IMPACTS OF DIFFERENT HARVESTING METHODS ON FOREST ENVIRONMENT

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A CAUTION TO THE READER

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ABSTRACT

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Harvesting methods are an important component of forestry management. Determining the impact of harvesting methods on forest environment can help us to do it more efficiently. In this paper, the methods, impact andw intensive of three harvesting methods are reviewed. The degree of influence was determined by comparing soil microorganisms, soil chemical properties and physical properties. The results show that high intensive harvesting methods will have a high damage level to the forest environment. Harvested area should be regenerated immediately after harvest.

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INTRODUCTION

1. Introduction

Canada has the third largest forest area in the world, reaching 4.02 million hectares, and the forests plays an important role in timber production and the global carbon cycle. According to the purpose of harvesting, Canadian forest harvesting can be divided into three types: clear-cutting, selective cutting and shelterwood cutting, and the most commonly used way is shelterwood cutting and clear-cutting. Those harvesting methods have been widely used in production practice, and their impact on forests is quite different. This study aims at analyzing the current forest harvesting measures of Canada, and the effects of different harvesting methods on forests and vegetation were discussed by reviewing the relevant literature. Based on the current situation of Canadian forest system, this study will summarize the suitable measures for Canadian forest harvesting, and provide the appropriate suggestions for the sustainable development of Canadian forests.

The analysis of this study is based on the following three objectives:

1. The impact of clear-cutting on the forest environment.
2. The impact of shelterwood cutting on the forest environment.
3. The impact of selective cutting on the forest environment.

Clear-cutting refers to harvesting down all the trees in the harvesting area during the harvesting period. Researchers found that horizontal strip clearcutting, vertical strip clear-cutting and gap strip clear-cutting had obvious effects on the transformation of low-quality stands, and the survival rate of trees reached more than 90% (Brose, 2008). The forest ecosystem after selective cutting can not only maintain steadily, but also be conducive to the renewal and development of the forest, but also effectively avoid natural disasters such as windfall. Shelterwood cutting is carried out according to the development process of natural forest regeneration. It not only provides abundant provenances for forest regeneration but also provides better conditions for seed germination, seedling growth, and development of young trees. At the same time, more timber can be obtained in a relatively short time (Olsson & Staaf, 2008).

The method of this paper is compared to the change of forest structure, productivity and forest soil before and after harvesting. The results show that high intensive harvesting methods will have a high damage level to the forest environment. The nutrient content in the soil increases immediately after harvest but decreases over time. The physical properties of the soil change dramatically, and intensive harvesting operations can degrade the soil. A certain degree of harvesting can promote the growth of tree diameter and improve stand productivity. The results suggest that the harvested area should be regenerated immediately after harvest. First, the increased nutrients in the soil can promote the growth of regenerated seedlings, and second, the regeneration of seedlings can reduce the loss of nutrients from the soil. Finally, the seedling regeneration process can improve the physical properties of the soil and reduce the damage to the soil by harvesting operations.

2. Effects of harvesting on forest ecosystem

2.1 Effects of logging on forest structure and productivity

For the forest ecosystem, there are some relatively stable structural rules within it. Without natural or human disturbance, the system structure is relatively stable and sustainable development. As a form of disturbance, harvesting changes forest density and tree distribution, which inevitably affects forest ecosystem structure and productivity, which is affected by harvesting methods and harvesting intensity.

2.1.1 Effect on Forest Structure

Harvesting has a great influence on the structure of the forest. In the growth and development stage of forest, because density of the forest is too high, space of above-ground and underground parts is increasingly crowded, the competition between trees is fierce, the contradiction between species is fierce, the structure of the forest is chaotic, the primary and secondary status is not obvious, resulting in the decline of the overall development of the system (Caspersen et al., 2000). Harvesting can effectively alleviate the competition among trees. It makes the distribution and utilization of light, water, and nutrients more reasonable, and can effectively improve the inter-species, intra-species relationship and ecological environment of trees, optimize the forest structure, and a certain degree of harvesting is conducive to the cultivation of large-diameter timber. Intermediate cutting can highlight the dominant position of the target tree species by cutting down diseased trees, poor growth trees, and shrubs, thus making the structure of the forest more obvious and the utilization of nutrients and water more rational. The main harvesting, as a harvesting method of forest products after maturity, also plays an obvious role in promoting the optimization of forest structure (Bradley, Titus & Hogg, 2001). However, when the harvesting intensity is too high, the forest density decreases, which increases the invasion opportunities of other species and leads to the instability of forest structure, which is not conducive to forest growth. Reasonable density structure is very important for forest growth. Combining with the actual growth status of the forest, it is one of the main means to promote the good development of forest trees to regulate the appropriate forest density structure through harvesting (Morneault et al., 2004). The ultimate goal of harvesting and regulating forest structure to distribute nutrients, water, light, and other resources reasonably is to improve the overall quality of forests and to achieve economic benefits while taking into account ecological benefits. Forests with different management objectives need different forest structures. Forests mainly producing large-diameter timber need lower forest density, so they need higher harvesting intensity. But firewood forests mainly producing firewood have lower harvesting intensity and maintain higher forest density (Sagheb-Talebi & Schütz, 2002). Therefore, only appropriate harvesting intensity can optimize and adjust the structure of forests.

