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SOCIO-ECONOMIC STUDY OF COMMUNITY FORESTS IN MID HILLS REGION OF NEPAL

THESIS

A thesis submitted in partial fulfillment of the

requirements for the degree of Master of Science in the

College of Agriculture at the University of Kentucky

By

Birendra K.C.

Lexington, Kentucky

Director: Dr. G. Andrew Stainback, Assistant Professor of Forest Policy

2012

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ABSTRACT OF THESIS

SOCIO-ECONOMIC STUDY OF COMMUNITY FORESTS IN MID HILLS REGION OF NEPAL

This research looks at some issues confronting community forestry in Nepal. Analytic Hierarchy Process (AHP) was used to analyze the issues confronting community forestry in mid hills region of Nepal. Results indicate that experts as well as local community users think positive aspects of community forestry to be more important than its negative aspects. In addition, through the comparison of three forest types, *Alnus nepalensis* found to be the most important forest type for conservation and *Schima-Castanopsis* to be the most important forest type for local benefits. Similarly, results also indicate that increase in carbon prices lengthen an optimal rotation age. Also, Land Expectation Value (LEV) increases substantially with the increase in carbon prices.

Keywords: Community forestry, Analytic Hierarchy Process, *Alnus nepalensis*, *Schima-Castanopsis*, Land expectation value

Birendra K.C.

6/14/2012

SOCIO-ECONOMIC STUDY OF COMMUNITY FORESTS IN
MID HILLS REGION OF NEPAL

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6/14/2012

Dedication

I would like to dedicate my work to my family for supporting and encouraging me to pursue my academic career.

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Chapter 1: Introduction

Background

Nepal is a developing country located in south Asia with an area of 1, 47,181 square kilometers. It lies between 80^0 04' to 88^0 12' E longitude and 26^0 22' to 30^0 27' N latitude. The altitude ranges from 70m above sea level to 8848m. Topography as well as climate has much variation from southern Terai to northern Himalaya. Similarly, forest types vary from sub-tropical forests to alpine meadows in the high Himalaya. There are 35 major forest types and 118 ecosystems in Nepal. Although, Nepal is small in size, it is rich in biodiversity. Globally, it is in 26th position and on a continental basis, it is in 11th position (MFSC 2008).

Nepal has total of 4.2 million ha (29%) of forest area and 1.6 million ha (10.6%) of shrub land. The major tree species in terms of proportion of total stem volume are sal (*Shorea robusta*) with 28.2% of total volume, oak (*Quercus spp*) with 9.3%, asna (*Terminalia tomentosa*) with 7.6%, chir pine (*Pinus roxburghii*) with 6.3%, talis patra (*Abies spectabilis*) with 4.4%, laligurans (*Rhododendron spp*) with 4.2%, and utis (*Alnus nepalensis*) with 2.9% (DFRS 1999). Forestry is an extensive land use system in Nepal that provides vast array of goods and services for human welfare. Nepal's forests comprise of private forest and state owned national forests. There are five major categories under state owned national forests i.e. government managed, protected areas, community forests, leasehold forests, and religious forests. So far, the total of 1,652,654 ha of forest has managed by 17,685 Community Forest User Groups (CFUGs) involving 2,177,858 households (DoF 2011); with average size of community forests of 93 ha.

Nepal is a pioneer country in adopting the concept of community forestry (CF). It started in 1970's to curb forest degradation particularly in the Himalayan region. The initiation of community forestry was mainly due to realization of active participation of local community in forest resource management. Forestry in Nepal has been delineated into three phases i.e. Privatization (until 1957), Nationalization (from 1957 to late 1970s), and Decentralization (from the late 1970s onward) (Hobley 1996). Initially, forests were managed by local community users which were nationalized after late 1950s. However, government realized that it is not possible to manage forests without involving local community users. Then after, decentralization was started in late 1970s by giving rights to local community to manage those resources.

From the time community forestry was adopted, there has been significant improvement in the management of forest resources. Community forestry in the hills has been a success story in Nepal and has been proved that the hill forests have been recovering rapidly with the community forestry management approach. Based on macro level studies and visual interpretation, it has been said that forest coverage and condition is significantly improving due to community forestry intervention (MFSC 2008; Pandit and Bevilacqua 2011). Community forestry is considered to be especially successful in terms of enhancing access to forest products by local communities, improving livelihood opportunities, and improving ecological conditions of the forest.

Community forests play an important role in fulfilling primary necessities (e.g. fuel wood, timber, fodder etc.) for rural livelihood. More than ninety percent of Nepal's population lives in rural area, where forests are an essential part of their rural livelihood. Sixty-nine percent of households use firewood for cooking, sixty-one percent of

households collect fuel wood from community forests as well as from government forests and seventy-five percent of people collect fodder for various purposes (Pokharel and Byrne 2009). Community forestry has net positive effect on livelihood leading to a direct and indirect positive impact on rural livelihoods and welfare (Ojha et al. 2009). Community forests have direct effect on rural livelihood from sustaining their lives through fulfillment of primary necessities as well as improving their livelihoods by generating income through selling of forest products within and outside the CFUGs. Thus, community forestry has made rural lives easier in terms of providing forest resources for their daily livelihood, and is a promising sector for social, environmental, and economic development.

Food and Agricultural Organization (FAO) has estimated that Nepal's forestry sector contribute 3.5% to the country's Gross Domestic Product (GDP) in the year 2000 and 4.4% for the period of 1994-2000. Likewise, it has been estimated that forestry sector alone contribute 15% to the country's GDP (MFSC 2008). Now, the role of forest has been changed from basic needs fulfillment to broader focus of social, environmental, and economic extents. Community forests are moving towards commercialization of forest resources besides simply managing their forests. During 1970's and 1980's priority in community forestry was in supply of forest products to fulfill basic needs (Gilmour and Fisher 1991), later priority shifted towards development of institutionally robust community groups and economically productive forests for the maximization of economic benefits (Hobley et al. 1996). Now, the priority is in commercialization of forest products to generate increased financial benefits (Paudel et al. 2010).

Community forestry has shifted its focus from environmental protection to various social and political agendas such as good governance, poverty reduction, and democratic practices. Community forestry is successful in fulfillment of basic needs of people and is known for their positive impacts like improving the ecological conditions of forest, enhancing biodiversity, good governance, and community development etc. Nevertheless, there exist several issues that are still prominent in community forestry such as equity issues, exclusion, institutional corruption etc. which equally have negative impact on it. Therefore, it is essential to look at community forestry from the perspective of forestry experts and community users to evaluate these positive and negative features, so that their perspective can be considered and incorporated in the formulation and implementation of policies in the future.

Recently, community groups are thriving in collaboration and partnership with external institutions like Non Governmental Organizations (NGOs), private sectors, academics, and political forces (Chapagain and Banjade 2009). Therefore, community forestry is an interface between local communities and external factors (Paudel et al. 2010). Thus, looking at the changes that are taking place in community forestry in Nepal, it becomes even more essential to analyze forestry issues both from experts' and community users' perspective, so that necessary steps could be taken forward to strengthen community forestry in Nepal.

Research Objectives

This research project has three objectives namely; (1) to identify the positive features and challenges of community forestry by utilizing the knowledge of forestry experts and community users; (2) to compare three major forest types in the mid hills based on their relative benefits to conservation and local communities using expert and user focus groups; and (3) to assess the potential revenue from managing chir pine (*Pinus roxburghii*) for carbon offset payment, timber and resin. SWOT analysis and AHP with the help of focus group discussions were used for the first two objectives. For third objective, primary as well as secondary data were used with a Hartman model to do an economic analysis of *Pinus roxburghii* for carbon offset payment, timber and resin benefit.

Assessing Experts' and Community Users' Perception on positive features and challenges of Community Forestry

This objective combines AHP with SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis in order to analyze positive and negative aspects of community forestry. The concept of SWOT-AHP has not been used so far in analyzing forestry issues in Nepal. Therefore, this research will use this concept for the first time for analytical study of forestry issues. It is essential to know SWOT factors in community forestry and their relative importance because those factors have tendency to affect community forestry. The concept of SWOT-AHP is very useful in decision making process. The combination of SWOT-AHP is always appropriate and can be more informative than doing SWOT analysis alone. SWOT analysis allows participants in a

focus group discussion to identify factors (Strengths, Weaknesses, Opportunities, and Threats) but does not quantitatively analyze those factors.

AHP on the other hand allows comparison of factors within each category of strengths, weaknesses, opportunities and threats as well as among those categories. Therefore, AHP technique developed by Saaty (1977) is combined with SWOT analysis that helps in estimating the relative importance of each identified factor. SWOT-AHP is very effective for strategic management of any organization or system. It has been extensively used in various fields by different researchers (Kurttila et al. 2000; Masozera et al. 2006; Dwivedi and Alavalapati 2009; Stainback et al. 2011; Catron 2012). They found it appropriate for incorporating peoples' perception in the decision making system which effectively and precisely analyze their perception through quantitative information.

Focus group discussion was carried out separately with experts and community user groups in Kaski district (Figure 1.1). They separately identified and compared those factors. The reason behind doing this study with community users and experts separately was because they might have different perceptions about the subject matter. Therefore, it could be more informative than it would have been while doing with experts and community users in a single group. Community user groups might identify and compare factors and their importance differently than by forestry experts because they are completely at two different levels. The way community users understand community forestry at user's level could be different than the way experts understand. Hence, the idea of analyzing SWOT factors with experts and community user groups separately was developed.

Comparison of three major forest types of the mid hills based on their relative benefits to conservation and local communities using expert and user focus groups

This objective uses the concept of AHP to compare three different forest types (*Pinus roxburghii*, *Alnus nepalensis*, and *Schima-Castanopsis*) of mid hills region of Nepal. These three major forest types have been compared based on their relative benefits to conservation and local communities. The meaning of forest management in community forestry has changed dramatically over the last ten years (Pokharel et al. 2007). The market is playing significant role in deciding which forest types are worth growing (Paudel et al. 2010). Most importantly, the priority in community forestry has been shifted towards commercialization along with environmental protection from simply supplying forest resources to local communities for basic needs fulfillment. Therefore, it is essential to compare these forest types to analyze their effectiveness for meeting dual goal of conservation and local benefits.

Focus group discussion was carried out separately with conservation experts (for conservation) in Kaski district and with local community users (for local benefits) in Kaski, Parbat and Baglung district (Figure 1.1). Local community users are more familiar with the benefits that are received from each forest type; therefore, comparison can be more effective than it would have been while doing with conservation experts. Because local communities are the real users of forest resources, they probably have the best idea about the effectiveness of each forest types for each local benefit factors. Likewise, for conservation, conservation experts can better compare those forest types for each conservation factors because local users' knowledge would be more specific to the local

area. Therefore, conservation experts are perhaps the best source to compare these forest types in the regional context.

Assessing the potential revenue from managing chir pine (*Pinus roxburghii*) for carbon offset payment, timber and resin

In this objective, an economic analysis of *Pinus roxburghii* takes into account for carbon offset payment, timber and resin. This forest type is mainly used as timber and resin. Nevertheless, economic benefit could be increased significantly if income from carbon offset payment is considered along with benefit from timber and resin. With the increased scope of carbon markets in the face of climate change and global warming, carbon sequestration is a potential benefit from this forest type. It takes into account for timber, resin and carbon benefits and considers decay functions and management costs. The Hartman model (1976) has been used for economic analysis which basically includes timber and non-timber benefits into calculation. Primary as well as secondary data has been used to carry out this economic analysis. Primary data refers to those data that were collected from field visit or by contacting users and experts. Similarly, secondary data are those data that were used by reviewing published and unpublished literatures.

