INTRODUCTION

Forest soil plays an important role in forest water conservation (Zheng et al., 1997). The effects of silviculture on forest stands, especially forest soils, concern many aspects. Thinning forests will interfere with in different ways and the final conclusions regarding the effects of the thinning are inconsistent among existing studies (Li et al., 2003). For instance, thinning significantly affected soil fertility and increased the contents of soil micro-organisms and soil nutrient (Hu and Zhu, 1999). Soil microbial quantity, enzyme activity, total porosity, available nutrients and soil fertility were improved and soil bulk density were all reduced, after 2 year thinning in Cunninghamia Lanceolata, Pinus massoniana, Fokienia hodginsi, Cryptomeria fortunei and Schima superba (Zhang et al., 2001). The activities of phosphatase, chitinase and phenol oxidase were enhanced significantly in Loblolly Pine (Pinus taeda) forest soil after thinning (Boerner et al., 2006). Weak intensity thinning improved soil physicochemical properties, but under medium or intensive intensity, the soil condition was not significantly different from the control stand (Chi et al., 2006). Soil enzyme activities including catalase, urease, alkaline phosphatase, invertase and polyphenoloxidase were improved and enzyme activities in the A layer were more affected than those in the B and C, based on 5 years of Pinus tabulaeformis forest tending (Guo et al., 2007). The results of natural forest and Korean Pine (Pinus koraiensis) were slightly better than non-thinning area except Mongolian oak forest’s (Quercus mongolica) through studying soil properties of the natural forests under different thinning intensities in east Liaoning Province. The soil chemical properties were improved to different levels and weak thinning intensity stand contained the largest soil microbial quantity (Sun, 2007). The 18 year thinning program in pine forests indicated that with enhanced thinning intensity, the forest soil total porosity, capillary moisture holding capacity, soil nutrient level and enzyme activities were significantly enhanced. It demonstrates that forest thinning can improve the forest soil quality (Yu et al., 2008). Thinning significantly improved soil alkaline phosphatase activity and other

Keywords: Forest thinning, principal component analysis, soil enzyme activity, soil nutrient level, soil organic matter, soil physical properties

Research Article

Soil Properties Responding to Pinus tabulaeformis Forest Thinning in Mountainous Areas, Beijing

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Abstract: Studied soil physicochemical properties of Pinus tabulaeformis plantations under varying silviculture intensity in shade, slope and thick soil areas in mountain areas of Beijing. The results show that at intensive (50%), medium (45%), weak (33%) thinning intensity compared with the control, (1) soil bulk density was reduced by 7.9, 5.7 and 3.9%, respectively in depth from 0 to 10 cm (layer 0-10) and soil properties in layer 0-10 were better than in depth of 10-20 cm (layer 10-20). (2) Total soil porosity increased by 7.3, 5.4 and 2.9%, respectively; the effects of thinning intensity on soil non-capillary porosity ranked as: weak>medium>intensive>control and the total soil porosity and non-capillary porosity both changed similarly in the two layers. (3) Water infiltration capacity and total soil pondage capacity were enhanced by thinning intensity. (4) Soil organic matter, total Nitrogen and rapidly-available Phosphorus were maximized in the medium thinning plot, while the rapidly-available Potassium was maximized in the intensive thinning plot, demonstrating that medium and intensive thinning can improve the P. tabulaeformis forest soil nutrient level. (5) The effects of thinning intensity on catalase and urease activities ranked as: medium>intensive>control>weak, which revealed that the soil enzyme activity can be improved by forest thinning. In conclusion, to improve soil physiochemical properties of P. tabulaeformis plantation in shade, slope and thick soil areas in mountain areas of Beijing, we prefer intensive thinning management.