2.1.2 Impact on Forest Productivity

As an important form of disturbance and tending measures, harvesting directly affects forest quality and productivity, and is directly related to harvesting objectives and intensity. Some studies have found that there is a positive correlation between forest productivity and harvesting intensity, but excessive harvesting will lead to the decline of system productivity. The main objective of tending and harvesting is to cultivate high-quality forests and prepare for obtaining high-quality timber after planting. Within a certain intensity, with the increase of harvesting intensity, tending and harvesting can increase the diameter at breast height of the target tree species and the volume growth of the individual tree (Paquette, et al, 2006). However, after reaching a certain intensity, the positive effect of the volume increase of individual tree cannot compensate for the negative effect of the decrease of the number of trees, which leads to the decrease of the total volume of the forest.

The main objective of the final felling is to harvest forest products. In most cases, excessive harvesting will have a negative impact on forest follow-up productivity, and the degree of impact is directly related to the intensity of harvesting. Generally speaking, the changes of forest canopy density are relatively small under low-intensity harvesting, and the changes of light, temperature, and humidity in the forest are mild, which is beneficial to the growth of trees, increase the stock and increase the productivity of forests; while the intensive or extremely intensive harvesting makes the canopy sparse, the light sharply enhanced, the temperature and humidity change dramatically, which greatly increases the invasion opportunities of herbaceous plants, the competition of nutrients and so on, and increases the forest productivity. Forest productivity is affected (Glöde & Sikström, 2001). Therefore, the appropriate intensity of harvesting for different forests is conducive to improving productivity. The forest with different slope zones has different nutrient, moisture, climate and retention density, and the appropriate harvesting intensity is also different. The actual situation should be taken into account in the production of harvesting operations.

2.2 Effects of Harvesting on Forest Soil

The soil is an important part of the forest ecosystem, and it is the basis for animals and plants to survive. At the same time, forest trees react to the soil through transpiration, respiration and other metabolic activities, soil microbial activities, litter decomposition, nutrient cycling and so on. Harvesting can affect the microenvironment, physical and chemical properties and quality of forest soil by changing tree composition and energy distribution in the system.

2.2.1 Effects of Harvesting on Soil Microorganisms

As an important biological factor of soil, soil microorganisms metabolize in soil through life activities, and biochemical effects such as oxidation, nitrification, ammoniation, nitrogen fixation, and sulfuration occur at all times. It promotes the decomposition of soil organic matter and the transformation of nutrients. It is highly sensitive and is one of the most sensitive indicators reflecting soil quality, human disturbance and land use change. The "key" and "power" of nutrient and energy cycle in the whole ecosystem are also important sources and sinks of soil nutrients (Donoso, 2002). In the process of forest harvesting, the distribution, activity, and diversity of soil microorganisms will be affected by the change of microclimate environment in the forest.

Relevant studies showed that harvesting had significant effects on soil microbial biomass and activity. After harvesting, microbial biomass increased significantly, mainly distributed in the

0-20 cm soil layer, especially in the 0-10 cm soil layer, and microbial activity also increased. After harvesting, the illumination increased, the microclimate in the forest improved, the soil structure was stable, the litter accumulated more, the microorganisms decomposing organic matter were more, and the microbial activity increased. When the intensity reached a certain level, the soil structure was destroyed, the litter under the forest decreased, and the water and nutrient loss resulted in the decrease of the number and activity of microorganisms. In addition, some scholars have studied the relationship between harvesting and soil microbial species, and found that harvesting significantly reduced the diversity of soil microorganisms in forests (Wear & Murray, 2004), possibly because the microbial species were closely related to soil nutrients and C/N ratio. After harvesting, environmental changes such as temperature and humidity of forest land accelerated soil nutrient consumption, thus affecting the C/N ratio, thereby affecting soil microbial growth. Biodiversity of organisms.

2.2.2 Effects of Harvesting on Soil Chemical Properties

After harvesting, canopy density decreases light intensity increases, temperature, and humidity changes. Especially, high-intensity harvesting exposes the forest surface, increases the absorption of solar radiation, leads to the increase of surface temperature, accelerates the decomposition of harvesting residues, litter and ground cover. At the same time, the increase in water loss and diurnal temperature difference directly affects the physical and chemical properties of soil. The effects of harvesting on soil chemical properties are mainly manifested in the changes of nutrients and pH values.

