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SUSTAINABILITY ISSUES RELATED TO COMMUNITY MANAGEMENT OF NATIONAL FORESTS IN BHUTAN

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Preface

The fieldwork for this dissertation was carried out in 2004 and 2005 at the end of a five year assignment in Bhutan for the Swiss Agency for Development Cooperation (SDC)/Helvetas. The original intention of the research was to contribute to a series of case studies on the community forestry program of Bhutan produced by the Participatory Forest Management Project (PFMP). The preliminary findings of the research were distributed in Bhutan as PFMP reports in August 2005 and December 2006.

In January 2005, the Honorable Secretary of the Ministry of Agriculture provided written authorization to utilize the data and expand the analysis for a doctoral dissertation. In the process of preparing this dissertation, the author prepared three journal articles on different aspects of the research in collaboration with his academic advisors and Bhutanese colleagues for submission to international journals.

This edited version of the approved dissertation includes an executive summary.

Abstract

Governments around the world are increasingly devolving authority for forest management to the local level through community forestry programs. However, concerns have been raised about the level of equity in community forests (CF) and the ecological sustainability of harvesting approaches, especially in broadleaved CFs that are also used for forest grazing. This study examined these issues in the context of Bhutan's new community forestry program using a combination of ecological and social research. The study area included the first three CFs in the country to start harvesting operations. The research methodology included a forest inventory, study of harvested trees, household survey, and analysis of timber permits. The research found that harvesting levels did not exceed the annual allowable cut for combined or individual species. Selection cutting did not appear to have a negative impact on the natural regeneration of preferred timber species or the diversity of trees, even when harvesting was combined with a moderate level of forest grazing (0.4 cattle*ha^{-1}). These findings, which contrasted with the experience in an adjacent commercially-managed forest, were attributed to the smaller opening size created by selection cutting and stricter control of grazing. The analysis of equity in the CFs found that political equity (participation in decision making) was comparable to neighboring countries but economic equity (distribution of benefits) was much higher, with no indications of domination by richer members, male members, or the management committees. The high level of equity was attributed to socio-cultural factors and environmental conditions, supportive government policy and strong extension support. The study concluded that community forestry in Bhutan offers potential for sustainable forest management and equitable distribution of benefits.

Keywords: Bhutan, Community Forestry, Selection Cutting, Natural Regeneration, Forest Grazing, Equity

Abstract

Weltweit kann ein zunehmender Trend zur Verlagerung von Verfügungsrechten auf lokale Ebenen von WaldnutzerInnen beobachtet werden. Dies gibt Anlass zu Sorge hinsichtlich der gerechten Verteilung der Ressourcen („equity“), und der eingeschränkten Nachhaltigkeit der Nutzungen in Gemeinschaftswäldern, besonders in Laubwäldern, die auch einer Waldweidenutzung unterliegen. In der vorliegenden Arbeit wurden diese beiden Hauptkritikpunkte am Beispiel des in Bhutan neuen Gemeinschaftswald – Programms untersucht. Dazu wurden ökologische und soziologische Untersuchungsmethoden kombiniert. In drei Gemeinschaftswäldern in Bhutan wurden eine Waldinventur, Waldnutzungserhebungen, eine Haushaltsbefragung und eine Analyse der Nutzungsbewilligungen durchgeführt. Die Untersuchungen ergaben, dass die durchgeführten Nutzungen den jährlichen Hiebssatz nicht überstiegen. Die durchgeführten Einzelstammentnahmen hatten keine negative Auswirkung auf die Naturverjüngung und die Baumdiversität, auch auf Standorten mit moderater Waldweide (0.4 Kühe*ha^{-1}). Diese Ergebnisse stehen im Gegensatz zu Erfahrungen in benachbarten kommerziell bewirtschafteten Wäldern, was auf kleinflächigere Nutzungen und strengere Kontrolle von Waldweide zurückgeführt wird. Die Analyse nach sozio-politischen und ökonomischen Gerechtigkeitsindikatoren ergab, dass politische Teilhabe ungleich verteilt war. Die Verteilung ökonomischer Ressourcen war allerdings ausgeglichener; die in anderen Studien oft gefundene Dominanz reicherer TeilnehmerInnen, männlicher Teilnehmer oder von Mitgliedern im Management-Komitee konnte nicht festgestellt werden. Diese ausgeglichene Verteilung der Ressourcen wird auf sozio-kulturelle Faktoren, Umweltbedingungen, unterstützend wirkende Politiken und starke Beratung zurückgeführt. Die Arbeit kommt zum Schluss, dass Gemeinschaftswaldbewirtschaftung in Bhutan eine Alternative für nachhaltige Waldbewirtschaftung unter Wahrung einer gleichmäßigen Verteilung der Ressourcen darstellt.

Schlüsselwörter: Bhutan, Gemeinschaftswaldbewirtschaftung, Einzelstammnutzung, Naturverjüngung, Waldweide, Equity

Executive Summary

Governments around the world are increasingly devolving authority for forest management to the local level through community forestry programs. However, concerns have been raised about the capability of user groups to manage community forests (CF) in a sustainable manner, especially broadleaved forests that are also used for forest grazing. There is also increasing evidence that community forestry programs do not provide benefits equally to all social groups and in some cases actually exacerbate inequality. This study focused on three issues related to community forestry in the context of Bhutan's new community forestry program:

- The ecological sustainability of the harvesting approach utilized by user groups in broadleaved CFs;
- The ecological sustainability of combining forest grazing and timber production in broadleaved CFs; and
- The equity of CF management, considering distribution of benefits and participation in decision making.

This study examined these issues in the first three CFs in Bhutan to start harvesting operations: Yakpugang CF in Mongar District, Masangdaza CF in Mongar District, and Shambayung CF in Bumthang District. The research methodology combined ecological and social research and included a forest inventory, study of harvested trees, household survey, and analysis of timber permits.

Impact of Selection cutting in Broadleaved Community Forests

The first research component assessed six aspects of the ecological sustainability of harvesting by user groups in Yakpugang CF. Specific research questions included:

- Were any species harvested at unsustainable levels?
- How did the forest condition change after five years of community management?
- Did harvesting affect the diversity of trees in the forest?
- Did harvesting intensity affect the composition of natural regeneration?
- Did harvesting affect the bole shape and form of remaining trees?
- Did harvesting affect the diameter distribution of the forest?

Key findings included:

- The diameter class distribution of Yakpugang CF was comparable to the distributions of three other cool broadleaved forests that have been studied in Bhutan, which indicated that Yakpugang is representative of broadleaved forests in the country. The research plots contained 39 species of trees, representing 22 families and 32 genera.
- The CF members utilized most of the species in the CF: only six of 39 species were classified by the members as having no use, and these species contributed less than 2% of the total basal area (BA). The forest had been harvested regularly over the past five decades, and contained an average of 150 stumps per ha. In terms of BA, the most harvested species were *Castanopsis hystrix* (for shingles), *Persea clarkeana* (for timber), *Quercus lamellosa* (for shingles and firewood) and *Cinnamomum bejolghota* (for timber). In terms of number of stumps, the most common genus was *Symplocos.*

- There were no indications that harvesting during the period of community management exceeded the current annual allowable cut (AAC). There were no cases where the harvesting of any individual species or any use category (including the 1st class timber trees) significantly exceeded the AAC. The same was true for every ten year period during the past 60 years. Even when the rotation period was increased from 100 to 150 yrs, the AAC was significantly higher than the volume harvested for all use categories during the past 20 years. However, the results were inconclusive for some individual species.
- When the 2005 inventory was compared to the 2000 inventory, there were no significant differences between the total number, volume or BA standing trees (over 9 cm dbh). However, the numbers of seedlings and saplings were significantly greater in 2005, which indicated that natural regeneration increased after the handover of the CF. The number of saplings of timber trees also significantly increased.
- Harvesting did not appear to have a negative impact on the bole shape and form of remaining trees. This was contrary to the experience in the adjacent Korilla FMU, where the removal of trees of best form for rural use was reported to have jeopardized future productivity. No species in Yakpugang CF exhibited a significant correlation between the percentage of trees with good form and the number of trees harvested. The same was true for timber species.
- Harvesting did not appear to have a negative impact on tree diversity, in terms of the abundance and evenness of tree genera. The diversity of trees was positively correlated with increased intensity of harvesting, as was diversity of seedlings, saplings, and size classes up to 30 cm dbh. There were no indications of impact on the diversity of trees over 30 cm dbh.
- Harvesting appeared to have a positive effect on the composition of natural regeneration. Harvesting intensity was positively correlated with the percentage of saplings of timber species; and negatively correlated with the percentage of saplings of species which were not used by the members. The most open plots in the study area contained the highest percentage of saplings of timber species.
- Harvesting appeared to have a positive impact on the diameter distribution of the most preferred timber trees. The first class timber trees exhibited an “inverse J” diameter distribution with steeper negative exponential curves in plots that were more intensively harvested. This was in contrast to the situation in the adjacent Korilla FMU, where logging and grazing reportedly altered the forest structure so that only non-palatable *Symplocos*, *Daphniphyllum* and *Rhododendron* species exhibited “inverse-J” distributions and timber species exhibited bell-shaped distributions. However, harvesting in Yakpugang appeared to have a negative impact on the diameter distribution of the *Quercus* species, which could affect long term productivity. This issue requires further study.
- The findings suggest that community management of broadleaved forests may avoid some unresolved silvicultural problems associated with FMU cable crane logging operations. Research in Korilla FMU reported that regeneration of timber species was higher in small openings of 0.15 ha than in openings of 0.5ha or 6 ha, but concluded that financial viability could only be maintained with a reduction of opening size to 0.36 ha. However, limiting opening size to 0.15 ha or less in CFs is fully consistent with the selection cutting approach of user groups.
- These findings were attributed to two main factors, both of which were enhanced by strong support from the forest extension service: (1) harvesting did not exceed the AAC because the management plan provided clear guidance on harvesting limits of different size classes and the user group developed a simple yet effective system for monitoring harvesting; and (2) the improved marking and discipline by the user group spread out the harvesting in different forest stands, which reduced the effect of high-grading and avoided the creation of large openings which would attract livestock. The resulting irregular pattern of harvested trees created a wide range of light conditions which may have promoted natural regeneration.

Impact of Forest Grazing in Broadleaved Community Forests

The second research component assessed the impact of forest grazing on natural regeneration to determine whether the combination of forest grazing and timber management is ecologically sustainable in broadleaved CFs. This topic was studied primarily in Yakpugang CF with supplemental data from Masangdaza and Shambayung CFs. Specific research questions included:

- How did livestock ownership and grazing patterns change in the five year period between 2000 and 2005?
- How did grazing affect natural regeneration?
- What is the threshold of grazing intensity for sapling recruitment in cool broadleaved forests?

Key findings included:

- The average cattle holdings per household decreased significantly between 2000 and 2005 as traditional cattle were replaced with smaller numbers of improved breeds (Brown Swiss or Jersey Cross). The main reason for the decrease was a shortage of labor due to increased school attendance and greater availability of seasonal employment for adults on government construction projects.
- The overall reduction in livestock holdings and the shift to improved breeds contributed to a reduction in grazing intensity in Yakpugang CF. The number of improved breeds grazing on private land increased six-fold during the five year period. The number of traditional cattle grazing on private land also increased as the owners found it more convenient to keep their reduced livestock holdings closer to home. The same trends were also observed in the other two CFs.
- The changes in livestock holdings and grazing patterns applied equally to all socio-economic groups, and to both male and female members. There were no indications of favoritism in terms of access to the CF for forest grazing, as has been reported in Nepal.
- The number of animals belonging to CF members that were grazed in other national forests decreased significantly during the five year period, so there was no evidence that the users protected their own CF by increasing the utilization of other national forests.
- During the same five year period, the frequency of seedlings and saplings in Yakpugang CF significantly increased. The increased natural regeneration in Yakpugang CF did not appear to be the result of recent changes in harvesting intensity, because the volume and BA of trees harvested during the five year period were not significantly different than any other five year period, and the forest was harvested at levels below the AAC during the past 20 years. Furthermore, the comparison of the 2000 and 2005 forest inventories did not reveal any significant change in the number, volume or BA of trees with dbh ≥ 10 cm. Therefore the increased natural regeneration appeared to be primarily due to reduced grazing intensity.
- Grazing intensity of 0.4 cattle*ha^{-1} appeared to be below the threshold of sapling recruitment of the preferred species in the broadleaved forest of Yakpugang CF. This finding was consistent with the reported carrying capacity of 0.54 livestock units*ha^{-1} for temperate rangelands in Nepal associated with oak, mixed broadleaf, *Quercus,* or bluepine.
- The only genus in Yakpugang that did not exhibit adequate sapling recruitment was *Quercus.* This was consistent with the findings of controlled grazing studies in Denmark, and with other studies in Bhutan which have noted the limited regeneration of *Quercus* in forests used for grazing.

These findings suggested that cool broadleaved forests like Yakpugang can be managed for timber with moderate levels of forest grazing without negative impacts on natural regeneration. The findings supported the policy of allowing grazing in CFs in Bhutan, and were in agreement with other studies which have concluded that forest grazing can be ecologically sustainable as long as grazing intensity is controlled.

Equity in Community Forests

The third research component assessed the equity of community forestry in Bhutan. The study assessed three indictors of political equity (decision making within the CF) and seven indicators of economic equity (distribution of benefits). This topic was studied in Yakpugang, Masangdaza and Shambayung CFs. Specific research questions included:

- Did all members of the user groups, including disadvantaged groups and female members, participate equally in the decision making process of the user group?
- Was the distribution of benefits from the CF equitable in terms of access to products by different socio-economic groups and female members?

Key findings included:

- The level of political equity (participation in decision making) was moderate. The management committees generally included both rich and poor members, even though the laborers were somewhat under-represented while the large farmers were somewhat over-represented. Representation of women was high, but men held the powerful positions of chairman and secretary. Attendance at CF meetings was very high for all socio-economic groups as well as for both women and men. However, the members exhibited a remarkable lack of knowledge abut CF administration. Although there were no indications of corruption in the three CFs, such a high lack of awareness opens the door for manipulation by the management committees. Even though the level of political equity in Bhutan was only moderate, it was higher than what has been reported in neighboring countries.
- The level of economic equity (distribution of benefits), on the other hand, was very high. There were no indications of domination by wealthier members in terms of permits for timber. In fact, the poorest members received more timber permits than average members for all size classes. All of the socioeconomic groups appeared to have equal access to other products/services from the CF, such as firewood, non-wood forest products, and forest grazing. The same applied to female members. A higher percentage of committee members received timber permits, but the average number of trees per recipient was not significantly different.

The high level of equity in Bhutan was attributed to supportive government policy, environmental conditions, socio-cultural conditions, and strong support from the forestry extension service.

Conclusions

The study concluded that community forestry in Bhutan offers potential for sustainable forest management and equitable distribution of benefits. The research findings have policy implications for Bhutan and other countries:

- The selection cutting approach used in Yakpugang CF appears to be ecologically sustainable and appropriate for the cool broadleaved forests of Bhutan. Selection cutting appears to avoid some unresolved silvicultural problems of cable crane logging operations related to the promotion of natural regeneration of preferred species.
- The existing policy of allowing forest grazing in community forests in Bhutan appears to be appropriate: moderate levels of forest grazing and timber harvesting can be combined on an ecologically sustainable basis. However, the long term effect of grazing on natural regeneration of *Quercus* species needs further study.
- The policy of handing over well-stocked forests to communities appears to be appropriate, as it allows the user groups to obtain some immediate benefits while they invest in the improvement of the degraded portions of the CFs.
- Involving CF user groups in the process of forest resource assessments by developing simple inventory methodologies (e.g. replacing volume calculations with the number of trees of different size classes) appears to have a positive impact on the subsequent ability of the user group to manage harvesting operations.
- User groups require intensive and ongoing institutional strengthening, especially in the area of record keeping. Even though the forest management activities and distribution of forest products in the three CFs were satisfactory, the low level of knowledge of members regarding CF finances and the low standard of record keeping could lead to equity problems in the future.

List of Abbreviations

AAC	Annual Allowable Cut
BA	Basal Area
CF	Community Forest
dbh	Diameter at Breast Height
DFO	Divisional Forest Officer
DOF	Department of Forests
DzFO	Dzongkhag Forest Officer
F	F-ratio – ANOVA Test Statistic
FNC	Forest and Nature Conservation
GSF	Global Site Factor
H	Shannon-Wiener Index of Diversity
HH	Household
i-J	Inverted J (diameter distribution)
J	Jonckheere-Terpstra Test Statistic (Observed)
LU	Livestock Unit
Mdn	Median
MOA	Ministry of Agriculture
N	Number
Nu	Ngultrum
n.s.	Not significant
OR	Odds Ratio
NWFP	Non Wood Forest Product
p	Probability
PFMP	Participatory Forest Management Project
r	Pearson's Correlation Coefficient
R^2	Coefficient of determination
RBA	Relative Basal Area
RC	Research Centre
RGOB	Royal Government of Bhutan
RNR	Renewable Natural Resources
SDC	Swiss Agency for Development and Cooperation
SE	Standard Error
SFD	Social Forestry Division
t	T Test Statistic
T	Wilcoxon Signed Rank Test Statistic
U	Mann-Whitney Test Statistic
V	Volume
Z	Two-Sample Kolmogorov-Smirnov Test Statistic

Greek Symbols

τ	Kendal's tau Test Statistic
x^2	Chi-square Test Statistic

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1 Introduction

1.1 Rational for Study

Governments around the world are increasingly devolving authority for forest management to the local level in an attempt to increase community participation in the management of national forests (CARTER 2005; LAWRENCE 2007; MENZIES 2002). By 2002, governments had given communities legal rights to manage 380 million hectares of forest, 57% of which had been transferred during the previous 15 years (WHITE and MARTIN 2002).

This approach has been particularly widespread in South Asia. Nepal and India have the largest programs in the region: more than 13,000 forest user groups in Nepal are managing 25% of the total national forests (POKHAREL and PAUDEL 2005), while in India 53,000 Forest Protection Committees are managing 18% of national forests (AGRAWAL and OSTROM 2001). The experience of Nepal and India in the 1980s and 1990s influenced forestry programs in many other countries (HOBLEY 2005), and had a particularly strong influence on the development of Bhutan’s community forestry program due to the strong links between the forestry professionals of the three countries (BUFFUM and TEMPHEL 2004).

Community Forestry is now widely recognized as providing a range of economic and social benefits to the participating user groups (CARTER 2005; LAWRENCE 2007; MENZIES 2002). Community forestry supports the efforts of governments in biodiversity conservation and forest protection since illegal logging on public lands costs $10-15 billion per year (WHITE and MARTIN 2002). Community forests (CF) exhibited greater increases in forest cover than government forests, according to studies based on analyses of satellite imagery and aerial photography (GAUTAM et al. 2002; GAUTAM et al. 2004; SAKURAI et al. 2004) and forest inventories (BRANNEY and YADAV 1998; YADAV et al. 2003).

However, concerns have been raised about the capability of user groups to manage CFs in a sustainable manner (CARTER 2005; KELLERT et al. 2000; ROBERTS and GAUTAM 2003; WHITE and MARTIN 2002). There are examples of failures as well as successes: “Members of some groups fail to perceive the growing scarcity of their local forests, fail to create effective rules to counteract the incentives to overharvest, and fail to enforce their own rules” (GIBSON et al. 2000, p 228). There is also increasing evidence that community forestry programs do not provide benefits equally to all social groups and in some cases actually exacerbate inequality (HOBLEY 2005; SCHRECKENBERG et al. 2006).

The current research was designed to address three specific issues related to community forestry:

- The harvesting approach of selection cutting utilized by CF user groups may not be ecologically sustainable in diverse broadleaved forests.
- The use of CFs for forest grazing as well as timber production may have negative impacts on the natural regeneration of preferred tree species.
- The distribution of benefits from CFs may not be equitable.

The first issue, ecological sustainability of harvesting in CFs, has rarely been addressed - a recent review of participatory forest management (PFM) concluded that: “perhaps the most conspicuous absence from the PFM literature is a thorough analysis of forestry itself, the technology of intervention in a forest ecosystem to provide a reliable supply of the products and benefits required by the users” (LAWRENCE 2007, p 2). Other studies also reported that foresters have not yet devoted adequate attention to the development of more productive silvicultural systems for natural forests under community management (CARTER 2005; DONOVAN 2001; VICTOR 2001).

A key aspect of this issue is the ecological sustainability of selection cutting as practiced in the CFs. While experience with the plenter system in Central Europe has demonstrated that selection cutting can be highly sustainable (O'HARA and GERSONDE 2004; O'HARA et al. 2007), the use of simpler systems of selection cutting in the USA is widely reported to have a negative impact on the form, bole shape and species composition of residual stands (NYLAND 2006b; OLIVER and LARSON 1996). With the rapid expansion of community forestry in developing countries, it is important to assess the sustainability of CF harvesting practices, which are generally based on indigenous knowledge and traditional practices of selection cutting. If these harvesting practices are not sustainable, there is an urgent need for technical assistance and training. Studies of CF management to date have only assessed simple indicators of forest quality, such as number of stems and amount of forest cover (GAUTAM et al. 2002; YADAV et al. 2003). This research attempted to conduct a more thorough study of selection cutting in CFs by assessing six indicators of ecologically sustainable forest management.