INTRODUCTION

Forest soil plays an important role in forest water conservation (Zheng et al., 1997). The effects of silviculture on forest stands, especially forest soils, concern many aspects. Thinning forests will interfere with in different ways and the final conclusions regarding the effects of the thinning are inconsistent among existing studies (Li et al., 2003). For instance, thinning significantly affected soil fertility and increased the contents of soil micro-organisms and soil nutrient (Hu and Zhu, 1999). Soil microbial quantity, enzyme activity, total porosity, available nutrients and soil fertility were improved and soil bulk density were all reduced, after 2 year thinning in Cunninghamia Lanceolata, Pinus massoniana, Fokienia hodginsi, Cryptomeria fortunei and Schima superba (Zhang et al., 2001). The activities of phosphatase, chitinase and phenol oxidase were enhanced significantly in Loblolly Pine (Pinus taeda) forest soil after thinning (Boerner et al., 2006). Weak intensity thinning improved soil physicochemical properties, but under medium or intensive intensity, the soil condition was not significantly different from the control stand (Chi et al., 2006). Soil enzyme activities including catalase, urease, alkaline phosphatase, invertase and polyphenoloxidase were improved and enzyme activities in the A layer were more affected than those in the B and C, based on 5 years of Pinus tabulaeformis forest tending (Guo et al., 2007). The results of natural forest and Korean Pine (Pinus koraiensis) were slightly better than non-thinning area except Mongolian oak forest’s (Quercus mongolica) through studying soil properties of the natural forests under different thinning intensities in east Liaoning Province. The soil chemical properties were improved to different levels and weak thinning intensity stand contained the largest soil microbial quantity (Sun, 2007). The 18 year thinning program in pine forests indicated that with enhanced thinning intensity, the forest soil total porosity, capillary moisture holding capacity, soil nutrient level and enzyme activities were significantly enhanced. It demonstrates that forest thinning can improve the forest soil quality (Yu et al., 2008). Thinning significantly improved soil alkaline phosphatase activity and other

Keywords: Forest thinning, principal component analysis, soil enzyme activity, soil nutrient level, soil organic matter, soil physical properties
properties in *Platycladus orientalis* forests, especially in intensively thinned forests (Xu et al., 2008).

However, some research shows thinning did not significantly improve soil quality, even damaging soil structure. For instance, after 5 years of thinning a pine forest in northeast Germany, soil microbial activity was not significantly improved and soil enzyme activities including xylanase, phenol oxidase and peroxidase in both the organic layer and mineral layer were not significantly different from the control stand (Maassen et al., 2006). Forest soil nutrients in Larch-fir forest stands did not significantly change under <40% thinning intensity, indicating that long-term effects of thinning were not significant (Wang et al., 2009). With a 7 years thinning program, the activities of dehydrogenase, catalase, urease and phosphatase in soil were significantly reduced but protease activity did not change (Garcia et al., 1997). In *Pinus massoniana* forests, thinning reduced soil structure stability, soil total porosity, soil moisture storage capacity and holding capacity, but increased soil volume quality (Jing and Xiao, 1998).

Thinning disturbs surface soil including water, heat and other material redistribution. And soil properties will be changed corresponding to the method, time, intensity of thinning, forest types and other aspects (Li et al., 2003).

*Pinus tabulaeformis* is one of the main planting species in Beijing. The existing area is 79,000 hm², accounting for 25% of the whole forest area in the city; the planted area is 61,000 hm² with 86% of young and half-mature trees (Ma et al., 2005). These forests play an important role in improving the ecological environment of Beijing.

This study is focused on a five-year thinning program of *P. tabulaeformis* stands in mountainous areas in Beijing. We analyzed how soil physical properties changed before and after thinning. The results could help to manage and improve stand quality for young and immature stands in mountainous regions. In addition to potential stand quality improvements it could also allow for the study of protective effects of ecological public welfare forests.

**METHODOLOGY**

**Setting of sample plots:** In April, 2004, the *P. tabulaeformis* plantation on shady thick soil slope was chosen owing to its representativeness (0.04 hm²) for thinning operation. The target limbs to be cut off were mainly those with serious diseases and insect pests, or the overstocked trees and shrubs interfering with the growth and suitable density of *P. tabulaeformis*. Thinning intensity was divided into control (0%, C), weak (33%, W), medium (45%, M) and intensive (50%, I). Before the thinning operation, each sample plot was detailed surveyed in details, including breast height diameter of each trees, plot altitude, the position aspect and grade of slope, soil thickness and litter thickness. The statues of sample plot are shown in Table 1.