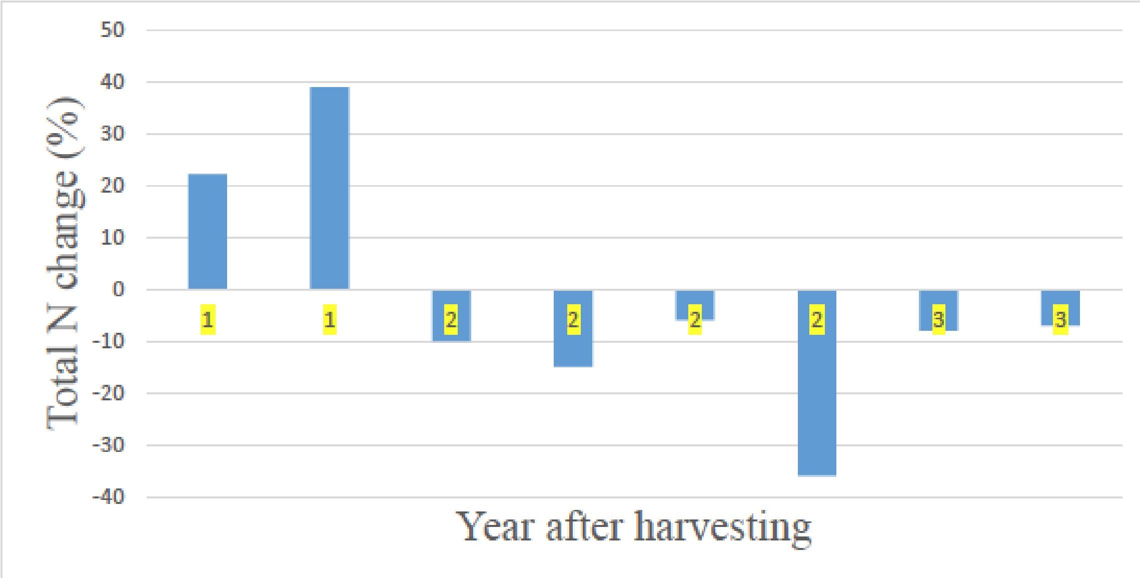

Figure 1. Total N change (%) after harvesting.

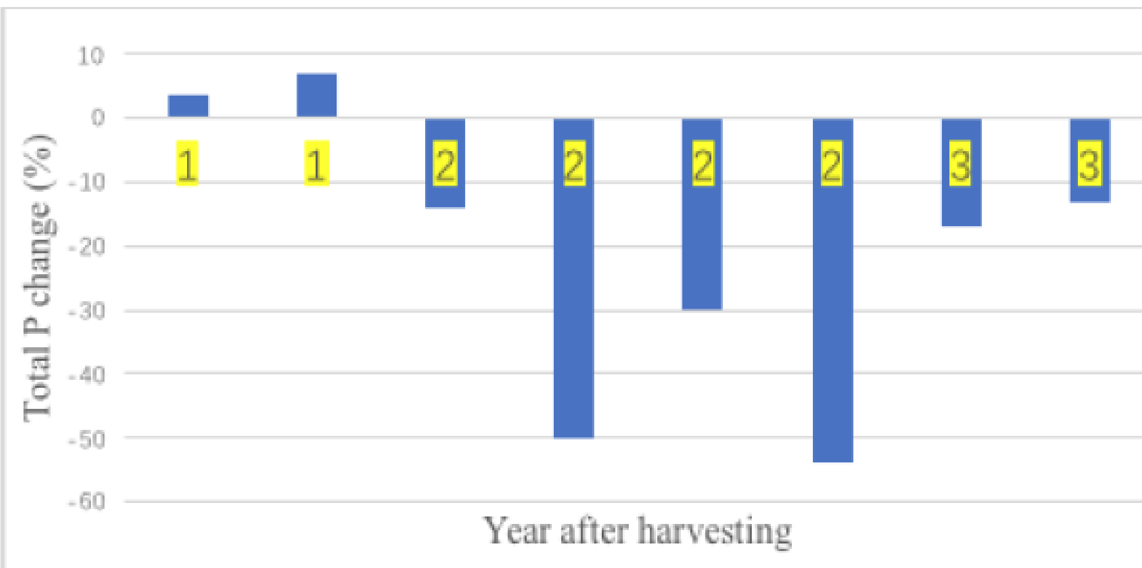

Figure 2. Total N change (%) after harvesting.

Figure 1 and Figure 2 shows that total N and total P changes after harvesting. Total N and total P increased immediately after harvesting, and clear cut increased high than selection cut. But for long-term data, total N and total P decreased after harvest.

Van der Werf, G. et al. (2009) conducted a harvesting experiment in Larix gmelinii forests in Daxing'an Mountains. The results showed that harvesting increased the organic matter content by 40.7% and 20.3%, ammonium nitrogen by 2.1% and 2.0%, total nitrogen by 38.9% and 22.2%, respectively. Harvesting also improved the chemical properties and nutrient content of the soil. Ploton et al. (2012) carried out experiments on the transformation of low-quality forest in Xiaoxing'an Mountains with different harvesting intensities. The results showed that the chemical properties of the forest changed significantly after harvesting, and the nutrient content was significantly higher than that of the control plot. With the passage of time, the difference became more and more obvious, and the overall chemical properties of the forest land gradually improved. However, Woodburyet al. (2007) found that the content of organic matter and nutrients decreased and the soil pH increased after clear cutting. Therefore, the effects of harvesting on soil chemical properties are directly related to harvesting intensity, and high-intensity harvesting may reduce soil nutrient content and soil microbial diversity.