The second issue, the ecological sustainability of forest grazing in CFs, has also not been the focus of much research to date, despite the importance of forest grazing to the livelihoods of many farmers around the world (RODER et al. 2002). The impact of forest grazing in general has been extensively studied (GRATZER et al. 1999; MAYER et al. 2006; PALMER et al. 2004; VANDENBERGHE et al. 2007), and several studies have investigated the impact of forest grazing after logging in commercially managed forests (DARABANT et al. In Press; KRZIC et al. 2001; VAN IJSSEL 1990), but a literature search did not locate a singe study investigating the impact of forest grazing in conjunction with logging in a broadleaved CF. Lawrence (2007) noted the absence of silvicultural guidelines for forests managed by communities for forest grazing and other non-wood forest products

The third issue, the equity of community forestry, has been the focus of considerable research around the world since the lack of equity in CFs emerged as the weakest aspect of community forestry programs (CARTER 2005; HOBLEY 2005; SCHRECKENBERG et al. 2006). However, this issue has not yet been addressed in Bhutan. A study of local perceptions of equity has been conducted (NAMGAY and SONAM 2006), but the current research was the first time that the actual distribution of products from Bhutanese CFs was assessed. Bhutan’s unique socio-cultural aspects offer a new context to understand the issues affecting the equity of community forestry programs.

1.2 Research Objective

The objective of the research was to test two hypotheses in the context of Bhutan: a) user groups are capable of managing CFs in an ecologically sustainable manner; and b) user groups are capable of equitable decision making and distribution of products from CFs.

The research focused on three particular issues:

- The ecological sustainability of the harvesting approach utilized by user groups in broadleaved CFs;
- The ecological sustainability of combining forest grazing and timber production in broadleaved CFs; and.
- The equity of the community forestry, considering both political equity (decision making) and economic equity (distribution of benefits).

1.2.1 Impact of Selection cutting in Broadleaved Community Forests

The first research component assessed six aspects of forest development to assess the ecological sustainability of selection cutting by user groups in Yakpugang CF. Specific research questions included:

- Were any species harvested at unsustainable levels?
- How did the forest condition change after five years of community management in terms of the number and composition of trees and seedlings?
- Did harvesting affect the diversity of the forest in terms of abundance and evenness of tree genera?
- Did harvesting intensity affect the composition of natural regeneration?
- Did harvesting affect the bole shape and form of remaining trees?
- Did harvesting affect the diameter distribution of the forest?

1.2.2 Impact of Forest Grazing in Broadleaved Community Forests

The second research component assessed the impact of forest grazing on natural regeneration to determine whether the combination of forest grazing and timber management is ecologically sustainable in broadleaved CFs. This topic was studied primarily in Yakpugang CF with supplemental data from Masangdaza and Shambayung CFs. Specific research questions included:

- How did livestock ownership and grazing patterns change in the five year period between 2000 and 2005?
- How did grazing affect natural regeneration?
- What is the threshold of grazing intensity for sapling recruitment in broadleaved forests?

1.2.3 Equity in Community Forests

The third research component assessed the equity of community forestry in Bhutan. The study assessed three indictors of political equity (decision making within the CF) and seven indicators of economic equity (distribution of benefits). This topic was studied in Yakpugang, Masangdaza and Shambayung CFs.

Specific research questions included:

- Did all members of the user groups, including disadvantaged groups and female members, participate equally in the decision making process of the user group?
- Was the distribution of benefits from the CF equitable in terms of access to products by different socio-economic groups and female members?

1.3 Research Approach

Newmann (2006, p. 34) described three basic purposes for research, as can be seen in Table 1. Purposes of research.

Table 1. Purposes of research

Exploratory	Descriptive	Explanatory
Become familiar with the basic facts, setting, and concerns	Provide a detailed, highly accurate picture	Test a theory's predictions or principle
Create a general mental picture of conditions.	Locate new data that contradict past data	Elaborate and enrich a theory's explanation
Formulate and focus questions for future research.	Create a set of categories or classify types	Extend a theory to new issues or topics.
Generate new ideas, conjectures or hypotheses.	Clarify a sequence of steps or stages	Support or refute an explanation or prediction
Determine the feasibility of conducting research.	Document a causal process or mechanism	Link issues or topics with a general principle.
Develop techniques for measuring and locating future data.	Report on the background or context of a situation.	Determine which of several existing explanations is best

This research had a combination of descriptive and explanatory purposes. The descriptive purpose was to provide a detailed description of harvesting and forest grazing practices and their impact on natural regeneration in a broadleaved community forest in Bhutan. Without such a description it would have been impossible to address the specific research questions. The explanatory purpose was to support or refute an explanation or prediction. The prediction, as stated in the two basic hypotheses, was that user groups in Bhutan are capable of managing CFs in an equitable and ecologically sustainable manner.

The research used a combination of quantitative and case study approaches. In all three research components, quantitative data were collected and statistically significant results were reported. However, the number of CFs that could be studied was limited because of the limited experience in the country. The studies on the impact of harvesting and grazing in broadleaved forests were conducted in the only broadleaved CF that had experience with harvesting at the time of the study. The study of equity issues was extended to include the two other CFs with experience with harvesting, both of which were conifer CFs. Therefore, the sample of CFs could not be assumed to be representative of all CFs in the country, even though the sample included 100% of the potential cases at the time. For this reason, a case study approach was used to develop the explanatory power of the findings. According to Newman (2006, p. 63), "… explanation implies logically connecting what occurs in a specific situation to a more abstract or basic principle about 'how things work'. A researcher explains or answers the question Why? by showing that one particular situation is a case of, or a particular instance of, the more general principle."

The research utilized both longitudinal and cross sectional approaches. The availability of baseline data collected five years earlier made it possible to assess changes in forest condition during the five year period. Detailed records of timber permits also provided data for a longitudinal approach. However, most of the socio-economic issues were investigated though cross sectional research which focused on observations at a specific time.

1.4 Structure of Dissertation

The dissertation is divided into six chapters:

- Chapter 1 provides the rational and objectives for the research, and presents the detailed research questions.
- Chapter 2 describes the context for the research, including an overview of Bhutan and the forestry sector and a description of the study sites.
- Chapter 3 presents the findings of a literature review of topics addressed by the research.
- Chapter 4 describes the research methodology.
- Chapter 5 presents the research results.
- Chapter 6 discusses the significance of the results.
- Chapter 7 summarizes the findings and conclusions of the research.

2 Context

2.1 Bhutan Country Overview

Bhutan is a land-locked Himalayan country bordering with China (Tibet) and India, lying between the latitudes of 26º 45' and 28º 10' north and longitudes of 88º 45' and 92º 10' east. Bhutan has an area of 40,006 square kilometers and an estimated population of 672,425 (RGOB 2005). At least nineteen languages in four major language groups are spoken by many different ethnic groups (WANGCHUK 2000). Bhutan has probably been populated since 2000 BC, but according to local tradition, the history of the country began when the Tibetan king, Songtsen Gampo, constructed the first two Buddhist temples in Bhutan in the 7th century AD (POMMARET 1991). Bhutan is a monarchy, but in 1998 executive power was handed over to the Council of Ministers and the National Assembly.

Figure 1. Map of South Asia

Source: USA Today Travel Guides

Figure 2. Map of Bhutan

Source: Lonely Planet

Elevation ranges from 100 m near the Indian border to 7,554 m on the northern border with China, which results in a diverse range of forest types. Bhutan has a rich biodiversity and is part of one of the ten global biodiversity ‘hotspots’ (MYERS et al. 2000). The country’s biodiversity assets include 5,446 species of vascular plants, of which 750 are endemic to the Eastern Himalayas and 50 are endemic to Bhutan itself; 770 species of birds; and 178 species of mammals (DOF 2002a). Bhutan is well known for its commitment to conservation: 26% of the country has been set aside for protected areas (DOF 2002a). See Appendix 1 for map of protected areas.

Most of the country is forested, as can be seen in Table 2. Land cover of Bhutan. The protection of watersheds contributes to the production of hydroelectricity, which is the major source of foreign income for the nation.

Table 2. Land cover of Bhutan

Land Cover	Percent of Total Land
Forest	64.5%
Scrub forest	8.1%
Pasture	3.9%
Permanent Agriculture	7.8%
Snow/Glacier/Rock Outcrop	12.5%
Other	3.4%
Total	100%

Adapted from (MOA 2002)

Forest land in Bhutan can be classified in two major categories:

- National forests on government land, and
- Forests on private registered land. This land is generally used for shifting cultivation or was used for permanent agriculture in the past, and the owners still pay tax to the government on an annual basis. It is estimated that 28% of the area of Bhutan is used for shifting cultivation (MOA 2002). Until 2000, forest trees on private land legally belonged to the government. Under the new Private Forestry Program approved in 2000, land owners can apply for legal rights to manage forests on certain categories of private land (MOA 2000, 2006b). The government is in the process of quantifying the amount of private forested land, but it is generally assumed that only a small percentage of forested land in the country will be eligible for registration as private forests.

National forests can be subdivided into several categories:

- National parks and protected areas (26% of national forests). Nine protected areas, which cover portions of 17 of Bhutan's 20 districts, include four national parks, four wildlife sanctuaries and one strict nature reserve. Six protected areas are currently operational and three are in the pipeline. Many villages are located inside the protected areas, so the government must seek creative solutions to protect biodiversity and at the same time support the socio-economic development of the communities (SPIERENBURG 2003). The protected areas are intensively managed by national park staff under the supervision of the Nature Conservation Division of the Department of Forests (DOF).
- Biological Corridors (9% of national forests). This new program was initiated in 1999 to link the national parks and protected areas and allow migration of flora and fauna between protected areas. The government plans to impose some restrictions on land use in the biological corridors, but the restrictions will be less than in the protected areas.
- Forest Management Units (FMU) (8% of national forests). These forests are managed intensively by the DOF with cable crane logging operations. Thirteen FMUs have been established and forest management plans were operational for 143,840 ha of forests in 2002 (DOF 2002a). The FMUs are managed by the Forest Development Cooperation Ltd. under supervision of DOF field staff. Villagers are allowed to harvest trees in the FMUs after receiving permits from the DOF.
- Other National Forests (56% of national forests). These are managed extensively by the DOF by giving permits to individuals or contractors for small scale logging operations and collection of non-wood forest products The DOF presence in these forests is limited in comparison to the national parks and FMUs. In 2000 the DOF started a new initiative to

prepare simple management plans for all national forests based on a modified forest inventory process, but this has not yet been realized for most national forests (SCHINDELE 2005).

- Community forests which are handed over to a group of traditional users for management (1% of national forests). Most CFs were originally in the category of other national forests, however several CFs have been established inside national parks or FMUs.

Bhutan's 29,045 square km of forest have been categorized on the basis of interpretation of satellite imagery, as can be seen in Table 3. Forest types and area in Bhutan.

Table 3. Forest types and area in Bhutan

Type of Forest	Area in Km^2	Percent of total area
Conifer Forest	10,616	26.5%
Broadleaf + Conifer	1,358	3.4%
Broadleaf forest	13,749	34.3%
Conifer Plantation	20	0.1%
Broadleaf Plantation	44	0.1%
Forest Plantation	64	0.2%
Scrub Forest	3,258	8.1%
Total Forest Area	29,045	72.5%

Source: (DOF 2002b)

The first detailed description of forest types in Bhutan was provided by Grierson and Long (1983). The description below is an adaptation of Grierson and Long's forest types with additional information from Davidson (2000).

Subtropical Forest occurs in the southern foothills at elevations of 200 to 1,000 m in areas receiving an annual rainfall of 2,500-5,000 mm. Although Bhutan does not contain any true tropical forests, this zone contains some typically tropical genera such as *Shorea.*

Warm Broadleaved Forest occurs at elevations of 1,000 to 2,100 m) in areas with less rainfall (2,300 - 4,000 mm^*yr^{-1}) than subtropical forest. Tropical species are absent from this zone and are replaced by temperate and subtemperate species. Common genera include *Alangium*, *Alnus*, *Altingia*, *Betula*, *Castanopsis*, *Dendrocalamus*, *Tetradium*, *Lithocarpus*, and *Schima.* In the deeper valleys this forest type penetrates far into the interior.

Chirpine Forest occurs at elevations of 900 to 2,100 m on shallow soils and southerly aspects in drier (1,000 - 1,500 mm^*yr^{-1}), deeper valleys. These sites are characterized by an extended dry season during which fires are common. Chirpine (*Pinus roxburghii*) is resistant to these annual and semi-annual fires except in the seedling stages. Naturally regenerating seedlings are highly resistant to grazing, and chirpine is often the only tree species present. More fire-susceptible shrub species are limited to moist depressions and watercourses. An abundant herb-grass understory develops during the monsoon, often dominated by lemon grass (*Cymbopogon flexuosus*), which is collected for the distillation of essential oils.

Cool Broadleaved Forest occurs on moist slopes above the warm broadleaved zone and the wetter sites of the Chirpine zone at elevations of 2,000 - 2,800 m. This is a more mixed forest type in which species of FAGACEAE (*Quercus, Castanopsis*) are mixed with LAURACEAE (*Persea, Lindera* and *Litsea*) and other genera such as *Daphniphyllum*, *Exbucklandia*, *Acer*, *Beilschmiedia*, *Betula*, *Michelia, and Symplocos*. In the absence of grazing, the moist microclimate under the main tree canopy stimulates a dense growth of shrubs and climbers. Epiphytes are common.

Evergreen Oak Forest occurs at elevations of 2,000 - 2,800 m instead of cool broadleaved forests in dryer sites (2000 - 3,000 mm*yr^{-1}). It is dominated by *Quercus and Castanopsis*. Other representative species include *Acer campbellii* and *Juglans regia*. Shrubs are generally poorly represented and the shaded forest floor is dominated by small herbs, ferns and club-mosses.

Mixed Conifer Forest occurs at elevations between 2,100 and 3,200 m, with different species composition depending on the site conditions and disturbance regime. Blue pine (*Pinus wallichiana*) is the temperate equivalent of chirpine, occupying the mid-elevations (2,100 - 3,000 m) of dry interior valleys (700 to 1,200 mm*yr^{-1}). Unlike chirpine, blue pine and Bhutanese blue pine (*P. bhutanica*) are very susceptible to fire. These pines often form almost pure stands with a diverse understory of shrubs. Blue pine is a common pioneer species appearing after disturbance in cool broadleaved forests and the lower elevation range of mixed conifer forests. Spruce (*Abies*) occurs at elevations from 2,700 to 3,200 m with precipitation of 700 to 1,200 mm*yr^{-1}. It transitions into blue pine and evergreen oak forests at the lower levels, and horizontally into hemlock (*Tsuga)*. Hemlock is the latest successional, most shade tolerant component of the mixed conifer stands (Gratzer et al. 2004), and the transition from spruce dominated stands to hemlock dominated stands in the course of succession can be observed frequently. Stands vary from almost pure spruce to mixtures of spruce, pine and oak at lower elevations, and mixtures of spruce, *Larix*, *Acer, Betula* and *Tsuga* in the transition to hemlock. Disturbed areas in the upper elevation range of mixed conifer forests are often colonized by dense thickets of bamboo (*Arundinaria*).

Fir Forest is the highest elevation forest zone in Bhutan, ranging from 3,200 to 3,800 m in areas receiving greater than 1,300 mm*yr^{-1} precipitation. *Abies densa* occurs in almost-pure, very dense stands along the higher ridge tops, mixing with hemlock and spruce only in the lower elevations of the range. In freshly disturbed areas, *Betula utilis* is found as an early successional component. This zone characteristically has an understory of tree and shrub rhododendrons, other shrubby genera, and bamboo (*Yushania maling*).

Juniper forest occurs above the tree line from approximately 3,700 to 4,200 m, typically consisting on scattered shrubs of *Juniperus recurva*, *J. squamata*, *Rhododendron lepidotum* and *Potentilla arbuscula,* with a rich herb layer appearing during the monsoon.

2.2 Department of Forests

The DOF was created in 1952 under the Ministry of Agriculture (MOA). See Appendix 2 for MOA organogram. The DOF has four functional divisions at the central level:

- The Forest Protection and Utilization Division (FPUD) undertakes tasks related to protection of forest from pest and diseases, land inspection, utilization of timber and non wood forest products mostly in collaboration with the Territorial Forest Divisions and National Parks.
- The Forest Resources Development Division (FRDD) is responsible for the preparation of FMU management plans, forest demarcation, and monitoring of non-wood forest products (NWFP) outside protected areas.
- The Social Forestry Division (SFD) technically backstops the district forestry sectors in the implementation of decentralized forestry activities and participatory forest management.
- The Nature Conservation Division facilitates the activities of the national parks and wildlife sanctuaries (MOA 2007a).

In 1969 the government attempted to strengthen the management of Bhutan's forests by nationalizing all forests and introducing a system of issuing permits for the harvesting of timber and other forest products. The DOF administers national forests through Divisional

Forest Officers (DFO) in twelve Forest Divisions. The new forest policy retained some traditional rights in national forests, such as *tsamdro:* individual or community rights to graze livestock in designated blocks of forest (RODER et al. 2002; URA 2002) and *sokshing*: individual or community rights to produce leaf litter in designated blocks of forest (DORJI et al. 2003; DORJI et al. 2006). The nationalization of forests eliminated the legal basis for many traditional practices of forest management related to timber and firewood production, including the exclusion of outsiders (MESSERSCHMIDT et al. 2001).

Participatory forest management (PFM) is a key component of the 9th Five Year Plan (FYP) for the forestry sector of Bhutan. A new Social Forestry Division (SFD) was created within the DOF at the beginning of the 9th FYP to support the implementation of an ambitious program of PFM activities.

The MOA provides agriculture extension support through Renewable Natural Resources (RNR) extension teams located in each of Bhutan's 20 districts. Each RNR extension team includes a District Forestry Extension Officer (DzFO) who reports to the district administration, whereas the DFOs report directly to the DOF. In the mid 1990s, the DOF started to decentralize authority for some forestry activities to the districts, but the DFOs still have the ultimate responsibility for the conservation and management of national forests.

2.3 Development of the Community Forestry Program

Despite Bhutan's abundant forest resources, several problems related to the nationalization of forests in 1969 emerged during the following 25 years which eventually led to the initiation of the community forestry program in 1995:

- While the nationalization of forests was viewed positively by the DOF, rural people considered that the elimination of their traditional rights made their lives more difficult, and repeatedly voiced their opposition at the National Assembly (NAMGYEL 2006).
- The DOF did not have enough staff to effectively manage all national forests, and some forests previously managed by local communities became progressively degraded (DOF 1996).
- Overexploitation of forest resources in many areas was compounded by the expanding road network which enabled commercial exploitation by outsiders (DRDS 2002).
- The DOF was unable to process requests for permits for villagers and mark the trees on a timely basis. Villagers with urgent needs for timber sometimes harvested trees without prior marking by DOF and were charged with illegal felling (WANGCHUK 1998).
- The demand for timber grew rapidly, and DOF needed to find alternate means of supplying timber to the public (DOF 1996).

The development of Bhutan's community forestry program started in 1979 with the initiation of the national social forestry program. The legal framework for Bhutan's community forestry program was outlined in the Forest and Nature Conservation Rules 2000 (MOA 2000), and the first CF was legally handed over in 1997.

The development of community forestry program was given a boost in May 1993 when the Planning Commission of Bhutan recommended that the DOF decentralize some forestry activities to the district administrations. The DOF responded by assigning forestry extension staff to each district and giving them responsibility for a range of activities, including the new community forestry program (MOA 1997).

As the decentralization process gained momentum, the district administrations started to request greater decentralization of the forestry sector. In the late 1990s, the introduction of local elections at the village level provided a new forum for villagers to voice their complaints about the difficulty in obtaining permits for timber and firewood from the DOF. This increased the pressure on the DOF to decentralize greater authority for forest management to the district level.

The community forestry program was initially intended to hand over degraded land for CFs. However, in 1993, the DOF recommended modifying the Social Forestry Rules to allow CFs to include a mix of well-stocked and degraded forests in order to give communities more incentive to invest in the management of the CFs (CHHETRI 1992; UPADHYAY 1992). This was unusual in that governments in many countries have only been willing to hand over degraded forests for community management (CARTER 2005; MENZIES 2002), as has generally been the case in Nepal and India (HOBLEY 2005).

The MOA was the most influential stakeholder in the development of the community forestry policy. But there was considerable difference of opinion about community forestry within the MOA, and even within the DOF. Over time, many DOF and MOA staff members were exposed to community forestry in Nepal and other neighboring countries during study tours, which stimulated interest and support for the program (TSHERING et al. 2004). The staff members of DOF's Social Forestry Section became strong advocates of participatory forestry, and as the initial pilot programs demonstrated success, the DOF gradually became more receptive to participatory approaches (BRANNEY et al. 2004).

Other stakeholders that might have been active in other countries, such as political parties, associations, and the private sector, were not involved in the policy formulation stage. Bhutan did not have any political parties at the time, although they will be permitted under the new constitution. There were no associations that actively lobbied for community forestry. An Association of Wood Based Industries was established in 2000, but it was mostly concerned with private sector issues (BUFFUM and SCHALTENBRAND 2002).

Bhutan is quite unique among developing countries in that it has been able to remain firmly in control of its development process and resist pressure from donors. So the phenomenon of "donor driven development" prevalent in many developing countries is rare in Bhutan. The government has repeatedly demonstrated its willingness to turn down funding for projects that do not support its priorities. Nevertheless, Bhutan does rely upon its "development partners" for technical assistance and funding, and international agencies were involved in the development of the community forestry policy as members of the policy arena, if not the direct policy network.