**Measurement of soil physical properties and moisture holding capacity:** Soil samples were collected before thinning in 2004 and 5 years after thinning in April, 2009, from depth 0-10 cm (layer0-10) and 10-20 cm (layer10-20) by digging out soil profile along the diagonal of each plot, with three repetitions in each sample. The formulas are as follows:

- Measuring soil bulk density by using loop-cutting method, soil bulk density (g/cm³) = dried soil weight/volume
- Soil total porosity (%) = [1-(soil bulk density/soil specific gravity)] ×100%, soil specific gravity: 2.65 g/cm³
- Maximum moisture holding capacity (t/hm²): W_i = 10000 P_h, P_i is soil total porosity (%); h is soil thickness (m)
- Non-capillary moisture holding capacity (t/hm²): W_o = 10000 P_h, P_o is for soil non-capillary porosity (%)

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Table 1: Basic characteristics of *Pinus tabulaeformis* sample plots
Measurement of soil permeability: Soil permeability was measured by Bicyclic infiltration method. Sampling method and time were the same with Measurement of soil physical properties and moisture holding capacity. The calculation methods are:

- Initial permeability rate = Initial infiltration amount/initial infiltration time, in this research the initial infiltration time is 2 min.
- Steady infiltration rate is infiltration rate thinning to be stable in a unit time.
- Average infiltration rate is the average rate of water infiltration of the soils.
- Total amount of infiltration was for comparison. Because each plot had reached steady infiltration before 36, 36 min was taken as unified time.

Measurement of soil nutrient level: The measurement methods were: total Nitrogen, Kjeldahl determination; available Phosphorus, NaHCO₃ leaching with Molydenum- Antimony- D-iso-Ascorbic- acid- Colorimetry (MADAC); available Potassium, NH₄OAc leaching with flame photometer method (CACCSI, 1984). Sampling time was the same with Measurement of soil physical properties and moisture holding capacity and sampling depth was 5-10 cm, with three repetitions in each plot.

Measurement of soil organic matter and enzyme activity:
- Organic matter: Potassium dichromate dilution heat method.

Soil urease: Indophenol colorimetric method. The steps are: get 10 g of air-dried soil sample screened by a 1 mm sifter, put into a 100-mL volumetric flask, add 2 mL toluene, place at room temperature for 15 min and injected in 10 mL of matrix (10% urea solution) and 20 mL of citrate buffer (pH 6.7). Blended carefully, put the flask into a constant temperature box at 37°C; for each group, set no-matrix soil (10 g soil+10 mL distilled water+and 20 mL citrate buffer) as control; the whole test was using soil solution (0 g soil+10 mL urea solution+and 20 mL citrate buffer) for comparison. After 24 h, add 38°C distilled water to the constant volume of 100 mL (toluene should float above scale line), then filter the solution and save the filtrate. Put 1 mL of filtrate in a 50-mL volumetric flask, immediately add 20 mL of distilled water, 4 mL of phenol sodium solution and 3 mL of sodium hypochlorite solution and shake up the flask. After 20 min when color changes, add to constant volume for colorimetry at 578 nm. Enzyme activity was represented by mg of amino Nitrogen per gram of soil hydrolysis generated.

Soil catalase: Titration method. The steps are: get 5 g of air-dried soil sample screened by the 1 mm sifter, put into a 150-mL triangular flask and add 40 mL of distilled water and 5 mL of 0.3% H₂O₂. Meanwhile, set a control by injecting 40 mL of distilled water and 5 mL of 0.3% H₂O₂ into a triangular flask without soil. Plug in the stopper and, put in a Dual-Action shaker at 120 rpm, for 30 min. Then inject 5 mL of 15 mol/L sulfuric acid to terminate reaction and filter the solution using quantitative filter paper. Get 25 mL of filtrate and titrate until slightly red using 0.1 mol/L KMnO₄ solution. The KMnO₄ solution (mL) represented enzyme activity within a unit weight of soil.

Data analysis: A data were analyzed using Least Significant Difference (LSD) multiple comparison on SPSS 16.0 (SPSS Inc., Chicago, US). Principal Component Analysis (PCA) was used to evaluate the comprehensive effect of thinning improvement on soil.

RESULT ANALYSIS

Effects of thinning on soil bulk density and porosity: Woodland soil is the main place in the forest to store water and the quantity and mode of soil moisture storage are strongly affected by soil physical properties (Yu and Wang, 1991). For instance, soil bulk density can directly affect the soil moisture storage capacity; soil total porosity can directly affect the soil air permeability and penetrating capacity; the non-capillary porosity can decide soil moisture storage quantity, the main aspect of forest soil moisture conservation and soil/water conservation function. This research determined the effects of different thinning intensities on the above three soil physical properties.