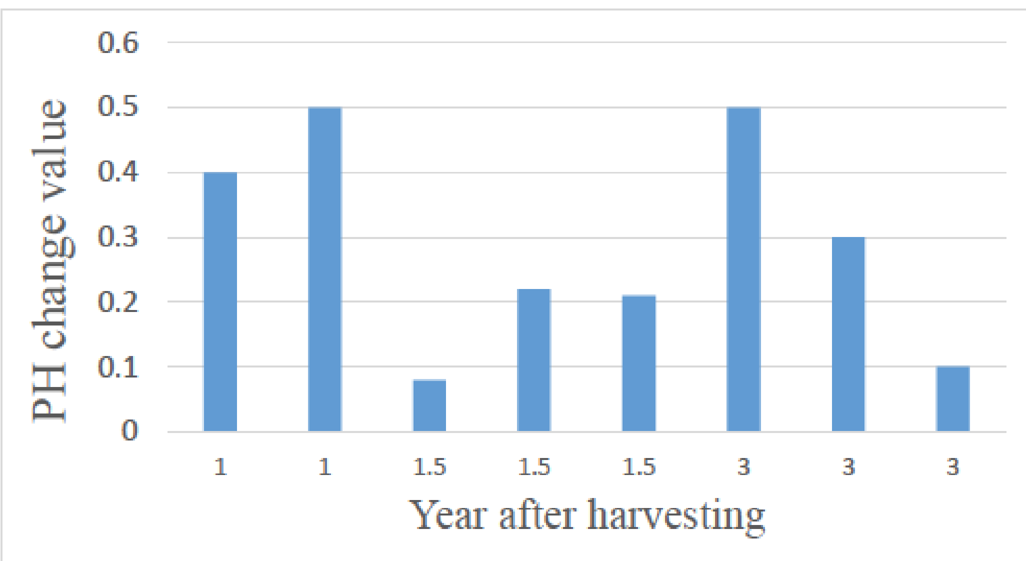

Figure 3. PH change after harvesting.

Figure 3 shows that soil PH increased after harvesting, as the forest regenerates, the PH will return to its original level.

2.2.3 Effect on Soil Physical Properties

Soil physical properties mainly include soil bulk density, pore size and water holding capacity, which can affect soil chemical properties and the survival of soil microorganisms. Some studies have shown that although low-and medium-intensity logging has an impact on soil physical properties, but the impact is not significant. Because of the changes of light, temperature, and humidity of the forest after logging, combined with the interference of trampling in logging operations, soil physical properties have changed to varying degrees.

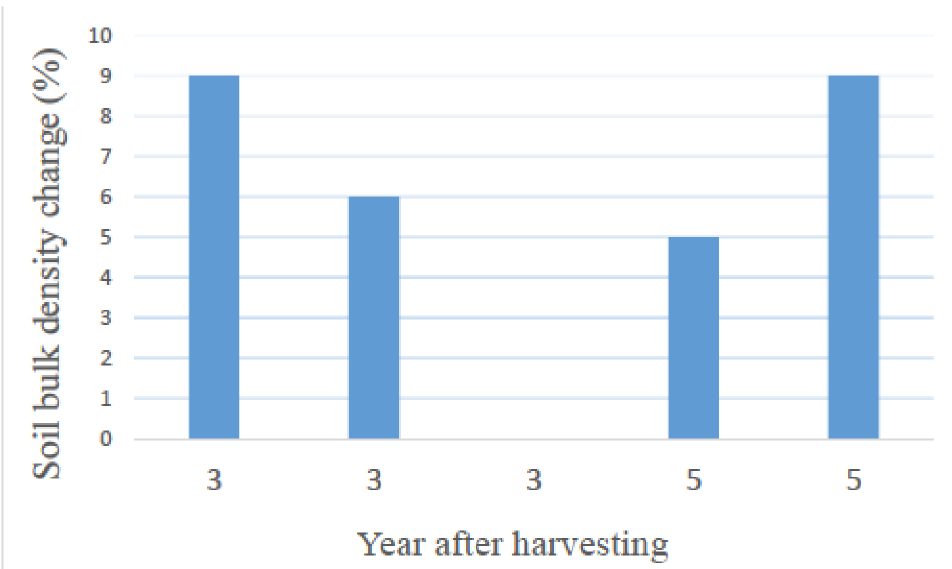

Figure 4. Soil bulk density change (%) after harvesting.

Figure 4 shows that soil bulk density increased after harvesting, The increased percent around 0-9%. After harvesting, the soil bulk density of forest land increased slightly, and the other indicators were improved. With the increase of harvesting intensity, soil bulk density increases gradually (Amiro et al., 2010), but physical properties such as capillary porosity, non-capillary porosity, total porosity and maximum water holding capacity decrease gradually (Birdsey & Heath, 1995). After reaching a certain harvesting intensity, soil properties such as compaction, drainage, and air permeability decrease easily due to the reasons of skidding transportation and soil bareness, resulting in soil degradation. Therefore, reasonable harvesting is beneficial to the change in soil physical properties.

