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Influence of Plantation Stand Structure Change by Thinning Operation

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Abstract

Taiwan Kagome Co., Ltd has implemented understory thinning operation in their *Swietenia macropnylla* plantation since 2011. Thinning rates set from 25% to 45%. In this study, we investigate the juvenile trees, which from 14 to 20 years. We use Three Parameter Weibull Probability Distribution, conducted from Maximum Likelihood Method to simulate the diameter distribution before thinning and after. As results, the Dn values of K-S test are all lower than threshold value ($D_{0.05}$). The estimation results by Weibull Probability Distribution of different age trees demonstrate well, validate with 100%. It means this method is effective to display diameter distribution with different age plantations. With parameter of Weibull, a value, which is annual increasing of thinning plots shows from 0.81 to 0.93, all higher than Control plots (0.26). The b values represent three stages, which are before thinning, after thinning and six years after thinning. Operation method contains four groups, which are 1,760 trees/ha (Group A, b value = 13.5, 13.5, 14.5), 1,200 trees/ha (Group B, b value = 12.9, 10.0, 12.2), 1,000 trees/ha (Group C, b value = 9.9, 10.7, 9.1), and 800 trees/ha (Group D, b value = 13.6, 12.3, 14.7). The b value become lower as the distribution curve become smaller in Group A, B and D. After six years, diameter distribution goes bigger as tree age goes on. However, Group C has opposite results. The reason we found that lots of trees were dead because of pest and diseases hazards.

疏伐作業對於台南關廟地區大葉桃花心木林分結構變化之影響

Influence of Plantation Stand Structure Chang by Thinning Operation

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摘要

可果美公司民國 100 年於擁有之關廟農場進行下層疏伐，疏伐率介於 25-45%，本研究設置永久樣區於 100-106 年間調查 14 至 20 年生之幼齡林之桃花心木，以 3 參數 Weibull 機率密度函數進行分析，採最大概似法進行疏伐前、後不同疏伐度之徑級分布模擬，結果顯示，經 K-S 檢定其 Dn 值均小於臨界值($D_{0.05}$)，所推估之 Weibull 機率密度函數於不同時期之林分徑級分布推估良好，檢測通過率達 100%，表示此方法可有效表示各時期之林分徑級分布情形，各 Weibull 函數參數方面，a 值年平均增加量疏伐區介於 0.81-0.93，均大於對照區 0.26，b 值於疏伐前後、疏伐後 6 年，對照區的變化為 13.5、13.5、14.5，留存 1,200 株/ha 為 12.9、10.0、12.2，留存 1,000 株/ha 為 9.9、10.7、9.1，留存 800 株/ha 為 13.6、12.3、14.7，對照區、留存 800、1,200 株/ha 樣區，下層疏伐後使分布曲線基部範圍變小(b 值變小)，後隨林齡增加而變大；另留存 1,000 株/ha 者是由 1,800 株/ha 調整而來，疏伐強度高(株數疏伐率 42.2%，斷面積疏伐率 26%)，疏伐後胸徑分布趨向較大徑級，b 值隨徑級分布增加，但疏伐後 1 年調查發現小徑級留存木大量枯死，b 值由 10.7 降為 7.9，推測應為疏伐強度過高使立地環境快速改變，留存木適應不良枯死，造成徑級分布縮短，b 值先變小，之後再隨林齡增加而變大。

Taiwan Kagome Co., Ltd has implemented understory thinning operation in their *Swietenia macropnylla* plantation since 2011. Thinning rates set from 25% to 45%. In this study, we investigate the juvenile trees, which from 14 to 20 years. We use Three Parameter Weibull Probability Distribution, conducted from Maximum Likelihood Method to simulate the diameter distribution before thinning and after. As results, the Dn values of K-S test are all lower than threshold value ($D_{0.05}$). The estimation results by Weibull Probability Distribution of different age trees demonstrate well, validate with 100%. It means this method is effective to display diameter distribution with different age plantations. With parameter of Weibull, a

value, which is annual increasing of thinning plots shows from 0.81 to 0.93, all higher than Control plots (0.26). The b values represent three stages, which are before thinning, after thinning and six years after thinning. Operation method contains four groups, which are 1,760 trees/ha (Group A, b value = 13.5, 13.5, 14.5), 1,200 trees/ha (Group B, b value = 12.9, 10.0, 12.2), 1,000 trees/ha (Group C, b value = 9.9, 10.7, 9.1), and 800 trees/ha (Group D, b value = 13.6, 12.3, 14.7). The b value become lower as the distribution curve become smaller in Group A, B and D. After six years, diameter distribution goes bigger as tree age goes on. However, Group C has opposite results. The reason we found that lots of trees were dead because of pest and diseases hazards.