Effects of thinning on soil bulk density: To evaluate the effect of thinning on soil bulk density, we compared data before thinning and five years after thinning of P. tabulaeformis forests (Fig. 1). The results showed that soil bulk density was lower after thinning and decreased with improved intensity. Under thinning intensity W, M and I, the soil bulk density was reduced by 3.2, 6.1 and 10.3%, respectively in layer0-10 and by 3.2, 7.4 and 15.3%, respectively in layer10-20.

Five years after cutting, soil bulk density was lower in all the thinned forests. Under thinning intensity W, M and I compared to control, soil bulk density from 0-10 cm reduced by 3.9, 5.7 and 7.9%, respectively in layer0-10 and by 3.5, 7.2 and 8.1%, respectively in layer10-20.

The Analysis of Variance (ANOVA) showed that soil bulk density ranked as intensive<medium<weak <control intensity, which was negatively related with thinning intensity, after 5 years of thinning in the P. tabulaeformis forest. Comparisons of soil bulk density in intensively thinned plots in layer0-10...
Fig. 1: Diversification of the soil bulk density of *Pinus tabulaeformis* before and after thinning

were significantly different from weak intensity and control plots (p<0.05), but there was no significant difference among plots in layer 0-10 cm (p>0.05), indicating that soil bulk density was reduced 5 years after cutting, but not remarkably. These results showed that forest thinning significantly reduced the soil bulk density in *P. tabulaeformis* forests, which effectively improved the surface soil structure especially at depth 0-10 cm.

**Effect of thinning forest on soil total porosity:** To evaluate the effect of thinning on soil total porosity, we compared soil total porosity data collected from the *P. tabulaeformis* forest before and 5 years after cutting (Fig. 2). The results showed that after 5 years of forest thinning, soil total porosity was higher than before thinning and as the porosity increased more as forest intensity increasing. At intensity W, M and I compared with the control, the forest soil total porosity increased by 3.0, 5.7 and 10.2% respectively in layer 0-10 cm and by 3.1, 7.2 and 17.8%, respectively in layer 10-20 cm.

Five years after cutting, the forest soil porosity was higher than before. At intensity W, M and I compared with the control, soil total porosity increased by 2.9, 5.4 and 7.3%, respectively in layer 0-10 cm and by 3.4, 7.1 and 7.9%, respectively in layer 10-20 cm.

Through investigating the soil porosity 5 years after cutting, we found that stand soil porosity increased after cutting, in positive relation to the thinning intensity: intensive>medium>weak>control. LSD analysis showed that soil total porosity was significantly improved in layer 0-10 cm (p<0.05) after thinning, but not significant in layer 10-20 cm, indicating that thinning can improve soil at depth 0-10 cm more obviously than at depth 10-20 cm.

Fig. 2: Diversification of the soil porosity of *Pinus tabulaeformis* before and after thinning

**Effect of thinning forest on soil non-capillary porosity:** To analyze the effect of thinning on the non-capillary porosity, we compared data collected from *P. tabulaeformis* forests before and 5 years after thinning (Fig. 3). The results showed that the non-capillary porosity was improved as thinning intensity increased. At intensity I, M and W, the non-capillary porosity increased significantly by 26.2, 49.6 and 52.5%, respectively in layer 0-10 cm (ANOVA, p<0.05); and increased by 2.8, 22.6 and 43.2%, respectively in layer 10-20 cm, with ANOVA showing no significant difference between intensity levels. These results indicated that thinning has its greatest effect on non-capillary soil porosity at soil depths between 0-10 cm.

Meanwhile, comparing data after thinning with control, the non-capillary porosity of each thinning plot was obviously higher. At intensity W, M and I, the non-capillary porosity increased by 26.2, 49.6 and 52.5%, respectively in layer 0-10 cm and by 3.0, 22.6 and 43.2%, respectively in layer 10-20 cm.

ANOVA showed that the non-capillary porosity was positively related to the thinning intensity and the
non-capillary porosity increased as intensive>medium >weak>control. Multiple comparisons showed that the non-capillary porosity in layer\textsubscript{0-10} cm was significant (p<0.05), indicating that the non-capillary porosity improved after five years of thinning; but non-capillary porosity increased a little as intensive>medium>weak>control in layer\textsubscript{10-20}, but not remarkable (p>0.05). This result indicated that the non-capillary porosity in layer\textsubscript{10-20} cm was improved less than in layer\textsubscript{0-10}.