The international agency most involved in the community forestry policy development was the Food and Agriculture Organization (FAO) of the United Nations. In 1991, FAO assisted the government to prepare the first draft of the FNC Act which outlined the key elements of the community forestry program, most notably that the government would transfer ownership of the forest produce in the CFs to user groups for sustainable use in accordance with approved management plans (RGOB 1995). In 1993, FAO provided additional technical assistance to finalize the Act (CHRISTY 1993), which was subsequently approved in 1995. The World Bank and the Swiss Agency for Development Cooperation (SDC) contributed to the policy development in 2002 by including a community forestry component in the Third Forestry Development Project (WORLD BANK 2003).This project, which was implemented from 1993 to 2002, provided credit of $5.2 million for the forestry sector and was the largest donor-assisted forestry project in Bhutan at the time.

The community forestry program is supported by an intensive forestry extension program. The ratio of government forestry extensionists to rural residents in 2000 was approximately 1:4,000, based on a cadre of 117 forestry extension staff (DOF 2002b) and a rural population estimated to be 69% of the total population of 672,425 (RGOB 2005). The 9th Five year Plan included an ambitious target to more than double the number of extension staff (DOF 2002b).

The forestry extension agents responsible for the CFs provide strong support during the management planning phase, which relies heavily on participatory rural appraisal exercises to increase the involvement and awareness of the users (DOF 2004b). The extension service also provides strong support in monitoring and evaluation through a standard set of monitoring formats for use in CFs, which enables the users to monitor their own compliance with the rules (DOF 2004d).

Community forestry was a major component of the 9th Five Year Plan for the forestry sector (DOF 2002b). By 2004, DOF had handed over 26 community forests. An initial evaluation of the community forestry program concluded that the user groups were managing their CFs conservatively in accordance with their management plans (OBERHOLZER et al. 2003). However, some MOA and DOF officers were concerned that the user groups might not harvest the forests sustainably or distribute products equitably (BUFFUM and TEMPHEL 2004). Based on these concerns, a DOF Working Group proposed revising the FNC Rules to only allow the handover of degraded forests for community management, which would have fundamentally changed the community forestry program (BRANNEY et al. 2004). However, before a final decision was made, DOF conducted a study of 15 CFs which concluded that the user groups were managing the CFs effectively (TEMPHEL et al. 2005). In addition, the preliminary results of the equity component of this research were distributed in Bhutan, which concluded that the distribution of benefits from CFs was highly equitable (BUFFUM et al. 2005).

These two studies helped to increase awareness within the government about the positive aspects of the community forestry program. During the 2006 annual MOA conference, a decision was made to continue the community forestry program in its current form (MOA 2006a), and the proposal to only allow the handover of degraded forests for CFs was dropped. Instead the FNC Rules became potentially more favorable for users due to the elimination of the requirement that CFs should be 50% degraded, stating that “any area of Government Reserved Forest, in and around villages and human settlement including government land situated in the interspaces between registered private land, suitable for management by a Community Forest Management Group (CFMG) may be designated as Community Forests” (MOA 2006b, p. 27). By March 2007, the total number of CFs had increased to 42, but only three CFs had started harvesting substantial quantities of timber. See Appendix 3 for list of approved CFs.

2.4 Management of CFs

After the approval of a CF management plan by DOF, a CF management committee elected by the members assumes responsibility for management of the CF. The management committee organizes regular meetings of the users to implement the work plan for the coming period. An important activity in all CFs is patrolling to ensure that illegal harvesting or forest grazing is not taking place. In some CFs, one ore more forest guards are hired, while in other CFs the members take turns patrolling the forest on a voluntary basis. Other management activities include nursery management, tree-planting in degraded areas, thinning and tending operations, and creation of firelines. These activities are generally carried out on specified work days. Each member household must provide one person during the workdays, and members that do not participate are penalized with fines or assigned additional work.

When members require wood products, they request the management committee to issue a permit. The management committee verifies whether the member has already received his/her allocation of products, which is specified in the management plan. Most CFs distinguish between *drashing* (trees of at least 50 cm dbh which are used for sawn timber), *cham* (trees of 30-50 cm dbh which are used for beams), *tsim* (trees of 20-30 cm dbh used for large poles), and *dangchung* (trees of 10-20 cm dbh which are used for small poles). The management plans provide harvesting limits for each size class of timber. Other common products harvested in CFs include firewood, fence posts, flagpoles, and NWFPs such as bamboo, cane, wild vegetables, and medicinal plants.

After issuing a permit using a standard permit book provided by DOF, a member of the CF management committee enters the forest with the applicant and marks the trees for harvesting with the official CF marking hammer, which leaves an imprint on the stump of the tree. After marking, the applicant harvests the trees at his/her convenience. Generally the members carry out some initial processing in the forest before transportation to the village. Most sawn timber is prepared with traditional pit saws, but recently villagers have started sawing boards with portable sawmills using a chainsaw frame attachment. Most harvesting and transportation is done by individuals, but groups of users often collaborate in harvesting and transporting firewood.

The CFs generate income from royalty payments from the harvesting of wood products and contributions from visitors. The funds are used for a variety of purposes, including providing loans to members, constructing CF offices, providing meals during work days and meetings, and contributing to schools and temples.

2.5 Study Area

2.5.1 Yakpugang Community Forest

The primary research area was Yakpugang CF in Mongar District of Eastern Bhutan. The CF has an area of 260 ha with an elevation range of 1,800 to 3,200 meters. The CF is located four km east of the District Center of Mongar, and ten minutes by foot from the nearest road. See Appendix 5 for map of Yakpugang CF, and Figure 2 for Map of Bhutan. Average annual rainfall in the District Center at an elevation of 1,520 m is 697 mm (FAO 1982), but the annual rainfall in the CF may be as high as 3,000 mm (MONGAR DZONGKHAG 2001). The main rock in the area is sericite-chlorite phyllite, which is the dominant component in the parent material of the soils. The site is located on the Shumar Formation, which consists of a succession of phyllites and quartzites, with some limestone bands (DORJI et al. 2000).

The forest can be classified as cool broadleaved forest, and includes at least 32 genera of tree species dominated by *Quercus*, *Castanopsis*, *Persea*, *Elaeocarpus* and *Symplocos*. A few *Pinus wallichiana* trees were observed in the upper regions of the CF, but not in the study blocks. Most of the forest floor was relatively open, but dense stands of thorny bamboo (*Chimonobambusa callosa*) existed in the higher elevations.

The forest is typical of many cool broadleaved forests in Bhutan. Bhutan has an estimated 1.37 million hectares of broadleaf forests, representing almost half of the total forested area (DOF 2002b). Gap phase regeneration is a crucial process affecting the structure and dynamics of temperate broadleaved forests in Bhutan (DAVIDSON 2000).

Yakpugang CF was formally initiated in May 2001 with the approval of the CF Management Plan by DOF. The CF has 113 member households, which includes primary and secondary members. The primary members from the village of Yakpugang rely on the CF for timber, firewood, forest grazing and non wood forest products, while the secondary members from Kilikhar and Tongsing generally only utilize the CF for timber. The forest has been harvested for more than a century. Timber and firewood trees are harvested by individual members after being marked by a member of the CF management committee. After semi-processing in the forest with traditional tools or portable sawmills, the wood products are carried or dragged from the forest. During recent years some user group members have started to use a chainsaw with a frame attachment to produce sawn timber in the forest. The CF has generated income of more than Ngultrum (Nu) 87,000 from visitor fees, permit fees and community contributions, of which approx Nu. 65,000 has been spent on the construction of a CF Office (1 Euro = 57 Nu in October 2007).

2.5.2 Masangdaza Community Forest

Masangdaza Community Forest, in Mongar District has an area of 87 ha and an elevation range of 690 – 980 m. The CF is located 8 km southwest of the District Center of Mongar, and 45 minutes by foot from the nearest road. The average annual rainfall recorded at the nearby meteorological station in Lingmethang was 1,000 mm, with more than 200 mm/month in June and less than 5 mm/month in December; the average mean temperature ranged from 9º C in January to 23 º C in August (DORJI and CHONG 1998). Most of the CF is a well-stocked conifer forest dominated by *Pinus roxburghii*, but there is a small patch of broadleaved forest in the center of the CF. The CF is located close to the border of Lingmethang FMU, which was established in 1998 (DORJI and CHONG 1998). The CF area was used in the past for resin tapping, and shows signs of past fire damage. The CF is currently used for timber harvesting, firewood and NWFP collection, and forest grazing.

The CF was formally handed over in August 2002 to 37 member households. The ten year management plan includes activities such as timber harvesting, plantation in degraded areas, fire control and patrolling. At the time of the research, all boards were produced using a traditional pit saw. By 2006, the user group had contributed more than 400 person days of labor for forest management activities. The CF has generated income of more than Nu 26,000 from visitor fees, permit fees and community contributions, of which approx Nu 7,000 has been spent on providing loans to members, temple restoration, and refreshments.

2.5.3 Shambayung Community Forest

Shambayung CF in Bumthang District has an area of 46.5 ha at an elevation of 3,000 – 3,500 m. The CF is located 16 km northeast of the District Center of Jakar, and 30 minutes by foot from the nearest road. The annual rainfall in Hurchi, Bumthang, located in the western part of the same district at an elevation of 3,270 m is 1,299 mm (DORJI 2001). The CF includes a well-stocked conifer forest dominated by *Pinus wallichiana.* The forest has profuse regeneration and high potential for timber production. The CF is currently used for timber harvesting, firewood and NWFP collection, and some forest grazing.

The CF was handed over to 23 member households in August 2003. The ten year management plan includes activities such as timber harvesting, plantation in degraded areas and patrolling. During the past few years some user group members have started to use a chainsaw with a frame attachment to produce sawn timber in the forest. The CF has generated income of more than Nu 60,000 from visitor fees, permit fees and community contributions, which has been used to purchase furniture and install a telephone in the CF office.

3 Literature Review

3.1 Introduction

A literature review was conducted on the topics addressed by the research. The review included applied literature as well as academic literature, as field practitioners are experimenting with innovative approaches to participatory forest management that have not yet been documented in peer-reviewed journals. The applied literature included reports by the government of Bhutan and international development agencies.

The chapter on the literature review is divided into four sections covering:

- Common property regimes and community forestry,
- Selection cutting in broadleaved forests,
- Forest grazing in broadleaved forests, and
- Equity of community forestry.

Each section starts with a presentation of international experience with the issue including relevant analytical frameworks, and continues with experience with the issue in Bhutan.

3.2 Common Property Regimes and Community Forestry

3.2.1 International Experience

Property regimes in natural resources management can be divided into three classes: state property regimes, common property regimes, and individual property regimes (BROMLEY 1990). Forests around the world are managed under all three classes of property regimes: it has been estimated that 77% of global forests are managed under state property regimes, 11% under common property regimes, and 12% under individual property regimes. In developing countries the percentage of forests under common property regimes is somewhat higher at 22%, vs. 71% for state property regimes and 7% for individual property regimes (WHITE and MARTIN 2002).

Common property resources have two distinguishing attributes: a) the resources are subtractable (rivalrous in consumption), and b) exclusion of potential users is difficult or costly: this combination of qualities can create situations in which the short term interests of individuals do not necessarily match the long term interests of the wider community (OSTROM et al. 1999).

There have been many forestry examples to support Hardin's famous statement that "freedom in a commons brings ruin to all" (HARDIN 1968, p.1244). Hardin argued that the users of a commons are caught in a process that eventually leads to the destruction of the resource upon which they depend, because each individual continues to use the resource until the expected costs of utilization equal the expected benefits. Since each individual does not consider the costs imposed on others, the accumulated individual decisions result in the overuse of the commons.

Ironically, the nationalization of forests and the establishment of forest services have contributed to deforestation in some cases. For example, in Nepal "the new laws (related to forest nationalization) undermined existing systems of management and led to widespread deforestation" (AGRAWAL and OSTROM 2001, p 499). Nationalization of forests also reportedly undermined local stewardship practices in developed countries such as Canada (ROBERTS and GAUTAM 2003).

However, there are many examples of successful common property regimes, which are defined by McKean as “a property-rights arrangement in which a group of resource users share rights and duties towards a resource” (2000, p 30). A number of recent reviews of common property resources management throughout the world have documented successful management by user groups. Ostrom concluded that “the empirical and theoretical research stimulated over the past 30 years by Garrett Hardin's article has shown that tragedies of the commons are real but not inevitable” (1999, p 280). Carter found that collaborative forest management “can clearly lead to better forest management” (2005, p 1). White and Martin reported that “there are many examples of sound community management (of forests) where harvest levels appear sustainable and benefits are distributed more equitably to community members (2002, p 16). Roberts and Gautam concluded that community forestry “appears to be achieving remarkable success in its aims of sustainable forest management and securing socio-economic benefits for local communities“ (2003, p 1).

Several attempts have been made to identify the attributes of successful common property regimes. McKean (2000) prepared a list of ten attributes:

- User groups need the right to organize, or at least no interference with their attempt to organize.
- The boundaries of the resources must be clear.
- Criteria for membership in the user group must be clear.
- Users must have the right to modify their use rules over time.
- Use rules should be environmentally conservative to provide a margin for error.
- Use rules must be clear and easily enforceable.
- Infractions of rules must be monitored and punished.
- Decision making and distribution of benefits need not be egalitarian, but must be viewed by the members as “fair”.
- Inexpensive and rapid methods are needed for conflict resolution.
- Institutions for managing very large systems need to be layered with devolution of authority to small components to give them flexibility and control over their fate.

Ostrom (1999) prepared a more detailed list of attributes distinguishing between attributes of the users and attributes of the forest. The attributes of the users included:

- Users should be dependent on the resource for a major portion of their livelihood or other variables of importance to them.
- Users should have a shared image of the resource and how their actions affect each other and the resource.
- Users should have a sufficiently low discount rate in relation to future benefits to be achieved from the resource. This may be because they have lived in the area for a long time and expect that their children and grandchildren will remain there, or because they have a secure bundle of property rights to the forest.
- Users with higher economic and political assets should be similarly affected by a current pattern of use.
- Users should trust each other to keep promises and relate to one another with reciprocity.
- Users should be able to determine access and harvesting rules without external authorities countermanding them.
- Users should have learned at least minimal skills of organization through participation in other local associations or learning from neighboring groups.

Ostrom (1999) also reported that four attributes of the forest were associated with successful CFs:

- The forest should not be so degraded that it is useless to organize, or so underutilized that there is little advantage from organizing.
- Reliable and valid information about the general condition of the resource should be available at reasonable costs.
- The availability of resource units should be relatively predictable.
- The resource should be sufficiently small, given the transportation and communication technology in use, so that users can develop accurate knowledge of external boundaries and internal microenvironments.

Some authors have challenged Ostrom's economic-institutional modeling of common property regimes. For example, Mosse (1997) argued that symbolic interests can be as important as material interests. Carter (2005) argued against trying to identify a set of ideal conditions for community forestry: each user group has its own unique circumstances, and whether the user group can find an effective way to address these circumstances will determine its success or failure. Nevertheless, Carter agreed that many case studies of successful user groups did indeed exhibit the attributes identified by Ostrom and McKean. These attributes will be discussed in relation to Bhutan's community forestry policy and the three studied CFs in Section 5.2.5.

3.2.2 Bhutan Experience

Bhutan has a long standing tradition of local management of natural resources, which predates the unification of Bhutan in the 17th Century (URA 2004). Before the nationalization of forests in 1969, villages had primary responsibility for forest management, and observed traditional practices that were similar in many ways to the current management of CFs. For example, many villages defined harvesting areas for exclusive use by community members for products such as firewood, bamboo, cane and other non-timber forest products (DRDS 2002). Villages often marked traditional forest boundaries with cairns and collected fines when cattle from neighboring villages entered their forest (WANGCHUK 2000). Some villages practiced *ridam:* prohibiting access to certain forests during specified periods of the year (MESSERSCHMIDT et al. 2001; TEMPHEL et al. 1990). Often a specific person was given authority to oversee the management of the local forests: "The community managed its natural resources like forests and water through its indigenous institutions and unwritten customary laws, and ensured their sustainability by instituting positions of authority such as forest protector (*risungpa*)…(who) ensured proper distribution of fuelwood and timber for construction" (PENJORE and RAPTEN 2004, p. 23).

Even though the nationalization of forests in 1969 eliminated the legal basis for these traditional practices, many continued throughout the country. According to Wangchuk (2000, p.12) "customs meet formal laws and are negotiated, contested, used and abused by the local actors… To look at the Forest Act and to assume forest usage existing on the ground as legislated in the Act would be an incomplete picture".

Other traditional practices in national forests remained legal even after the nationalization. For example, the new forest policy retained traditional rights such as *tsamdro:* individual or community rights to graze livestock in designated blocks of national forest (RODER et al. 2002; URA 2002) and *sokshing*: individual or community rights to produce leaf litter in designated blocks of national forest (DORJI et al. 2003; DORJI et al. 2006).

Several authors have claimed that Buddhism has a positive influence on natural resources management in Bhutan (PENJORE and RAPTEN 2004; POMMARET 1991; TFDP 2000). The Biodiversity Action Plan for Bhutan explains that "according to Buddhist and pre-Buddhist philosophies, the mountains, rivers, streams, rocks and soils of Bhutan are believed to be the domain of spirits... This, coupled with the Buddhist tenet that the acts of this life will be rewarded or punished in the next, provides a powerful motivational principle for sustaining Bhutan's natural resource base including its outstanding biodiversity" (MOA 2002, p.34).

3.3 Selection Cutting in Broadleaved Forests

3.3.1 International Experience

Selection cutting has been defined as: "a silvicultural system used to regenerate and maintain uneven-aged stands. Selection cuttings are used to remove individual or small groups of mature trees to regenerate a new cohort, as well as to thin the immature age classes to promote their growth and improve their quality" (KENEFIC and NYLAND 2005 p.18). Clearcutting, on the other hand, is a silvicultural system commonly used in commercial logging operations in which large openings are created by harvesting all trees in the opening.

Selection cutting is often advocated because it is assumed to mimic natural forest development by leaving trees distributed in all age classes (OLIVER and LARSON 1996). Some studies claim that selection cutting causes less damage to forests than harvesting systems that create large gaps in the forest canopy (RICE et al. 1997). It has been argued that selection cutting can be operationally more efficient than group selection because the larger tree size for selection cutting reduces the time consumption per m^3 of harvested tree volume (SUADICANI and FJELD 2001).

The impact of selection cutting on diversity of tree species has been hotly debated. Some authors claim that selection cutting does not have a negative impact on tree diversity (CANNON et al. 1998; DEKKER and DE GRAAF 2003; KARIUKI et al. 2006; MONTAGNINI et al. 1998; WEBB and PERALTA 1998). However, other studies reported that selection cutting did not promote natural regeneration of preferred species and maintain forest diversity (JENKINS and PARKER 1998, 2001; SCHULER 2004). Regeneration and stem density of six important species had not recovered 24 years after selection cutting in India (GANESAN and DAVIDAR 2003). Native diversity had not recovered 150 years after logging in Madagascar (BROWN and GUREVITCH 2004).

There is also controversy on the impact of different disturbance regimes on diversity. Connell (1978) theorized that the highest diversity is maintained at intermediate scales of disturbance. However there is still little evidence to support the application of the intermediate disturbance hypothesis (IDH) to diverse rain forests where patch size disturbances are the most prevalent (MOLINO and SABATIER 2001). Hubbel et all (1999) found that natural treefall gaps in Panama did not result in increased diversity. However, Molino and Sabatier (2001) found strong support for the IDH in Guiana. Sheil and Burslem (2002) concluded that the findings of both studies were consistent with the IDH because of the "species decline paradox": disturbances at different successional stages can lead to increased or decreased diversity, even though all disturbances help prevent the ultimate decline in diversity associated with the final stage of succession.

Perhaps the best examples of selection cutting can be found in Central Europe, where some forests have been continuously managed for more than 200 years with the plenter system, a single tree selection system based on removal of trees exceeding a diameter threshold. Removal of these single trees is the only management activity and is thought to initiate regeneration. Since multi-cohort stands are created by this system, no thinning is required (OLIVER and LARSON 1996). The plenter system attempts to maintain a negative diameter distribution in order to reach an sustainable equilibrium where harvest equals growth and standing volume remains constant from one cutting cycle to the next (O'HARA and GERSONDE 2004; O'HARA et al. 2007). The plenter system is most successful for shade tolerant trees with strong epinastic control and narrow crowns so that the lower strata can survive the effects of the trees in the upper strata (OLIVER and LARSON 1996).

The experiences with section cutting in North America, on the other hand, have been much less positive. Diameter limit harvesting is an example of selection cutting which has been widely practiced in the USA for more than three centuries (KELTY and D'AMATO 2006). Diameter limit harvesting, which involves harvesting any tree over a certain diameter, is easy to implement because the marking requirements are simple, and it provides high initial financial returns: however the practice has a negative impact on the form, bole shape and species composition of residual stands (KENEFIC and NYLAND 2005; OLIVER and LARSON 1996), and over the long term diameter limit harvesting it is not as profitable as selection cutting based on silvicultural principles (NYLAND 2006b).

