Effects of Selective Logging on Community Structure and Dynamics of Broadleaved Korean Pine Forests in Jiaohe, Jilin (Postprint)

Authors: Fan Chunyu, Zhang Chunyu, Zhao Xiuhai

Date: 2017-11-01T00:00:00+00:00

Abstract

Scientific forest management can optimize stand structure and serves as an effective means of regulating forest productivity and biodiversity. As one of the important approaches to forest management, the impacts of selective logging on forest structure and community dynamics have remained inconclusive, necessitating long-term monitoring of selective logging and post-logging stand characteristic changes using more comprehensive data. Following the protocols for establishing large forest dynamics plots, a 42-ha broadleaved Korean pine forest dynamics monitoring plot was established in Jiaohe, Jilin in 2010. In winter 2011, selective logging was implemented on a portion of the area. Using the managed plot as the study object, numerical variables were employed to characterize logging activities and analyze changes in community structure before and after selective logging. Simultaneously, incorporating secondary survey data from 2015 and using a control plot with essentially consistent site conditions as a reference, differences in mortality and recruitment rates at both stand and species levels were compared, and linear mixed-effects models were utilized to investigate the influence of selective logging activities on individual radial growth. The research results revealed that: the selective logging intensity in the managed plot was 5.4%, with species significantly affected by logging disturbance primarily including Acer mono, Acer mandshuricum, Ulmus laciniata, Juglans mandshurica, Carpinus cordata, Fraxinus mandshurica, and Tilia amurensis. Logging was mainly concentrated on canopy layer species, with few individuals from the sub-canopy and shrub layers being involved. Species composition and diameter class structure did not exhibit significant changes before and after selective logging. Over the five-year period, stand density decreased in both the managed and control plots. Compared to the control plot, the managed plot exhibited lower mortality, but its recruitment status was not superior to that of the control plot. In terms of basal area, the overall mean annual increment of the managed plot was higher than that of the control plot, indicating that the

thinning effect induced by selective logging exerted a certain promotional effect on individual growth and survival. When logging intensity was incorporated into the linear mixed-effects model analysis, diameter at breast height (DBH) consistently emerged as the most important factor influencing individual growth, followed by asymmetric competition among individual trees. The mean annual increment of the seven main species involved in logging was higher than that of the control plot, but only Tilia amurensis demonstrated a significant response in radial growth to logging disturbance. Overall, low-intensity selective logging had minor impacts on community structure and dynamics, and different species exhibited varying responses in radial growth to selective logging.

Full Text

Preamble

Acta Ecologica Sinica • ChinaXiv Partner Journal
Vol. 37, No. 20 • October 2017
DOI: 10.5846/stxb201607291550

Effects of Selective Harvest on Community Structure and Dynamics in a Mixed Broadleaved Korean Pine Forest in Jiaohe, Jilin Province

Fan Chunyu, Zhang Chunyu, Zhao Xiuhai*
Key Laboratory for Forest Resources & Ecosystem Processes of Beijing, Beijing Forestry University, Beijing 100083, China

---

Abstract

Scientific forest management can optimize stand structure and is an effective means to regulate forest productivity and biodiversity. However, the effects of selective harvest—an important forest management method—on forest structure and community dynamics have not yielded consistent results in previous research. Accordingly, there is an urgent need for long-term monitoring using comprehensive data to evaluate selective harvest and post-harvest stand characteristics. Following the protocols of the Center for Tropical Forest Science (CTFS) forest dynamic plot, we established a 42-ha plot in a mixed broadleaved Korean pine forest in Jiaohe, Jilin Province, in 2010. In the winter of 2011, we selected 19 ha of this plot for management. Using simple numeric variables to characterize harvest activities, we analyzed changes in community structure before and after harvest. We then compared mortality and recruitment rates between the managed plot and a control plot with similar site conditions at both stand and species levels, using data from a second inventory conducted five years later. A linear mixed-effects model was employed to explore the effects of harvest on individual tree growth.

The results showed that the harvest intensity in the managed plot was 5.4%

based on basal area. Harvesting focused primarily on canopy-layer species, with the most affected species including *Acer mono*, *Fraxinus mandshurica*, *Juglans mandshurica*, *Carpinus cordata*, and *Tilia amurensis*. Sub-canopy and shrub layer individuals were rarely harvested. The harvest did not noticeably alter species composition or diameter at breast height (DBH) distribution. Over the five-year period, stand density decreased in both plots, but the managed plot exhibited lower mortality than the control plot. However, recruitment was not better in the managed plot. The annual basal area increment in the managed plot was greater than in the control plot, indicating that thinning from harvest promoted individual growth. When harvest intensity predictors were incorporated into the linear mixed-effects model, DBH emerged as the most significant variable influencing growth, followed by asymmetric competition. Only *Tilia amurensis* showed a significant growth response to harvest. In general, low-intensity selective harvest had minimal impact on community structure and dynamics, though radial growth responses varied among species.