2.3 Impacts of harvesting on forest biodiversity

Logging has a great impact on the biodiversity of the forest ecosystem, rich biodiversity is conducive to the evolution of forest ecosystem function, and is the basic guarantee to maintain the balance and stability of the forest ecosystem. In recent years, there have been relatively more studies on the impact of logging on the species diversity of understory vegetation. Scientific logging has improved the light and other conditions in the forest, resulting in changes in microclimate and nutrient in the forest, reduced inter-plant competition, better growth space for species and increased biological diversity (Birdsey & Heath, 1995). A large number of studies have shown that both tending and final felling can increase the species diversity of stands, and different intensities of harvesting lead to varying degrees of changes in species diversity. With the increase in harvesting intensity, species diversity first increases and then decreases (Donoso, 2002). Harvesting changed the age structure and composition of trees, at the same time changed the Lin points of light and other environmental conditions, which is beneficial to the invasion of other species, abundant plant species, to improve the species diversity of low-quality forest, when harvesting after reaching a certain intensity, the drastic changes in illumination, makes no longer adapt to stand in some species, stand structure damage is too big, the effects on the stability of the stand is bigger, lead to some of the original species disappear, although after a long time to recover, step by stable stand structure, but the main characteristics of forest stand than before there are still differences. The diversity of stands also changes (Wear & Murray, 2004). Therefore, excessive human disturbance intensity will reduce the biological diversity of stands. However, low-intensity logging has the least impact on stands, but the change in plant diversity is also small. Therefore, medium-intensity logging is the most beneficial for the improvement of biological diversity of stands.

3. The relationship between forest harvesting and forest regeneration

The harvesting of mature forests is called final harvesting. The purpose of correct determination of final harvesting method and harvesting amount is not only to obtain wood, but also to improve the function of the forest, to ensure the forest renewal after final felling, to form mixed multi-layer and different age forest as far as possible, and to realize sustainable management of the forest. The final felling and renewal must be regarded as a unity, and even the final felling should be regarded as the preparatory work for forest renewal, rather than the acquisition of wood as the main purpose (Glöde & Sikström, 2001), which is mainly dependent on the planned application of the protection forest or the protection benefit as the renewal method, rather than just convenient for forest harvesting and harvesting.

3.1 Clearcutting

Clearcutting is to cut all trees, suitable for all trees are the mature or over-mature stand, or need to carry out stand transformation and regeneration tree species stand, after clearcutting through artificial or natural regeneration formed by the next generation of forests will be the same age forest. Clearcutting can be divided into strip spacing clear cutting, strip continuous clear cutting and block clearcutting. Strip spacing clear cutting is every other belt cutting belt, in a few years after the renewal of the cutting belt and then cutting conservation belt; Continuous strip clear cutting is one cutting zone followed by another (Buckley, et al, 1998); Block clear-cutting is only block clear-cutting in the case of irregular woodland or forestage or mixed patches. However, it is still necessary to make the cutting area as narrow as possible and maintain a certain space and time interval between the cutting areas, so as to make full use of the protection and planting of the reserved trees. In order to maintain soil and water, the block clear-cutting area shall not exceed 5hm at a time, and the steep slope and inferior site shall be reduced to 1-3hm (Cronan & Grigal, 1995).

3.2 Shelterwood cutting

Namely, in a relatively long period of time, cut all mature trees in the same forest land in several times (no more than one age grade), and use the reserved wood to provide shade for natural seeding and seedling. Shelterwood felling is suitable for forests of the same age or relative of the same age when almost all trees have reached the felling age, and the forests formed after felling are still basically forests of the same age. Shelterwood thinning can be divided into uniform thinning, strip thinning and group thinning (Caspersen et al., 2000).

3.3 Selection cutting

Selection cutting is to cut only a part of the over-mature trees at a time to form and maintain the structure of multi-layer uneven-aged forest. The form of selection cutting can be divided into group form, individual form or mixed form. Selection cutting is most suitable for multi-layered uneven-aged forests, and its natural regeneration is very close to the original forest regeneration process. Therefore, selection cutting, especially the use of individual trees, is the essence of near-natural forestry. When deciding the final felling mode, we should consider several aspects comprehensively (Pothier & Prévost, 1995). First, we should consider the ecological benefits of forest types and stands. For example, the main function of forests is to conserve water and soil, conserve water resources and protect rare species. We must not clear cutting but selection cutting, and create conditions for natural regeneration. Secondly, different structural characteristics, such as forest composition, age, origin, canopy density, level, and level allocation, all affect the final felling and regeneration mode. If it is uneven-aged multi-layer forest, small and medium-sized trees are precious species, then selective cutting synchronizes with natural regeneration (Williams, 2003); if it is uneven-aged but overmature forest lacking small and medium-sized trees, small area clear cutting synchronizes with artificial regeneration. Third, make full use of the regeneration ability and characteristics of stand and tree species, if the regeneration under the forest is better, then carry out different degrees of selection cutting and shelterwood cutting; if the seeds of the target tree species are easy to disperse and spread, the seedlings are easy to grow, and the seedlings grow well in full light (such as larch), natural regeneration after clearcutting and artificial promotion of natural regeneration can be achieved (Crow, 1998).

3.4 The contrast of different cutting processes

The following is the detail of different cutting process (Hånell, et al, 2010):

Table 1. The detail of different cutting process.