The practice of "high-grading" is an even more inappropriate form of selection cutting, in which excessive removal of the straightest stems of economically valuable species can produce residual stands which contain crooked and otherwise deformed overstory trees and lead to genetic selection of inferior genotypes (CLATTERBUCK 2006; NYLAND 2006a; OLIVER and LARSON 1996). High-grading occurs when forest managers maximize current profits without considering long term productivity, and is very common in broadleaved forests in the USA (KENEFIC and NYLAND 2005, 2006).

Several authors have noted that professional foresters have not yet been able to provide silvicultural guidance to meet the diverse needs of community forestry user groups (CARTER 2005; DONOVAN 2001; LAWRENCE 2007; VICTOR 2001). Victor (2001p. vi) sums up as follows: "Unfortunately, the development and spread of alternative forest management practices (barefoot silviculture) for community forest management has yet to really begin. Most foresters' knowledge is limited to mensuration and silviculture developed for timber production at an industrial scale… As a result, it is difficult for government foresters to readily provide appropriate advice to users and to recognize good and bad community forestry practice or to suggest feasible improvements."

3.3.2 Bhutan Experience

Ohsawa (1991; 2002) studied the distribution of montane evergreen broadleaved forests throughout Bhutan and discussed the transitional nature of mixed broadleaved forests from lowest evergreen to mid-altitude deciduous to uppermost coniferous forests. Wangda and Ohsawa (2002; 2006a; 2006b; 2006c) reported that broadleaved forests in central Bhutan were limited at the lower elevation (1,650 m) by low soil moisture (<20%) and at the upper elevation (3,000 m) by temperature. They described how the regeneration pattern of major dominant species shifted from an inverse-J (i-J) distribution in the lower altitudes, to sporadic in the mid-altitudes, and uni-modal in the upper altitudes, corresponding to three regeneration trends: (1) invasive at the lower, warm, dry forest under relatively strong human disturbances; (2) stable/balanced at the mid-altitude in a relatively stable, mature moist evergreen broadleaved forest with gap regeneration; and (3) poor/low regeneration at the upper, cool, humid conifer forest with a continuously cattle-grazed understory.

Cool broadleaved forests in Bhutan contain many valuable timber species but commercial management has proved challenging: the species composition of logged forests is reported to be gradually shifting towards non-timber species (CHAMLING and PUSHPARAJAH 1993; DAVIDSON 2000; DAVIDSON et al. 1999; SANGAY 1997). Commercial logging operations in broadleaved forests in Bhutan face a dilemma because the only economically viable silvicultural options are clearfelling systems which are not likely to perpetuate forest diversity (SEYDACK 2001). The major set up costs are construction of logging roads and installation of cable cranes to remove the harvested trees (WINKLER 1999).

No study in Bhutan has investigated the impact of selection cutting on natural regeneration in a CF, but two studies have been carried out in broadleaved FMUs. Davidson (2000) reported that the net gain of seedlings of timber species in Korilla FMU two years after logging was higher in 0.15 ha openings (750 stems*ha^{-1}) than 0.5 ha openings (425 stems*ha^{-1}) and 6 ha openings (262 stems*ha^{-1}); but financial viability could only be maintained with an opening size of at least 0.36 ha. In Gedu FMU, Van Ijssel (1990) reported that regeneration was higher after selective felling than strip felling.

Several studies carried out in conifer forests to examine the relationship between natural regeneration and opening size in Bhutan have reported that regeneration of mixed conifer forests is generally higher in smaller openings (< 0.2 ha) than larger openings (> 0.6 ha) (DARABANT et al. 2001; DARABANT et al. In Press; DORJI 2004; GRATZER et al. 1997; GRATZER et al. 2002; GRATZER et al. 2001; ROSSET and RINCHEN 1998; TSHERING 2005).

The effect of high-grading in Bhutan has not been studied in detail, however Davidson (2000) concluded that high-grading due to removal of trees of best form and wood quality for rural use had jeopardized future productivity of the Korilla FMU.

3.4 Forest Grazing in Broadleaved Forests

3.4.1 International Experience

Forest grazing is practiced in many parts of the world. Forest grazing is common in the mountainous regions of Europe and other areas where tree cover is high and pressure on agriculture land is low such as Scandinavia (MCADAM April 2004). In the Swiss Alps, 15% of mountain forests are grazed during summer, mainly by cattle (MAYER et al. 2006). In the US more than 75% of forests in some states have been used for grazing for two centuries (WRAY 1998).

Forest grazing reportedly has negative impacts on forest ecosystems, such as soil erosion, depletion of nutrients, soil compaction and soil acidification (BARNES et al. 1998; BELSKY and BLUMENTHAL 1997; SMIT and KOOIJMAN 2001). Forest grazing causes tree damage through trampling and browsing (LINHART and WHELAN 1980; MAYER et al. 2006; PALMER et al. 2004; VANDENBERGHE et al. 2007) and loss of species richness and diversity (FLEISCHNER 1994; PETTIT et al. 1995). Grazing is considered to be the most serious cause of forest degradation in the Himalayas (CARSON 1992). In Switzerland, several cantons have enacted forest laws to discourage the practice of forest grazing, which is seen as a detrimental form of land use (MAYER et al. 2006).

However, many authors have argued that forest grazing can be sustainable if grazing intensity is controlled (ADAMS 1975; KRZIC et al. 1999; KRZIC et al. 2001; MAYER and HUOVINEN 2007; PATRIC and HELVEY 1986; POLLOCK et al. 2005). Far from being an outmoded practice, forest grazing and silvopastoral systems are widely accepted as modern forest-management tools (KUITERS et al. 1996; RODER et al. 2002). Forest grazing can enhance tree growth by reducing biomass of grasses and sedges which otherwise outcompete tree seedlings (BELSKY and BLUMENTHAL 1997; DARABANT et al. In Press) or reducing the intensity of rodents which damage tree regeneration (EVANS et al. 2006). Silvopastoral management has potential to be more financially viable than either pure forestry or pure livestock management (GARRETT et al. 2004; RODER 2002). Grazing has also been reported to promote biodiversity: intermediate levels of grazing increased the diversity of flora and fauna (MITCHELL and KIRBY 1990; MOUNTFORD and PETERKEN 2003). Contrary to popular belief in Switzerland, forest grazing is adequate to nourish improved breeds of cattle without the need for significant amounts of supplementary feeds (MAYER et al. 2003).

In many cases, wild ungulates have a greater impact on the forests than domestic livestock, for example, in Switzerland wild ungulates browse three times as many young trees during the winter as do cattle during the summer (MAYER et al. 2006). Several studies have documented the negative impact of wild ungulates on regeneration of forests after logging

(AMMER 1996; HORSLEY et al. 2003) and without logging (DE LA CRETAZ and KELTY 2002; GILL 1992; GILL and BEARDALL 2001; ROSS et al. 1970; ROSSELL et al. 2005) .

The intensity of grazing and its impact on forests are not linearly related (PALMER et al. 2004). However, certain thresholds of grazing intensity appear to exist for sapling survival of different species, thus it is important to understand the impact of different intensities of grazing rather than simply evaluating the impact of grazing vs. no grazing (HESTER et al. 2000). For example, a review of controlled grazing studies in the UK reported that sapling recruitment of rowan and birch was only suppressed at grazing levels of .15 livestock units (LU)*ha^{-1}; and that in Denmark oak and rowan were suppressed at summer/winter grazing levels of 0.28/0.57 LU*ha^{-1} while other species were only suppressed at a higher grazing summer/winter levels of 0.4/0.8 LU*ha^{-1} (HESTER et al. 2000). In Switzerland, detrimental affects on young Norway Spruce were only found at stocking levels at least 1 LU*ha^{-1} (MAYER et al. 2006).

3.4.2 Bhutan Experience

In Bhutan forest grazing is an important part of the socio-economic structure of households and communities (WANGCHUK 2002). Forest grazing contributes 22% of the national fodder requirement (RODER et al. 2002). Cattle are owned by 90% of households (NORBU 2002). Migratory grazing is common, with herds traveling up to 15 days at 15 km/day to reach winter or summer grazing areas (MOKTAN et al. 2006; URA 2002), although this practice was not common in the study area for the current research. Customary rights still govern access to forests in many villages: boundaries are clearly marked with cairns, and people from other villages have to pay fines if their cattle enter the forests of another village (WANGCHUK 2000).

Forest grazing in Bhutan is widely considered to have a negative impact on the natural regeneration of broadleaved tree species (FISCHER 1976; MOKTAN et al. 2006; NORBU 2000, 2002; ROSSET and RINCHEN 1998; SANGAY 1997; VAN IJSSEL 1990). Forest grazing in FMUs after logging operations led to the replacement of valuable timber species with unpalatable non-timber species (CHAMLING and PUSHPARAJAH 1993; DAVIDSON 2000; DAVIDSON et al. 1999; SEYDACK 2000, 2001). Kleine (1996) studied nine forest stands in central Bhutan and concluded that most broadleaved forests have poor regeneration due to grazing pressure. Miehe and Miehe (2002) analyzed 180 inventory plots in central and eastern Bhutan and concluded that broadleaved forests were unsuitable for intensive grazing and that future development should aim for a separation of forests and rangelands.

However positive effects of forest grazing in Bhutan have also been documented (RODER et al. 2002; WANGCHUK 2002). Forest grazing promoted regeneration of tree seedlings in conifer forests by reducing the height of palatable bamboo and increasing light interception on the forest floor (DARABANT et al. In Press; GRATZER et al. 1999). Furthermore, forest grazing is a vital component of Bhutanese agriculture, providing a critical source of phosphate via manure which allows farmers to maintain crop yields with minimal inputs of chemical fertilizers (RODER et al. 2003).

There is controversy about whether the level of forest grazing in Bhutan is increasing or decreasing: studies have reported both increasing trends due to the demand for dairy products (NORBU 2002), and decreasing trends as farmers replace traditional cattle with smaller numbers of improved breeds which are often not grazed in the forest (SPIERENBURG 2003). Wang and MacDonald (2006), on the other hand, found no change in livestock holdings in recent years.

3.5 Equity of Community Forestry

3.5.1 International Experience

Community forestry can provide a range of socio-economic benefits to the local users (AGRAWAL and OSTROM 2001; CARTER 2005; DEV et al. 2003; LAWRENCE 2007): however, there is increasing evidence that community forestry programs are not providing benefits equally to all social groups and in some cases are actually exacerbating inequality (HOBLEY 2005; SCHRECKENBERG et al. 2006). The emerging equity issues are an important aspect of what the donor and practitioner literature has called the “second generation” issues of community forestry (LAWRENCE 2007).

Equity has two dimensions – economic equity which involves the distribution of benefits, and political equity which involves participation in decision making and the ability of stakeholders to express their ideas and concerns (MAHANTY et al. 2006). Equity in the context of community forestry is usually understood to refer to ‘fairness’ rather than ‘equality’; although this can appear to be intangible, it is culturally contextualized, i.e. the situation is considered to be equitable if the members consider their share of use and decision-making rights to be fair (MCKEAN 2000).

A key aspect of political equity of user groups concerns the level of participation. Arnstein (1969) described the relationship between central and local actors as a typology from ‘manipulation’ by central actors to ‘citizen control. Lawrence (2006) adapted Arnstein’s types while pointing out that a given relationship might include examples of all four types:

- Consultative: the center asks for information and makes decisions, whereas local actors simply contribute information.
- Functional: the center makes decisions and then involves local people to help implement them, whereas local actors contribute information and take action based on decisions already made.
- Collaborative: the center and the local people collaborate in deciding what is needed, and both contribute expert knowledge.
- Transformative: the center provides informational support, whereas local people make decisions, seek experts where needed, and implement decisions.

Many studies have investigated the lack of political equity in CFs. Management committees in some countries were dominated by men and high caste groups (KELLERT et al. 2000). Cultural norms discouraged women from participating in CF meetings in several countries (SPRINGATE-BAGINSKI et al. 2003). Women were excluded from decision making even in seemingly participatory user groups in India and Nepal (AGARWAL 2001). Even when Dalit (untouchable) members held the key CF Management Committee posts, discrimination by high caste members continued in Nepal (UPRETY 2006). Dalits make up 20% of the population of Nepal, where untouchability is still widely practiced, despite being made illegal by the 1963 National Code and the 1990 Constitution (SOB 2001). Menzies (2002, p. 17) warned that “traditional societies are rarely equitable and participatory… there may be aspects of traditional social capital that do not favor ‘just and wise’ management of forest resources.” In contrast to the above studies, some authors have reported the positive impacts of increased understanding and collaboration between dominant and disadvantaged ethnic groups, and between men and women (BHATTARAI 2006; LUINTEL 2006).

Many studies have documented a lack of economic equity in community forestry. For example, management committees practiced favoritism in distributing products in Nepal (SPRINGATE-BAGINSKI et al. 2003; VARALAKSHMI 2002). CF rules were biased towards meeting the needs of richer households in Nepal (ADHIKARI 2005). Influential members were allowed to graze their animals in CFs even when the bylaws of the CF prohibited forest grazing in Nepal (PANDIT and THAPA 2004). In other cases the poorest members of the user groups and Dalits had less access to CF products than the richer and higher caste in Nepal and India (ADHIKARI et al. 2004; CHHETRY et al. 2005; MALLA et al. 2003; NIGHTINGALE 2003; SARIN 1998), and benefited less from loans from user group funds (POKHAREL and NURSE 2004). Traditional Dalit users were excluded from CFs even when the user group formation was facilitated by non-government organizations in projects that specifically intended to empower Dalits in Nepal (BUFFUM 1993; BUFFUM and CHETTRI 2000).

Agrawal and Gupta (2005) have argued that political equity is a prerequisite for economic equity because villagers who participate actively in government supported user groups are also the ones that benefit the most from the resources. They reported that participation in government-promoted user groups in Nepal was associated with higher income, larger land holdings, higher caste, and more frequent visits to government offices. Supportive evidence has been provided by Adhikari (2005) who attributed the greater level of income from CFs earned by male-headed households to the limited number of women in CF management committees.

Equity has environmental as well as social consequences: a study of 95 CFs in the Indian Himalayas found that improved forest condition was associated with reduced levels of conflict among users and greater involvement of women in decision making, because conflict-ridden groups were unable to make effective decisions about forest protection, and women were able to make sound management decisions due to their strong involvement in the collection of forest products (AGRAWAL and CHHATRE 2006). The linkage between equity and conservation is reflected in the objectives of the UN Convention on Biological Diversity, which include conservation of biological diversity, sustainable use of its components, and fair and equitable benefit sharing (KNAPP 2003).

3.5.2 Bhutan Experience

In contrast to the wealth of studies on equity issues in Nepal and India, there is very limited information available about equity of CFs in Bhutan. Oberholzer et al. (2003) assessed several indicators of political equity and concluded that greater transparency could help avoid future equity problems. Namgay and Sonam (2006) reported that most CF user group members perceive the distribution of benefits to be equitable. However no study to date has assessed the actual distribution of CF benefits by different socio-economic groups in Bhutan.

Several studies have investigated the role of Bhutanese women in natural resources management. Women in Bhutan tend to be actively involved in forestry issues (NAMGAY and SONAM 2006; TFDP 2000) and participate actively in community meetings (UNESCO 2006). Studies of the role of Bhutanese women in natural resources management found that women and men had almost equal roles in forestry, and that cultural or educational barriers did not inhibit direct interaction between women and male extensionists (TFDP 2000). This may be due to inheritance practices: daughters traditionally inherit the family home and farm, whereas the sons are expected to move to their wives' homes after marriage (UNESCO 2006). As a result, women take greater responsibility for decisions about house maintenance, taking the lead in deciding when timber was needed for house repairs or construction (DUBA et al. 1998).

In addition to the studies mentioned above, several other studies of natural resources management in Bhutan are described in Appendix 4.

4 Materials and Methods

4.1 Forest Inventory of Yakpugang Community Forest

4.1.1 Inventory Design

A forest inventory of Yakpugang CF was conducted in three study blocks of the CF which have been the focus of harvesting operations in the past as well as at present. Each study block had a rectangular shape with a narrow base (150 m) and longer sides (700 m) running up the slope. This layout included a greater harvesting intensity in the lower portion of the block (closer to the village) and a lower harvesting intensity in the upper portion of the block.

- Block 1. Zhimsang: eastern portion of the CF with a northwest aspect.
- Block 2. Shanzing Brangtsha: western portion of the CF with a northeast aspect.
- Block 3. Kaptang Pai, central portion of the CF with a north aspect.

In each block, twelve inventory plots of 25 m x 25 m were established, for a total of 36 plots ranging in elevation from 1,920 m to 2,430 m. The location of the plots was determined in the field using global positioning system (GPS) equipment to identify coordinates extracted from digital maps prepared with OziExplorer (Version 3.95.4). Each inventory plot included:

- A 25 m x 10 m detailed inventory plot of all live trees (including NWFPs). The plots were laid out with the long sides perpendicular to the slope and a 5 m x 5 m regeneration subplot in the center. The plot dimensions followed the 1995 guidelines for CF inventories (DEMANSKI 1995) endorsed by the DOF in 2004 (DOF 2004b). The same plot dimensions were used in the original 2000 inventory of Yakpugang CF (NURSE and WANGDI 2000).
- Two auxiliary plots (25 m x 7.5 m) plots up and down hill to record timber-size trees (30 cm dbh or greater).
- Stumps of all sizes were recorded in the entire 25 m x 25 m plots.

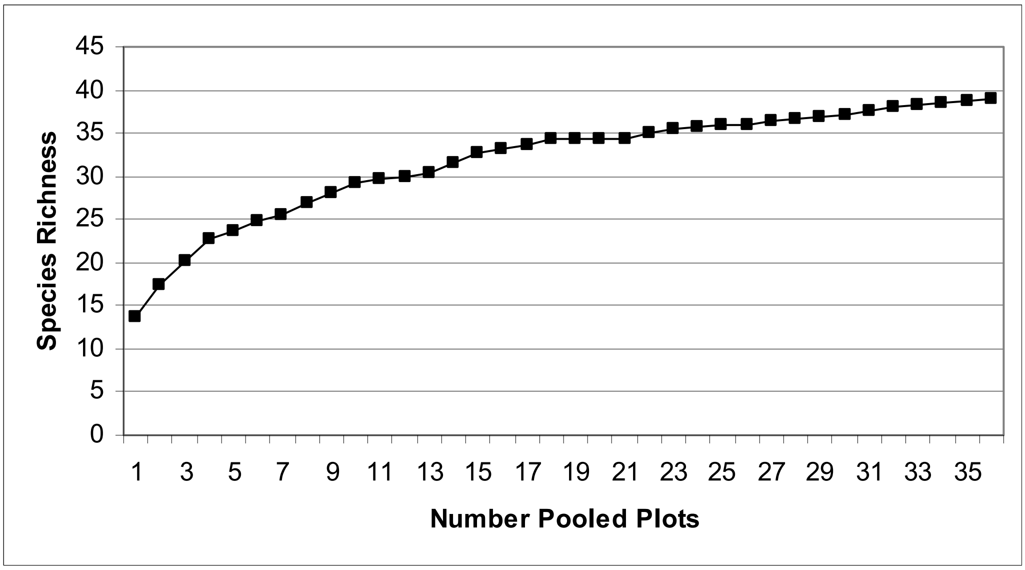
The inventory team included six CF management committee members who were intimately familiar with the forest. Two of the committee members had worked as professional loggers in the adjacent FMU. Without their local knowledge, the inventory would have been very difficult, especially the study of the stumps.

In each plot, the following data were recorded:

- Live trees and NWFPs: species and size class.
- Assessment of form and bole shape of trees with dbh over 29 cm, based on whether the CF members considered them suitable for timber.
- Number of seedlings (up to 1.3 m height), recorded in 5 m x 5 m subplots.
- Stumps: species, size class, and estimated time of harvesting.
- Description of each plot (slope, aspect, elevation, microsite conditions etc.)
- Assessment of light climate (with a hemispherical camera).
- Visual estimation of the upper canopy percentage (above the plot and to south of the plot), lower canopy percentage, and average height of the lower canopy.
- List of mature trees surrounding the plot, by species and number.

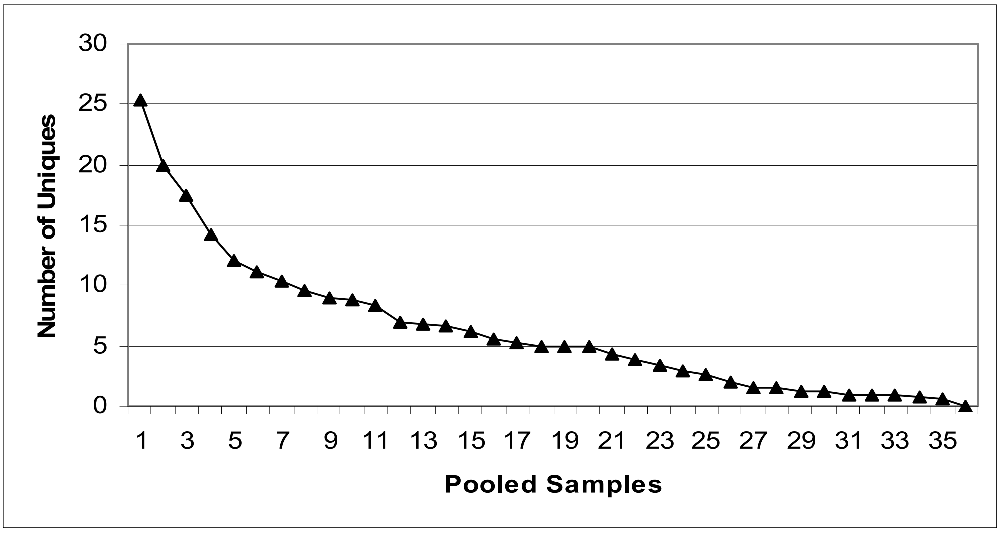
In order to assess the adequacy of the sampling, a species accumulation curve was prepared using Biodiversity Professional (Version 2). The number of new species accumulating as the samples were randomly pooled and plotted as can be seen in Figure 3. Species richness in pooled plots. When the species richness curve flattens, it can be assumed that all species in the region have been collected and no additional plots are required (HAYEK and BUZAS 1997; MAGURRAN 1988; WILLIAMS et al. 2007).