Keywords: selective harvest; stand structure; harvest preference; dynamics; linear mixed-effects model

---

Introduction

Forests constitute a vital component of terrestrial ecosystems, providing essential resources for human survival and development. However, excessive exploitation in recent history has led to declining forest quality and impaired ecological functions, highlighting the critical importance of scientific forest management. Contemporary forest management increasingly emphasizes maintaining and restoring stand structure while ensuring timber production and maximizing ecological functions. The mixed broadleaved Korean pine forest (*Pinus koraiensis*) represents the zonal forest vegetation of Northeast China and is a typical temperate coniferous-broadleaved mixed forest. Selective harvest has been practiced in these forests to gradually restore native vegetation while ensuring sustainable economic returns.

Compared to clear-cutting, selective harvest is considered an optimal forest management strategy that can improve light conditions within the stand and promote forest structure, growth, and regeneration. However, harvest effects vary significantly among species, size classes, and geographic regions. While some studies demonstrate increased radial growth of residual trees following selective harvest, others show that heightened temperatures and water loss from increased light availability can cause drought stress, leading to mortality or growth inhibition in some individuals. Most domestic research has focused on short-term results, lacking long-term monitoring of harvest impacts on mortality rates and community dynamics. This study addresses these gaps by examining how selective harvest influences mortality, recruitment, and radial growth in a mixed broadleaved Korean pine forest, and whether these effects differ among species.

Materials and Methods

Study Area

The study area is located within the Jiaohe Forestry Experimental Area Administration in Jilin Province. This region experiences a temperate continental mountain climate influenced by monsoons, with a mean daily temperature of -18.6°C in January and 21.7°C in July. Annual precipitation averages 695.9 mm. The vegetation belongs to the Changbai Mountain flora and represents a typical natural secondary coniferous-broadleaved mixed forest. Dominant tree species include Korean pine (*Pinus koraiensis*), Manchurian fir (*Abies holophylla*), mono maple (*Acer mono*), Manchurian ash (*Fraxinus mandshurica*), Manchurian walnut (*Juglans mandshurica*), Amur linden (*Tilia amurensis*), and others. Shrubs primarily include Amur lilac (*Syringa reticulata*), Manchurian hazel (*Corylus mandshurica*), and Daurian buckthorn (*Rhamnus davurica*).

Plot Establishment

In the summer of 2010, we established a permanent monitoring plot of 42 ha (500 m × 840 m; 43°57.524 -43°58.042 N, 127°44.111 -127°44.667 E) in a mixed broadleaved Korean pine forest. Following CTFS protocols, we divided the plot into 20 m × 20 m subplots, which were further subdivided into 5 m × 5 m quadrats. All woody individuals with DBH 1 cm were tagged, identified to species, and measured for DBH. We recorded the location of each individual by measuring distances to subplot vertices. Canopy openness was measured using a canopy analyzer (WinSCANOPY, Quebec, Canada) by taking hemispherical photographs at 1.5 m height in each quadrat and processing them with WinSCANOPY software. Soil nutrients were analyzed from 500 g samples collected at the center of each quadrat, with measurements including total nitrogen, pH, and available nitrogen. Due to relatively uniform topography, slope, aspect, and species composition across the plot, we selected a portion for forest management while maintaining an untreated control area.

Selective Harvest Treatment

In the winter of 2011, we implemented selective harvest on 19 ha of the plot. Unlike traditional approaches with predetermined harvest intensity, we established principles for selecting harvest and reserve trees to enable long-term monitoring. The overarching goals were to protect biodiversity, maximize site productivity, and optimize economic output. Harvest trees were identified as diseased or decayed individuals, poorly formed trees, forked trees, and non-target species impeding the growth of target species. Target species included Korean pine, Manchurian ash, Amur linden, and other high-value timber species. Reserve trees included healthy individuals of target species, trees with non-timber economic value, large trees providing wildlife habitat, rare species such as Korean pine and Manchurian walnut, and species with potential artistic or ecological value. Special attention was paid to maintaining species diversity.