Harvesting Process	Ease of Logging	Cost	Ecological Protection
Clear-cutting	Very easy- When the clear-cut area is replanted, the new forest grows up uniformly in species and size. This makes it much easier to log this forest when trees reach maturity in the future.	Cheapest harvesting process	If replanting not occur, or if it is not successful, it can be detrimental. Less desirable species may grow, soil may erode, and the land may be damaged.
Shelterwood cut	More difficult than clear-cutting. Seed trees need to be sought out and left standing so their seeds can regenerate the harvest area.	More expensive than clear-cutting	This is not as bad for the environment as clear-cutting is, as the forest will naturally regenerate itself.
Selection cut	Difficult- needs extra time and care to ensure the trees are cut in a way that doesn't damage the rest of the forest. Also difficult in the long run, because it does not allow the replanting of a new, uniform forest.	The most expensive harvesting process.	The least disruptive method to the forest environment.

Where there are natural regeneration conditions and shelterwood cutting and selective cutting sites, emphasis should be laid on the use of natural regeneration to form mixed forests of different ages (Crow, 1998). Artificial regeneration should be adopted in clear cutting sites and places without natural regeneration conditions. Of course, in the same forest land, according to specific conditions, flexible use of several renewal methods or their combination forms.

4. Influence of cutting methods on forest regeneration

4.1 Clear cutting

Because of dramatic change of the forest environment, there will be significant changes in microclimate, plant and soil conditions, which will directly affect the success or failure of regeneration. The temperature and humidity of the clear-cut area were all higher than that in the forest, and the amplitude of variation was increased and the humidity was decreased, making the seedlings vulnerable to frost, sunburn, drought, disease and insect damage. However, it was also possible to promote the growth of young trees due to the increase of light intensity (Nowacki & Abrams, 2004), although sometimes the material was decreased due to the failure of natural pruning. Clear-cutting of trees after the initial 1 ~ 2 year, forest vegetation rare but extremely unstable, the original forests negative by shelterwood replaced positive for plants, plants within 3 ~ 5 year after clearcutting grass coverage and grassroots intertwining degree increase rapidly, five years later to become stable shrubs and grass, make woodland environment change greatly, is not conducive to natural regeneration and artificial regeneration. Therefore, clear cutting land renewal should be completed in the year or year after logging. Artificial regeneration is generally used in clear cut areas and can be promoted if the natural regeneration of the target tree species is guaranteed (Cronan & Grigal, 1995). Manual update is mainly for seedling renewal, and the success of seedling renewal is better. The artificial renewal should make full use of the existing natural renewal seedlings, which not only shortens the forest growth time but also saves the labor cost. It is necessary to cultivate stably mixed forest consciously during artificial regeneration.

4.2 Shelterwood cutting

Shelterwood cutting and regeneration are carried out under the shade of some old trees. The original cutting is for the benefit of seed-bearing and regeneration. The reserved old trees can provide shade protection for the young trees, but when the shade becomes an the obstacle to the growth of the young trees, it shall be cut down to complete the process of shelterwood cutting and regeneration. In order to facilitate shelterwood cutting and regeneration, the typical shelterwood cutting is divided into three steps: preparation cut, seeding cut, removal cut. First, preparatory stage is in the mature forest to update the preparation conditions of the cutting, often in crown density, canopy, dense forests and was weak, death was thick and hinder in seed germination and seedling education stands in line, the first thing to cut to grow not good wood, promoting optimal good sturdy trees and ground by decomposition of pick cutting strong degree is as forest wood product storage of 25% ~ 30%. The canopy density after logging reached 0.6 ~ 0.7. If the degree of stand depression is 0.5 to 0.6, no preparation is required (Caspersen et al., 2000). Seeding cut is a regeneration cut that removes all the mature trees provided enough growth space for new regeneration. After seeding cut only shelter-trees left in the stand. Planting and cutting can make the required seeds fall to the woodland more, and the disturbance of cutting activities to the ground cover also increases the chances of seeds and ground cover contact. The cutting intensity was 10% ~ 25%, and the canopy density was 0.4 to 0.6, to protect the seedlings under the canopy. Sometimes a strip or block of land can be prepared to facilitate renewal. If the canopy density is only 0.4 to 0.5. Enough young trees and seedlings have already been planted in the stands, and may not be cut down. At the end stage of new seeding regeneration removal cut will be used to remove all shelter-trees. Depending on the situation, it may be used more than once. Because young trees still need a certain forest environment, so the woodland still needs to retain part of the forest to provide shelter. The cutting intensity was 10% ~ 25%, and the canopy density was 0.2-0.4. The remove cutting depends on the shade tolerance and climate suitability of the sapling, in order to maximize the protective effect of the reserved trees and avoid hindering the growth of the sapling. After seeding cut, young trees with accelerated growth have acquired the ability to resist sunburn, frost, weeds and other hazards. Retaining the shade effect of old trees is no longer beneficial but harmful (Nowacki & Abrams, 2008). Therefore, it is necessary to cut down all old trees.

4.3 Selection cutting

Natural regeneration of selected cutting sites is very close to the process of natural forest regeneration and easy to be successful. The ideal selective cutting stand is a multi-generation continuous stand, which has always been selective cutting and has always been updated. In order to facilitate forest regeneration and maintain the growth of trees, the principles of selecting cutting trees are as follows: leave all AGS trees and remove all UGS trees. The problem of excessive selective cutting intensity often exists in production, which makes selective cutting unable to give full play to its due advantages. If the intensity of selective cutting is properly controlled, the amount of cutting should not exceed the growth between two selective cutting, and the canopy density of the cut stand should be kept from 0.6 to 0.7 (Crow, 1998).