Figure 3. Species richness in pooled plots



Since it was not clear whether the species accumulation curve had flattened, a second analysis of plotting the number of unique species in the pooled samples was carried out using Biodiversity Professional (Version 2). As can be seen in Figure 4. Number of unique species in pooled samples, the line dropped to zero in the final sample, which indicates a likelihood that all species in the population had been collected (MCALEECE 1977).

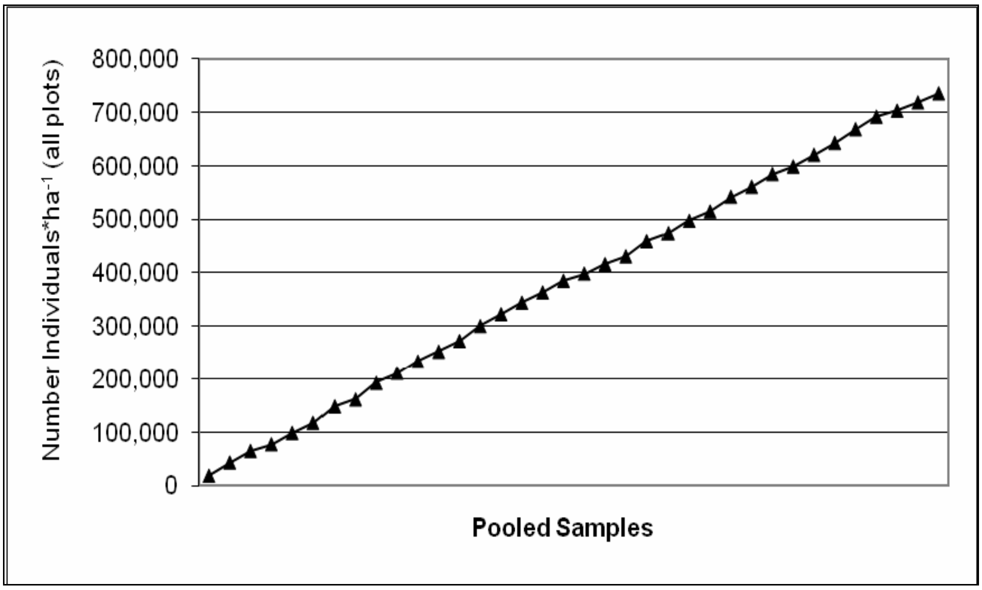
Figure 4. Number of unique species in pooled samples



The three study blocks of Yakpugang were compared to see if the data could be combined for subsequent analyses. There were no significant differences between the blocks in terms of the number, volume (V), and BA of trees. When the data were broken down by species composition (on the basis of the five use categories), no significant differences were detected between blocks. The variation between the upper and lower portion of each block (which included an elevation range of 500 m) was analyzed: there were no significant differences in terms of number, volume, and BA of trees between any of the three blocks.

The homogeneity of the forest was assessed by plotting the number of individuals accumulating as the samples were pooled, using Biodiversity Professional (Version 2). The resulting graph produced a straight line as can be seen in Figure 5. Number of accumulated individuals in pooled samples. This implied that the samples were replicates, whereas a noticeable kink in the line would have suggested that an ecotone line had been crossed (MCALEECE 1977).

Figure 5. Number of accumulated individuals in pooled samples



Note: the accumulated number of individuals must be divided by 36 plots to produce the actual number of individuals*ha^{-1}.

Since the study blocks were found to be quite similar in terms of number, volume and BA of trees and variation with elevation, the data from the three blocks were combined for some analyses.

4.1.2 Species Identification

The inventory plots contained 39 tree species representing 32 genera and 22 families. This did not include two species of bamboo. See Table 5. Summary of 2005 inventory of Yakpugang CF. Specimens of all species were collected, photographed, and taken to Thimphu for further analysis. The primary resource for identification of trees was Grierson and Long (1983). Other valuable resources included Polunin and Stainton (1984) for identification of trees; Tshering and Hellum (1990) for identification of seedlings; and DOF (2004e) and Thinley (2004) for information about local names of species. Valuable assistance in identification was provided by the staff of the Planning and Policy Division of the MOA and the Royal Society for the Protection of Nature. Identification was complicated by the fact that many species were not flowering or fruiting at the time of the data collection. Four of the 39 species (representing 4% of the BA of the forest) could only be positively identified to the genus level.

4.1.3 Volume Calculation

The volumes of trees and stumps were calculated using the volume tables prepared by UNDP/FAO/MOA for the adjacent Korilla Forest Management Unit (FAO 1993; LAUMANS 1994).These included separate tables for *Quercus*, *Persea*, *Castanopsis*, chirpine and “general hardwoods”. The tables provide volumes for 28 diameter classes starting with 10-14 cm, and include five site classes. Following the FAO guidelines, a sample of tree heights was recorded with a hypsometer to assess which site classes to use. In all cases, the average site class was found to be appropriate.

The 1980 Preinvestment Survey of Bhutan estimated the annual increment of hardwood forests in eastern Bhutan at 5.956 m^3 for an average growing stock of 234.787 m^3*ha^{-1} (DORJI and CHONG 1998). The DOF does not consider this estimate to be reliable (DOF 2005), but has not yet updated the 1980 estimates (STIERLIN and RAI 1999). Therefore a range of methods are used in Bhutan for calculation of annual allowable cut (AAC) in FMUs (DOF 2004c).

The AAC for the current study was calculated using the approach of the management plan for the adjacent Korilla FMU (DOF 2005).

$$AAC = \frac{\text{Net operable area}}{\text{Rotation}} \text{*Average standing Volume*Ha}^{-1}$$

There has been debate about the appropriate rotation period for broadleaved forests in Bhutan. The 1993 Management Plan for the adjacent Korilla FMU assumed a rotation period of 80 years (CHAMLING and PUSHPARAJAH 1993). The 2005 management plan for the same FMU assumed a 100 year rotation, which is the current standard for broadleaved forests in Bhutan. It has been suggested that the rotation period should be even longer for unlogged forests (DOF 2004c; WHITFIELD 2001).

In calculating the AAC for the study area, a rotation period of 100 years seemed appropriate, considering that the forest has been harvested regularly for more than 60 years. Additional analyses were done for a rotation period of 150 years. The net operable area for the study was 100%, because there were no cliffs or inaccessible areas in any of the 36 plots. It should be stressed that the resulting AAC only applied to the study area and not to the entire CF, which included some open areas.

In calculating the volume and BA of the harvested trees, the stump diameter was used as a proxy for dbh, as most stumps were approx 1 m high. Taking diameter readings below 1.3 m meant that the volume and BA of the harvested trees were over-estimated. Stump diameters and dbh exhibit a nonlinear relationship with stump taper varying at different rates by tree size for some species (MCCLURE 1968). According to models developed for two broadleaved forests in Nepal at elevations of 1,449 m and 1,691 m, the average dbh was 94.4% of the diameter of a 1 m tall stump (KHATRY CHHETRI and FOWLER 1996). Similar results were reported in the USA: the average dbh of 36 temperate hardwood species was 95% of the diameter at 1 m height (MCCLURE 1968).

When a 95% diameter correction is applied to the Bhutan volume tables (FAO 1993), the actual volume is 12% lower than the volume calculated from the diameter of a 1 m tall stump. However, since the main purpose of calculating the volume/BA of harvested trees was to assess whether the amount of harvesting had exceeded the AAC, an overestimation of harvested volume was a conservative error that did not negate any significant results. Furthermore, taper studies have not yet been conducted for these species in Bhutan.

Therefore this study used volume and BA figures based on the actual diameters of the stumps rather than applying a diameter correction.

The stumps were well preserved even 50 years after being harvested, and it was possible to estimate the approximate year of harvesting. The stumps were classified into eight harvesting periods: 0-4 years ago, 5-9 years ago, 10-19 years ago, 20-29 years ago, 30-39 years ago, 40-49 years ago, 50-59 years ago, and 60+ years ago. For each category except the last (60+ years), the average volume harvested per year was calculated for comparison with the current AAC of the study area. Comparisons were done for all combined species, each species category, and individual species.

DOF discourages the wasteful practice of leaving 1 m tall stumps, but the villagers consider the lower portion of the tree to be of no use. The same practice has been identified in CFs in Nepal (DHITAL et al. 2001).

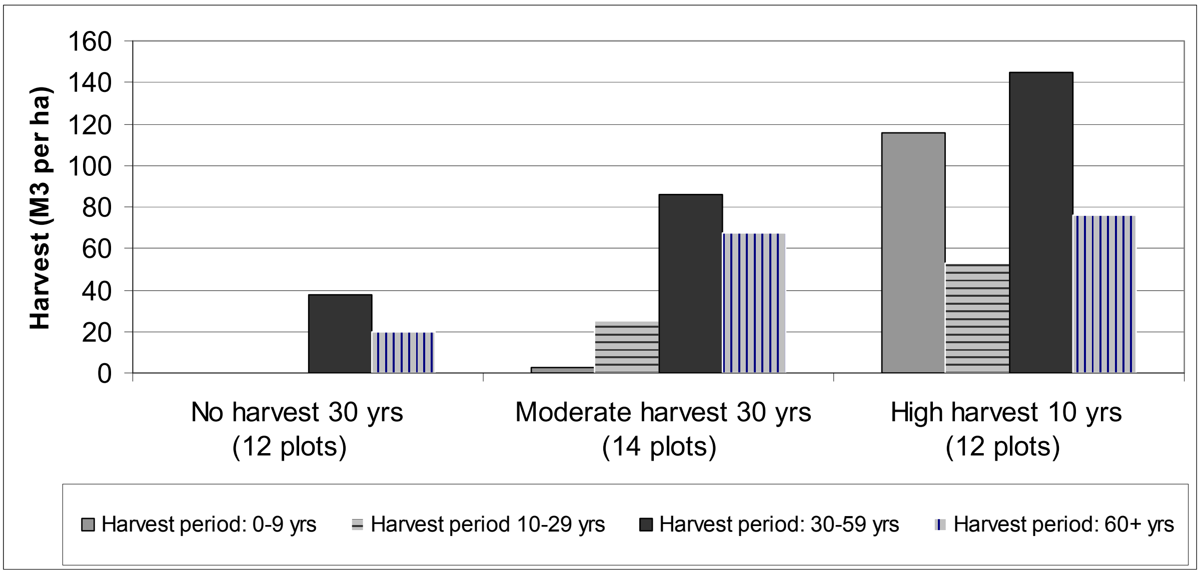
4.1.4 Categorization of 2005 Inventory Plots by Harvesting Intensity

The 36 inventory plots were separated into three categories of harvesting intensity:

- No harvesting for at least 30 years (twelve plots),
- Moderate harvesting during past 30 years, but limited during past ten years (14 plots), and
- High harvesting during the past ten years (ten plots).

The volume harvested in the three categories during four time periods can be seen in Figure 6. Volume harvested*ha^{-1} by harvesting intensity.

Figure 6. Volume harvested*ha^{-1} by harvesting intensity



4.1.5 Comparison with 2000 Inventory

The 2005 inventory data were compared with the 2000 data to see how the forest had changed during the five years of community management. The 2000 inventory was based on a stratified sample of 26 plots covering the entire CF. Twelve of the 26 plots fell within the 2005 study area. The 2000 inventory was analyzed to determine if the twelve plots which overlapped with the 2005 inventory were representative of the entire set of 2000 plots. No significant differences were found between the overlapping and non-overlapping 2000 plots for number, volume or BA of trees. There were also no significant differences when the data were broken down by the five use categories.

Since the 2000 inventory did not include size classes over 50 cm, an average volume and BA for trees over 50 cm was calculated for each of the four volume tables based on the actual trees measured in the 2005 inventory. This enabled a comparison of the volume and BA of the 2000 and 2005 inventories with the Kolmogorov-Smirnov Z test.

4.1.6 Hemispherical Photography

Hemispherical photos were taken in April 2005 in the center of the regeneration plots. See Figure 7. Example of hemispherical photograph in Yakpugang CF. The 400 ASA black and white slides were scanned and analyzed with HemiView Version 2.1. The key HemiView outputs were Global Site Factor (GSF): the proportion of global radiation under a plant canopy relative to that under the open; and canopy cover: the vertically projected canopy area per unit of ground area.

Figure 7. Example of hemispherical photograph in Yakpugang CF

Due to variable cloud-cover conditions, the hemispherical photos were useable for only 23 plots. These plots were spread evenly between and within the three study blocks. In order to ascertain whether the 23 plots with HemiView Outputs were representative of the entire 36 plots, the 23 plots were compared with the other 13 plots for 12 variables related to seedling and sapling composition, using the Kolmogorov-Smirnov Z test. There were no significant differences between the two groups of plots, implying that the 23 plots were representative of the study area.

In order to study the relationship between light intensity and seedling/sapling composition, the same 12 variables related to seedling and sapling composition were correlated with the HemiView outputs. (See Section 5.1.5.4 for results.)

4.1.7 Diversity

Diversity was analyzed using the Shannon-Wiener index (*H*), which is the most common indicator for assessing diversity (MAGURRAN 1988; MCALEECE 1977). *H* accounts for both abundance and evenness of the species present by measuring the degree of uncertainty in predicting the species of a randomly selected individual: a larger number of species and a greater degree of evenness causes more uncertainty and a higher value of *H* (WILLIAMS et al. 2005). *H* was calculated with Biodiversity Professional (Version 2): the proportion of species *i* relative to the total number of species (p_i) was calculated and multiplied by the natural logarithm of this proportion (lnp_i). The resulting product was summed across species, and multiplied by -1 to cancel the negative result of the logarithm:

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

The number of genera in the study area was almost as high as the number of species: only four of the 32 genera were represented by more than one species. Since the occurrence in a plot of closely-related species, such as *Symplocos ramosissima* and *S. glomerata,* had a large effect on the resulting *H* value, the diversity of genera rather than species was calculated.

The diversity of all stems was analyzed by three indicators of disturbance to see if the data supported the intermediate disturbance hypothesis (IDH).

- Frequency of disturbance: the number of years during last 50 years that at least one tree with a dbh of 50 cm or more was harvested in a plot
- Time since disturbance: the number of consecutive years since a tree with a dbh of 50 cm or more was harvested.
- Intensity of disturbance: the total BA of trees harvested in the plot.

A regression curve fit analysis was carried out for each disturbance indictor to determine if the relationship between diversity and the disturbance indicator exhibited a stronger fit with a quadratic curve than with a linear curve, as predicted by the IDH.

4.2 Household Survey of Three Community Forests

4.2.1 Introduction

A household survey provided detailed information on the use of the three CFs and the adjacent national forests. Household surveys are considered to provide more reliable data for forestry equity studies than more participatory approaches which are prone to overestimation of production and income (RICHARDS et al. 2003). The study area included the first three CFs in Bhutan to start timber harvesting operations. The analysis included data from the first three years of harvesting operations in each CF.

A random sample stratified by CF and socio-economic group included 29% (N = 51) of the total 173 members of the three CFs. The primary and secondary members of Yakpugang CF were sampled separately. If the actual CF member was not available, another member of the household was interviewed. 65% of the respondents were female, whereas 51% of the actual CF members were female. Individual issues, such as knowledge about the CF Fund, were analyzed by the gender of the respondent. Household issues, such as the allocation of permits, were analyzed by the gender of the actual member. See Appendix 6 for questionnaire.

4.2.2 Socio-Economic Groups

All members of the three CFs were categorized into four socio-economic groups to assess how the different socio-economic groups benefited from the CFs and participated in decision making. This was achieved through a wealth ranking exercise, which involved a team of five or more persons in each CF, including the responsible extension agent and three or more community leaders. The criteria for the four socio-economic groups were established in consultation with the local community leaders in the first CF, and were based on a combination of the primary source of income, land and livestock holdings, size of house, and ownership of vehicles and mechanized equipment. The criteria were discussed in the subsequent CFs and were considered to be appropriate with some minor adjustments:

- Laborer: Earned most income from daily wage labor; had limited land holdings (usually just a kitchen garden) and livestock; owned a small house.
- Small Farmer: Produced most of his/her food; supplemented income with seasonal daily wage labor; had average holdings agriculture land and livestock; sold a small amount of agricultural production; owned an average sized house.
- Large Farmer: Sold lots of surplus agriculture production; had very good agricultural land and/or livestock; owned a power tiller, motorcycle or chainsaw; owned a larger than average house.
- Salary Earner: owned a private business (such as contractor) or worked for the government; owned a vehicle, power tiller or chainsaw; owned a larger than average house.

Several other options for wealth ranking were considered but found to be less appropriate for Bhutanese conditions. For example, Adhikari (2004) used four indicators to divide households in Nepal into three income groups: the amount of land owned, the number of livestock owned, loans given and taken, and income from off-farm agricultural activities. Malla et al. (2003) categorized user group members in Nepal into four groups based largely on the number of months that they were self sufficient for food production. Amborse-Oji (2003) used several indicators in Cameroon which were irrelevant for Bhutan and showed the need to develop location specific indicators; for example indicators of high socio-economic status included being married and not relying on the forest, while indicators of low socio-economic status including drinking heavily.

4.2.3 Equity Indicators

The study addressed political equity by assessing three indicators. These indicators were developed in consultation with the CF members, and expanded on the equity indicators assessed in an earlier study in which the author participated (OBERHOLZER et al. 2003):

- Representation on management committees,
- Attendance in CF meetings, and
- Knowledge about CF administration and finances.

The study addressed economic equity by assessing five indicators based on access to the major products of the CFs and a sixth indicator related to the perception of having benefited from the CF:

- Access to permits for timber and firewood trees,
- Distance to marked trees,
- Access to dry firewood collection,
- Access to collection of NWFPs,
- Access to forest grazing, and
- Perception of personal benefits from the CF.

Most of the same indicators have been used in other studies of equity. Malla et al. (2003) assessed the political equity of CFs in Nepal based on representation on management committees and awareness of CF issues, and assessed economic equity based on the distribution of the various products from the CF. Kellert et al. (2000) used comparable but more general indicators in a study of community forestry in Kenya, Nepal and the USA: they assessed political equity on the basis of participation in decision making, distribution of power and status within the groups, and handling of conflicts over resources; and assessed economic equity based on the distribution and allocation of benefits. Adhikari (2004) based a study of economic equity in Nepal on the distribution of CF products (without specifically assessing political equity).

Two new indicators of economic equity were piloted during this study: the distance to the marked tree (in order to assess whether some socio-economic groups were given permits for trees closer to the village) and the perception of personal benefits from the CF. Richards et al. (2003) measured the amount of time that CF members in Nepal devoted to collection of different products, but their intent was to asses whether the establishment of the CF and the new restrictions on harvesting products in the CF had differential impacts on rich vs poor farmers – they did not specifically look at whether rich members were given preferential treatment in terms of the harvesting locations within the CF. The distance to the marked tree seemed to be an objective indicator, but proved problematic because the slope and other topographic considerations were often more important than the distance in terms of the ease of transporting the forest products to the village. The perception of personal benefits from the CF included both past and future benefits. This indicator was very subjective, but provided useful qualitative data. Pregernig (2002) documented the importance of perceptions in explaining participation in forest restoration activities in Austria: the extent to which forest owners/managers felt affected by forest damage was more closely correlated to their level of participation than to their objective assessment of the forest damage.

An important source of data was the lists of permits issued in the three CFs during the first three years of harvesting operations. The DOF introduced a standard process for CF Management Committees to maintain detailed records of permits issued for CF products (DOF 2004d). The research team compiled the permits by household with the assistance of the committee members (the original permits were listed under the name of the individual who requested the permit rather than the CF member). Since this information was available for 100% of the members of the three user groups, statistical analysis of the data was not required. The data from the permit lists were verified during the household survey.

4.2.4 Livestock Holdings and Grazing Patterns

Data on livestock holdings and grazing patterns were collected for the year the research was conducted (2005) and five years earlier when the CF was legally established. Although Bhutanese farmers can be reluctant to provide cattle numbers due to tax implications (NORBU 2000), the participation of village leaders and the government forestry extension agent during the survey process is believed to have increased the reliability of the data. Fortunately, the establishment of the CFs was a major event in each village which immediately affected grazing practices due to the new ban on overnight grazing: this may have increased the ability of the respondents to recall their livestock holdings and grazing pattern at the time.

4.3 Focus Group Discussions in Adjacent Villages

Focus group discussions were conducted in the nearest adjacent village to each CF to collect additional information about the historical use of the forests. Each focus group discussion involved a group of farmers and local leaders, and followed a standard set of questions to assess whether the establishment of the CFs had a negative impact on villagers who were not members of the user groups. For example, traditional users could have been excluded from the user groups, as was documented in Nepal (BUFFUM 1993; BUFFUM and CHETTRI 2000); or user groups could have protected their CFs at the cost of other national forests by moving livestock out of the CFs or requesting permits in other national forests. There has been speculation that the improved forest condition in some CFs in Nepal may have been partially offset by increased degradation of adjacent national forests (CHHETRY et al. 2005; POKHAREL and NURSE 2004). See Appendix 7 for the questionnaire for the focus groups.