Data Analysis

Harvest Activity Analysis Temperate forests typically exhibit distinct vertical stratification. We classified all woody individuals into canopy, sub-canopy, and shrub layers to examine harvest patterns across species and strata. We analyzed the six most heavily harvested species, calculating harvest intensity as the proportion of basal area removed (rG) and the proportion of stems removed (rN). The ratio $N\mathrm{G} = r\mathrm{N}/r\mathrm{G}$ describes size-selective harvest preference, where larger values indicate a tendency to harvest smaller trees. We also examined how harvest affected the DBH distribution of major species.

Community Dynamics Analysis We conducted a complete re-census of all trees in 2015, recording growth status and DBH, identifying dead individuals, and tagging newly recruited trees (DBH 1 cm). Mortality and recruitment rates were calculated at both species and stand levels for both managed and control plots.

Linear Mixed-Effects Models To analyze factors affecting individual radial growth in the managed plot, we used linear mixed-effects models (LMMs). Previous studies have identified individual DBH, environmental conditions, and competition as key predictors. Given the nonlinear relationship between basal area increment and DBH, we included a centered DBH^2 term. Biotic variables characterized competition intensity, specifically using the relative basal area of larger trees (relBAL) within a 10 m radius, which measures asymmetric competition where larger individuals suppress smaller ones. Abiotic variables included soil nutrients and canopy openness. To assess harvest effects, we incorporated two harvest indicators: the proportion of basal area removed and the proportion of residual basal area within the neighborhood. Models were fitted separately for major species to account for species-specific growth differences. The marginal R^2 was calculated to assess the proportion of variance explained by fixed effects.

Results

Effects of Selective Harvest on Stand Structure

In 2010, the managed plot contained 20,696 individuals with DBH 1 cm. While species composition changed minimally, harvest altered the relative dominance of some species. For example, *Acer mono* decreased in relative dominance, whereas *Fraxinus mandshurica* and *Carpinus cordata* increased. The harvest intensity was 5.4% by basal area, representing a low-intensity treatment. Harvesting targeted almost exclusively canopy-layer species, with canopy individuals accounting for the vast majority of basal area reduction. Sub-canopy and shrub layers were largely unaffected.

shows species composition before and after harvest. Among the six primary harvested species, *Acer mono* experienced the highest harvest intensity (10% by basal area). The DBH distribution of harvested individuals ranged from 15–35 cm. *N*G values indicated that harvest focused on medium-sized trees (20–40 cm DBH) for most species, while *Carpinus cordata* showed a lower *N*G due to removal of some large individuals despite most harvested stems being small.

[Figure 1: see original paper] illustrates DBH distributions before and after harvest. The distributions remained largely unchanged, with most species showing inverse-J patterns except *Fraxinus mandshurica* and *Tilia amurensis*, which exhibited approximately unimodal distributions. Harvest primarily removed individuals near the peak of each species' DBH distribution.

Effects on Mortality and Recruitment

The control plot contained 30,095 individuals in 2010. Species composition was similar between plots, with *Acer mono*, *Pinus koraiensis*, and *Tilia amurensis* as dominant species. At the stand level, the managed plot showed lower mortality than the control plot, while both plots had higher mortality than recruitment rates, indicating density decline over the five-year period. However, recruitment in the managed plot was not significantly higher than in the control plot, suggesting that low-intensity harvest did not substantially promote regeneration.

presents stand-level dynamics. At the species level, shrub species such as *Acer barbinerve* and *Corylus mandshurica* experienced high mortality. When individuals were grouped by DBH class, most mortality occurred in small-diameter classes. Recruitment correlated positively with species abundance—species with higher abundance showed greater recruitment. In both plots, most species exhibited population declines, though *Corylus mandshurica* in the managed plot showed higher recruitment than mortality.

Growth Analysis

Basal area increased in both plots over five years, with a net increase of 1.37 m^2/ha in the managed plot compared to 1.12 m^2/ha in the control plot. This difference primarily resulted from growth of existing individuals rather than recruitment. The average annual basal area increment per tree was higher in the managed plot, indicating that harvest-induced thinning promoted individual growth.

[Figure 2: see original paper] shows basal area changes in both plots. Among the primary harvested species, *Fraxinus mandshurica* and *Tilia amurensis* exhibited significantly greater growth in the managed plot, while *Juglans mandshurica* and *Ulmus laciniata* showed no significant differences.

Linear mixed-effects models revealed that DBH was the dominant factor influencing individual growth, explaining 29-58% of growth variation. Asymmetric competition (relBAL) showed significant negative relationships with growth, confirming that larger neighbors suppress smaller individuals. Among abiotic factors, soil potassium correlated more strongly with growth than other elements. Biotic factors generally exerted stronger influence than abiotic factors.