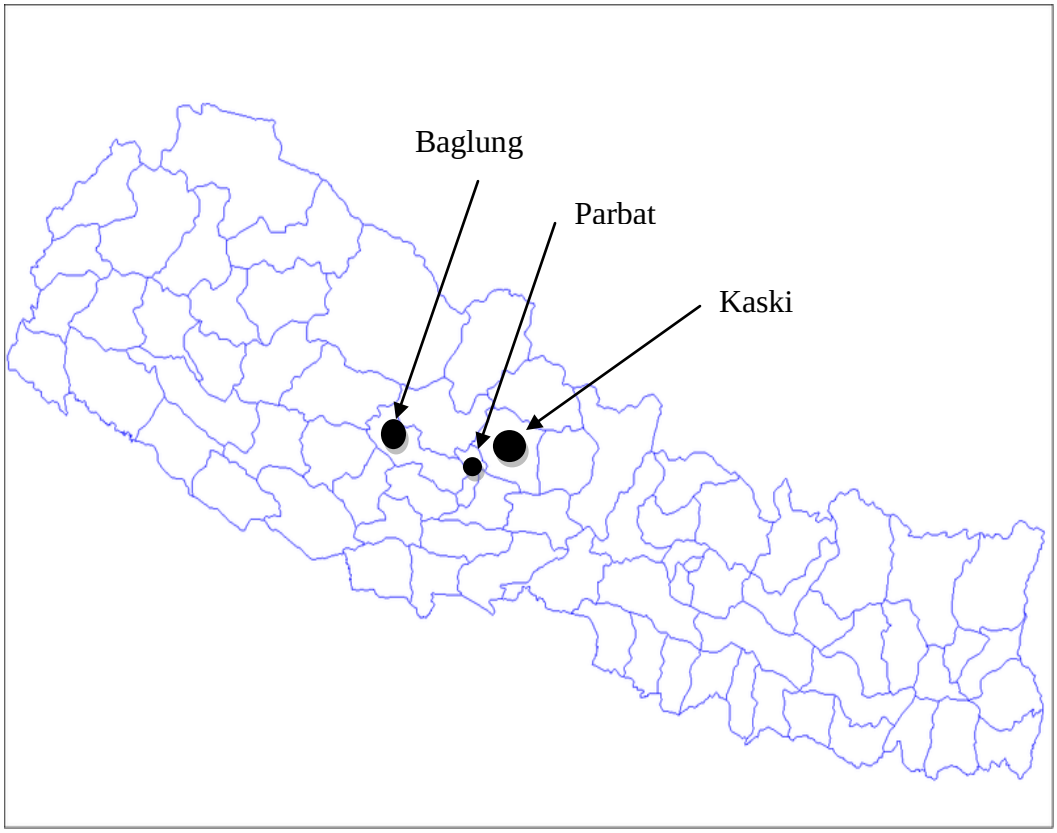


Figure 1.1: Map showing study area (Kaski, Baglung and Parbat district)

Chapter 2: SWOT-AHP Analysis in Community Forestry

Introduction

SWOT-AHP analysis in community forestry is an important step to inform policy makers about internal (strengths and weaknesses) and external (opportunities and threats) factors and their relative importance in community forestry. According to Kotler (1988), external factors can be classified based on their attractiveness and success probability (opportunities) and seriousness and probability of occurrence (threats). Likewise, internal factors can be classified based on their performance and importance. Both forestry experts' and community users' perspective on SWOT factors is important for sustainable management of community forestry. Their perspective on SWOT factors can have significant input in the policy formulation and implementation, making community forestry program even more effective. For any program or organization, it is important to incorporate feed back in the decision making process. SWOT-AHP analysis, particularly in this context will inform about the positive and negative aspects of community forestry along with their potentiality to affect the system. Thus, it will give an opportunity to inform policy makers about the positive side of community forestry and potential threats at the same time.

From the time community forestry was institutionalized, priority has been shifted from supply of forest products (Gilmour and Fisher 1991) to development of institutionally robust community groups and economically productive forests for the maximization of economic benefit (Hobley 1996), and now towards commercialization of forest products to get increased financial benefits (Paudel et al. 2010). The priority shifting from environmental protection and supply of forest resources to

commercialization of forest products is significant. This change in community forestry has led to systematic management of financial resources in some cases and corruption and mismanagement in others (Paudel et al. 2010). Also, there are various issues such as elite dominancy, exclusion, institutional corruption etc. which are still thriving in community forestry.

In order to continue community forestry as a successful program in the future in the presence of priority shifting scenario as well as other issues, it is absolutely necessary to inform policy makers about the factors affecting community forestry and the factors that could potentially affect it in the near future. In the context of commercialization of forest products in community forestry, it is important to notice that the market cannot operate in itself just based on demand and supply curve; rather there is alliance among community elites, forest bureaucrats and contractors (Paudel et al. 2010). Here, assessing the perception of forestry experts and community users will provide information regarding importance of internal and external factors in community forestry that will help analyzing present scenario and the future direction to be taken for sustainable management of community forests.

Several studies in the past have found SWOT-AHP analysis to be very useful in a decision making process. Kurttila et al. (2000) used SWOT-AHP in Finnish case study on forest certification where they found this technique useful. They concluded that this technique analyzes the situation more precisely and in more depth. Likewise, Masozera et al. (2006) used similar concept in assessing the suitability of community-based management for the Nyungwe forest reserve, Rwanda. They analyzed the perceptions of representatives from different stakeholders towards the suitability of community-based

management approach to the Nyungwe forest reserve in Rwanda. Also, Dwivedi and Alavalapati (2009) studied stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. Similarly, Stainback et al. (2011) used the same technique to study the perception of various stakeholders about smallholder agroforestry adoption as a strategy for smallholder farmers in Rwanda by investigating SWOT framework with AHP. SWOT framework with AHP give quantitative information on identified factors and analyzes it more accurately and therefore, considered this hybrid technique to be very useful and effective.

Methodology

SWOT-AHP Framework

SWOT analysis is a strategic management tool that helps to identify internal strengths and weaknesses and external opportunities and threats for any organization, project, or individual (Houben et al. 1999; Dyson 2004; Dwivedi and Alavalapati 2009). In general, SWOT analysis identifies internal and external factors that affect strategic decisions, but it does not quantitatively rate those factors based on their importance in strategic decisions which is a limitation of SWOT analysis. However, the use of AHP with SWOT analysis makes it possible to compare factors identified within each SWOT category as well as among those categories quantitatively. The importance of each factor from each SWOT category and an effect of each single factor in overall decisions can be assessed quantitatively with the help of AHP (Saaty and Vargas 2001). Therefore, SWOT analysis is combined with AHP. Initially, Kurttila et al. (2000) developed an idea of combining SWOT with AHP. Since then, the idea of combining SWOT analysis with AHP has been used extensively by researchers. However, it is recommended that the

factors should not exceed 10 because the number of pairwise comparison increases rapidly with the increase in number of factors identified (Saaty 1980).

SWOT-AHP is conducted in three step process. The first step includes identification of SWOT factors that lists factors important to each category. In the second step, pairwise comparisons are made within each category using the fundamental scale developed by Saaty and Vargas (2001). Table 2.1 shows the fundamental scale for comparison. Comparisons are made based on the relative importance of one factor over another factor (Figure 2.1). The eigenvalue method is used to calculate a local priority value for each factor for the entire set of comparisons. The factor with the highest priority value from each SWOT category is brought forward for further comparison. In the third step, the four most important factors, one from each category representing that particular category is compared and scaling factor or global priority value for each category is determined. Finally, a scaling factors or global priority values and local priority values are used to calculate the overall priority of each factor. The process of determining the overall priority of each factor is presented below:

$$\text{Overall priority of factor}_{ij} = \left(\text{Priority value of factor}_{ij}\right) * \left(\text{Scaling factor of SWOT category}\right) \tag{2.1}$$

The overall priority of each factor calculated in this way can be used to rank the importance of factors identified. The sum of overall priority values equals to 1 and the factor having value closer to 1 would be more important in comparison to other factors. Therefore, ranking of importance of each factor is made with the help of overall priority values.

For estimation of relative priorities, results from pairwise comparison can be represented in a reciprocal matrix where relative weight enters into the matrix as a_{ij} and it's reciprocal on the opposite side of the main diagonal as $1/a_{ij}$.

$$A = a_{ij} = \begin{pmatrix} w_1 / w_1 & w_1 / w_2 & \cdots & w_1 / w_n \\ w_2 / w_1 & w_2 / w_2 & \cdots & w_2 / w_n \\ \vdots & \ddots & \cdots & \vdots \\ w_n / w_1 & \cdots & \cdots & w_n / w_n \end{pmatrix} \tag{2.2}$$

In a matrix A, rows represent the ratios of each factor with respect to the others. When i=j, a_{ij}=1. When the transpose of the vector of weights w is multiplied by matrix A we get a vector represented by λmax w, where

$$\mathrm{Aw} = \lambda_{\max} \mathrm{w}, \text{ where } \mathrm{w} = \left(\mathrm{w}_1, \mathrm{w}_2, \ldots \mathrm{w}_n\right)^{\mathrm{T}} \tag{2.3}$$

$$\left(\mathrm{A} - \lambda_{\max} \mathrm{I}\right) \mathrm{w} = 0 \tag{2.4}$$

λ_{max} w is the largest eigen value of matrix A and w is the transpose of the vector of weights.

I refer to the identity matrix. The λ_{max} is equal to or greater than n or the number of rows or columns in the matrix A (Saaty 1977). The more consistent the responses are with each other, the closer λ_{max} is to n. If the pairwise comparisons do not include any inconsistencies, λ_{max} = n (Kurttila et al. 2000). In human decisions making, some inconsistency can be expected and therefore a consistency of 10% or less is generally deemed acceptable (Saaty 2004; Kurttila et al. 2000; Catron 2012). Matrix A can be tested for consistency using the following formula:

$$CR = CI / RI \tag{2.5}$$

$$CI = \left(\lambda_{max} - n\right) / \left(n - 1\right) \tag{2.6}$$

CR= consistency ratio

CI= consistency index

RI= consistency index of a random matrix of order n.

SWOT-AHP Application

Five focus group discussions were conducted with community users and one with forestry experts for identification of SWOT factors in community forestry and for pairwise comparisons. Twenty experts participated in a focus group discussion (June 9, 2011) which was held at Institute of Forestry, Kaski, Nepal. The experts here refer to a group of people from different organizations working in forestry issues in Nepal, people from academia, and government. There was a representation from Federation of Community Forest Users' Nepal (FECOFUN) and Community Based Forest Management in the Himalayas (ComForM); professors from Institute of Forestry, Tribhuvan University, Pokhara; Government Forest Officers and Rangers working in different districts of the country.

Participants were contacted to participate on a focus group discussion and were informed about the objective of doing focus group discussion. They were also provided with a list of SWOT factors that were identified during informal contacts with forestry experts (i.e. government officers and rangers from Kaski, Tanahun, Parbat, Baglung, Myagdi, Syangja, Palpa districts). A short presentation was given before identification of

factors and pairwise comparison to make participants familiar with the process of identification and comparison.

After a short presentation, all the participants were asked to identify SWOT factors individually. Again, all the participants were requested to discuss their listed SWOT factors. A list of possible SWOT factors was made. And finally, a new list of SWOT factors was made through group discussion. With that final SWOT factors, pairwise comparisons were made (Figure 2.1). The fundamental scale developed by Saaty and Vargas (2001) was used for comparing factors (Table 2.1). Consistency ratio was below 10% throughout the comparisons. During pairwise comparisons, firstly, comparisons were made within each group and then most important factor (with the highest priority value) from each category was chosen. The four most important factors from each category were further compared representing their group. The factor priority was determined from the comparison of those most important factors which was further used to calculate the global priority of each identified factors in each category.

Similarly, the focus group discussion with local community users was conducted in Kaski district. The following three criteria were made to select CFUGs for conducting a focus group discussion:

I. Community forest handed over before 10 years
II. Number of households more than 50
III. Area of the forest more than 50 ha

There were total of 459 CFUGs in Kaski district which were narrowed down to 52. Five CFUGs were randomly selected from a group of 52 in order to carry out focus group

discussion with the user groups. Each focus group consisted of 10-15 people. These criteria were made to reduce the number of CFUGs because the numbers of CFUGs in the district were very high (i.e. 459). Also, these criteria give good representation among the CFUGs because the selected CFUGs are older (i.e. handed over before 10 years) with high population (number of households more than 50) and large area of community forest (i.e. area of the forest more than 50 ha).

The users from those selected community forests were contacted in advance in order to schedule a meeting for discussion. A list of potential factors was made during contacts with experts and meeting with key informant. Key informants are persons who are either involved with an issue as a regular part of their job or as part their volunteer activity or knowledgeable about the community, its citizens and history (Maurer 2002). This list was then made available to users to familiarize them with the possible factors and also to encourage them to participate actively on a discussion. The fundamental scale (Table 2.1) and the process of comparing factors were same as it was with the experts (Figure 2.1). Since five focus group discussions were carried out with CFUGs, their AHP weightings were aggregated. The geometric mean method (Xu 2000) was used in order to aggregate their responses for the comparison. The geometric mean method is the most common group preference aggregation method in AHP. Judgments from all the focus group discussions were weighted equally which were finally analyzed using Expert Choice 11.5 that provided priority values for each SWOT category (Expert Choice Inc. 2010).

Results and Discussion

SWOT-AHP (Community users)

SWOT-AHP results from community users, *management and conservation of forest resources* found to be the most important strength followed by *social integrity*, *basic needs fulfillment*, and *community development* respectively. Similarly, for weaknesses, *impracticality of forest policy* was the most important weakness followed by *lack of cooperation within user groups* and *lack of technical assistance*. Likewise, *increased scope of resource conservation and management* was the most important opportunity with *biodiversity enhancement*, *help in livelihood improvement*, and *ecotourism development* to be the 2nd, 3rd, and 4th important opportunities respectively. Within the threats category, *forest fire* was the most important threat followed by *overstocking* and *conflicts* respectively (Table 2.2, 2.3 & Figure 2.2).

