopting a simple method of excavators and windlass at Fengqihu Station of FANCA. The steel cables and pulley hooks were used for skidding yarding operations. Weeds, soil, and stones on operation roads were cleaned up prior to skidding yarding operations. Steel cables were tied to king posts for erecting skidding cables. Support pillars near the king posts were selected to fix steel cable to disperse tensile force during skidding. After hanging skidding cables onto pulleys of four corners, they were put in order. Meanwhile, the skidding cables were laid downward to clear the cutting area below. The skidding cables were pulled to the stern post and fixed. They were pulled and fixed to a support pillar behind the stern post to disperse the tensile force. Logs were tied up with steel cables for skidding. Hooks were hung until confirming that the skidding cables were tensioned. Weights were hung on pulleys to ensure the pulleys were able to move down smoothly. Logs were hung onto hooks of pulleys on the woodland below and pulled up by skidding cables. Steep cables were unfastened, and logs were placed beside operation roads. Logs were picked up with clamps of excavators and placed onto a tractor for transportation and storage.

Measurement and release

Felled logs were all stacked in a timber yard. The number and position of logs needed to be checked with in charge operations. The diameter class of logs was recorded. After measuring and recording the diameter of every log, a release check was conducted. The selected logs were marked by spraying paint after impressing/applying the release stamp at Fengqihu Station of FANCA.

Comparison before and after thinning operations

This research implemented thinning from below, patch cutting, and improvement cutting. A period with no operation before and after thinning were to be provided to compare the change of forest form before and after thinning. Areas circled with red frames in Fig. 3 were areas for patch cutting. There was an obvious clearing after felling (Fig. 3 right). It can be used to update forest form and plant native tree species. Areas circled with orange frames were areas for improvement cutting, where 27% of cull trees were deforested. The woodland thinned according to the comparison of forest formed before and after thinning. Due to such gaps, retained trees can obtain more growing space, sunshine can go through the underwood, and other plants also obtain more growing space (Kershaw *et al.*, 2003). It is recommended to update tree species with native tree species after thinning. The forest mainly includes *Taiwania cryptomerioides*, *Cunninghamia lanceolata* var. konishii, and *Chamaecyparis formosensis*. The latter has a natural seed–updating ability. Management is necessary to develop in the direction of sustainable forest coverage, and the forest stand of *Cryptomeria japonica* (Japanese cedar) is gradually thinned. This is consistent with the target benefit of updating native forest forms of ecoclimate and improving the landscape (Forest commission, 2007; 2011).

Skidding cableway operation

The mechanical cableway cable skidder is adopted for skidding yarding to overcome topographical difficulties (Husch *et al.*, 2002). Key points of small area thinning and skidding yarding practice are as follows: (1) reduce mechanical harm and interference to retained trees; (2) reduce the soil erosion and soil loss caused by disturbance of forest surface soil; (3) reduce damage and interference to existing vegetation (Forest commission, 2011). For the convenience of transportation, cableways were planned and set between two different felling methods. Existing operation roads were adopted, 3 m wide skidding yarding roads were set up, and no operation road was established separately. Felling with a chainsaw was a preferential felling method for skidding yarding operations. Standing trees were felled first and marked for the selection operation of trees to be thinned. It is suggested that it is better to have 3 opera-

Table 2. Estimation of tree diameter for age of Japanese cedar and *Cunninghamia konishii*

Species		Diameter (cm)	Age (year)
JC[1)]	> 30 cm	35.86 (1.76)	54.60 (2.03)
	< 30 cm	24.31 (3.72)	51.87 (2.03)
Cunninghamia konishii[2)]		38.85 (4.63)	51.50 (1.29)

[1)] JC: Japanese cedar; [2)] only 4 logs

> 30 cm JC (e.g.)

< 30 cm JC (e.g.)

Cunninghamia konishii (e.g.)

Table 3. Volume measurement and diameter average dimension for Japanese cedar

Means	Average diameter (cm)	Length (m)	Volume of selected log	Volume of log for sale at FANCA[1)]	Total Volume (m^3)
CNS 442	28.26 (7.33)	3.6	66.064	94.172	160.236
Log volume	28.35 (7.32)		62.584	89.740	152.325
JAS[2)]	27.16 (7.26)		62.330	85.600	147.930

[1)] FANCA: Forestry and Nature Conservation Agency;
[2)] JAS: Japanese agricultural standards

tion personnel to operate jointly. The felled trees were arranged in a head–to–tail side–by–side manner based on the bucking specification of 3.6 m (Forest Bureau, 2016; Yang and Lin, 2008).

Tree age calculation and volume measurement of logs

The tree age of thinned logs was calculated after logs arrive at the timber yard of Fengqihu Station. Japanese cedar logs with diameters above 30 cm, and with diameters below 30 cm were need to be sampled by 12, and *Cunninghamia lanceolata* were sampled by 4. A camera was used to shoot the end after placing measuring tape on one end of a log to record the diameter of the log. The number of rings on a log was taken as tree age, with results (Table 2) indicated by average value (standard deviation).

After felling and bucking in the forest area, logs were transported to a timber yard for classification and measurement. Log measurement was based on three calculation methods: National Standards of the Republic of China (CNS) 442, Forestry and Nature Conservation Agency log scale, and Japanese Agricultural Standard (JAS). Based on CNS 442, the average diameter and total volume were 28.26 cm and 160.236 m^3, respectively. Based on the FANCA log scale, the average diameter and total volume were 28.35 cm and 152.325 m^3, respectively. Based on JAS, the average diameter and total volume are 27.16 cm and 147.93 m^3, respectively (Table 3).

CONCLUSION

This study reviewed three thinning methods for thinning areas of plantation management planning: thinning intensity (50, 40, and 30%), patch cutting, and improvement cutting. The area of practical operations was about 3.0 ha in the thinning operation area. The thinning operation planning area contained the forest entertainment area, stream–protective green belts, and a geologically sensitive zone. It was divided into an area for thinning intensity and an area for thinning in patches. The remaining area was for improvement cutting. Short–standing trees and dead wood were deforested in improvement cutting woodland to facilitate growth and keep the health of the original forest stand. The practical operations about skidding yarding, transportation, and volume measurement were learned. The teaching connotation can be innovated, the education foundation for the felling practice of forest management can be enhanced, and samples for practical thinning operations of forestry products can be established.

AUTHOR CONTRIBUTION

Ming–Hsun Chan provided the equipment and performed the course/experimental data with the statistical

analysis. Wan–Ting Xie carried out the experimental data. 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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