4.4 Different harvesting methods' impacts on the forest's regeneration

Different harvesting methods have a different disturbance to the forest. Different tree species showed different regeneration effects. Cutting operation mode affects seed source, quantity, quality, germination, and life ability, and affects the environment of forest land. Block thinning significantly promotes the growth and renewal of seedlings. Because only part of the upper forest is cut down selectively and the provenances of mother trees are preserved, the illumination conditions in the forest can be improved, and the artificial forest window can be formed, which not only promotes seed germination and seedling growth but also makes the seedlings sheltered by the canopy, which is most beneficial to the regeneration of the community composed of shade-tolerant tree species. After selective cutting, there was no significant difference between the regeneration of mixed forest and that of natural forest. Shelterwood cutting could open the canopy several times, which not only improved the germination conditions of seeds but also made the growth conditions change, which was beneficial to the regeneration of shade-tolerant tree species. Clear-cutting results in drastic changes in environmental conditions, and short of seeds, which is not conducive to the rapid regeneration of successive top species. For example, natural forests in the Canary Islands cannot be restored to their original structure after 60 years of clear-cutting. Shelterwood and selective cutting of *Abies fabri* forests can achieve good natural regeneration, but natural regeneration after clearcutting is generally difficult. Some studies have shown that clear-cutting causes temporary nutrient enrichment in soil and promotes the growth of young seedlings and trees. In the past few years after clearcutting, fast-growing positive tree species were rapidly renewed. With the passage of time, the proportion of shade-tolerant tree species increased and entered the main forest layer. The optimum cutting intensity had a parabolic relationship with the annual average cumulative growth and the number of regenerated trees. Some scholars also found that the cutting intensity of broad-leaved mixed forest was the most appropriate when it was 25%.

5. Discussion and prospect

Forests can not only protect the environment as ecological public welfare forests but also provide a series of forest products such as wood for human beings. They can not only provide daily necessities but also increase income. They are an indispensable part of the human development process. Cutting has a great impact on forest structure, biodiversity, soil quality, and the whole forest ecosystem. According to different management objectives and stands in different growth stages and environments, scientific cutting measures can promote the healthy growth of forests. But there is a conflict between the unlimited needs of human beings and the limited forest resources. A lot of unreasonable cutting ways in order to obtain more forest resources, which caused great damage to the forest resources and waste. So strengthening research, scientific and reasonable way of deforestation on forest ecosystem protection and economic and social development is particularly urgent (Fralish, 2004). In view of this, the following aspects should be further studied. First, we need to conduct scientific tending and harvesting research on different soil conditions, management objectives and target tree species. Species-rich resources in our country, the geographical environment and climate change is complex, thinning of different tree species in different geographic conditions, time and strength is different, way of cutting mainly for the domestic present research planting area of the larger part of the traditional forestation tree species, and to achieve maximum economic benefits is the management goal (Sutherland, Hale & Hix, 2000), with good ecological value for many other fine tree species also study is less, the social environment to strengthen the construction of ecological civilization in the new period disagrees, thus strengthening the balance of multiple tree species in different geographical conditions more effective scientific and reasonable way of raising the cutting research is necessary. The above discussion on the basis of forest harvesting methods confirms the hypothesis proposed in this paper to a certain extent. However, due to the high cost of selective felling, it is not used as the main interview method in Canada, while what is discussed in this paper is clear felling and gradual felling. Selective felling can be used as a supplementary method to increase efficiency. However, in addition to the selection of logging methods, studies on the impact of different logging methods on forests should also include more considerations, such as logging intensity, climate, biodiversity and so on. Based on these factors, the following aspects should be further discussed in future studies:

5.1 Research on how to choose right harvesting methods

It is necessary for the sustainable development of the forest and the development of the economy to study the scientific feeling of different soil conditions, management objectives, and target tree species. Canadian resource variety, complicated geographical environment and climate change, the thinning of different tree species in different geographic conditions, time and strength is different, the ways of harvesting mainly for the domestic present research planting area of the larger part of the traditional forestation tree species, and to achieve maximum economic benefits is the management goal, with good ecological value for many other fine tree species also study is less, the social environment to strengthen the construction of ecological civilization in the new period, and thus strengthen the multiple tree species in different geographical conditions cover the benefit of more scientific and the research on the reasonable ways of harvesting is necessary.

5.2 Effects of different harvesting methods on forest soil microorganism

Forest soil microbial distribution and activity of forest ecosystem in material circulation and energy flow is of great significance, at present, the harvesting of forest soil microbial distribution and activity of study is less, therefore, further study on the harvesting of forest soil microbial distribution and the influence of the reactive mechanism for reasonable forest logging has a realistic significance.