SWOT-AHP (Forestry Experts)

On the other hand, SWOT-AHP results from forestry experts says that *basic needs fulfillment* was the most important strength followed by *management and conservation of forest resources*, *community development*, *leadership development*, and *social integrity* respectively. Similarly for weaknesses, *equity issue not addressed* was the most important weakness followed by *technical resource management in shadow*, *donor driven CF management*, *obstacles to the poor due to controlled access*, and *participatory exclusion* respectively. For opportunities, *increased scope of resource conservation and management* was the most important opportunity followed by *help in livelihood improvement*, *networking between stakeholders*, *good governance*, and *scientific forest management* respectively. For threats category, *changing political scenario of the country*

was the most important threat followed by *institutional corruption*, *political aberration*, *exclusion*, and *organizational encroachment* respectively (Table 2.2, 2.4 & Figure 2.3).

Strengths

Community users identified four factors in strength category i.e. *social integrity*, *basic needs fulfillment*, *management and conservation of forest resources*, and *community development*. Community forest users as well as a group of expert think that unity within the community regarding management and utilization of forest resources is very important. *Social integrity* is the one that enhances management and conservation of forest resources more effectively. They think that community forestry program is promoting social integrity. CFUG is a strong medium at local level that enables people to think and discuss about their resources themselves (Timsina 2002). Their common interests and needs bring them together that maintain unity within the CFUG. Likewise, *basic needs fulfillment* is also an important strength for community users and experts because community forest is playing a vital role in supplying forest products (i.e. fuel wood, timber and fodder) to local community users. Pandit and Bevilacqua (2011) found that CF in hills has increased forest product supply during assessing the perception of socio-economically heterogeneous forest users.

Since community forestry was initiated, its main priority was to reduce deforestation rate and conserve forest. Community forestry so far is very successful with its previous objective because forest condition is improving due to community forestry intervention (MOFSC 2008). Yadav et al. (2003) also found that community forestry impact on forest resources has been very positive. No matter whether the priority is in commercialization of forest products in order to increase the net benefit to the local

people, it will still continue to conserve and manage forest resources in a more effective way. Hence, community forest users and experts viewed *management and conservation of forest resources* as the most important strength of community forestry. Likewise, *community development* is another important factor in strength category for both users and experts. The significant portion of CFUGs fund are mainly utilized for community development activities such as development of rural infrastructure (roads, schools, irrigation channels, drinking water etc.) and this type of community development activities has increased substantially over the last ten years (Paudel et al. 2010). Therefore, both users and experts viewed *community development* as one of the important strengths of community forestry.

However, forestry experts identified *leadership development* additionally to the strength category. Forestry experts think that there has been significant improvement in leadership development due to community forestry program. Currently, users are ready to take a lead within the group and voice their opinion. In fact, there should be a proportionate representation of poor, dalit[1], women, indigenous people and ethnic group during formation of user group. There should be 50% representation of woman representing these groups and remaining 50% should include proportionate representatives from poor, dalit, indigenous people and ethnic groups. Similarly, either chairperson or secretary should be a woman (DoF 2009). Dalits are one of the groups of people within Hindu caste system whose social, economic, health status and political conditions are lowest compared to other caste in Nepal (Gaire 2007). This would provide

[1] Dalit includes Damai, Kami, Sarki, Badi, Gandarba, Pode, Khadgi, Dhobi, Kaar, Kakaihlya, Kori, Khatik, Chidimar, Tatma, Patharkatta, Pasi, Bantar, Mester (Halkhor), Sarbanga, Chamar, Musahar, Dusa (Pasman), Dom, Halkhor, Khatwe (DoF 2009)

an opportunity for women and other groups to develop their leadership who were supposed to be the passive users in the society.

Weaknesses

Community users think that existing forest policy has not been implemented in grass root level. According to the guidelines for community forestry development program, at least 25% of income from community forest should be used in forest development, protection, and management of community forest. Similarly, 35% of the income should be mobilized for the program targeting poor (women, dalit, indigenous people and ethnic group) as identified by the participatory well being ranking (DoF 2009), but it is unlikely to happen. Although *social integrity* was identified as one of the strengths, *lack of cooperation within user group* is second important weakness for them. They mentioned that there still exists uncooperativeness within user groups whenever time comes for making decision unanimously, and executive committee members in CFUGs have to take complete responsibility on behalf of the entire community users. Likewise, *lack of technical assistance* is another weakness identified by community users. For example, community users mentioned that they don't get enough technical assistance for carrying out forest management activities which is essential for effective management of community forests. Giri and Ojha (2010) found similar results from their study i.e. there is inefficient service provisioning from state forest officials.

A group of forestry experts have identified a completely different set of weaknesses that from community users. They think lack of equity to be the most important weakness because elite dominancy still exists and the poor are marginalized. Equity, in general, entails fair distribution of resources, rights, opportunities and wealth

among people over time (Agarwal 2001; Kothari 1999; Bhattarai et al. 2009). Although commercialization in community forestry has been the most important priority, it has benefited local elite members, government officials and contractors where marginalizing the poor people (Iversen et al. 2006; Yadav et al. 2008). Community forestry is criticized for not being able to address the needs of women, low caste and poorer segments of society who are the real users of forest (Hobley 1991; Baral 1993; Graner 1997; Timsina 2001; Parajuli et al. 2010). The poor, disadvantaged and socially marginalized groups are often ignored or excluded from participating in decision making in most communities (Gilmour and Fisher 1991; Baral 1993; Graner 1997; Parajuli et al. 2010). The issue of equity and poverty within community forestry has not been adequately addressed (Timsina and Luintel 2003; Bhattarai et al. 2009). Similarly, *technical resource management in shadow* is the second important weakness for experts because according to them, community forestry does not follow any scientific management principles. Therefore, in the absence of technical forest management, community forestry is somehow not getting there where it really needs to be.

Similarly, forestry experts viewed *donor driven community forestry management* as one of the weaknesses because they think that community forestry is highly influenced by donor agencies and are more dependent in terms of carrying out several activities in the user's level and have influence on decision making. The partnership developed by CFUGs with multiple institutions and individuals including donor agencies, NGOs and local government has created conditions by which voices and interests of the outsiders are stronger in community affairs (Paudel et al. 2010). In addition, community forests are managed based on operational plan where there are certain rules and regulations for

utilization of forest resources. These limitations for resource use pattern significantly affect poor segment of the society. Hence *obstacle to the poor due to controlled access* is one of the weaknesses. Lastly, *participatory exclusion* is another weakness where few people in CFUGs take decision on behalf of the entire users. The users are involved during decision making but they are passively involved in the process. Although social relationship and patterns of interaction have changed over time, access and control of the poor, women and dalits to the institution and resources are still minimal. During attending meeting, assemblies and various other activities, their presence is merely physical, without actually voicing concerns and expectations (Timsina 2002).

Opportunities

For opportunities, both the group identified *increased scope of resource conservation and management* as one of the most important opportunities. Although community forestry played significant role in controlling deforestation and promoting sustainable management, it still has greater scope in conservation of forest resources regardless of other priorities in community forestry. Hence, both users and expert viewed *increased scope of resource conservation and management* as one of the most important opportunities. Community users identified *biodiversity enhancement*, *help in livelihood improvement*, and *ecotourism development* to be the 2nd, 3rd, and 4th important opportunities respectively. Likewise, result from experts reveals that *help in livelihood improvement*, *net working between stakeholders*, *good governance*, and *scientific forest management* to be the 2nd, 3rd, 4th, and 5th important opportunities respectively.

Again, both users and expert group viewed *help in livelihood improvement* as one of the opportunities because community forestry has several programs including development of infrastructure in the community, reducing poverty by introducing pro-poor programs such as income generating activities, soft loans, scholarship etc. There is a provision that at least 35% worth cash or kind or both should be spent on livelihood improvement of the poor (DoF 2009). Also, there is a promotion for development of forest based enterprises that can utilize raw materials available in the forest. Some CFUGs are involved in paper making and producing juice from fruits that engage local people in income generation activities. Thus, community forestry is a promising sector for rural people to use their forest resources in the local level for livelihood improvement.

Community users perceived *biodiversity enhancement* as one of the important opportunities because they think that community forestry could be equally important for establishing diversity in terms of forest flora and fauna besides managing forest resources for supply of forest products in order to fulfill daily needs. In addition, community users viewed *ecotourism development* as one of the important opportunities of community forestry as tourism is the important source of income for the country and is a potential sector for economic development of the country. On the other hand, expert group see *net working between stakeholders* as another important opportunity because with the development of community forestry, it provides ample opportunities to establish good networking among stakeholders.

Good governance was another opportunity identified by expert group. Several actions practiced in community forestry such as discussion about the income, expenditure, programs and decisions made by the group among user groups; involvement

of poor, dalit, women, disabled, ethnic group in the decision making process etc. helps strengthening good governance in community forestry and those actions have been recommended and promoted in order to improve transparency and accountability within user group (DoF 2009). Although forestry experts identified *technical resource management in shadow* as a weakness, they still believe that *scientific forest management* as an opportunity of community forestry.

Threats

Community users identified three factors in threats category. They think *forest fire* to be the most important threat with *overstocking* to be the second most important threat and *conflicts* to be the least important threat. On the other hand, forestry experts identified five different threats where *changing political scenario of the country* was viewed as the most important weakness. They mentioned that conflicts and biases within user groups due to political reasons are directly affected by the changing political scenario of the country. Thus, they think political instability in the country to be a major threat to community forestry. *Institutional corruption* was found to be the second important threat. A group of experts mentioned that corruption does occur in community forestry that is negatively affecting community forestry. Although systematic management of financial resources is there in some cases, corruption and mismanagement is prevalent most of the time (Paudel et al. 2010). Also, *political aberration* is something that is harming community forestry. Political aberration here refers to deviation of people's attitude and behavior due to political reasons from their responsibility within user group. According to users, bias and lack of cooperation within user group are created due to political reasons most of the time.

Likewise, *exclusion* was viewed as another potential threat by forestry experts. Sometime people are not involved in CFUGs and are excluded from the management and utilization of the forest resources. This is because community users tend to avoid a group of people who did not play any role during formation of community forests or someone who migrated after community forest was already formed. The people who are excluded from becoming a part of community forests are believed to involve in illegal extraction of forest resources. Therefore, *exclusion* was seen as a threat to community forestry. Lastly, *organizational encroachment* was viewed as one of the threats by a group of experts. They think that some organizations are encroaching part of national forest in the name of urban squatters, particularly common in western terai. And those organizations being close to some political parties are not penalized. The national forest which can potentially be managed as community forest has been reducing. Therefore, encroachment by some organizations over national forest is a potential threat to community forestry.

In overall, *management and conservation of forest resources*, *impracticality of forest policy*, *increased scope of resource management and conservation*, and *forest fire* found to be the most important strength, weakness, opportunity, and threat from the SWOT-AHP result with community users. For community users, the combined positive priority value (strengths and opportunities) was 0.762 (76%) which is much bigger than the combined negative priority value (weaknesses and threats) i.e. 0.238 (24%). Similarly, from the SWOT-AHP results with forestry experts, *basic needs fulfillment*, *equity issue not addressed*, *increased scope of resource conservation and management*, and *changing political scenario of the country* were found to be the most important factors representing each category. For experts, the combined positive priority value

(strengths and opportunities) was 0.685 (69%) which is much bigger than the combined negative priority value (weaknesses and threats) i.e. 0.314 (31%). Hence, both the group (i.e. community users and forestry experts) think that community forestry dominates weaknesses and threats with its strengths and weaknesses.

Conclusions

This study takes advantage of utilizing the knowledge of both community users and forestry experts in analyzing the positive features and challenges in community forestry in Nepal. It can be concluded from the results that community users and forestry experts think strength and opportunities of community forestry to be more important than its weaknesses and threats. The result shows that *management and conservation of forest resources* is one of the most important strengths of community forestry realized by both experts and community users. The previous studies have also indicated that community forestry is successful in forest conservation (Yadav et al. 2003; Thoms 2008). *Social integrity* is an important factor in community forestry because management of community forestry requires cooperation among users, and local users have to maintain that integrity to conserve that common resource. But, lack of cooperativeness and conflicts still exist within and among CFUGs due to exclusion, controlled access to the poor and elite capture. Several studies have shown that elite members of the society tend to occupy all the key positions of the executive committee and to make decisions regarding harvest, product distribution and mobilization of fund (Baral and Subedi 1999).

Community forestry plays a vital role in supplying forest resources to fulfill the basic needs of local users. At the same time, community forestry supports for community development through development of rural infrastructure (i.e. schools, road, irrigation

channels etc.). Additionally, community forestry enhances leadership development among community users because there are several provisions in community forestry where poor, women, dalits, indigenous people and ethnic group are empowered. Therefore, community forestry is important for conservation of forest resources, fulfilling daily needs for forest products (i.e. fuel wood, fodder, leaf litter etc.) along with leadership development and community development at the same time.