4.4 Statistical Analysis

The data were analyzed using SPSS (Version 15.0.1). The distributions of data sets for live trees were generally normal, whereas the distributions of data sets for stumps were generally non-normal, especially when categorized by age class or species. Transformation of the non-normal data sets was generally not feasible due to the prevalence of 0 values. Therefore a combination of parametric and non parametric tests was used (BAILEY 1995; FIELD 2005), as can be seen in Table 4. List of statistical tests.

Table 4. List of statistical tests

Analysis	Statistical Test	Test Statistic
Group differences	Normal: T test, ANOVA	*t, F*
	Non-normal: Mann-Whitney, Kolmorgorov - Smirnov Z, Kruskal-Wallis	*U, Z, H*
Trends	Non-normal: Jonckheere-Terpestra	*J*
Repeated measures	Non-normal: Wilcoxon Signed Rank Test	*T*
Correlations	Normal: Pearson	*r*
	Non-normal: Kendal’s tau	τ
Curve analysis	Regression Curve fit	F, R^2
Distribution	Kolmorgorov - Smirnov Z	*Z*
Odds Ratio	Chi Square	*OR*

Means were reported for parametric tests, whereas medians were reported for non-parametric tests. An indicator of effect (r) was calculated separately for non-parametric tests. All reported results were significant with a probability of $p \leq .05$. Detailed statistical results for some tests are included in Appendix 8 when it was not practical to include the results in the main report. All results are two-sided unless otherwise specified.

5 Results

5.1 Forest Inventory of Yakpugang Community Forest

5.1.1 Introduction

Thirty nine tree species were recorded in the 2005 inventory, representing 22 families and 32 genera, as can be seen in Table 5. Summary of 2005 inventory of Yakpugang CF. The most dominant genera were *Quercus* and *Castanopsis*, which contributed 43% of the total BA.

Additional information is provided for each species, as can be seen in Table 6. Additional information on species of Yakpugang CF.

Local name: The local names were specific to Yakpugang, and often did not agree with the local names in the same language (Sharchopa) used in other villages and noted in species lists (DOF 2004e; THINLEY 2004).

Palatability and Preference: The CF members rated their preference level (high, medium, low) for each species and its relative palatability to grazing livestock (high, medium low).

Use Category: The CF members categorized the species by local use. Five use categories were established: "1st class timber", "2nd class timber", "other use", "*Quercus*" and "no use". The CF contained eight species considered by the CF to be 1st class timber, which contributed 11.6% of the BA. These species were: *Exbucklandia populnea, Schima khasiana (*often identified as *Nyssa javanica* in Bhutan)*, Michelia doltsopa, Phoebe attenuata, Prunus cerasoides, Juglans regia, Acer nivium*, and *Alcimandra cathcartii* in order of descending BA. The category of "2nd class timber" included *Castanopsis hystrix*, which was highly preferred for shingles. The category of "other use" consisted of trees used for firewood, tools or fodder. A separate category was used for the four species of *Quercus*, because they were highly preferred but had multiple uses.

The user group members utilized almost all of the species in the forest. Only six of the 39 species were classified as having no use, and these species combined contributed less than 2% of the total BA. The use categories were specific to Yakpugang and do not necessarily represent use by other villages. For example, the Yakpugang user group members did not use *Acer campbellii* to make wooden bowls, so this species was classified as having no use. Similarly, some timber species might be considered to be 1st class timber in other regions, whereas the Yakpugang villagers considered them to be 2nd class, since they had easy access to a range of other timber species.

Table 5. Summary of 2005 inventory of Yakpugang CF

Species	Family	Trees (dbh > 9 cm)				Seedlings
		N*ha^{-1}	V*ha^{-1} *	RBA	BA*ha^{-1}*	N*ha^{-1}
Acer campbellii	Aceraceae	4.5	2.7	1%	0.4	12.5
Acer nivium	Aceraceae	0.5	2.4	0%	0.2	0.0
Acer sikkimense	Aceraceae	0.0	0.0	0%	0.0	25.0
Alcimandra cathcartii	Magnoliaceae	0.0	0.0	0%	0.0	25.0
Beilschmiedia gammieana	Lauraceae	12.0	6.4	1%	0.7	249.5
Betula utilis	Betulaceae	6.0	6.8	1%	0.6	0.0
Carpinus viminea	Corylaceae	4.7	6.5	1%	0.6	124.8
Castanopsis hystrix	Fagaceae	111.0	83.3	14%	7.8	162.2
Cinnamomum bejolghota	Lauraceae	171.7	27.3	5%	3.0	1,609.6
Daphne sureil	Thymelaeaceae	591.4	0.1	0%	0.0	1,696.9
Daphniphyllum chartaceum	Daphniphyllaceae	303.9	9.5	3%	1.5	823.5
Elaeocarpus lanceaefolius	Elaeocarpaceae	15.5	36.3	6%	3.6	149.7
Exbucklandia populnea	Hamamelidaceae	4.5	26.9	4%	2.3	87.3
Fraxinus spp	Oleaceae	2.5	0.0	0%	0.0	0.0
Juglans regia	Juglandaceae	2.7	2.3	0%	0.3	12.5
Lyonia ovalifolia	Ericaceae	32.7	9.4	2%	1.0	99.8
Maesa chisia	Myrsinaceae	142.0	4.0	1%	0.7	1,472.3
Magnolia campbellii	Magnoliaceae	0.5	0.5	0%	0.1	0.0
Michelia doltsopa	Magnoliaceae	14.5	15.0	3%	1.5	324.4
Myrica esculenta	Myricaceae	6.5	2.5	0%	0.3	74.9
Myrsine semiserrata	Myrsinaceae	3.7	0.1	0%	0.0	25.0
Neolitsea spp	Lauraceae	46.9	14.1	4%	2.0	187.2
Persea clarkeana	Lauraceae	17.5	54.7	9%	4.9	773.6
Phoebe attenuata	Lauraceae	5.7	4.4	1%	0.5	49.9
Photinia spp	Rosaceae	5.7	3.3	1%	0.4	0.0
Prunus cerasoides	Rosaceae	1.5	3.1	1%	0.3	0.0
Prunus spp	Rosaceae	0.5	0.3	0%	0.0	62.4
Quercus acutissima	Fagaceae	0.5	2.6	0%	0.2	0.0
Quercus griffithii	Fagaceae	1.2	0.0	0%	0.0	0.0
Quercus lamellosa	Fagaceae	17.2	100.2	15%	8.6	0.0
Quercus semiserrata	Fagaceae	31.9	100.3	16%	9.1	336.9
Rhododendron grande	Ericaceae	6.0	3.2	1%	0.4	25.0
Rhus hookeri	Anacardiaceae	2.5	0.0	0%	0.0	0.0
Schima khasiana	Theaceae	369.6	10.5	3%	1.6	212.1
Symplocos glomerata	Symplocaceae	672.5	9.4	3%	1.6	2,445.5
Symplocos ramosissima	Symplocaceae	1,715.4	10.5	4%	2.0	4,891.0
Tetradium fraxinifolium	Rutaceae	1.2	0.0	0%	0.0	0.0
Toricella tiliifolia	Cornaceae	2.5	0.0	0%	0.0	99.8
TOTAL		4,329	559	100%	56	16,071

Table 6. Additional information on species of Yakpugang CF

Species	Local Name	Palatability	Preference	Use Category
Acer campbellii	Sermoling	high	low	None
Acer nivium	Awashing Baling	low	high	1st timber
Acer sikkimense	Lungmarma	medium	medium	2nd timber
Alcimandra cathcartii	Kar	medium	high	1st timber
Beilschmiedia gammieana	Shagoli	low	low	none
Betula utilis	Char	high	medium	Other use
Carpinus viminea	Lung	medium	high	Other use
Castanopsis hystrix	Tshai	low	high	2nd timber
Cinnamomum bejolghota	Buitshi	medium	medium	2nd timber
Daphne sureil	Shugu	low	medium	2nd timber
Daphniphyllum chartaceum	Awa	low	medium	Other use
Elaeocarpus lanceaefolius	Gashatong	high	medium	2nd timber
Exbucklandia populnea	Akulem	medium	high	1st timber
Fraxinus spp	Nogtang	high	medium	Other use
Juglans regia	Kheshing	low	high	1st timber
Lyonia ovalifolia	Shajula	low	medium	Other use
Maesa chisia	Khubarba	medium	low	Other use
Magnolia campbellii	Nawangmeto	low	low	None
Michelia doltsopa	Champai	high	high	1st timber
Myrica esculenta	Zer	low	medium	Other use
Myrsine semiserrata	Kongpujugpang	medium	medium	2nd timber
Neolitsea spp	Ekpa	medium	medium	Other use
Persea clarkeana	Pragoli	medium	medium	2nd timber
Phoebe attenuata	Khesarba	medium	high	1st timber
Photinia spp	Laiping	high	high	Other use
Prunus cerasoides	Sang	medium	high	1st timber
Prunus spp	Bethpa	medium	medium	2nd timber
Quercus acutissima	Namdhar	high	high	Quercus
Quercus griffithii	Bainang	high	high	Quercus
Quercus lamellosa	Fangolom	medium	high	Quercus
Quercus semiserrata	Sela	high	high	Quercus
Rhododendron grande	Takpa	low	medium	Other use
Rhus hookeri	Jar	low	low	None
Schima khasiana	Leymoma	low	high	1st timber
Symplocos glomerata	Ajang dom	low	low	Other use
Symplocos ramosissima	Dom	low	low	Other use
Tetradium fraxinifolium	Wayfolar	low	low	None
Toricella tiliifolia	Dengkhaling	low	high	2nd timber

The diameter distribution of Yakpugang CF was compared with the diameter distributions of three other broadleaved forests studied in Bhutan:

- Upper Lobesa (WANGDA and OHSAWA 2002; 2006a; 2006b; 2006c). Plots 5-9 contained broadleaved forest at comparable elevations to Yakpugang CF;
- Nahi (SEYDACK 2001); and
- Unlogged forest of Korilla FMU (CHAMLING and PUSHPARAJAH 1993).

For diameters over 49 cm, the distributions of the four forests were not significantly different, as can be seen in Figure 8. Frequency distribution of dbh in Yakpugang, Nahi and Korilla Forests, and Figure 9. Frequency distribution of dbh in Yakpugang and Upper Lobesa Forests.

For diameters over 29 cm, there were no significant differences between the distributions of Yakpugang, Nahi, and Korilla, but the distribution of Upper Lobesa was significantly different from the other three forests, $Z \geq 2.26$, $p < .001$. This was due to the larger number of trees in the 30-39 cm diameter class in Upper Lobesa.

For diameters over 19 cm, the distributions of all four forests were significantly different, $Z \geq 1.42$, $p \leq .01$, except for Nahi and Korilla.

Figure 8. Frequency distribution of dbh in Yakpugang, Nahi and Korilla Forests

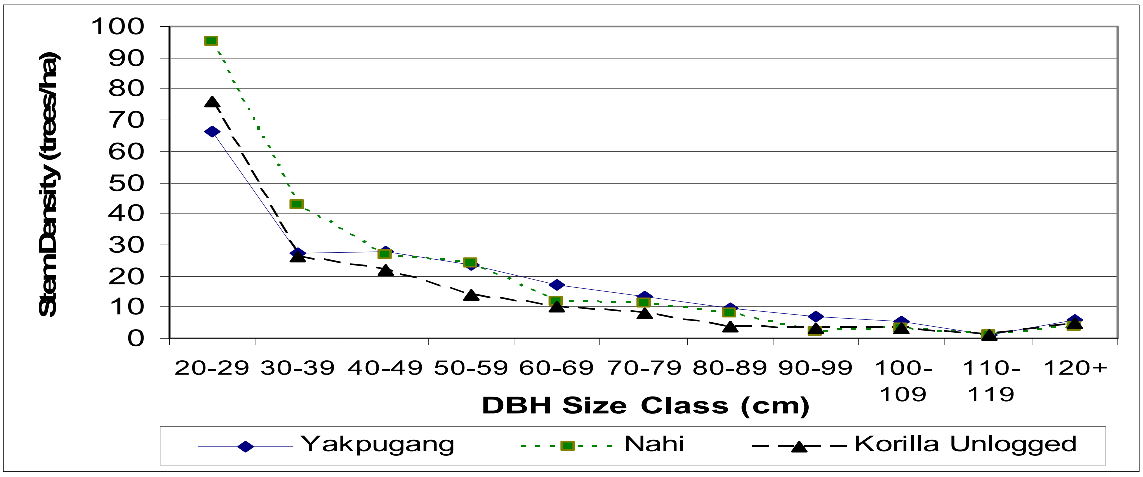
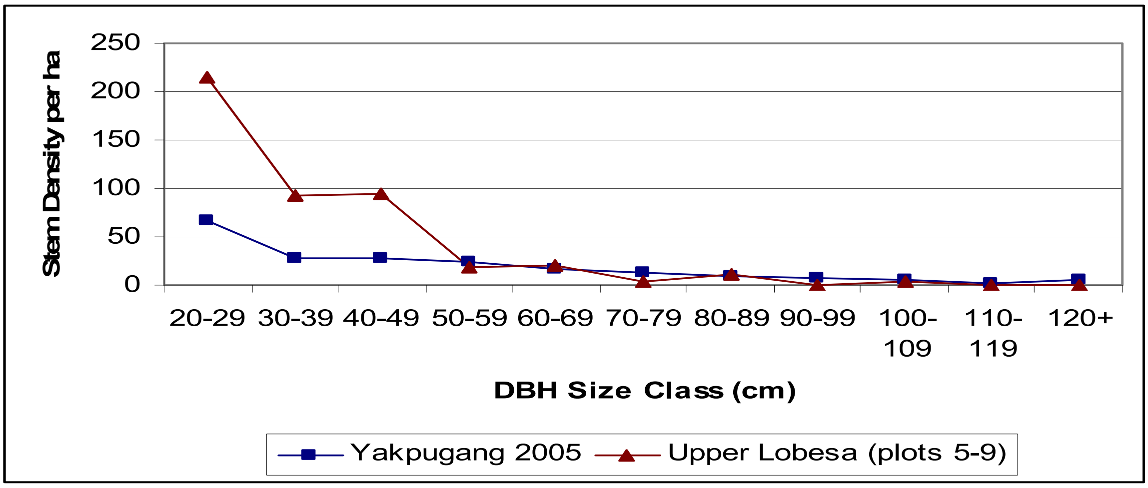
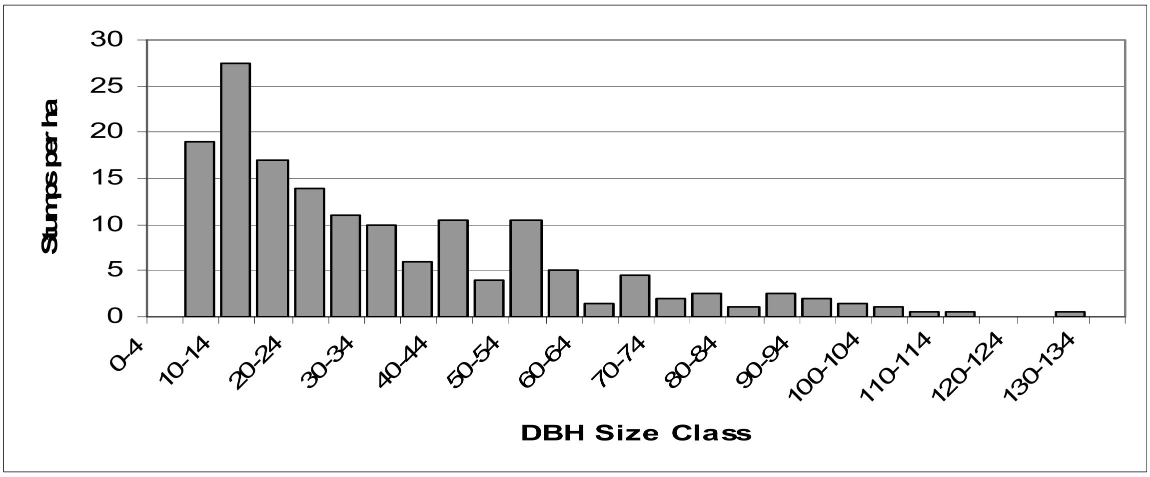


Figure 9. Frequency distribution of dbh in Yakpugang and Upper Lobesa Forests



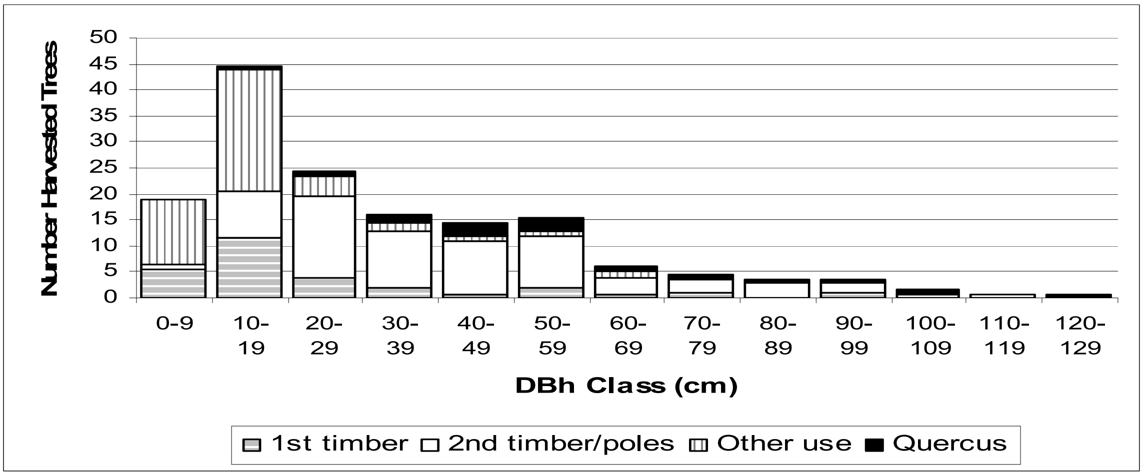
All but five of the 36 plots contained harvested trees, with an average density of 150 stumps*ha^{-1}. A wide range of size classes was harvested with the largest number of stumps in the 10-14 cm dbh class, as can be seen in Figure 10. Number of harvested trees*ha^{-1} by dbh class.

Figure 10. Number of harvested trees*ha^{-1} by dbh class



The trees in the "other use" category were often harvested in small dbh classes, whereas the "2nd class timber" and "*Quercus*" were generally harvested only in the large dbh classes, as can be seen in Figure 11. Number of stumps*ha^{-1} by dbh class and use category. Many trees of the "1st class timber" category were harvested in smaller size classes. This was particularly true for *Schima khasiana,* which was widely used for posts and poles, even though it was a preferred species for timber.

Figure 11. Number of stumps*ha^{-1} by dbh class and use category



Nineteen of the 39 species found in the study area had been harvested. In terms of BA, the most harvested species were *Castanopsis hystrix* (shingles), *Persea clarkeana* (timber), *Quercus lamellosa* (shingles and firewood) and *Cinnamomum bejolghota* (timber), representing 68% of the total BA harvested. See Table 7. Harvesting by species. In terms of number of stumps, the most common genus was *Symplocos* (two species), which was harvested in smaller dbh classes for fence posts.

Table 7. Harvesting by species

Species	Stumps*ha^{-1}				Local use
	N	V	RBA	BA	
Castanopsis hystrix	32.9	58.9	30.3%	6.0	Shingles
Persea clarkeana	19.0	31.5	15.4%	3.1	Timber
Quercus lamellosa	5.0	28.2	12.4%	2.5	Shingles firewood
Cinnamomum bejolghota	13.5	19.1	10.5%	2.1	Timber
Quercus semiserrata	7.5	16.6	8.2%	1.6	Firewood, tools, shingles, leaf litter
Michelia doltsopa	4.0	13.0	6.2%	1.2	Timber
Elaeocarpus lanceaefolius	3.0	9.2	4.3%	0.9	Timber
Schima khasiana	20.0	6.5	3.4%	0.7	Timber, poles, posts
Lyonia ovalifolia	4.0	5.5	3.0%	0.6	Leaf litter
Symplocos ramosissima	30.4	2.1	1.8%	0.4	Posts
Daphniphyllum chartaceum	3.5	2.1	1.2%	0.2	Poles, firewood
Prunus cerasoides	2.0	2.2	1.1%	0.2	Timber
Phoebe attenuata	2.0	1.3	0.9%	0.2	Timber
Betula utilis	0.5	0.0	0.8%	0.2	Tools
Myrica esculenta	1.0	0.3	0.2%	0.0	Tools, firewood, pegs
Symplocos glomerata	3.5	0.2	0.2%	0.0	Poles, firewood
Maesa chisia	1.5	0.1	0.1%	0.0	Posts
Beilschmiedia gammieana	0.5	0.1	0.1%	0.0	None
Toricella tiliifolia	0.5	0.0	0.0%	0.0	Posts
Total	154.2	196.9	100.0%	19.8	

Note: Species are listed in order of descending BA.

The three blocks were found to be similar in terms of the overall number of trees harvested, with no significant differences in the number, volume or BA of stumps. No significant differences in the species composition (on the basis of use category) of the harvested trees were detected between blocks.