**Effects on soil permeability:** Soil infiltration capacity is one major factor of erosion and reflects hydrological evaluation standards of soil/water conservation vegetation and water conservation function (Zhang et al., 2009). The higher soil infiltration capacity means the rainfall can be infiltrated and stored by the soil in wooded areas faster, with less surface runoff and soil erosion become; on the opposite, erosion will be the surface runoff (Luo et al., 2004). In this test, five indexes including initial permeability rate, average infiltration rate, the steady infiltration rate and penetration amount and saturated hydraulic conductivity were used to evaluate soil infiltration capacity.

Forest soil permeability of each thinning plot was enhanced significantly after thinning (p<0.05). Under Intensive thinning (I), the five indices were improved by 2.4, 2.3, 2.3, 2.3 and 2.3 times respectively at layer\textsubscript{0-10} cm was significant (p<0.05) at Medium thinning (M); no significant difference (p>0.05) was found at weak thinning or in the control. At depth 10-20 cm, all thinned forests were almost the same, without significant difference (p>0.05), which proved that thinning was beneficial for stand surface (0-10 cm) by improving permeability (Table 2).

**Effects on soil moisture conservation amount:** Woodland soil is the main place to store water. A study showed that the gravity water in the non-capillary pores plays the major role in adjustable storage in saturated moisture holding capacity (Hao and Wang, 1998). Therefore, forest soil moisture holding capacity mainly depends on the soil non-capillary pores and the quantity depends on the soil non-capillary porosity and soil thickness (Liu et al., 1996). Soil total storage is the sum of the water storage capacity of non-capillary and capillary pores. And the maximum of potential soil conservation reflects the potential storage, regulation ability and the soil moisture conservation ability as well (Wei et al., 2008). The resulting effects of 5 years of thinning on the amount of water conservation (non-capillary moisture holding capacity) are shown in Table 3. Water conservation quantities in the samples from thinned forests at depths of 0-10 and 10-20 cm were increased following the thinning. In layer 0-20 cm under thinning intensity by W, M and I, water conservation quantities were generally increased by 12.2, 48.7 and 44.4%, respectively. Compared with the control, the amounts of water conservation were all higher in a positive correlation with intensity. Specifically, under thinning intensity W, M and I the water conservation quantities were increased by 14.4, 36.0 and 47.8%, respectively. ANOVA showed that thinning significantly changed soil moisture conservation quantity, especially after intensive and medium thinning (p<0.05), but not after weak thinning. These results indicated that intensive and medium thinning intensities were an effective measure to improve the soil moisture conservation quantity.

The resulting effect 5 years of thinning had on total soil moisture storage is showed in Table 3.
Effect on soil nutrients: Thinning is an important measure to adjust forest stand soil nutrients. Thinning can change forest community structure, species composition, habitat conditions, and affect the productivity and soil fertility status (Zhang et al., 2001). Soil nutrients levels are important indicators of the soil fertility, while understanding the soil nutrient elements in thinning will be meaningful to promote benign nutrient circulation and maintain forest productivity (Fang et al., 1998). In this experiment, three indexes including total N, available P and available K were chosen to reflect the soil nutrient statuses before and after forest thinning.

Changes of soil nutrients: By comparing the pre and post thinning forest soil nutrient content in our plots we were able to see that; soil total N, effective P and K content (p<0.05) was increased in all plots. Five years later, the soil total N, effective P and K contents were improved by 43.1, 172.5 and 59.2%, respectively under Intensive thinning (I) and by 66.0, 63.3 and 41.2%, respectively under Medium thinning (M).

However, only the effective K content (23.224 mg/kg) was significantly increased under weak cutting (17.070 mg/kg) (p<0.05), while the other indicators were not significantly different (p>0.05) (Table 4).