So far, community forestry is playing significant role in protection and conservation of forest resources. Both expert and community users think that community forestry will continue to play an important role in conserving forest resources regardless of any changes in the priority. Further, community forestry has created several opportunities where local users can benefit from and enhance their overall living standard such as involvement in income generation activities, development of forest based enterprises etc. Community forestry has net positive effect on livelihood (Ojha et al. 2009). However, Giri and Ojha (2010) found that livelihood outcomes are unlikely to be generated automatically through improved participation and strengthened local institutions such as CFUGs. Instead, improving livelihoods requires continuous system of innovation, market linkages and empowerment of the poor and disadvantaged. Again, the study done by Paudel et al. (2010) revealed that economic activities or commercialization in community forestry are found to be not pro-poor and the CFUG funds are distributed unequally.

Community users think that some policies are not implemented in the grass root level, especially the proportionate use of community fund. Also, community users have to take permission from state forest officials for harvesting timber from their own

community forests. They have to wait until they get permission from state forest officials which lengthen the process of harvesting. Thus, community users think this process to be very impractical. Giri and Ojha (2010) also found that many CFUGs have similar complaints about the procedures which increase complexity and blurs the autonomic functioning of CFUGs. Community users think that the assistance from state forest officials is lacking in many ways. Giri and Ojha (2010) also found that there is inefficient service provisioning from state forest official, e.g. lack of facilitation to end impasse in CFUG management, state forest rangers do not visit CFUGs by giving some reasons or visit only during harvesting periods (in terai).

Similarly, weak and inefficient internal governance within CFUGs such as elite capture, inequitable forest products distribution and benefit sharing mechanisms, and lack of access to and influence in forest decisions, can hamper equitable benefit sharing among forest users, with limited benefits going to marginalized groups (Agarwal 2001; Giri 2006; Nightingale 2011). Also, the extensive partnership developed by CFUGs with multiple institutions and individuals including donor agencies, NGOs and local government, has created conditions by which voices and interests of the outsiders are stronger in community affairs (Paudel et al. 2010).

The important lesson learned from this study is that there is domination of strengths and opportunities over weaknesses and threats. However, weaknesses and threats identified by both experts and users should be considered in the future because they have significant negative impact on community forestry. Thus, success of community forestry depends on addressing its weaknesses and threats along with strengthening its positive aspects on the other hand. Similar results from various studies

should be considered in the formulation and implementation of future policies. Community forestry cannot operate fully with its positive features when its weaknesses and threats continue to grow. Therefore, some strategies should be adopted to mitigate these weaknesses and threats.

From this study, it can be recommended that there should be a proper implementation of policy and a strong monitoring system to see if those policies are implemented in the grass root level. Similar recommendation (i.e. monitoring policy implementation) was made by Timsina (2002). Pokharel et al. (2007) suggested that mechanisms for policy amendment and revision for community-based forest management need to be based on real-life experiences rather than top-down decision making. In this study, policy that enhances scientific management of community forests through technical assistance of government forest officials can addresses weaknesses, opportunity, threat i.e. lack of technical assistance and technical resource management in shadow, scientific forest management, overstocking respectively. Careful planning during policy formulation and its effective implementation help in mitigating weakness and threats as well as strengthen its positive aspects. Several other macro and micro level studies, their results and recommendations should be seriously considered while formulating new policies and during their implementation.

Table 2.1: The fundamental scale for comparison

Intensity of importance	***definition***	***Explanation***
1	**Equal importance**	**Two activities contribute equally to the objective**
2 3	Weak **Moderate importance**	**Experience and judgment slightly favor one activity over another**
4 5	Moderate plus **Strong importance**	**Experience and judgment strongly favor one activity over another**
6 7	Strong plus **Very strong or demonstrated importance**	**An activity is favored very strongly over another; its dominance demonstrated in practice**
8 9	Very, very strong **Extreme importance**	**The evidence favoring one activity over another is of the highest possible order of affirmation**

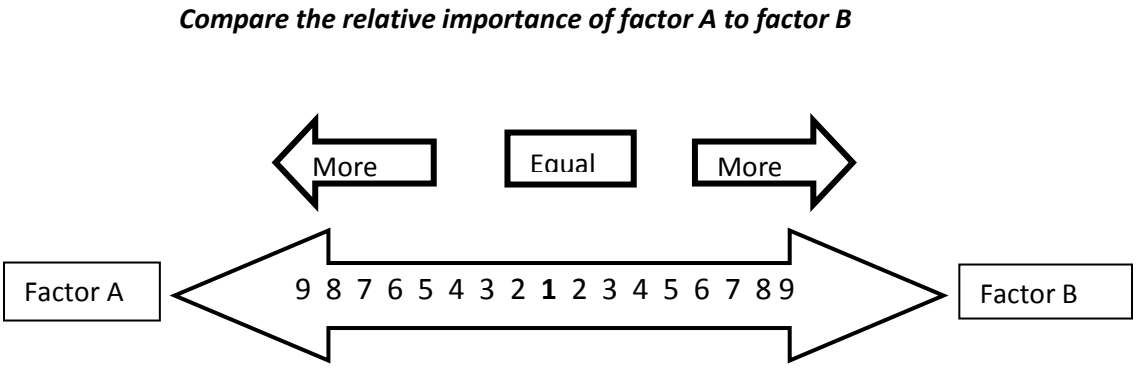


Figure 2.1: Graphical representation for pair wise comparison between two factors. If factor A is important than factor B then participants would move left from 1. 1 represents equal importance and moving from 2-9 either towards right or left would signify the factor is more important over another. 9 indicate extreme importance of that factor in comparison to other factor.

Table 2.2: SWOT factors identified by community users and forestry experts

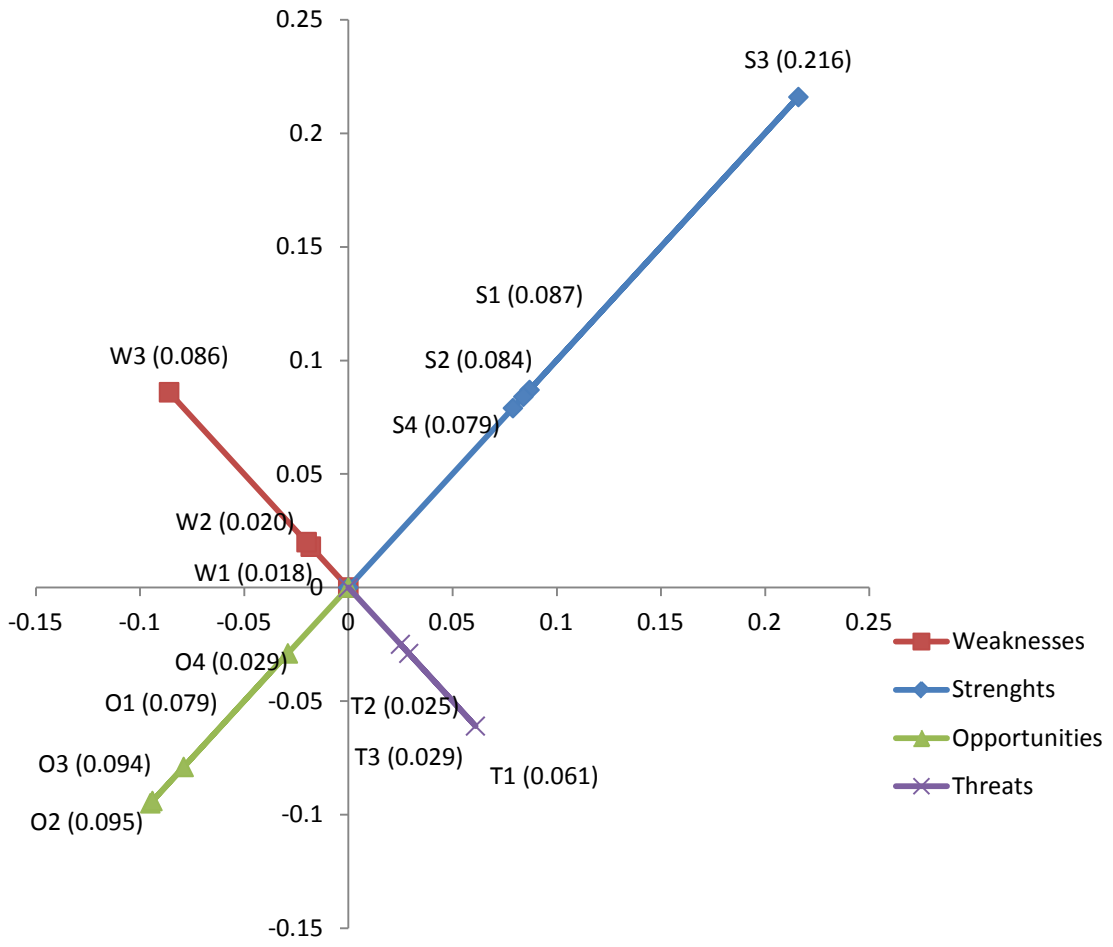
Community Users	**Forestry Experts**
Strengths: 1) Social integrity 2) Basic needs fulfillment 3) Management and conservation of forest resources 4) Community development **Opportunities:** 1) Help in livelihood improvement 2) Increased scope of resource conservation and management 3) Biodiversity enhancement 4) Ecotourism development **Weaknesses:** 1) Lack of technical assistance 2) Lack of cooperation within user groups 3) Impracticality of forest policy **Threats:** 1) Forest fire 2) Conflicts 3) Overstocking	**Strengths:** 1) Basic needs fulfillment 2) Management and conservation of forest resources 3) Community development 4) Social integrity 5) Leadership development **Opportunities:** 1) Increased scope of resource conservation and management 2) Help in livelihood improvement 3) Scientific forest management 4) Net working between stakeholders 5) Good governance **Weaknesses:** 1) Participatory exclusion 2) Equity issue not addressed 3) Obstacles to the poor due to controlled access 4) Technical resource management in shadow 5) Donor driven community forestry management **Threats:** 1) Political aberration 2) Institutional corruption 3) Organizational encroachment 4) Changing political scenario of the country 5) Exclusion

Table 2.3: SWOT factors and their priority scores for community users

SWOT group	Factor priority	Priority of the factor within the group	Overall priority of the factor
Strengths	**0.465**		
S1- Social integrity		0.186	0.087
S2- Basic needs fulfillment		0.180	0.084
S3- Mgt and conservation of forest resources		**0.465**	0.216
S4- Community development		0.169	0.079
Weaknesses	**0.123**		
W1- Lack of technical assistance		0.144	0.018
W2- Lack of cooperation within user groups		0.159	0.020
W3- Impracticality of forest policy		**0.698**	0.086
Opportunities	**0.297**		
O1- Help in livelihood improvement		0.266	0.079
O2- Increased scope of resource cons. & mgt		**0.319**	0.095
O3- Biodiversity enhancement		0.318	0.094
O4- Ecotourism development		0.097	0.029
Threats	**0.115**		
T1- Forest fire		**0.526**	0.061
T2- Conflicts		0.219	0.025
T3- Overstocking		0.254	0.029

Table 2.4: SWOT factors and their priority scores for forestry experts

SWOT group	Factor priority	Priority of the factor within the group	Overall priority of the factor
Strengths	**0.395**		
S1- Basic needs fulfillment		**0.376**	0.149
S2- Mgt and conservation of forest resources		0.266	0.105
S3- Community development		0.169	0.067
S4- Social integrity		0.081	0.032
S5- Leadership development		0.108	0.043
Weaknesses	**0.138**		
W1- Participatory exclusion		0.167	0.023
W2- Equity issue not addressed		**0.294**	0.041
W3- Obstacles to the poor due to controlled access		0.176	0.024
W4- Technical resource management in shadow		0.186	0.026
W5- Donor driven CF management		0.178	0.025
Opportunities	**0.290**		
O1- Increased scope of resource cons. & mgt		**0.282**	0.082
O2- Help in livelihood improvement		0.278	0.081
O3- Scientific forest management		0.103	0.030
O4- Net working between stakeholders		0.180	0.052
O5- Good governance		0.158	0.046
Threats	**0.176**		
T1- Political aberration		0.158	0.028
T2- Institutional corruption		0.243	0.043
T3- Organizational encroachment		0.111	0.020
T4- Changing political scenario of the country		**0.361**	0.064
T5- Exclusion		0.127	0.022