5.3 The influence of harvesting on the stability of the forest ecosystem

In recent years, scholars have carried out more and more studies on the impact of deforestation on the forest ecosystem, especially the discussion on deforestation mode is getting deeper and deeper. Although the clear-cutting operation has high efficiency and large harvest, it is also of great damage to forest land, easy to cause soil erosion and heavy damage to the environment. Researchers generally agree that selective cutting is conducive to maintaining the efficient and sustainable operation of the forest ecosystem. However, selective logging also has obvious disadvantages, such as time-consuming, laborious and high cost, which is not conducive to mechanized operation. In today's rapidly rising labor cost, selective logging has more prominent defects, such as low efficiency and high cost. Therefore, according to forest types and management objectives, clear-cutting, shelterwood cutting and selective logging in small areas may be a more rational choice. It is extremely important to further study a reasonable forest harvesting system for different types of stands. While ensuring the stable and efficient output of forest products, it is also conducive to maintaining the healthy and stable forest ecosystem and achieving the win-win goal.

LITERATURE CITED

Amiro, B. et al. (2010). Ecosystem carbon dioxide fluxes after disturbance in forests of North America. J. Geophys. Res, 115.

Buckley, D.S.; Sharik, T.L. & Isebrands, J.G. (1998). Regeneration of northern red oak: positive and negative effects of competitor removal. Ecology. 79(1), 65-78.

Birdsey, R. A. & Heath, L. S. (1995). Carbon changes in U.S. forests, in Productivity of America's Forests and Climate Change. Tech. Rep, 271, 56–70.

Bradley, R.L., Titus, B.D. & Hogg, K. (2001). Does shelterwood harvesting have less impact on forest floor nutrient availability and microbial properties than clearcutting? Biol Fertil Soils, 34:162–169.

Cronan, C.S. & Grigal, D.F. (1995). Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. Journal of Environmental Quality, 24, 209–226.

Caspersen, J. P. et al. (2000). Contributions of land-use history to carbon accumulation in US forests. Science 290, 1148–1151.

Crow, T.R. (1998). Reproductive mode and mechanisms for self-replacement of northern red oak (Quercus rubra) – a review. Forest Science, 34(1), 19-40.

Donoso, P.J. (2002). Structure and Growth in Coastal Evergreen Forests as the bases forUneven-Aged Silviculture in Chile. Ph.D. Thesis, SUNY-ESF, New York, USA.

Dixon, R. K. et al. (1994). Carbon pools and flux of global forest ecosystems. Science 263,185–190.

Fralish, J.S. (2004). Th e keystone role of oak and hickory in the central hardwood forest. In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station, 78-87.

Glöde, D. & Sikström, U. (2001). Two felling methods in final cutting of shelter-wood, singlegrip harvester productivity and damage to the regeneration. Silva Fennica, 35, 71–83.

Hånell, B., Nordfjell, T., & Eliasson, L. (2000). Productivity and costs in shelterwood harvesting. Scandinavian journal of forest research, 15(5), 561-569.

Lusk, C.H. & Contreras, O. (1999). Foliage area and crown nitrogen turnover in juvenilerainforest trees of differing shade tolerance. J. Ecol, 87, 973–983.

Morneault, A.E., Naylor, B.J., Schaeffer, L.S. & Othmer, D.C. (2004). The effect of shelterwood harvesting and site preparation on eastern red-backed sala-manders in white pine stands. Forest Ecology and Management, 199, 1–10.

Nowacki, G.J. & Abrams, M.D. (2008). The demise of fire and "mesophication" of forests in the eastern United States. BioScience, 58(2), 123-138.

Olsson, B. A. & Staaf, H. (1995). Influence of harvesting intensity of logging residues on ground vegetation in coniferous forests. J. Appl. Ecol, 32, 640–654.

Paquette, A., Bouchard, A. & Cogliastro, A. (2006). Successful under planting of red oak and black cherry in early-successional deciduous shelterwoods of North America. Annals Journal of Forest Science, 63, 823−831.

Ploton, P. et al. (2012). Assessing aboveground tropical forest biomass using Google Earth canopy images. Ecol. Appl, 22, 993–1003.

Pothier, D. & Prévost, M. (2008). Regeneration development under shelterwoods in a lowland red spruce – balsam fir stand. Canadian Journal of Forest Re-search, 38, 31–39.
Sutherland, E.K., Hale, B.J. & Hix, D.M. (2000). Defining species guilds in the central hardwood forest, USA. Plant Ecology, 147, 1-19.
Sagheb-Talebi, K. & Schütz, J.P. (2002). The structure of natural oriental beech (Fagus orientalis) forests in the Caspian region of Iran and the potential for the application of the group selection system. Forestry, 75, 465–472.
Van der Werf, G. et al. (2009). CO2 emissions from forest loss. Nat. Geosci, 2, 737–738.
Wear, N. D. & Murray, B. C. (2004). Federal timber restrictions, interregional spillovers, and the impact on US softwood markets. J. Environ. Econ. Manage. 47, 307–330.
Woodbury, P. B., Smith, J. E. & Heath, L. S. (2007). Carbon sequestration in the US forest sector from 1990 to 2010. Forest Ecol, Manage. 241, 14–27.
Williams, R.A. (2003). Use of stand density index as an alternative to stocking percent in upland hardwoods. Northern Journal of Applied Forestry, 20(3), 137-14