關鍵字：疏伐、林分結構、Weibull 機率密度
Keywords: Thinning, Stand Structure, Weibull Probability density function

研究目的

可果美公司為響應政府環境綠化、植林減碳，配合政府一鄉一農場計畫，自民國85年～88年開始於台南關廟地區進行造林，造林樹種包括肯氏南洋杉、桃花心木、印度紫檀、香楠等，造林面積近100 ha，於民國100年進行撫育疏伐，依立地環境不同及造林地的地被植群現況，疏伐率介於25-45%，本研究調查14至20年生之幼齡林之桃花心木，並設置永久樣區探討疏伐前、後不同疏伐度之平均胸徑、平均樹高與株數等之變化，並以3參數Weibull機率密度函數進行分析，採最大概似法進行徑級分布模擬，其結果可作為此區桃花心木直徑分布量化基礎，提供管理者未來進行不同經營目標及撫育作業之參考。

Taiwan Kagome Co. in order to follow government promoting environment greenness and decrease carbon by reforestation. From 1996 to 1999, they planting trees 100 ha including *Araucaria cunninghamii*, *Swietenia mahogoni*, *Pterocarpus indicus*, *Machilus zuihoensis*, etc. in Guanmiao Tainan. They did tend cutting based on different forest land and vegetation. The tending rate were from 25 to 45%. To compare with the tending effects before and after, we investigated the juvenile *Swietenia mahogoni* and established permanent plots to discuss the average tree stem, average tree height and amount of trees. Using 3 parameters Weibull PDF with Maximum Likelihood Estimator (MLE) to simulate the stem distribution situation. This result can be diameter at breast height (DBH) quantity basis to provide references for different management target and tending.

材料與方法

I. 研究區域與地面樣區設置

本研究以可果美公司於台南市關廟區所擁有之關廟農場為研究範圍，依所提供之造林資料、造林地地籍圖，數化套疊至林務局農林航空測量所所拍攝之數值正射航照影像，現場實際調查確認桃花心木分布現況，本研究共設置9處樣區，樣區大小為0.05 ha，以下層疏伐為主，疏伐前每公頃平均株數為1,547株，調整後為每公頃約800株(原1200株/ha，株數疏伐率33.3%，斷面積疏伐率14%)、1,000株(原1800株/ha，株數疏伐率42.2%，斷面積疏伐率26%)、1,200株(原1,640株/ha，株數疏伐率26.8%，斷面積疏伐率14%)及對照區1,500株，調查時間為疏伐前後(14年生)、疏伐後第1年(15年生)、第2年(16年生)、第4年(18年生)、第6年(20年生)，調查內容包括胸高直徑、樹高、株數。

We use Kagome farm as the research area for this study in Guanmiao Tainan. By overlapping to the forestation data, cadastral map and digital ortho-images taken by Aerial Survey Office. We investigate the distribution of *Swietenia mahogoni* and set 9 plots with each 0.05 ha mostly lower thinning. Before thinning, there are 1,574 amount of trees per ha. After adjustment, the amounts of trees are 800/ha as A group (from 1,200 amounts/ha by thinning rate33.3% and basal area 14%), 1,000/ha as B group (from 1,800 amounts/ha by thinning rate 42.2% and basal area 26%), 1,200/ha as C group (from 1,640 amounts/ha by thinning rate 26.8% and basal area

14%) and references group for 1,500/ha. Investigating period from before to after, we survey for 14 years after thinning, 15 years after thinning, 16 years after thinning, 18 years after thinning and 20 years after thinning as five times with DBH, tree height and amounts.

II. 林分直徑分布模擬

林分結構為描述一樣區胸徑大小的分布情形，本研究採 3 參數(a 表示位置，b 表示尺度，c 表示形狀)的 Weibull 機率密度模擬胸徑頻度分布，以最大概似法(Maximum Likelihood Estimator, MLE)及牛頓代疊法逼近參數值，再以 Law and Kelton(2000)所提出之 Kolmogorov-Smirnov(K-S)檢定進行 Weibull 分布之適合度測驗，臨界值為 α =0.05，若 K-S 檢定結果其觀測值的累計頻度的最大差異量(Dn)小於臨界值($D_{0.05}$)，則林分直徑分布符合 Weibull 分布，反之則否。

Stand structure describe the size of DBH distribution. We use three parameter (a represents location, b represents scale and c represents shape) Weibull PDF to simulate frequency distribution. Using MLE and Newton's Method to narrow the parameter value. Then we use Kolmogorov-Smirnov (K-S) test to examine Weibull distribution fitting test, threshold α =0.05. We accept Weibull distribution results if K-S test results demonstrate observation value counting frequency by most gap amount (Dn) fewer than threshold value ($D_{0.05}$), otherwise are reject.