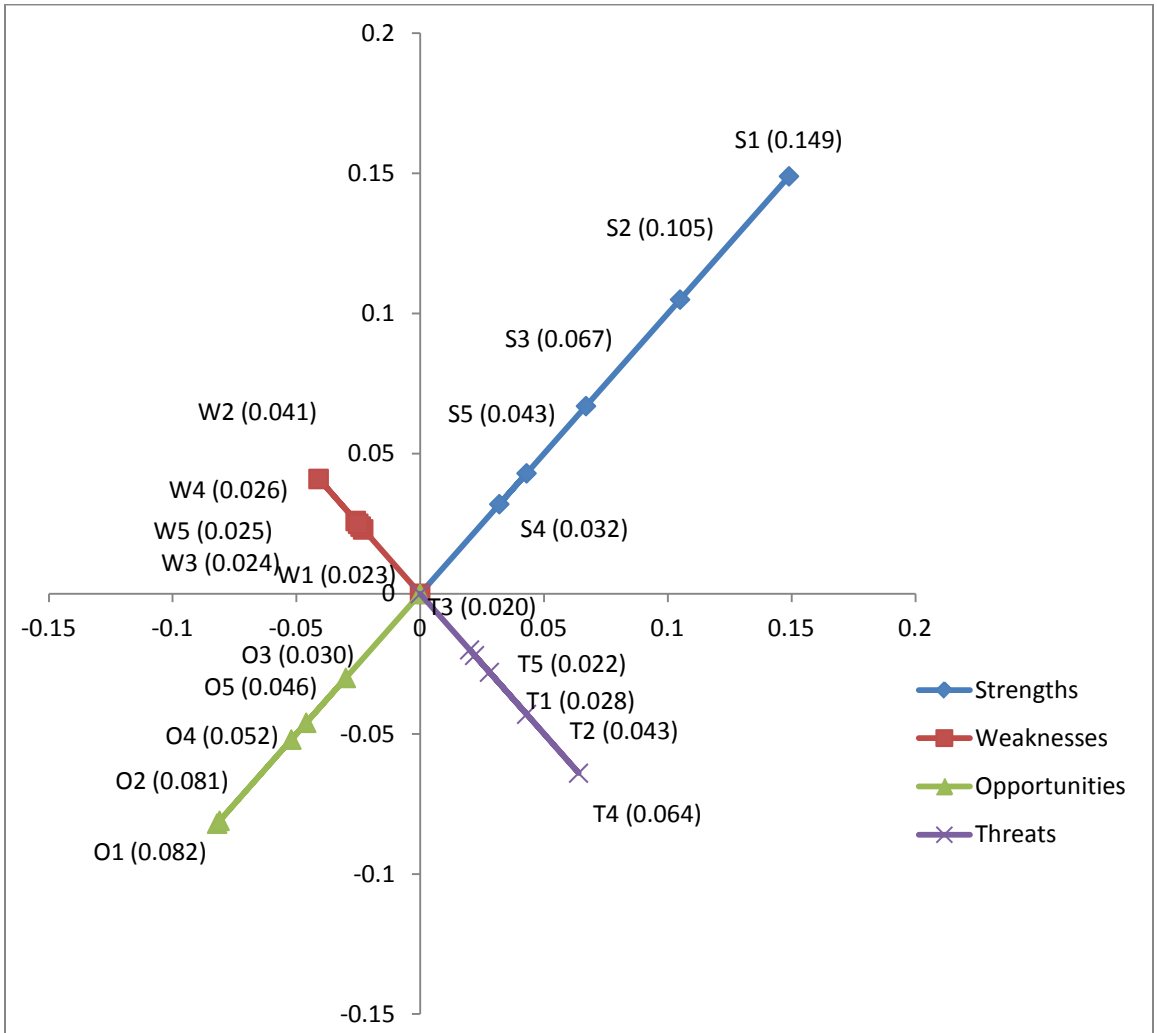
Weaknesses:
W1- Lack of technical assistance
W2- lack of cooperation within user groups
W3- Impracticality of forest policy

Opportunities:
O1- Help in livelihood improvement
O2- Increased scope of resource cons. and mgt
O3- Biodiversity enhancement
O4- Ecotourism development

Strengths:
S1- Social intergrity
S2- Basic needs fullfilment
S3- Mgt and conservation of forest resources
S4- Community development

Threats:
T1- Forest fire
T2- Conflicts
T3- Overstocking

Figure 2.2: Global priority scores of SWOT factors as determined through AHP analysis with community users



Weaknesses:
W1- Participatory exclusion
W2- Equity issue not addressed
W3- Obstacles to the poor due to controlled access
W4- Technical resource mgt in shadow
W5- Donor driven CF mgt

Opportunities:
O1- Increased scope of resource cons. and mgt
O2-Help in livelihood improvement
O3- Scientific forest mgt

Strenghts:
S1- Basic needs fulfillment
S2- Mgt and cons. of forest resources
S3- Community development
S4- Social integrity
S5- Leadership development

Threats:
T1- Political aberration
T2- Institutional corruption
T3- Organizational encroachement
T4- Changing politicaly scenario of the country

Figure 2.3: Global priority scores of SWOT factors as determined through AHP analysis with forestry experts

Chapter 3: Comparison of Three Major Forest Types of Mid Hills

Introduction

In this chapter, three major forest types of mid hills have been compared for conservation and local benefits. The three forest types are *Pinus roxburghii*, *Alnus nepalensis*, and *Schima-Castanopsis*. Most community forests in mid hills have one of these forest types or combination of these forest types. Community forests are the source of forest products and means of environmental protection in the region. Major benefits from community forests are fuel wood, fodder, timber, leaf litter along with some income generating activities. Likewise, they have additional use and importance besides supplying forest products to community users which is landscape conservation. Hence this study will look at the importance of these forest types for conservation and local benefits from community users' and conservation experts' perspective. This study uses AHP to analyze and compare these three forest types thorough identification of conservation and local benefit factors and their pairwise comparison.

Pinus roxburghii (Nepali name: khote salla, aule salla, and rani salla) is one of the major forest types of mid hills. Naturally, it has been distributed from Bhutan (only in drier areas), Northern India, Nepal, south of Tibet, Pakistan to Afghanistan (Dogra 1985; Yi and Raven 1999; Gauli et al. 2009). This species is very tolerant of poor soil conditions and can even grow on hard, eroded red clay loams if tended properly. *Pinus roxburghii* produces a useful constructional timber and a very valuable resin that is used in manufacture of turpentine, rosin and other products. It burns rapidly and produces a lot of smoke; however it is still used widely as fuel wood. It is the most widely planted forest tree in Nepal not only in community forests and government managed forest but also by

individual farmers. It is because this species survive and grow well on the areas of very poor soil which are often the only sites available for forestry plantations in the mid hills region (Jackson 1994).

Alnus nepalensis (Nepali name: utis) is a common and often gregarious species of mid hills of Nepal. Naturally, it has a wide range, descending as low as 500 m, but most common from 900 m upwards with extreme upper limit of 2700 m. At lower elevations, it is characteristic of moist sites such as ravines but is also a colonist of shaly and gravelly land exposed by landslips and of abandoned cultivation (Jackson 1994). Outside of Nepal it is found in the Himalaya as far west as Kumaon and in the east it reaches to Upper Burma. It is also a pioneer species that grows well on soils with high water content in full light. It does not require high soil fertility but prefers moist permeable soils. Although it is commonly occurs near streams and in other wet places, it can be planted in other sites too. However, it does badly on dry, exposed, ridge-top sites. It is also one of the trees species most favored by farmers for plantation, especially as a source of fuel wood, small timber, and in the east as a shade tree for certain crops (Jackson 1994).

Schima-Castanopsis is other common forest types of eastern and central Nepal of mid hills. In this forest type *Schima wallichii* occurs with *Castanopsis species* throughout the mid hills. Naturally, *Schima wallichii* is distributed between 900 and 2000 m, it forms the dominant forest type at these altitudes together with *Castanopsis species* on north-facing slopes in the drier areas and on both north and south facing slopes in wetter areas. It is occasionally found in association with *Pinus roxburghii* (Jackson 1994). Similarly, three different species of *Castanopsis* are *Castanopsis hystrix*, *Castanopsis indica*, and *Castanopsis tribuloides*. *Schima wallichii* is most commonly associated with *Castanopsis*

indica (Nepali name: dhale katus, banj katus) and *Castanopsis tribuloides* (Nepali name: musure katus).

Castanopsis indica grows between 1200 and 2900 m. It is found in higher elevation *Shorea robusta* forest, and in association with *Schima wallichii*, is very common in high rainfall areas in the Annapurna region and east Nepal. However, in lower rainfall areas it tends to be less common than *Castanopsis Tribuloides*. *Castanopsis indica* is used for buildings and shingles, and also lopped for fodder. However, only the mature leaves are used mainly for sheep and goats. Likewise, *Castanopsis tribuloides* is the most widely distributed species of *Castanopsis* in Nepal which grows between 450 and 2300 m, being common in higher elevation *Shorea robusta* forests, in the extensive *Schima* forests between 1000 and 2000m, and in *Quercus lamellose* forest above 2100 m (Jackson 1994). Outside of Nepal, it extends from Kumaon in the west to Indochina in the east. The wood of *Castanopsis tribuloides* is used for planking and shingles, and is not durable. This species is lopped for fodder and it has been estimated that one tree can produce 40-60 kg of fresh fodder each year. It is not considered as one of the best fodder tree species but is widely used, farmers rate it fairly highly for nutritional value, and also nuts are edible (Jackson 1994).

Methodology

Only community users were used during identification and pairwise comparison of local benefit factors for comparison of three major forest types. Whereas, conservation experts were separately used for identification and pairwise comparison of conservation factors for comparing those forest types. Four focus group discussions with community users for local benefit factors and one with conservation experts for conservation factors were carried out.

Identification of Factors

Twenty experts participated in a focus group discussion (June 9, 2011) which was held at Institute of Forestry, Tribhuvan University, Pokhara, Kaski, Nepal. These are the same group of experts who identified SWOT factors in community forestry. These are the experts who deal with the sustainable management of forest resources putting equal emphasis on conservation as well as for benefits from forest resources. The experts were from different organizations working in forestry issues in Nepal, people from academia and government. There was a representation from Federation of Community Forest Users' Nepal (FECOFUN) and Community Based Forest Management in the Himalayas (ComForM); professors from Institute of Forestry, Tribhuvan University, Pokhara; Government Forest Officers and Rangers working in different districts of the country.

The participants were contacted to participate on a focus group discussion and were informed about the objective of doing focus group discussion. They were also provided with a list of potential factors that were identified during informal contacts with experts. A short presentation was given before identification of factors and pairwise comparison to make participants familiar with the process of identification and

comparison. On the other hand, four CFUGs were selected from Kaski, Parbat and Baglung district to carry out focus group discussion with community users. Each focus group consisted of 10-15 people. CFGUs were purposively selected looking at three major forest types found in the region.

The opinion from several forestry experts were taken before selecting community users for doing focus group discussion. After consultation with experts, Kaski, Baglung and Parbat district were selected to do the focus group discussions. It was essential to have all three forest types in the region and users' familiarity with all three forest types, so that they can better compare those forest types in terms of their importance in local benefits. Community users were contacted in advance in order to schedule a meeting for discussion. A list of potential factors was made during contacts with experts and meeting with key informant. This list was then made available to users to familiarize them with the possible factors and also to encourage them to participate actively in a discussion.

Pairwise Comparison (Between Factors and Between Three Forest Types)

After identification of factors, pairwise comparisons were made between the factors. The conservation experts made pairwise comparison between conservation factors and between forest types for each conservation factor. On the other hand, community users made pairwise comparison between local benefit factors and between forest types for each local benefit factors. The fundamental scale developed by Saaty and Vargas (2001) was used during pairwise comparisons (Table 3.1). The process of comparison has been presented in the figure 3.1. Table 3.2 shows an example for pairwise comparison between factors (i.e. conservation factors). Table 3.3 shows an example of comparison between forest types for each factor (i.e. three forest types have

been compared for one conservation factor-*restoration of degraded forest site*, the comparison between forest types were done in the same way for rest of the conservation and local benefit factors).

The eigenvalue method was used to calculate a local priority value for each factor, and for forest types for each factor (conservation and local benefit). Since four focus group discussions were carried out with CFUGs, their AHP weightings were aggregated. The geometric mean method (Xu 2000) was used in order to aggregate their responses for comparison. The geometric mean method is the most common group preference aggregation method in AHP. Judgments from all the focus group discussions were weighted equally which were finally analyzed using Expert Choice 11.5 that provided priority values for each factor identified and for each forest type (Expert Choice Inc. 2010).

Synthesis

Finally, synthesis was done with distributive mode based on the priority vector (y) calculated during pairwise comparison of factors and with the normalized priorities (x) calculated during pairwise comparison between forest types for each factor. Table 3.4 shows the process of synthesis. Global priorities of each forest types are determined by multiplying each column vector (local priorities of each factor) by the corresponding local priorities of each forest types with respect to each factor and adding across each row, which results in composite or global priority vector of each forest types (Table 3.4, 3.7 and 3.8).