When harvest variables were included in species-level models, only *Tilia amurensis* showed a significant growth response to harvest—individuals in neighborhoods with higher harvest intensity exhibited greater growth. Other species did not show significant relationships between growth and harvest variables.

and summarize model variables and significant predictors.

Discussion

Effects on Stand Structure

Unsustainable management has led to over-harvested stands with simple composition and poor stability in Northeast China' s broadleaved Korean pine forests. Adjusting stand structure is crucial for improving these conditions. Selective harvest, as an important optimization tool, can effectively alleviate growth suppression and pest problems caused by excessive density. Our low-intensity harvest (5.4%) caused minimal disturbance, consistent with previous studies showing that harvest intensities of 20–30% do not significantly alter species diversity or stand structure. Although harvest decisions involve subjective criteria, comprehensive long-term monitoring data can provide objective evaluations of harvest impacts to inform management policies.

Effects on Community Dynamics

Mixed-age, mixed-species forests contain individuals of varying ages, species, and size classes, making their dynamics complex and difficult to predict. Researchers increasingly use individual-based models such as LMMs to explore relationships between growth, mortality, and factors like size, competition, and environment. Selective harvest reduces stand density, modifies microclimate, and alters resource availability, which can reduce competition and improve survival. In our study, the managed plot showed lower mortality but no improvement in recruitment, suggesting that regeneration in natural stands is more sensitive to abiotic conditions and competition than to low-intensity harvest. While most studies confirm that selective harvest accelerates stand growth, with residual tree diameter growth increasing with harvest intensity, growth responses may exhibit time lags. Our five-year study period may be insufficient to detect all harvest effects.

Incorporating harvest intensity indicators into dynamic models remains rare but essential, as forest dynamics represent the combined effects of natural processes and management interventions. Future studies should include more comprehensive variables such as stand density changes and structural metrics to better reflect harvest impacts on stand structure and dynamics.

References

[1] Effects of harvest intensity on spatial structure of broadleaved Korean pine forests. *Journal of Northeast Forestry University*, 2013, 41(9): 6-9.

[2] Effects of selective harvest on sustainable utilization of broadleaved Korean pine forest resources. *Acta Ecologica Sinica*, 2015, 35(1): 31-37.

[3] Zhang CY, Zhao XH, Gadow KV. Analyzing selective harvest events in three large forest observational studies in Northeastern China. *Forest Ecology and Management*, 2014, 316: 100-109.

[4] Forest growth and disturbance simulation. *Chinese Academy of Forestry*, 1998.

[5] Research on spatial structure optimization models for selective logging. *Forest Science*, 2004, 40(5): 25-31.

[6] Archambault L, Delisle C, Larocque GR. Forest regeneration 50 years following partial cutting in mixedwood ecosystems of southern Quebec, Canada. *Forest Ecology and Management*, 2009, 257(2): 703-711.

[7] Effects of selective harvest on radial and longitudinal growth of main species in broadleaved Korean pine forests. *Journal of Inner Mongolia Agricultural University*, 2010, 30(21): 5843-5852.

[8] Research progress on effects of selective harvest on regeneration, biodiversity, and growth in northern forests. *Journal of Inner Mongolia Agricultural University*, 2008, 29(4): 264-270.

[9] Pamerleau-Couturé É, Krause C, Pothier D, Weiskittel A. Effect of three partial cutting practices on stand structure and growth of residual black spruce trees in north-eastern Quebec. *Forestry*, 2015, 88(4): 471-483.

[10] Prévost M, Dumais D, Pothier D. Growth and mortality following partial cutting in a trembling aspen-conifer stand: results after 10 years. *Canadian Journal of Forest Research*, 2010, 40(5): 894-903.

[11] Deal RL, Tappeiner JC. The effects of partial cutting on stand structure and growth of western hemlock-Sitka spruce stands in southeast Alaska. *Forest Ecology and Management*, 2000, 159(3): 173-186.

[12] Bataiheh M, Kenefic L, Weiskittel A, Wagner R, Brissette J. Influence of partial harvesting and site factors on the abundance and composition of

natural regeneration in the Acadian Forest of Maine, USA. *Forest Ecology and Management*, 2013, 306: 96-106.

[13] Ruel JC, Fortin D, Pothier D. Partial cutting in old-growth boreal stands: an integrated experiment. *The Forestry Chronicle*, 2013, 89(3): 360-369.

[14] Zhang CY, Zhao YZ, Zhao XH, von Gadow K. Species-habitat associations in a northern temperate forest in China. *Silva Fennica*, 2012, 46(4): 501-519.