Changes of organic matter and enzyme activity in forest soil: Organic matter is an important component of soil, as it affects and restricts soil properties. It is generally thought that soil organic matter content and soil quality are in positive correlation (Shimizu, 1994). Improving soil organic matter content can promote the formation of aggregates, thereby improving their stability and thus, improving soil moisture holding capacity (Haynes et al., 1991). Organic matter is the energy of microbial activities, which can improve the microbial diversity and activity and soil physicochemical properties (Peverill and Judson, 1999). Meanwhile, organic matter can affect the quantity and speed of...
Non-soil and its activities can be used to analyze harm of management methods (Geng et al., 2008). The soil organic matter contents (g/kg) before and after cutting, we found that: under Intensive thinning (I), soil urease and catalase contents increased by 57.9% from 0.744 to 1.175 mg/g and by 92.0% from 0.474 to 0.910 mg/g, respectively; under Medium (M), thinning two contents rose by 224.9 and 47.1% respectively; under Weak thinning (W) and in the Control (C), the two indicators did not change significantly (p>0.05).

### Integrated evaluation of thinning effects on forest soil improvement:

Because different thinning intensities affected the soil in many ways, the effects of thinning on soil improvement can be clarified should be studied in greater detail in order to maximize its efficiency. To do so it would be necessary to analyze the data of all indicators after 5 years thinning. This study chose SPSS 16.0 and PCA.

The averages of the indicators from different soil layers were used for analysis, including 16 indicators: density, total porosity, non-capillary porosity, hydraulic conductivity, initial permeability rate, steady infiltration rate, average penetration rate, 36 min infiltration quantity, water conservation quantity, total storage capacity, total N, available P, available K, urease content, catalase content and organic matter. The results are shown below.

In Table 6 cumulative contribution rate of the first two principal components (F1 and F2) reached 96.853%, indicating that calculation of F1 and F2 was quite reasonable, F1 contributed more to soil physical properties and F2 did more to soil chemical properties such as total N, available P, available K, urease content, catalase content and organic matter. The results are shown below.

### Change of soil enzyme activity:

Soil enzyme activity is an important indicator of soil fertility. Its change to a certain extent can reflect the evolution trend of forest soil quality and the effects of forest management measures on soil quality. This can provide certain guidance for maintaining forest health and formulating management methods (Geng et al., 2008). The experiment was based on the activities of urease and catalase, so as to know the changes before and 5 years after the forest thinning. Urease as a hydrolytic enzyme, can decompose organic matter and promote the hydrolysis of ammonia nitrogen and carbon dioxide, among which ammonia nitrogen is the direct source of trees (Bai et al., 2005). Catalase is widely distributed in soil and its activities can be used to analyze harm of \( \text{H}_2\text{O}_2 \) to plant growth (Dai and Wang, 1994). Its activity is related to soil respiration intensity and can reflect microbial activity intensity (Dai and Bai, 1995).

Comparing both urease and catalase contents before and after cutting, we found that: under Intensive thinning (I), soil urease and catalase contents increased by 57.9% from 0.744 to 1.175 mg/g and by 92.0% from 0.474 to 0.910 mg/g, respectively; under Medium (M), thinning two contents rose by 224.9 and 47.1% respectively; under Weak thinning (W) and in the Control (C), the two indicators did not change significantly (p>0.05).
CONCLUSION

Thinning improves soil physical properties: Thinning effectively reduced the soil bulk density and increased soil porosity and structure in *P. tabuliformis* forest, especially in surface soil (0-10 cm) following intensive and medium thinning. Decreased forest canopy density, led to improved lighting conditions and light intensity in forested stands. This also led directly to speed up litter decomposition, resulting in increased soil humus content, which promoted the surface soil formation crumb structure and the soil’s air permeability.

In addition, thinning measures also greatly improved the soil permeability and water retention capacity of *P. tabuliformis* forested land (similarly, better in 0-10 cm), which was helpful to reduce surface runoff, increase infiltration of rainfall to soil and improve the ability of water conservation.

Thinning effectively improves the soil nutrients: The thinning effects on *P. tabuliformis* soil nutrient content were different among the thinning intensities: effective P and K contents increased the most under intense thinning and total N content increased the most under medium thinning. Soil nutrients did not improve much as under weak thinning.

Soil organic matter content rose the highest 5 years of weak thinning (up to 152.7%) by 41.1% after intensive thinning and by 105.4% after medium thinning.

Furthermore, soil urease content and catalase content were increased the most by Medium thinning (M) and Intensive thinning (I) respectively.

Integrated evaluation of thinning effects on forest soil improvement: Following 5 years of varied intensity thinning on *P. tabuliformis* forested stands; intensive thinning (50%) led to the greatest improvement of the forests’ soil physiochemical properties.

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