Results and Discussion

Conservation experts identified the five most important conservation factors to compare three forest types. Likewise, community users identified the five most important local benefit factors in order to compare three forest types. The factors that were identified are presented in the table 3.5 with their relative priorities. Conservation factors based on their relative importance are *restoration of degraded forest site* (39%), *biodiversity enhancement* (27%), *soil erosion protection* (18%), *water source and water quality enhancement* (10%), and *greenery promotion and carbon sequestration* (7%) respectively. Similarly for local benefit factors, *fuel wood* (52%) was the most important benefit factor followed by *timber* (22%), *fodder* (15%), *income generation and employment opportunities* (6%), and *leaf litter* (5%) respectively (Table 3.5). Each of these factors was further compared for three different forest types. The factors (conservation and local benefit factors) and their priority values for each forest types are presented in the table 3.6.

In overall, *Alnus nepalensis* was found to be the most important forest types for conservation (49%) followed by *Schima-Castanopsis* forest (29%) and *Pinus roxburghii* forest (22%) (Table 3.7). *Alnus nepalensis* naturally occurs on degraded sites, especially on wetter sites and is considered to play significant role in stabilizing the degraded sites and providing protection against soil erosion. Since, *restoration of degraded forest site* and *soil erosion protection* was among the top three important factors, this species turn out to be the most important forest types for conservation. Although *Pinus roxburghii* is found in the degraded sites and this species can survive on poor site quality, it does not play important role in *water source and water quality enhancement*, *soil erosion*

protection, and *biodiversity enhancement* in comparison to other two forest types. During comparison of factors between forest types, it was mentioned by a group of experts that local community users comment on *Pinus roxburghii* forest for negatively affecting the water source and water quality.

For local benefits, *Schima-Castanopsis* was found to be the most important forest types among all (62%) with *Pinus roxburghii* to be the second important (23%) and *Alnus nepalensis* to be the least important (15%) (Table 3.8). *Schima-Castanopsis* is the most important forest types for benefits like fuel wood and fodder which are first and third most important benefit factors and second most important forest types for timber. Hence, *Schima-Castanopsis* was chosen to be the most important forest types from the perspective of local community users. Fodder not only refers to those fodder directly used by lopping these species but also grasses and shrubs that are supplied from this forest types. Usually, *Pinus roxburghii* makes pure stands and does not allow growing other forest tree under their canopy and even this species is not use as a fodder in the region. Thus, this forest type does not have any significance for fodder benefit. Similarly, *Alnus nepalensis* is lopped for fodder but in comparison to *Schima-Castanopsis* forest, it is still less efficient for fodder benefits.

Community users are very much dependent on fuel wood and fodder on a daily basis. Forest products like fuel wood, fodder, timber, and leaf litter are primary necessities for rural livelihoods. Thus, forest types that are more important in supplying these benefits definitely have more influence on the importance of forest types for local benefits. These forest types are potential for several benefits. *Alnus nepalensis* is not a good fuel wood species with respect to calorific value but it dries and burns rapidly. It

has medium quality timber that is used for simple construction and furniture. Mature leaves are eaten by sheep and goats but not by cattle. For ecological use, it is a shade tree for cardamoms, direct sowing of seed is done for stabilizing landslips, moist ravines and roadsides. Tree is used for anti-erosion work. The wood of *Alnus nepalensis* yields 39% pulp suitable for news print and for ordinary wrapping and writing a paper (Thakur 2003). Similarly, timber from *Pinus roxburghii* is used for constructional purposes, furniture, packing cases, electric transmission poles, and railway slipper after treatment. It burns rapidly and is a good fuel wood. The seeds are eaten by inhabitants of hilly areas. Turpentine from resin is used in the pharmaceutical preparations, perfumery industry, and insecticide and also as solvent. Also turpentine oil is valued in medicine and acts as an expectorant and is useful in chronic bronchitis. The wood is suitable raw material for pulp and paper (Thakur 2003).

On the other hand, *Schima wallichii* is used for house building, railway sleepers and planks. It is considered to be a good fuel wood. According to Thakur (2003), it is medium quality fodder, contains 9.6% crude protein, but more valued for bedding than as a fodder. The young plants, leaves and roots are used medicinally against fevers. Timber from *Castanopsis species* which is associated species of *Schima wallichii* are suitable for construction work, railway sleepers after creosote treatment, cheap furniture, handles of axes etc. It is considered to be a good fuel wood and fruits are edible. Fodder from *Castanopsis indica* is supposed to be a good fodder having 15% crude protein and 29% crude fiber. It also has medicinal value where a paste of leaves is applied for headache; bark also showed anti-cancer activities in mice and leaves are used for wrapping Bidis. Leaves from *Castanopsis tribuloides* is used for fodder which have 10-12% crude protein

(Thakur 2003). The potential benefits from these forest types i.e. raw material for pulp and paper, medicinal use etc. are not properly utilized. Their uses are limited to fuel wood, timber for simple constructional work, fodder, leaf litter etc. in the region.

If we look at CFUGs' sources of income at national level then Paudel et al. (2010) reveals that income of CFUGs has found to be tremendously different according to the geographical locations with higher income in Terai and lower in mid hills. The factors influencing such variations in income are access to infrastructure, abundance of timber and NTFPs, connection to contractors, leadership of entrepreneurs in CFUGs, increased project's and NGOs' support, and the availability of local markets. Hence, there are various factors affecting income and benefits taken by CFUGs and there could be significant improvement if considered for those factors, especially in the mid hills. They also mentioned that sale of forest products comprises 83% of the total income which outweighs other sources of revenue like income from CFUG members (3%), external support (1%), and others (13%). Therefore, income in the mid hills tends to be less because of the lack of productive forest in comparison to Terai.

Conclusions

It can be concluded from the results that *Alnus nepalensis* should be promoted in community forests if the objective is conservation as long as local factors favors this forest types because this forest type is found on poor site quality and in wet areas. Topography of mid hills area characterizes by undulating landscapes with more prone to erosion and landslide. Hence, *restoration of degraded forest site* and *soil erosion protection* is important factors. *Alnus nepalensis* is a pioneer species that favors degraded land and usually occurring in the streams side and ravines which are more susceptible to

erosion. Therefore, this forest type is considered to be the most important forest types for conservation by forest experts. On the other hand, this species is equally used for other benefits too. However, considering all the benefits that are received by community users in the region, this forest types is the least important forest types among all three.

This species is also used for veneer production in the region that was grown in private land; but has not been extensively practiced in the region. Thus, this species seems to have more benefits. Also, it is popular to grow cash crops like cardamoms (alianchi) under this forest type. In eastern part of Nepal, it is used as a shade tree for certain crops (Jackson 1994). However, it has not been well practiced in the region. Focus group with users also mentioned that people grow mushroom on the surface of the timber of *Alnus nepalensis* but its production was only for household consumption. Thus, this species seems to have promising benefits through income generating activities like mushroom production, veneer production and growing cash crops. This research not only provides information regarding importance of those forest types in the region for conservation and local benefits but prepare us to promote these forest types for their potential benefits.

Similarly, *Pinus roxburghii* was considered to be the least important forest type for conservation purpose, but it is the second important forest types for local benefits. Although *Pinus roxburghii* is more important for restoring degraded forest site than *Schima-Castanopsis* forest, it does not play significant role in soil erosion protection, biodiversity enhancement and water source and water quality enhancement when compared to *Alnus nepalensis* and *Schima-Castanopsis* forest. It has explicitly been mentioned in the discussion that *Pinus roxburghii* is considered to have negative impact

on water source and water quality enhancement. *Pinus roxburghii* forests usually have pure stand and do not allow other forest trees to grow under its canopy. Therefore, it is not supposed to play substantial role in biodiversity enhancement.

Pinus roxburghii is known as multipurpose tree species because it is also tapped for resin besides providing other benefits. It has not been extensively tapped for resin in the region except resin tapping was practiced in Baglung and Parbat district, but this region has great potential to promote resin tapping along with taking other benefits. Fuel wood and fodder are the forest products that are most important for local users for their subsistence living; therefore, *Schima-Castanopsis* was most important forest types for benefits. Also fuel wood from this forest type is considered to be a very good quality and community users think that this forest type have significant role in supplying fodder in local use. Although, comparison of these three forest types shows that *Schima-Castanopsis* is more important for local benefits, other potential benefits from other two forest types i.e. *Alnus nepalensis* and *Pinus roxburghii* have other several benefits like resin tapping, veneer production, growing cash crops, use in pulp and paper making which are not practiced at all except for resin tapping is practiced to some extent. Hence, it can also be concluded from the results that these forest types should be practiced for other potential benefits in the region.

Table 3.1: The fundamental scale for comparison

Intensity of importance	***definition***	***Explanation***
1	**Equal importance**	**Two activities contribute equally to the objective**
2 3	Weak **Moderate importance**	**Experience and judgment slightly favor one activity over another**
4 5	Moderate plus **Strong importance**	**Experience and judgment strongly favor one activity over another**
6 7	Strong plus **Very strong or demonstrated importance**	**An activity is favored very strongly over another; its dominance demonstrated in practice**
8 9	Very, very strong **Extreme importance**	**The evidence favoring one activity over another is of the highest possible order of affirmation**

Compare the relative importance of factor A to factor B (or forest type A to forest type B)

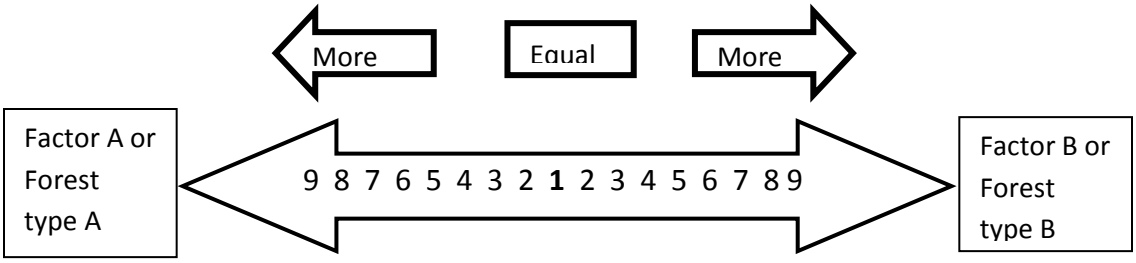


Figure 3.1: Graphical representation for pair wise comparison (between factors and between forest types). If factor A is important than factor B then participants would move left from 1. 1 represents equal importance and moving from 2-9 either towards right or left would signify the factor is more important over another. 9 indicate extreme importance of that factor in comparison to other factor.

Table 3.2: Pair wise comparison between factors (e.g. conservation factors)

Factors	Restoration of degraded forest site	Soil erosion protection	Water source and water quality enhancement	Biodiversity enhancement	Greenery promotion and carbon sequestration	**Priority vector (y)**
Restoration of degraded forest site						
Soil erosion protection						
Water source and water quality enhancement						
Biodiversity enhancement						
Greenery promotion and carbon sequestration						

Table 3.3: Pair wise comparison between three forest types for each factor (e.g. Restoration of degraded forest site)

Restoration of degraded forest site	*P. roxburghii*	*A. nepalensis*	*Schima-Castanopsis*	**Normalized priorities (x)**
P. roxburghii				
A. nepalensis				
Schima-Castanopsis				

Table 3.4: Synthesis (distributive mode)

	Factor 1 (y1)	Factor 2 (y2)	Factor 3 (y3)	Factor 4 (y4)	Factor 5 (y5)	Cumulative
P. roxburghii	X11	X12	X13	X14	X15	∑ Y*X
A. nepalensis	X21	X22	X23	X24	X25	∑ Y*X
Schima-Castanopsis	X31	X32	X33	X34	X35	∑ Y*X

Table 3.5: Factors identified to compare three forest types and their relative priorities

Conservation factors	**Relative priorities**	**Local benefit factors**	**Relative priorities**
Restoration of degraded forest site	0.393	Timber	0.219
Soil erosion protection	0.175	Fuel wood	0.521
Water source and water quality	0.098	Leaf litter	0.053
Biodiversity enhancement	0.265	Fodder	0.146
Greenery promotion and carbon sequestration	0.069	Income generation and employment opportunities	0.061

Table 3.6: Factors and their priority values for each forest types

Factors	**Forest types**		
	Pinus roxburghii	*Alnus nepalensis*	*Schima-Castanopsis*
Restoration of degraded forest site	0.308	0.615	0.077
Soil erosion protection	0.098	0.665	0.237
Water source and water quality enhancement	0.232	0.584	0.184
Biodiversity enhancement	0.085	0.239	0.676
Greenery promotion and carbon sequestration	0.534	0.151	0.315
Timber	0.457	0.115	0.428
Fuel wood	0.142	0.140	0.717
Leaf litter	0.088	0.359	0.553
Fodder	0.132	0.150	0.718
Income generation and employment opportunities	0.453	0.194	0.353