結果與討論

本研究採最大概似法模擬不同疏伐度之林分直徑分布，經 K-S 檢定結果其 Dn 值均小於臨界值(D0.05)，所推估之 Weibull 機率密度函數於不同時期之林分徑級分布推估良好，檢測通過率達 100%，表示此方法可有效表示各時期之林分徑級分布情形；各 Weibull 函數參數方面，a 值為人工林中最小直徑，本次採下層疏伐，對照區由疏伐前 2.7 增加為 4.3，留存 1,200 株/ha 由疏伐前 4.0 增加為 8.9，留存 1,000 株/ha 由疏伐前 6.0 增加為 11.6，留存 800 株/ha 由疏伐前 4.9 增加為 10.2，a 值年平均增加量疏伐區介於 0.81-0.93，均大於對照區 0.26。

In this study, we use MLE to simulate stand DBH distribution of different thinning levels through the K-S test with our stats Dn value lower than 0.05. The estimation effect shows positive of Weibull PDF in different thinning period. The passing rate is 100%. That means this method is effective to represent different stand DBH distribution. According to all the parameter of Weibull PDF, a value is the smallest DBH. With this lower thinning, reference group value increase from 2.7 to 4.3. C group shows from 4.0 to 8.9. B group shows from 6.0 to 11.6 and A group shows from 4.9 to 10.2. The Weibull a value increase annually from 0.81-0.93 in thinning area are all bigger than references group 0.26.

b 值於疏伐前後、疏伐後 6 年，對照區的變化為 13.5、13.5、14.5，留存 1,200 株/ha 為 12.9、10.0、12.2，留存 1,000 株/ha 為 9.9、10.7、9.1，留存 800 株/ha 為 13.6、12.3、14.7，b 值可決定林分徑級分布之高度與寬度，其值越大表示涵蓋的直徑範圍越廣，理論上經疏伐作業之樣區能獲得較大的生長空間，故 b 值會隨林齡增加而變大，相關研究認為中度疏伐或未疏伐，b、c 值均會隨林齡增加而變大，表示對徑級增加有影響，本次研究之對照區、留存 800、1,200 株/ha 樣區，下層疏伐後使分布曲線基部範圍變小(b 值變小)，後隨林齡增加而變大；另留存 1,000 株/ha 者是由 1,800 株/ha 調整而來，疏伐強度高(株數疏伐率 42.2%，斷面積疏伐率 26%)，因 b 值同時表示為有 63%的林分直徑小於此值，本區疏伐後胸徑分布趨向較大徑級，故 b 值隨徑級分布增加，但疏伐後 1 年調查發現小徑級留存木大量枯死，b 值由 10.7 降為 7.9，推測應為疏伐強度高使立地環境快速改變，留存木適應不良枯死，造成徑級分布縮短，b 值先變小，之後再隨林齡增加而變大。

The Weibull b value of before thinning, after thinning and after thinning 6 years in reference group shows 13.5, 13.5 and 14.5. C group shows 12.9, 10.0 and 12.2. B group shows 9.9, 10.7 and 9.1. A group shows 13.6, 12.3 and 14.7. The b value can determine the stand DBH distribution of height and width. As the value increase, it means covering range of DBH are larger. Theoretically, after thinning procedure the trees have more growing space. Therefore, the b value go larger as the tree ages are older. Some researches demonstrate that medium thinning or no thinning, b, c value increase when trees grow older. That means positive in DBH increasing. In this study, the reference group, A group and C group display that distribution curve in baseline are smaller (b value decrease), then it grows bigger as tree ages older. B group are adjust from 1,800/ha with high level thinning (thinning rate 42.2% and basal area rate 26%). Because the b value representing 63% stand DBH are smaller than this value, this group DBH distribution increase. Therefore, b value increase when DBH are bigger. However, we discover that small DBH trees die severely in first year after thinning, b value decrease from 10.7 to 7.9. We speculate that high level thinning caused environment changed rapidly. The trees in site cannot adapt the change and die back. It makes DBH distribution shorter and b value decrease. After adapting the b value increase when tree ages grows older.

c 值於各樣區均小於 3.6 呈現右偏分布，顯示目前林分結構仍以小徑木居多，可依立地環境差異規劃不同經營方式如大徑木生產區、循環經濟區、景觀林等。本研究將歷年監測資料，以 Weibull 函數量化直徑分布，應用上可做為推估林分蓄積量、生物量及碳貯存量的基礎，可提供該管理單位後續經營規劃及清潔發展機制碳交易之重要參據。

The Weibull c value in each plots are smaller than 3.6 displayed right deviation. It means stand structure for now is still in small size trees. The differences of site environment can be arranged in different management direction such as commercial plantation, cycle economic area and landscape forest. We use annual monitoring data to quantity DBH distribution by Weibull PDF. In application of stand stocking, biomass and carbon storage basis, we can

provide management arrangement direction and carbon trade system information by this study.