[15] Liang JJ, Buongiorno J, Monserud RA, Kruger EL, Zhou M. Effects of diversity of tree species and size on forest basal area growth, recruitment, and mortality. *Forest Ecology and Management*, 2007, 243(1): 116-127.

[16] Porté A, Bartelink HH. Modelling mixed forest growth: a review of models for forest management. *Ecological Modelling*, 2002, 150(1/2): 141-188.

[17] Hara T. Dynamics of size structure in plant populations. *Trends in Ecology & Evolution*, 1988, 3(6): 129-133.

[18] Zhang CY, Jin WB, Gao LS, Zhao XH. Scale dependent structuring of spatial diversity in two temperate forest communities. *Forest Ecology and Management*, 2014, 316: 110-116.

[19] Nakagawa S, Schielzeth H. A general and simple method for obtaining R^2 from generalized linear mixed-effects models. *Methods in Ecology and Evolution*, 2013, 4(2): 133-142.

[20] Effects of selective harvest on stand growth and structure of natural spruce-fir forests. *Forest Science*, 2011, 47(2): 15-24.

[21] Structured forest management. *World Forestry Research*, 2009, 22(1): 14-19.

[22] Effects of selective harvest intensity on spatial distribution pattern of natural spruce-fir forests. *Journal of Central South University of Forestry and Technology*, 2013, 33(1): 68-74.

[23] Dodson EK, Ares A, Puettmann KJ. Early responses to thinning treatments designed to accelerate late successional forest structure in young coniferous stands of western Oregon, USA. *Canadian Journal of Forest Research*, 2012, 42(2): 345-355.

[24] Effects of tending thinning on larch-spruce-fir mixed forests. *Forest Science*, 2005, 41(4): 78-84.

[25] Zucchini W, von Gadow K. Two indices of agreement among foresters selecting trees for thinning. *Forest and Landscape Research*, 1995, 1: 199-206.

[26] Nonlinear state equations for simulating diameter-class dynamics in uneven-aged forests: a case study of broadleaved Korean pine forest in Changbai Mountain. *Forest Science*, 2004, 23(5): 101-105.

[27] Coomes DA, Allen RB. Effects of size, competition and altitude on tree growth. *Journal of Ecology*, 2007, 95(5): 1084-1097.

[28] Kariuki M, Kooyman RM, Brooks L, Smith RGB, Vanclay JK. Modelling growth, recruitments and mortality to describe and simulate dynamics of subtropical rainforests following different levels of disturbance. *Forest Biometry Modelling and Information Sciences*, 2006, 1: 22-47.

[29] Burgess D, Robinson C, Wetzel S. Eastern white pine response to release 30 years after partial harvesting in pine mixedwood forests. *Forest Ecology and Management*, 2005, 209(1/2): 117-129.

[30] Simard SW, Blennert-Hassett H, Cameron IR. Pre-commercial thinning effects on growth, yield and mortality in even-aged paper birch stands in British Columbia. *Forest Ecology and Management*, 2004, 190(2/3): 163-178.

[31] Forget E, Nollet P, Doyon F, Delagrange S, Jardon Y. Ten-year response of northern hardwood stands to commercial selection cutting in southern Quebec, Canada. *Forest Ecology and Management*, 2007, 242(2/3): 764-775.

[32] Mäkinen H, Isomäki A. Thinning intensity and long-term changes in increment and stem form of Scots pine trees. *Forest Ecology and Management*, 2004, 203(1/3): 21-34.

[33] Rüger N, Gutiérréz ÁG, Kissling WD, Armesto JJ, Huth A. Ecological impacts of different harvesting scenarios for temperate evergreen rain forest in southern Chile—a simulation experiment. *Forest Ecology and Management*, 2007, 252(1/3): 52-66.

[34] Temesgen H, Martin PJ, Maguire DA, Tappeiner JC. Quantifying effects of different levels of dispersed canopy tree retention on stocking and yield of the regeneration cohort. *Forest Ecology and Management*, 2006, 235(1/3): 44-53.

[35] Thorpe HC, Thomas SC, Caspersen JP. Residual-tree growth responses to partial stand harvest in the black spruce (*Picea mariana*) boreal forest. *Canadian Journal of Forest Research*, 2007, 37(9): 1563-1571.

[36] Thorpe HC, Vanderwel MC, Fuller MM, Thomas SC, Caspersen JP. Modelling stand development after partial harvests: an empirically based, spatially explicit analysis for lowland black spruce. *Ecological Modelling*, 2010, 221(2): 256-267.

Note: Figure translations are in progress. See original paper for figures.