Table 3.7: Synthesis (Comparison of three major forest types for conservation factors)

Distributive Mode	Restoration of degraded forest site	Soil erosion protection	Water source and water quality enhancement	Biodiversity enhancement	Greenery promotion and carbon sequestration	Overall priority
	0.393	**0.175**	**0.098**	**0.265**	**0.069**	
Pinus roxburghii	0.308	0.098	0.232	0.085	0.534	**0.220**
Alnus nepalensis	0.615	0.665	0.584	0.239	0.151	**0.489**
Schima-Castanopsis	0.077	0.237	0.184	0.676	0.315	**0.291**

Table 3.8: Synthesis (Comparison of three major forest types for local benefit factors)

Distributive Mode	Timber	Fuel wood	Leaf litter	Fodder	Income generation and employment opportunities	Overall priority
	0.219	**0.521**	**0.053**	**0.146**	**0.061**	
Pinus roxburghii	0.457	0.142	0.088	0.132	0.453	**0.226**
Alnus nepalensis	0.115	0.140	0.359	0.150	0.194	**0.151**
Schima-Castanopsis	0.428	0.717	0.553	0.718	0.353	**0.623**

Chapter 4: Economic Analysis of chir pine (*Pinus roxburghii*)

Introduction

Pinus roxburghii forests are found ranging from longitudes of 70^0 E to 93^0 E and latitudes of 26^0 N to 36^0 N (Ghildiyal et al. 2009). It is a common coniferous species found in mid hills of Nepal. They occur between 900-1950m altitudes and grow up to 2700m (Jackson 1994). *Pinus roxburghii* is a strong light demander, frost hardy and fire resistant and is capable of growing in a severe condition (Thakur 2003). Standing volume of *Pinus roxburghii* is 6.3% of the total forest in the country (DFRS 1999) and has proportionally the fourth highest total volume in Nepal. *Pinus roxburghii* is the only species that was planted most widely in the mid hills in 1980's. Establishing *Pinus roxburghii* on heavily degraded forest site and grazing lands is an integral component of community forestry activities in the hill regions of Nepal. Due to its high survival rates, it has proved to be a successful pioneer of most degraded sites (Mohns et al. 1988). This species is a multipurpose tree species that provides timber benefits along with non-timber benefits like resin tapping and carbon sequestration. However, it is used equally for fuel wood and leaf litter as a bedding material in the region.

One of the objectives of this research project is to do an economic analysis of *Pinus roxburghii* for carbon, timber and resin benefits. *Pinus roxburghii* is usually been managed by local community for timber, fuel wood and resin. Additionally, another benefit from this forest type could be carbon. Hence, this research looks at financial return from plantation *Pinus roxburghii* when managed for timber, resin and carbon. The management of plantation *Pinus roxburghii* for timber, resin and carbon would be an

interesting idea in the presence of carbon market. Potential carbon market in this case could be Reducing Emissions from Deforestation and Forest Degradation (REDD), Clean Development Mechanism (CDM) and voluntary carbon market. Effective management of *Pinus roxburghii* forest would help maximizing the profit. Most importantly, this economic analysis would provide information regarding an optimal rotation age of *Pinus roxburghii* at different prices of carbon with timber and resin benefit to be constant.

Timber benefit is the most common benefit received by community users from *Pinus roxburghii* forests in mid hills region of Nepal. Timber is mainly used for constructional purposes like housing, making furniture, electric transmission poles etc. A part from that, it is also used for fuel wood and leaf litter as a bedding material. Fuel wood from *Pinus roxburghii* is considered to be a good fuel wood. *Pinus roxburghii* is also suitable for pulp and paper making but it has not been used for this purpose so far. Resin tapping is another benefit from *Pinus roxburghii* that has been in practice in Nepal. *Pinus roxburghii* forests make significant contributions to economic earnings and livelihood improvement of local people through marketing of resin along with timber. *Pinus roxburghii* is the only species in Nepal that is tapped for resin, and now resin tapping is being done in around 35 districts of Nepal out of the total of 75 districts. It has been found that on an average one person can earn up to NRs. 30,000 in eight months of a tapping period (Upadhyay 2008). Thus, resin tapping work enhances income along with creation of employment opportunities for people within and outside the CFUGs.

In recent years, policy makers have been searching for different ways to mitigate the effects of rising Green House Gases (GHGs) concentration. Particular interest has been directed towards carbon stocks in forests because these ecosystems are the main

terrestrial sinks for carbon (Balboa-Murias et al. 2006). Forests are an important source of carbon sequestration because they sequester carbon at a faster rate than other terrestrial sinks. Each cubic meter of wood stores approximately 200 kg of carbon in forests, and for every ton of carbon sequestered in forest biomass, 3.667 tons of CO_2 are removed from the atmosphere (Krcmar et al. 2001). Previous studies suggest that costs of carbon sequestration in forests are comparable to, and in some cases lower than, the costs of alternative mitigation and abatement approaches (Matthews et al. 2002). Therefore, a forest which is considered to be a major sink of atmospheric carbon is a cost effective way for mitigating global warming. It has been estimated that *Pinus roxburghii* forest sequester 218 ton of carbon per ha on average including both above ground and below ground carbon storage (K.C. 2008). The use of *Pinus roxburghii* forests for timber and resin tapping is common in mid hills, however its contribution through carbon sequestration should be considered at the same time.

With the development of community forests, their contribution in carbon sequestration and mitigation of global warming is significant. Recently, several programs are trying to address global topic like carbon sequestration. Various carbon trading mechanisms are available, in regards to terrestrial carbon, especially forests. Program that is mostly talked about in Nepal is Reducing Emissions from Deforestation and Forest Degradation (REDD). However voluntary carbon market could be another potential program for carbon trading. Policies makers are getting more attracted towards these programs and hence are doing researches related to carbon sequestration. Preliminary research findings from carbon monitoring surveys of selected community forests in Nepal suggest that the carbon stocks are increasing at the rate of 2 to 5 tons per hectare per year

(Dahal and Banskota 2009). Some research has been conducted on the carbon sequestration potential of *Pinus roxburghii* and other tree species in Nepal. However, economic analysis of *Pinus roxburghii* for carbon sequestration including other benefits like timber and resin has not been studied so far. This study would provide information on financial return from the management of plantation *Pinus roxburghii* for all three benefits i.e. resin, timber and carbon.

Methodology

Data Sources

The Hartman model (1976) was used for economic analysis of *Pinus roxburghii* that takes into account for timber and non-timber benefits. Thinning regime developed by Department of Forest Research and Survey (2007) was used for economic analysis of *Pinus roxburghii*. Thinning regime for plantation *Pinus roxburghii* has been presented in the table 4.1. Thinning regime developed by Department of Research and Survey (DFRS) considers harvesting age to be 75 for plantation *Pinus roxburghii*. Thus, all the calculations have been done only up to 75 years. Similarly, calculation of carbon factor (α) is based on carbon content (%) of *Pinus roxburghii* i.e. 46.32% (Negi et al. 2003). In general, carbon content is assumed to be 50% (0.5) of dry matter (Koach 1989; Negi et al. 2003; Lamlom and Savidge 2003; Sharma and Singh 2010). However, species specific carbon content (%) has been used in this analysis.

Carbon factor (α) refers to metric tons of carbon per cubic meter of timber biomass and value of α is 0.2302 in this study. Carbon factor (α) is calculated with

species specific dry wood density (i.e. 0.497) that has been used based on the following relationship established by Chaturvedi and Khanna (1982):

$$\text{Biomass} = \text{Volume} * \text{dry wood density of } \textit{Pinus roxburghii} (0.497) \quad (4.2)$$

This carbon factor has been used to convert timber biomass into amount of carbon in per hectare basis. Since, CO_2 equivalent is traded in the market not the carbon. Amount of carbon has been converted into CO_2 equivalent multiplying by 3.67. Hence, all the carbon benefits presented in this result represents CO_2 equivalent.

Calculations are based on growth and yield data from Indian context (Tewari 1994). Relationship between age, height and diameter used in this analysis has been presented in appendix 1. Those relationships were established by analyzing the data of 219 trees. These data neither considers plant density nor site quality. Some publications on *Pinus roxburghii* by Applegate et al. (1988) and Gilmour et al. (1990) provide data on particular age of *Pinus roxburghii* in the context of Nepal. Likewise, working paper by Rautiainen (1991) also provides some information regarding stocking, diameter and height for specific age of plantation *Pinus roxburghii* in Nepalese context again. However, they do not provide sufficient information on growth and yield for this species. Therefore, data from Tewari (1994) was used for economic analysis for this species.

Timber is measured from ground level up to the point of stem where diameter over bark is 20 cm. The portion of timber beyond 20 cm diameter up to 10 cm diameter is considered to be small timber. The portion of tree beyond 10 cm diameter was considered to be slash. Timber benefit calculated for the portion of timber up to 20 cm diameter without bark has been considered to be big size timber. Bark proportion has been

deducted for the big size timber and small timber in order to calculate timber benefit. The formulas for calculating timber portion up to 20 cm diameter, timber portion from 20 cm diameter up to 10 cm diameter, and calculation of bark portion have been adopted from Sharma and Pukkala (1990).

The equation for the calculation of volume:

$$\ln(v) = a\,(-2.9770) + b\,(1.9235)*\ln(d) + c\,(1.0019)*\ln(h) \qquad (4.3)$$

Where, V is the total stem volume with bark (dm^3). D is the diameter in centimeter and h is the height in meter. The parameters a, b, and c have values -2.9770, 1.9235, and 1.0019 respectively for *Pinus roxburghii* (Sharma and Pukkala 1990).

First of all, the portion of tree beyond 10 cm in diameter was deducted from the whole volume which gives volume of slash. Again, the portion of timber up to 10 cm diameter from the ground level was calculated separately. The portion of timber from the ground level up to a diameter of 20 cm (i.e. big size timber) was calculated separately. Likewise, the portion of timber up to 20 cm in diameter was deducted from the portion of timber from the ground level up to 10 cm in diameter that gives volume of small timber. All the timber calculation here deducts bark portion from it.

The equation that calculates the proportion of tree top (beyond 10 cm) is:

$$\ln(v_1 / v) = a\,(6.2696) + b\,(-2.8252)*\ln(d) \qquad (4.4)$$

Where, v_1 is the over bark volume of tree top and v is the total over bark stem volume. The values for the parameters a and b in the equation are 6.2696 and -2.8252 respectively for *Pinus roxburghii* (Sharma and Pukkala 1990).

The equation that calculates the proportion of timber beyond 20 cm diameter but greater than 10 cm diameter is:

$$\ln\left(v_2 / v_t\right) = a\ (8.5662) + b\ (-3.0486) * \ln(d) \tag{4.5}$$

Where, v_2 is the over bark volume of the portion of timber beyond 20 cm in diameter but greater than 10 cm in diameter and v_t is the total over bark volume up to 10 cm in diameter. The values for the parameter a and b in the equation are 8.5662 and -3.0486 respectively for *Pinus roxburghii* (Sharma and Pukkala 1990).

The equation that calculates the proportion of bark in timber which is greater than 10 cm in diameter is:

$$\ln\left(P_b\right) = a\ (1.1763) + b\ (-0.6997) * \ln(d) \tag{4.6}$$

Where, P_b is the bark proportion. The values for the parameter a and b in the equation are 1.1763 and -0.6997 respectively for *Pinus roxburghii* (Sharma and Pukkala 1990).

The equation that calculates the proportion of bark in timber which is greater than 20 cm in diameter is:

$$\ln\left(P_b\right) = a\ (1.2535) + b\ (-0.7194) * \ln(d) \tag{4.7}$$

Where, P_b is the bark proportion. The values for the parameter a and b in the equation are 1.2535 and -0.7194 respectively for *Pinus roxburghii* (Sharma and Pukkala 1990).