However there were differences between the more accessible lower portions of the blocks and the upper less accessible portions. The combined blocks exhibited a significant decreasing trend in the number of stumps*ha^{-1} with elevation, from the lower portion (*Mdn* = 176) to the middle portion (*Mdn* = 152) to the upper portion (*Mdn* = 38), J = 216, p < .01. This trend could not be verified for individual blocks due to limitations in the sample size. However, when the blocks were divided into just two portions (upper and lower), the lower portions consistently contained a greater number of harvested trees than the upper portions, as can be seen in Table 8. Number stumps*ha^{-1} in lower and upper portions of blocks.

Table 8. Number stumps*ha^{-1} in lower and upper portions of blocks

	Block 1 (2,266-2,416m)	Block 2 (2,1002,350 m)	Block 3 (1,920-2,430 m)
N stumps*ha^{-1} lower portion	243 *(M)*	334 *(M)*	142 (*Mdn*)
N stumps*ha^{-1} upper portion	87 *(M)*	89 *(M)*	0 (*Mdn*)
SE lower portion	28	122	
SE upper portion	32	21	
Statistic (single sided)	$t(10) = 3.66, p < .01$	$t(10) = 1.96, p < .05$	$U = 6.0, p < .05$

5.1.2 Harvesting Levels and Annual Allowable Cut

The volume of trees harvested per year was compared with the current AAC (100 years rotation period) to assess the ecological sustainability of harvesting, as can be seen in Table 9. Volume harvested compared with current AAC. The average volume harvested per year was calculated for six time periods, starting with the period since the approval of the CF Management Plan (0-4 years). During all six time periods, the volume harvested per year was lower than the current AAC with a significance level of p = .01 or lower.

Table 9. Volume harvested compared with current AAC

		Time period of harvesting					
		0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
AAC (m^3*ha^{-1})	*Mdn*	5.48	5.48	5.48	5.48	5.48	5.48
	M	5.59	5.59	5.59	5.59	5.59	5.59
V Stumps (m^3*ha^{-1})	*Mdn*	0	0	0	0	0	0.79
	M	4.64	2.43	1.34	1.14	2.25	2.71
Statistic		T = 156, p < .01, r = -.46	T = 98, p < .001, r = -.62	T = 60, p < .001, r = -.71	T = 36, p < .001, r = -.78	T = 91, p < .001, r = -.63	T = 123, p < 001, r = -.55

Note: Rotation = 100 yrs.

Even when the rotation period was increased to 150 yrs, the volume harvested per year was lower than the AAC for all six time periods with a significance level of p ≤ .05.

There was no case of a use category such as the 1st class timber trees being over-harvested for the combined blocks, as can be seen in Table 10. Volume harvested compared with current AAC by use category. The current AAC was significantly higher than the volume harvested per year during all time periods for all use categories except “2nd Timber”, and in that case the insignificant results were for harvesting that took place 30–50 years ago.

Table 10. Volume harvested compared with current AAC by use category

Use category	Time Periods in which harvest (m3) was significantly lower than current AAC (100 years rotation)					
	0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
1st Timber	*	*	*	*	*	*
2nd Timber	*	*	*	*	n.s.	n.s.
Other Use	*	*	*	*	*	*
Quercus	*	*	*	*	*	*

Notes: * = significant with $p \leq .05$, n.s. = not significant. Rotation period = 100 yrs. See Appendix 8 for statistical results and median volume figures

Even when the rotation period was increased to 150 yrs, the volume harvested per year was lower than the AAC for all use categories during the past 20 years with a significance level of $p \leq .01$.

There was no case of an individual block being over-harvested for combined use categories, as can be seen in Table 11. Volume harvested compared with current AAC by block. The current AAC was significantly higher than the volume harvested per year in each block for most time periods. However, several combinations were insignificant, including two during the time period of CF management.

Table 11. Volume harvested compared with current AAC by block

	Time Periods in which harvest (m3) was significantly lower than current AAC					
	0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
Block 1	n.s.	*	*	*	n.s.	*
Block 2	*	*	*	*	*	*
Block 3	n.s.	*	*	*	*	n.s.

Notes: * = significant with $p \leq .05$, n.s. = not significant. Rotation = 100 yrs. See Appendix 8 for statistical results and median volume figures

There was no case of a use category being over-harvested in an individual block, as can be seen in Table 12. Volume harvested compared with current AAC by use category and block. The current AAC significantly exceeded the volume harvested per year for most combinations, but the results for Block 1 were insignificant for many use classes and harvest periods.

Table 12. Volume harvested compared with current AAC by use category and block

Block	Use category	Time periods in which harvest (m3) was significantly lower than current AAC					
		0-4yrs	5-9yrs	10-19yrs	20-29yrs	30-39yrs	40-49yrs
1	1st Timber	n.s.	n.s.	n.s.	*	*	n.s.
	2nd Timber	n.s.	*	n.s.	n.s.	n.s.	*
	Other Use	*	n.s.	*	*	*	n.s.
	Quercus	n.s.	*	*	*	*	*
2	1st Timber	*	n.s.	*	*	n.s.	*
	2nd Timber	*	*	n.s.	*	n.s.	n.s.
	Other Use	*	n.s.	*	*	*	*
	Quercus	*	*	*	*	*	*
3	1st Timber	n.s.	*	*	*	*	*
	2nd Timber	*	*	*	*	n.s.	n.s.
	Other Use	*	*	*	*	*	*
	Quercus	n.s.	n.s.	*	*	*	n.s.

Notes: * = significant with $p \leq .05$, n.s. = not significant. Rotation = 100 yrs. See Appendix 8 for statistical results and median volume figures.

There was no case of over-harvesting for any of the eleven most-harvested species, which represented 90% of the total BA harvested, as can be seen in Table 13. Volume harvested compared with current AAC by species. *Lyonia* was not included because it was only found in eight of the 36 plots and did not give any significant results. In most cases, the current AAC significantly exceeded the amount of harvesting per year. In some cases, the results were not significant.

Table 13. Volume harvested compared with current AAC by species

Species	Time Periods in which Harvest (m3) was Significantly Lower than Current AAC					
	0-4 yrs	5-9yrs	10-19yrs	20-29yrs	30-39yrs	40-49yrs
Cinnamomum bejolghota	*	*	*	*	n.s.	*
Daphniphyllum chartaceum	*	*	*	*	*	*
Persea clarkeana	*	*	n.s.	n.s.	n.s.	n.s.
Michelia doltsopa	n.s.	*	n.s.	*	*	n.s.
Symplocos glomerata	*	*	*	*	*	*
Castanopsis hystrix	*	*	*	*	*	n.s.
Schima khasiana	*	n.s.	*	*	*	*
Quercus lamellosa	*	*	*	*	*	*
Elaeocarpus lanceaefolius	*	*	*	*	n.s.	*
Symplocos ramosissima	n.s.	n.s.	n.s.	*	*	*
Quercus semiserrata	*	*	*	*	*	*

Notes: * = significant with $p \leq .05$, n.s. = not significant. Rotation = 100 yrs. See Appendix 8 for statistical results and median volume figures.

5.1.3 Forest Development 2000 - 2005

The 2005 inventory was compared with the 2000 inventory plots that fell within the 2005 study area to see how the forest changed during the five year period. There were no significant differences between the total number, volume or BA standing trees (over 9 cm dbh) between 2000 and 2005. However, the BA of the 1st class timber trees was significantly higher in 2005 (*Mdn* = 3.32 *M = 7.03*) than in 2000 (*Mdn* = 0, *M* = 5.80), $U = 130$, $p < .05$, $r = .30$, whereas there were no significant differences for the less valuable categories of “no use” or “other use”.

Sapling density by use category was analyzed to assess changes in the quality of the forest during the five year period, as can be seen in Table 14. Comparison of sapling data between 2000 and 2005 inventories. The numbers of saplings of the 1^{st} and 2^{nd} class timber trees were significantly higher in 2005, as was the percentage of saplings of 2^{nd} class timber species (in comparison to saplings of all species). The number and percentage of *Daphniphyllum* saplings were also significantly higher in 2005.

Table 14. Comparison of sapling data between 2000 and 2005 inventories

			2005	2000	Statistic
Total N saplings	Saplings 0-4	*Mdn*	3,275	247	$U = 3$, $p < .001$, $r = -.73$
		M	3,335	277	
	Saplings 5-9	*Mdn*	394	89	$U = 50$, $p < .001$, $r = -.57$
		M	492	105	
N saplings by use category	1^{st} Timber 0-4 cm	*Mdn*	45	0	$U = 121$, $p < .001$, $r = -.36$
		M	289	7.49	
	2^{nd} Timber 0-4 cm	*Mdn*	623	45	$U = 57$, $p < .001$, $r = -.55$
		M	747	104	
	2^{nd} Timber 5-9 cm	*Mdn*	15	0	$U = 120$, $p < .01$, $r = -.37$
		M	68	3.74	
% saplings by Use Category	2^{nd} Timber 5-9 cm	*Mdn*	1%	0%	$U = 122$, $p < .01$, $r = -.37$
		M	16%	1%	
N *Daphniphyllum* saplings	0-4 cm	*Mdn*	51	0	$U = 104$, $p < .001$, $r = -.42$
		M	191	4	
	5-9 cm	*Mdn*	0	0	$U = 138$, $p < .05$, $r = -.35$
		M	67	0	
% *Daphniphyllum* saplings	0-4 cm	*Mdn*	2%	0%	$U = 108$, $p < .01$, $r = -.36$
		M	6%	1%	
	5-9 cm	*Mdn*	0%	0%	$U = 99$, $p < .05$, $r = -.32$
		M	9%	0%	

An analysis of seedling density (<1.3 m height) found that the total number of seedlings in 2005 was significantly higher, as can be seen in Table 15. Comparison of seedling data between 2000 and 2005 inventories. However, the only use category that showed a significant increase was “other use”. This was partially the effect of *Daphniphyllum chartaceum*, which significantly increased as a percentage of all seedlings.

Table 15. Comparison of seedling data between 2000 and 2005 inventories

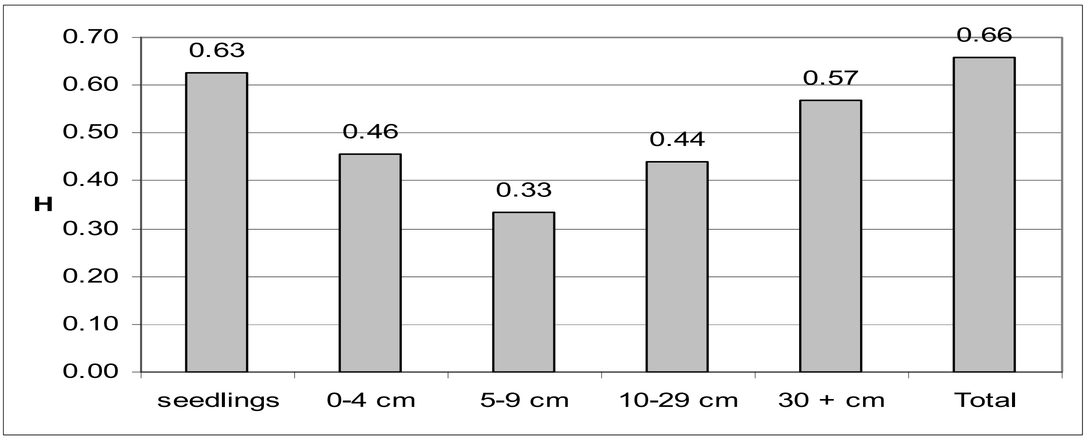
Seedlings	Item	2005	2000	Statistic
Total N seedlings	*Mdn*	12,864	7,636	*U* = 126, *p* < .05, *r* = -.31
	M	16,070	10,368	
N seedlings of “other use”	*Mdn*	8,100	3,818	*U* = 118, *p* < .05, *r* = -.34
	M	10,143	5,502	
% *Daphniphyllum* seedlings	*Mdn*	2%	0%	*U* = 142, *p* < .05, *r* = -.28
	M	4%	1%	

5.1.4 Harvesting Intensity and Diversity of Tree Genera

5.1.4.1 Shannon-Wiener Index

The Shannon-Wiener index (*H*) was calculated for each plot to assess the impact of different harvesting intensities on the diversity of trees. The distribution of *H* for the genera of 36 plots was normally distributed, with an overall mean of 0.66, as can be seen in Figure 12. Diversity *(H)* of genera in Yakpugang by size class. Diversity was highest for seedlings and large trees, and lowest for large saplings (5-9 cm dbh).

Figure 12. Diversity *(H)* of genera in Yakpugang by size class



There were no significant differences in the diversity of genera in the three study blocks. This was consistent with the findings that there were no significant differences between the three blocks in terms of the BA or volume of either live trees or stumps.

5.1.4.2 Diversity and Logging Intensity

The total diversity of all trees was positively correlated with logging intensity (BA stumps), and the same relationship existed for seedlings, saplings and small trees, as can be seen in Table 16. Correlation of diversity (H) and BA/volume stumps.

Table 16. Correlation of diversity (H) and BA/volume stumps

Size Class	Correlated with	Statistic (2-tailed)
All trees	Total BA stumps	$r = .47$, $p < .01$
Seedlings	Total BA stumps	$r = .41$, $p < .05$
Small saplings (0-4cm)	Total BA stumps	$r = .39$, $p < .05$
All saplings (0-9 cm)	Total BA stumps	$r = .43$, $p < .01$
Small trees (10-29 cm)	Total BA stumps	$r = .38$, $p < .05$

The relationship between diversity and time since harvesting was examined by comparing the diversity of four categories of plots:

- Plots that had been harvested during last 10 years,
- Plots that had not been harvested for at least 10 years,
- Plots that had not been harvested for at least 30 years, and
- Plots that had never been harvested.

The diversity of seedlings followed a significant decreasing trend with the time since harvesting, as can be seen in Table 17. Trends of diversity with logging intensity.

Table 17. Trends of diversity with logging intensity

Category of plot	N	Mdn Diversity (Shannon H)		
		Seedlings	Small saplings (0-4 cm dbh)	All stems
Harvest 0-9 yrs	15	.73	.56	.78
No harvest 10 years	8	.71	.50	.71
No Harvest 30 years	8	.67	.36	.74
No harvest ever	5	.36	.25	.38
Trend statistic		$J = 230$	$J = 214$	$J = 230$
Sig. level (2-tailed)		$p < .05$	$p < .005$	$p < .01$

The relationship between diversity and BA stumps was also examined by comparing the diversity in the upper, middle, and lower positions of the three blocks, as can be seen in Table 18. Comparison of diversity and BA stumps by position in block. The lower positions of the blocks were closer to the villages, while the upper positions were the least accessible. The BA of live trees was not significantly different in the three positions, but the BA of stumps showed a significant decreasing trend with higher position, and the diversity of the live trees followed the same pattern as the BA of stumps.

Table 18. Comparison of diversity and BA stumps by position in block

Portion of Study Blocks	Diversity all stems (Sh H)	BA Stumps*ha^{-1}
Lower portion	.79	29.12
Middle portion	.70	22.27
Upper portion	.49	9.20
Trend statistic	$J = 11.52$	$J = 15.71$
Sig. level (2-tailed)	$p < .005$	$p < .001$

Additional factors affecting diversity were analyzed through multiple regressions, but the small sample size allowed the consideration of only two variables per analysis. Several variables, such as the total number, BA, or volume of live trees in the plot, had no relation with the diversity of any size classes. Furthermore, there was no significant relation between the diversity of large trees (over 30 cm dbh) and diversity of either seedlings or saplings.

Findings included the following:

- The diversity of seedlings was most strongly related to a combination of BA of stumps and GSF ($r = .55$, $p < .01$). Significant but weaker relationships were found with the volume of stumps and GSF; and the number of stumps and GSF. There was no significant relation with the BA of stumps harvested in the last ten years.
- The diversity of small saplings (0-4 cm) was most strongly related to the BA of stumps and GSF, ($r = .63$, $p < .001$). Once again, there was no significant relation with the BA of stumps harvested in the last ten years.
- While GSF was related to the diversity of seedlings and small saplings, there was no relation between GSF and the diversity of larger stems.

5.1.4.3 Diversity and Intermediate Disturbance Hypothesis

The relationship between the level of disturbance and biodiversity was described by Connell (1978) as the intermediate disturbance hypothesis (IDH). Small scale logging operations as applied by the CF user groups in Bhutan could exert the same influence on biodiversity as would be expected from a natural disturbance. Intermediate levels of disturbance (frequency, intensity and time since harvesting) were assumed to be created by the forest users in the present study when compared to forests without utilization on the one hand and forests with larger openings or small clearcuts created by commercial logging on the other hand.

Since comparable data were not available from stands without utilization or with commercial logging, the IDH was tested within the study area by examining the relationship of diversity to three disturbance parameters (frequency of disturbance, time since disturbance, and intensity of disturbance).

Frequency of disturbance was defined as the number of years during the last 100 years that at least one tree with a dbh of 50 cm or more was harvested in a plot. As predicted by IDH, the relationship between diversity and frequency of disturbance was humped – exhibiting a significant fit with a quadratic curve, $F = 7.217, p < .005$, with a $R^2 = .304,$ whereas the R^2 of the linear curve was .176. For full statistical results see Appendix 8.

As can be seen in Figure 13. Curve fit for diversity and frequency of disturbance (all plots), the relationship was highly dependent on just one reading at the far right of the figure, even though the assumptions of the model were met.

Figure 13. Curve fit for diversity and frequency of disturbance (all plots)

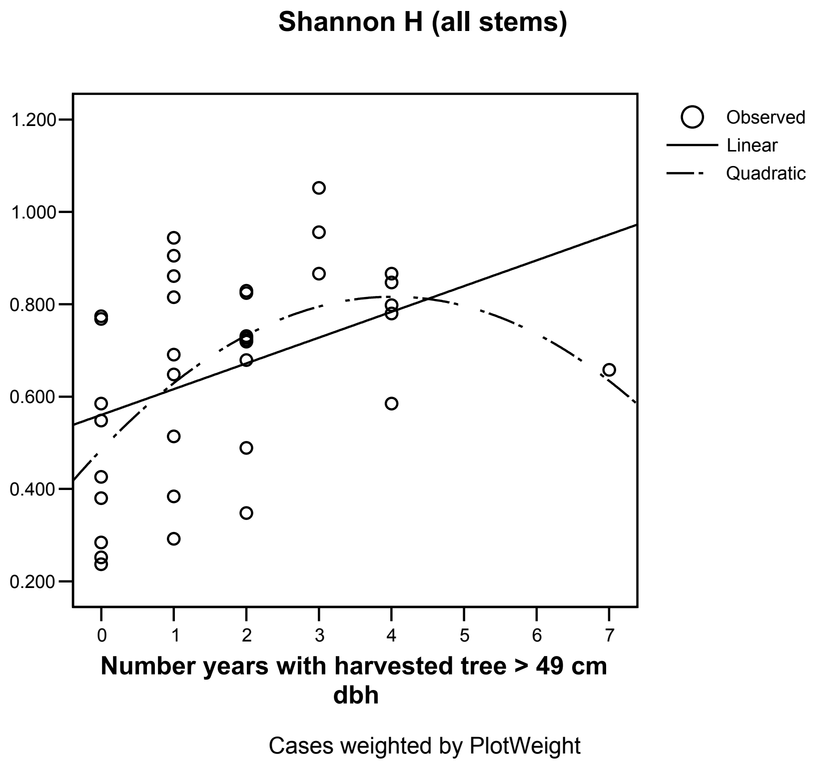
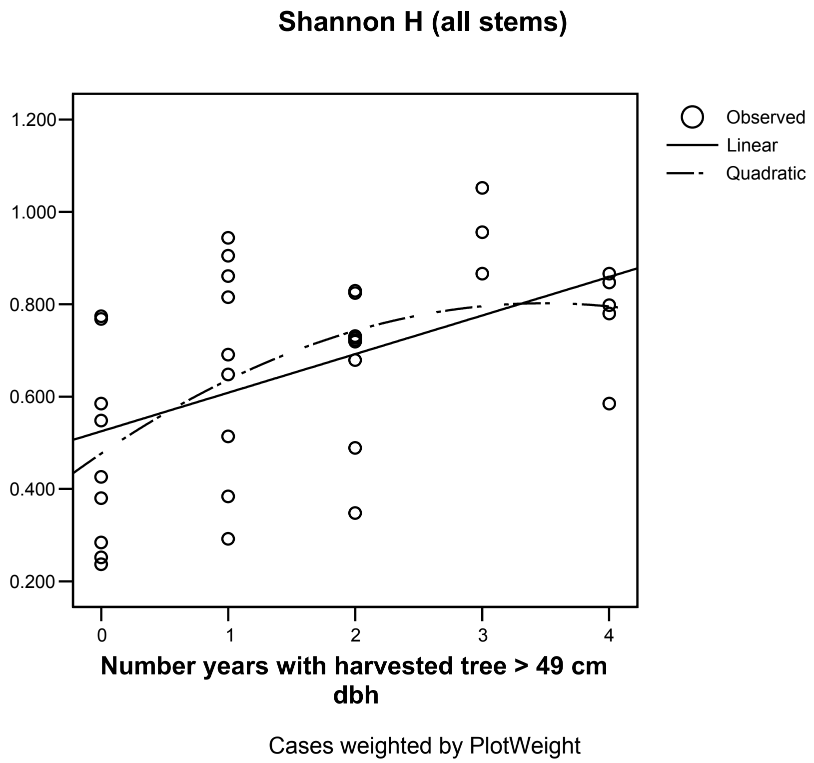


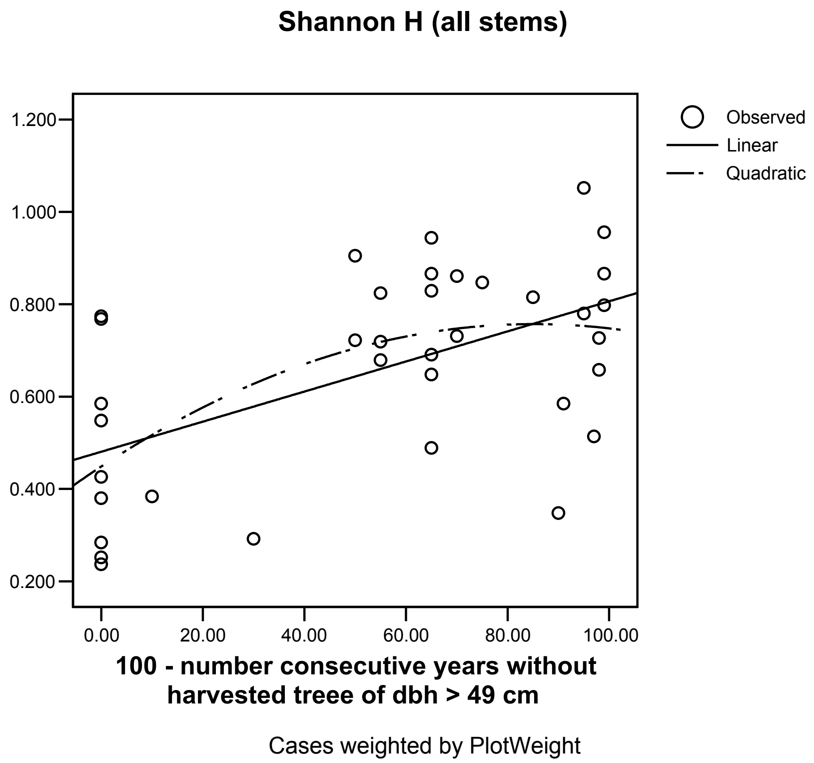
Figure 14. Curve fit for diversity and frequency of disturbance (without plot 201) shows the same relationship when the reading mentioned above is eliminated. The relationship exhibits a less humped relationship, but the fit is still significant with a quadratic curve, $F = 7.072$, $p < .005$, with a $R^2 = .307$ whereas the R^2 of the linear curve was.263.