Land Expectation Value (LEV) calculation

The Land Expectation Value (LEV) was calculated using the following formula:

$$LEV = (PV_C + PV_T + PV_R - EC) / (1 - e^{-rt}) \tag{4.8}$$

Where, LEV = land expectation value in \$/hectare, PVc = present value of carbon in \$/hectare, PV_T = present value of timber in \$/hectare, PV_R = present value of resin in \$/hectare, r = discount rate, and t = age of tree. In order to calculate LEV, present value of carbon (PV_C), present value of timber (PV_T) and present value of resin (PV_R) were calculated separately using the following equations:

$$PV_C = \sum_{0}^{t} P_C \alpha \{v(t) - v(t-1)\} e^{-rt} - P_C \alpha (1-\beta) v(t) e^{-rt} \tag{4.9}$$

Where, PV_C = present value of carbon in \$/hectare, P_C = price of carbon (\$/ton), α = (metric) tons of carbon per cubic meter of timber biomass, v (t) = volume of timber calculated at a particular age (t), β = pickling rate, r = discount rate, and t = age of tree. Here, β represents the portion of timber that does not decay and sequesters carbon in long lived products or in landfills. Present value of timber has been calculated at different values of β (0, ½, and 1). Where pickling rate of 0 says that all the carbon sequestered in timber biomass will be emitted back into the atmosphere when harvested. Likewise, pickling rate of 0.5 says that 50% of carbon sequestered in timber biomass will be emitted back into the atmosphere when harvested. And, pickling rate of 1 one says that all of the carbon sequestered in timber biomass will be locked up permanently. For the portion of stem beyond 20 cm in diameter (small timber and slash), pickling rate of 0 has been used, because I am assuming that the carbon sequestered in the entire portion of

those stem would be emitted back into the atmosphere when harvested. For big size timber (the portion of timber from ground level up to 20 cm in diameter), I am using pickling rate of 0, 0.5, and 1.

$$PV_T = P_T v(t) e^{-rt} \tag{4.10}$$

Where, PV_T = present value of timber in \$/hectare, P_T = price of timber in \$/cubic meter, r = discount rate, and t = age of tree.

$$PV_R = \sum_{0}^{t} P_R v_r(t) e^{-rt} \tag{4.11}$$

Where, PV_R = present value of resin in \$/hectare, P_R = price of resin in \$/ton, $v_r(t)$ = volume of resin calculated at a particular age (t), r = discount rate, and t = age of tree.

I am using timber price of Nepalese Rupees 50 (~\$0.625) per cubic feet for big size timber and 50% of this price for small timber (GoN 2005). Likewise, I am using resin price of Nepalese Rupees 6 (~\$0.075) per kg. According to Resin Tapping Guideline by Ministry of Forests and Soil Conservation (2007), resin tapping starts when diameter reaches 30 cm. I am assuming different carbon prices of \$0, \$2, \$5, \$10, \$25, and \$50. Since CO_2 equivalent is traded in the market not the carbon, calculated carbon has been converted in to CO_2 equivalent multiplying by 3.67. I am using exchange rate of \$1=Rs.75 in order to convert calculated LEV in Nepalese Rupees to US dollars. Discount rate of 10% has been used for the calculation of LEV based on literature review as well as personal contacts with experts.

Establishment cost is assumed to be NRs. 3200/ha (~$43) in the plantation year. I am assuming forest management and thinning costs to be zero because it will be carried out in community participation. Similarly, I am assuming harvesting cost to be zero because Timber Company or any individual whoever buys timber will bear all the costs associated with harvesting and extraction. If harvesting is done within the community by community users then all the harvesting operation will be done in community participation or if any individual community member is a buyer then buyer will bear all the costs. Since, costs associated with plantation *Pinus roxburghii* has not been well documented, the costs used are based on the personal contacts with experts (government officers).

Results and Discussion

The table 4.2 shows the optimal rotation age with their respective LEV at different prices of carbon with different pickling rates. Looking at the uncertainty of carbon market and prices associated with it, this analysis considers wide range of carbon prices from $2 to $50. All the results presented here are based on discount rate of 10%. Different values of pickling rate were considered that incorporates information on carbon emission during harvesting. Here, pickling rate of 0 represents that all the carbon sequestered in timber will be emitted back into the atmosphere when harvested, 0.5 represents that 50% of carbon sequestered in timber will be emitted back into the atmosphere when harvested, and a value of one says that all the carbon captured in timber would be locked up permanently. All the small timber and slash have been calculated with pickling rate of 0, whereas big size timber has been calculated with pickling rate of

0, 0.5, and 1. Therefore, LEV with pickling rate of 0.5 and 1 are higher than with pickling rate of 0.

When carbon price is 0 i.e. without including carbon benefit, optimal rotation age would be 35. However, with the increase of carbon price from $2 to $50, optimal rotation age as well as LEV increases rapidly keeping timber and resin benefit to be constant. As soon as carbon price increases from $0 to $2, rotation age increases from 35 to 40 with increase in LEV. Similar results can be seen as price increases to $5 and over until rotation age is 75 (Table 4.2 and figure 4.1). High proposed carbon prices certainly extend rotation age indefinitely (Price and Willis 2011). Here, increased carbon price lengthen the rotation age, with an effect of change more pronounced at higher carbon prices. Therefore, carbon price has significant effect on LEV as well as on optimal rotation age.

Although harvesting age for plantation *Pinus roxburghii* has been considered to be of 75 based on thinning regime developed by DFRS (2007), it is more profitable to harvest those stand before it reaches age of 75 when benefit from carbon is not considered (carbon price=0). The rotation age should be as minimum as 40 with the low carbon price (i.e. $2) with the constant benefit from timber and resin. The rotation age increases with the carbon price up to 75 or beyond that but calculation is based on the thinning regime that considers last cut at the age of 75. An optimal rotation age fluctuates with pickling rate, particularly with the higher carbon price (Table 4.2 and Figure 4.1). An optimal rotation age is higher with pickling rate of 0 than with 0.5 and 1. Therefore, permanency of sequestered carbon in timber biomass also determine the rotation age along with the price of carbon.

The bar graph (Figure 4.1) shows the overall results for optimal rotation age on y-axis and carbon prices on x-axis at three different values of pickling rate. We can see that an optimal rotation age is 35 when excluding benefit from carbon. As soon as carbon price increases to $2, $5, $10 and so on, optimal rotation ages increase with substantial increase in LEV until it reaches to an age of 75. However, there is some fluctuation in optimal rotation age at prices of $5, $10, $15 and $25. At higher prices of carbon with pickling rate of 0, rotation age will be higher than when pickling rate is 0.5 or 1. Pickling rate of 0 simply means that all the carbon sequestered will be emitted back into the atmosphere when harvested. With this pickling rate, there would be a deduction of higher emission costs from overall revenue which leads to increase in rotation age. It becomes more profitable to delay rotation age by 5 to 15 years in order to get higher LEV. Similar effect would have seen with the carbon price of $50 but we are doing all the calculations up to an age of 75. Therefore, we don't see that effect on carbon price of $50.

Conclusions

It can be concluded from the analysis that an optimal rotation age increases with the increase in carbon prices. Also, inclusion of carbon benefit to timber and other non-timber benefits would increase the LEV substantially. Other studies have shown that inclusion of carbon would increase an optimal rotation age (Romero et al. 1998; Stainback and Alavalapati 2002; Kooten et al. 1995; Price and Willis 2011). Also land expectation value increases when carbon payments are included (Stainback and Alavalapati 2002; Dwivedi et al. 2009). All the carbon prices were hypothetical and do not necessarily represent the real market price of carbon. This economic analysis uses wide range of carbon prices from $2 to $50 due to uncertainty of carbon market. The

results for optimal rotation age and their respective LEV should give price dependent results (i.e. different carbon prices with benefit from timber and resin to be constant). Thus, carbon price seems to play an important role to both optimal rotation age and LEV.

Figure 4.1 shows relationship between carbon prices and LEV. LEV has increased significantly with the increase in carbon prices. With carbon price of 0 (i.e. only with timber and resin benefit), LEV is minimum of $35.25. As soon as carbon price increases from $2 to $ 50, LEV increases from $51.18, $52.84, and $54.49 to $503.63, $538.19, and $572.75 at different pickling rate of 0, 0.5, and 1 respectively. Therefore, there would be a substantial increase in LEV with the increase in carbon prices at different values of pickling rate. There is higher LEV at pickling rate of 1 with least LEV when pickling rate of 0 which is associated with the emission cost (i.e. higher emission cost when pickling rate of 0, lower emission cost with pickling rate of 0.5, and no emission cost when pickling rate of 1).

Similarly, different values of pickling rate have effect on optimal rotation age at higher carbon prices (i.e. $5 and over). It tends to increase optimal rotation age at pickling rate of 0 in comparison to 0.5 and 1. At carbon price of $15, optimal rotation age is 75, 65 and 60 for pickling rate of 0, 0.5 and 1. This effect is seen when carbon price is $5 and this effect is more pronounced when carbon prices increases rapidly towards $50. This is because; emission costs are higher with the higher carbon prices. So that there will be a deduction of higher emission costs from overall revenue. Pickling rate of 0 means that all the carbon sequestered will be emitted back into the atmosphere during harvesting of timber stand; hence this would leads to a higher emission cost. Consequently, an optimal rotation age increases in order to get higher LEV to maximize benefit from the

stand. Therefore, pickling rate has significant effect in determining rotation age, particularly with the higher carbon prices.

Table 4.1: Thinning regime developed by DFRS (2007) for plantation chir pine (*Pinus roxburghii*) in Nepal

Age	Stem/ha	Stem/ha after thinning	Stem thinned/ha
Plantation year	1600	1600	0
5	1600	1600	0
10	1600	1600	0
15	1600	1400	200
20	1400	1050	350
25	1050	900	150
30	900	800	100
35	800	625	175
40	625	500	125
45	500	400	100
50	400	300	100
55	300	225	75
60	225	190	35
65	190	145	45
70	145	145	0
75 (last cut)	145	0	145
		Total	1600

Table 4.2: Optimal rotation age and LEV at different carbon prices with different pickling rates

Pickling rate	$\beta = 0$		$\beta = 0.5$		$\beta = 1$	
CO_2 /metric ton ($)	Rotation age (yrs)	LEV ($/ha)	Rotation age (yrs)	LEV ($/ha)	Rotation age (yrs)	LEV ($/ha)
0	35	35.25	35	35.25	35	35.25
2	40	51.18	40	52.84	40	54.49
5	45	75.46	40	79.55	40	83.69
10	65	122.04	60	129.25	60	136.57
15	75	169.43	65	180.07	60	190.80
25	75	264.92	75	282.20	65	299.68
50	75	503.63	75	538.19	75	572.75

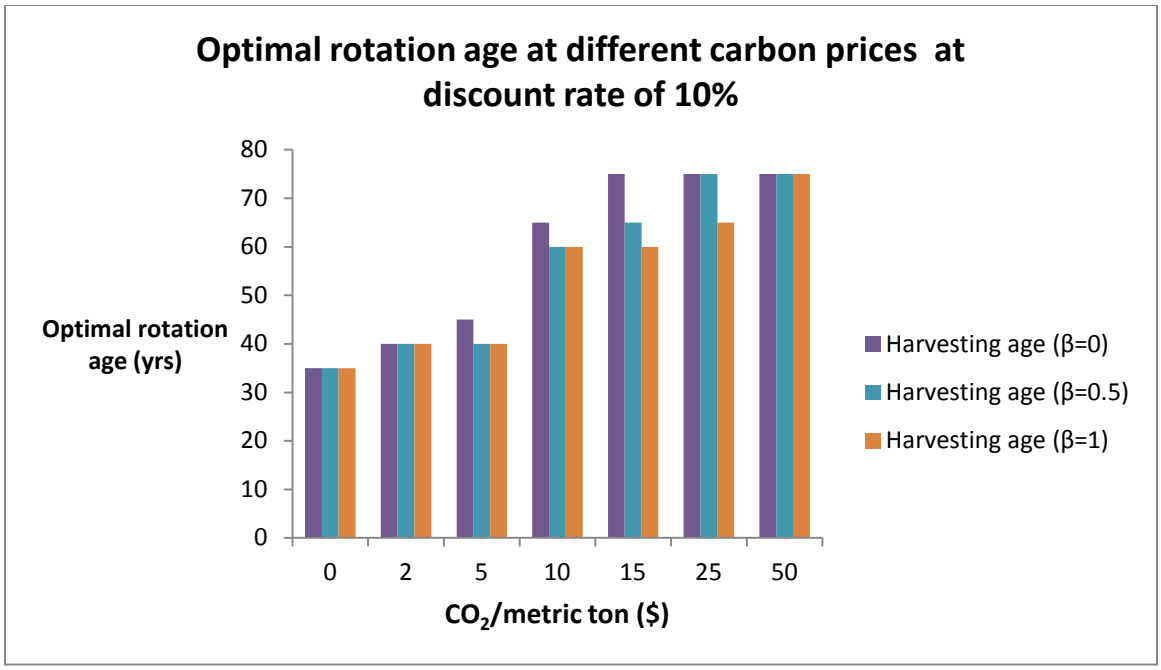


Figure 4.1: Optimal rotation age at different prices of carbon (i.e. \$0, \$2, \$5, \$10, \$15, \$25 & \$50) when β=0, 0.5, & 1

Appendix

Appendix 1: Relationship between age, height and diameter for *Pinus roxburghii* (Tewari 1994)

Age (yrs)	Height (m)	Diameter (cm)
10	5.8	6.0
20	8.3	11.5
30	10.8	17.2
40	13.3	22.8
50	16.9	28.3
60	18.3	33.6
70	20.6	39.0
80	22.7	44.3

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