Figure 14. Curve fit for diversity and frequency of disturbance (without plot 201)



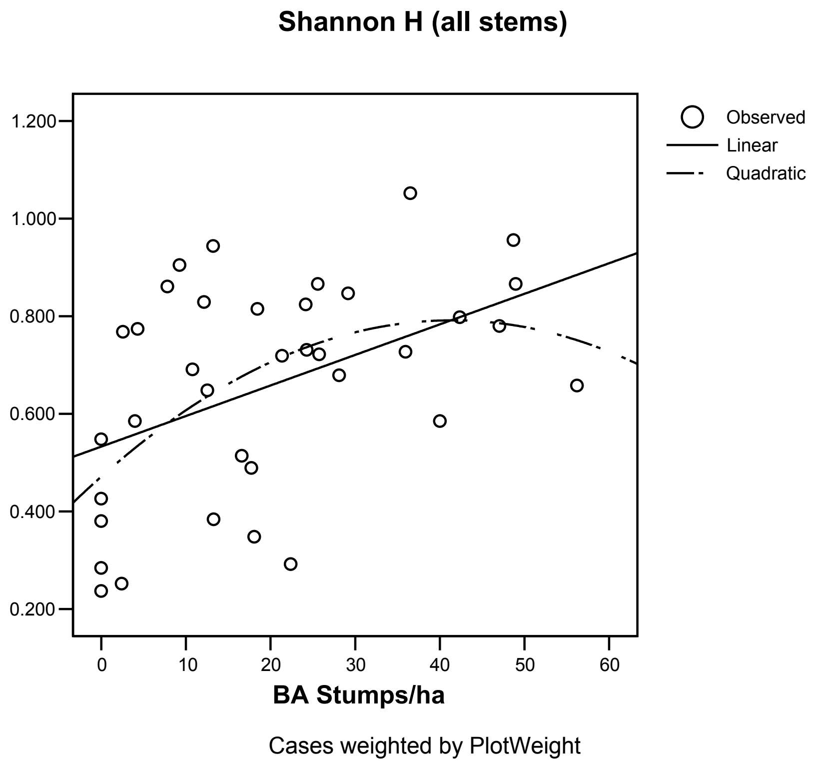
Time since disturbance was defined as the number of consecutive years during the past 100 years without the harvest of a tree with dbh of at least 50 cm. The value of the indicator was reversed by subtracting it from 100 in order to make the smaller values correspond to a smaller level of disturbance and vice versa. The relationship with diversity exhibited a significant fit with a quadratic curve, $F = 9.050, p < .001$, with a $R^2 = .354$ whereas the R^2 of the linear curve was .312. See Figure 15. Curve fit for diversity and time since disturbance.

Figure 15. Curve fit for diversity and time since disturbance



The intensity of the disturbance was defined as the total BA of harvested trees in the plot. This indicator provided limited support for IDH. The relationship with diversity exhibited a significant fit with a quadratic curve, *$F = 6.04$, $p < .01$, with a $R^2 = .27$* whereas the R^2 of the linear curve was .22. See Figure 16. Curve fit for diversity and intensity of disturbance.

Figure 16. Curve fit for diversity and intensity of disturbance



5.1.5 Harvesting Intensity and Natural Regeneration

The impact of harvesting intensity on natural regeneration was investigated in Yakpugang CF in four ways:

- Relationship between harvesting intensity and numbers of seedlings and saplings;
- Relationship between harvesting intensity and seedling/sapling composition;
- Relationship between light intensity and seedling/sapling composition; and
- Relationship between canopy cover and seedling/sapling composition.

5.1.5.1 Harvesting Intensity and Number of Seedlings/Saplings

As expected, the total number of seedlings was positively correlated with harvesting intensity, both in terms of volume stumps, *r = .23, p <.05 (one sided*), and BA stumps, *r = .23, p < .05 (one sided*). However, there was no significant correlation between the total number of saplings and harvesting intensity. The number of small saplings*ha^{-1} (0-4 cm dbh) in plots that had not been harvested for 30 years (*M = 3,173, Mdn = 3,330*) was not significantly different from the number in harvested plots (*M = 3,384, Mdn = 3,242*). Similarly the number of large saplings*ha^{-1} (5-9 cm dbh) in plots that had not been harvested for 30 years (*M = 477, Mdn = 453*) was not significantly different from the number in harvested plots (*M = 490, Mdn = 328*). Even the plots that had never been harvested contained dense regeneration of both small saplings*ha^{-1} (*M = 1,972, Mdn = 1,142*) and large saplings (*M = 708, Mdn = 482*).

When the data were aggregated by species, three of the 38 species exhibited significant correlations. All correlations were positive except for *Symplocos glomerata,* which exhibited consistently negative correlations, as can be seen in Table 19. Correlation between harvesting intensity and number of seedlings/saplings by species.

Table 19. Correlation between harvesting intensity and number of seedlings/saplings by species

Size Class	Harvest Intensity Indicator	Species		
		Daphniphyllum chartaceum	*Schima khasiana*	*Symplocos glomerata*
Seedlings	N stumps	τ = .55, p < .001	τ = .29, p < .05	n.s.
	V stumps	τ = .30, p < .05	n.s.	n.s.
	BA stumps	τ = .36, p < .01	n.s.	n.s.
Small sapling (0-4cm dbh)	N stumps	τ = .46, p < .001	τ = .47, p < .001	n.s.
	V stumps	τ = .28, p < .05	τ = .30, p < .05	n.s.
	BA stumps	τ = .31, p < .01	τ = .32, p < .01	n.s.
Large sapling (5-9cm dbh)	N stumps	τ = .33, p < .05	τ = .36, p < .01	τ = -.28, p < -05
	V stumps	n.s.	n.s.	τ = -.27, p < .05
	BA stumps	n.s.	n.s.	τ = -.27, p < .05

Note: n.s. = no significant result

When the data were aggregated by species category, there were no significant correlations.

5.1.5.2 Harvesting Intensity and Seedling/Sapling Composition

A stronger relationship was observed between harvesting intensity and seedling/sapling composition (defined as the percentage of seedlings and saplings of each use category). The number of harvested trees was positively correlated with percentage of small saplings (0-5 cm dbh) of timber species, and negatively correlated with the percentage of saplings of species which were not used or not preferred by the members, as can be seen in Table 20. Correlation between harvesting intensity and sapling composition by species category.

Table 20. Correlation between harvesting intensity and sapling composition by species category

	Harvest intensity indicator	Species Category			
		1st Timber	High Pref	No Use	Low Pref
% of all small saplings (0-4cm dbh)	N stumps	τ = .49, p < .001	τ = .30, p < .05	τ = -.29, p < .05	τ = -.46, p < .001
	V stumps	τ = .33, p < .01	n.s.	τ = -.27, p < .05	τ = -.35, p < .01
	BA stumps	τ = .35, p < .01	n.s.	n.s.	τ = -.39, p < .001

Note: n.s. = no significant result

When the data were aggregated by species, significant correlations were exhibited for seedlings and large saplings as well as for small saplings, as can be seen in Table 21. Correlation between harvesting intensity and seedling/sapling composition by species. The significant correlations were generally positive except for *Symplocos*. The data for *Symplocos* was analyzed separately for the two species and also for entire genus.

Table 21. Correlation between harvesting intensity and seedling/sapling composition by species

Size Class	Harvest intensity indicator	Species							
		Beilschmiedia gammieana	*Cinnamomum bejolghota*	*Daphniphyllum chartaceum*	*Elaeocarpus lanceaefolius*	*Schima khasiana*	*Symplocos glomerata*	*Symplocos ramosissima*	*Symplocos (2 species)*
Seedling	N stumps	n.s.	τ = .31, $p < .01$	τ = .57, $p < .001$	n.s.	τ = .29, $p < .05$	n.s.	n.s.	τ = -.31, $p < .01$
	V stumps	n.s.	τ = .29, $p < .05$	τ = .40, $p < .05$	n.s.	n.s.	τ = -.24, $p < .05$	n.s.	τ = -.31, $p < .01$
	BA stumps	n.s.	τ = .32, $p < .01$	τ = .36, $p < .005$	n.s.	n.s.	τ = -.23, $p < .05$	n.s.	τ = -.32, $p < .01$
Small sapling (0-4cm dbh)	N stumps	n.s.	τ = -.30, $p < .05$	τ = .49, $p < .001$	τ = .27, $p < .05$	τ = .48, $p < .001$	τ = -.27, $p < .05$	τ = -.25, $p < .05$	τ = -.46, $p < .001$
	V stumps	τ = .29, $p < .05$	n.s.	τ = .36, $p < .005$	τ = .27, $p < .05$	τ = .34, $p < .01$	n.s.	τ = -.25, $p < .05$	τ = -.38, $p < .001$
	BA stumps	τ = .29, $p < .05$	n.s.	τ = .40, $p < .001$	n.s.	τ = .36, $p < .005$	n.s.	τ = -.26, $p < .05$	τ = -.41, $p < .001$
Large sapling (5-9cm dbh)	N stumps	n.s.	n.s.	τ = .30, $p < .05$	n.s.	τ = .37, $p < .01$	τ = -.27, $p < .05$	n.s.	τ = -.35, $p < .01$
	V stumps	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	τ = -.31, $p < .01$
	BA stumps	n.s.	n.s.	n.s.	n.s.	n.s.	τ = -.26, $p < .05$	n.s.	τ = -.32, $p < .01$

Note: n.s. = no significant result

5.1.5.3 Timing of Harvesting and Number/Composition of Seedling/Saplings

The total number of seedlings exhibited a significant correlation with the number of stumps harvested during the most recent four year period, *r = .26, p < .05 (two sided*), but not with the number of stumps harvested during earlier periods. There were no significant correlations for saplings.

When the species data were aggregated by species category, significant correlations were exhibited for the number of small saplings, but not with the number of trees harvested during the most recent 0-4 year period, as can be seen in Table 22. Correlation between harvesting intensity (by time period) and sapling composition by species category. There were no comparable patterns of significance for seedlings or larger saplings.

Table 22. Correlation between harvesting intensity (by time period) and sapling composition by species category

Size Class	Harvest Intensity Indicator	Time Period since harvest	Species Category			
			1st Timber	High Pref	No Use	Low Pref
Small Sapling (0-4 cm dbh)	N Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.
		5-9 yrs	τ = .46, $p < .001$	τ = .33, $p < .05$	τ = -.37, $p < .05$	τ = -.28, $p < .05$
		10-19 yrs	τ = .40, $p < .01$	τ = .27, $p < .05$	n.s.	τ = -.42, $p < .001$
	V Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.
		5-9 yrs	τ = .40, $p < .01$	τ = .32, $p < .05$	τ = -.39, $p < .05$	τ = -.27 $p < .05$
		10-19 yrs	τ = .33, $p < .05$	τ = .30, $p < .05$	n.s.	τ = -.29, $p < .05$

Note: n.s. = no significant result

When the data were aggregated by individual species, significant correlations were exhibited for seedlings and large saplings as well as for small saplings, as can be seen in Table 23. Correlation between harvesting intensity (by time period) and sapling composition by species. Once again all species exhibited positive correlations except for *Symplocos*, however this time the results for *Symplocos* were not consistent: *S. ramosissima* exhibited two positive correlations, whereas the correlations for *S. glomerata* and for the entire genus were all negative.

Table 23. Correlation between harvesting intensity (by time period) and sapling composition by species

Size Class	Harvest Intensity Indicator	Years since harvest	Species						
			Daphniphyllum chartaceum	*Phoebe attenuata*	*Quercus semiserrata*	*Schima khasiana*	*Symplocos glomerata*	*Symplocos ramosissima*	*Symplocos (2 species)*
Seedling	N Stumps Per Time Period of harvesting	0-4 Yrs	τ = .47, *p* < .001	τ = .32, *p* < .05	n.s.	n.s.	n.s.	n.s.	τ = -.32, *p* < .05
		5-9 yrs	τ = .30, *p* < .05	n.s.	n.s.	n.s.	τ = -.31, *p* < .05	n.s.	n.s.
		10-19 yrs	τ = .37, *p* < .01	τ = .26, *p* < .05	n.s.	n.s.	n.s.	τ = .27, *p* < .05	n.s.
	V Stumps Per Time Period of harvesting	0-4 yrs	τ = .31, *p* < .05	τ = .38, *p* < .005	n.s.	n.s.	n.s.	n.s.	n.s.
		5-9 yrs	τ = .34, *p* < .05	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		10-19 yrs	τ = .37, *p* < .01	τ = .27, *p* < .05	n.s.	n.s.	n.s.	τ = .28, *p* < .05	n.s.
Small Sapling (0-4 cm dbh)	N Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		5-9 yrs	τ = .27, *p* < .05	n.s.	n.s.	τ = .33, *p* < .05	n.s.	n.s.	τ = .-36, *p* < .005
		10-19yrs	τ = .36, *p* < .01	τ = .29, *p* < .05	n.s.	τ = .38, *p* < .01	n.s.	n.s.	τ = .-36, *p* < .01
	V Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		5-9 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	τ = -.27, *p* < .05
		10-19Yrs	n.s.	τ = .27, *p* < .05	τ = .32, *p* < .05	τ = .29, *p* < .05	n.s.	n.s.	n.s.
Large Sapling (5-9 cm dbh)	N Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		5-9 Yrs	τ = .29, *p* < .05	n.s.	n.s.	τ = .35, *p* < .05	n.s.	n.s.	n.s.
		10-19 Yrs	τ = .32, *p* < .05	n.s.	n.s.	τ = .38, *p* < .01	τ = -.30, *p* < .05	n.s.	n.s.
	V Stumps Per Time Period of harvesting	0-4 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		5-9 Yrs	τ = .38, *p* < .01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		10-19 yrs	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

Note: n.s. = no significant result

5.1.5.4 Light Intensity and Sapling Composition

The relationship between light intensity and sapling composition was studied by comparing the numbers of trees in the four plot categories based on canopy cover, as estimated visually during the inventory:

- 10-19% upper canopy cover,
- 20-29% upper canopy cover,
- 30-49% upper canopy cover, and
- 50-80% upper canopy cover.

The relationship between light intensity and sapling composition followed the same pattern as the relationship between harvesting intensity and sapling composition described in Section 5.1.5.1. The total numbers of large saplings (5-9 cm dbh) (but not seedlings and small saplings (0-4 cm dbh)) exhibited a significant decreasing trend in relation to the categories of canopy cover, as can be seen in Table 24. Trend analysis for saplings and upper canopy cover of preferred species. When the data were aggregated by species category, the numbers and percentages of small and large saplings of valuable species also exhibited decreasing trends with increasing canopy cover.

Table 24. Trend analysis for saplings and upper canopy cover of preferred species

	Upper Canopy Cover	Saplings 0-4 cm dbh (Mdn)				Saplings 5-9 cm dbh (Mdn)				
		N 1st timber trees $^{*}ha^{-1}$	% 1st timber trees	N 1st pref. trees $^{*}ha^{-1}$	% 1st pref. trees	N all trees	N 1st timber trees $^{*}ha^{-1}$	% 1st timber trees	N 1st pref. trees $^{*}ha^{-1}$	% 1st pref. trees
Mdn	10-19%	360	16%	403	17%	390	101	14%	101	15%
	20-29%	215	7%	258	8%	482	44	3%	44	5%
	30-49%	45	1%	89	6%	402	0	0%	0	0%
	50-80%	0	0%	68	3%	277	0	0%	0	0%
Trend Statistic		*J*=132	*J*=126	*J*=152	*J*=153	*J*=171	*J*=158	*J*=159	*J*=157	*J*=171
Sig. level (2-tailed)		*p*< .01	*p*< .01	*p*< .05	*p*< .05	*p*< .05	*p*< .01	*p*< .05	*p*< .05	*p*< .05

In contrast, the numbers of the least valuable saplings exhibited significant increasing trends as the canopy cover increased, as can be seen in Table 25. Trend analysis for saplings and upper canopy cover of non-preferred species.

Table 25. Trend analysis for saplings and upper canopy cover of non-preferred species

	Upper Canopy Cover	Saplings 0-4 cm dbh (Mdn)		
		% low pref. trees	% *Symplocos*	% other use trees
Mdn	10-19%	49%	45%	54%
	20-29%	66%	63%	71%
	30-49%	62%	53%	70%
	50-80%	74%	69%	81%
Trend Statistic		*J* = 316	*J* = 326	*J* = 335
Sig. level (2-tailed)		*p* < .05	*p* < .01	*p* < .01

When the seedlings and saplings were divided into three classes of palatability to livestock, there were no significant trends for seedlings or smaller saplings (0-4 cm) with increasing canopy cover. For larger saplings (5-9 cm dbh) there was a decreasing trend of numbers of low palatability saplings with increasing canopy cover, $J = 160$, $p < .05$.

An attempt was made to study the relationship between light intensity and sapling composition with greater precision by correlating the values assessed through hemispherical photography for Global Site Factor (GSF) and canopy cover (the vertically projected canopy area per unit of ground area) with sapling composition. The relationship between light intensity and sapling composition followed the same pattern as the relationship between harvesting intensity and upper canopy cover. However, the results were only significant for one-tailed tests, and were thus inconclusive, as can be seen in Table 26. Correlation between GSF and number/percentage of saplings by species category.

Table 26. Correlation between GSF and number/percentage of saplings by species category

Size Class	Indicator	GSF		Canopy Cover	
		Sig. level (1-tailed)	Correlation	Sig. level (1-tailed)	Correlation
Saplings (0-4 cm dbh)	N trees 1st timber	*p* < .05	τ = .28	*p* < .01	τ = -.40
	% trees 1st timber	*p* < .05	τ = .26	n.s.	
	N trees 1st preference	*p* < .05	τ = .25	*p* < .05	τ = -.26
	% trees low palatability	*p* < .05	τ = -.25	*p* < .05	τ = .32
	% *Symplocos*	n.s.		*p* < .05	τ = .28
	% trees low preference	*p* < .05	τ = -.29	*p* < .05	τ = .29
Saplings (5-9 cm dbh)	N trees low preference	p < .05	*τ = -.26*	p < .01	*τ = .35*
	% trees low preference	p < .05	*τ = -.28*	p < .05	*τ = .32*
	N trees high palatability	p < .05	*τ = .32*	p < .01	*τ = -.40*
	% trees high palatability	p < .05	*τ = .30*	p < .01	*τ = -.40*
	N *Symplocos*	p < .05	*τ = -.31*	n.s.	

n.s. = not significant

5.1.6 Harvesting Intensity and Bole Shape and Form

The impact of single tree selection on quality parameters such as form and bole shape of the remaining trees was assessed by rating the form of all timber sized trees (>29 cm dbh) based on whether a typical CF member would accept the marking of the tree for his/her personal use. The percentage of trees with good form/bole shape ranged from 13% for *Lyonia ovalifolia* to 100% for *Schima khasiana,* as can be seen in Table 27. Percentage of trees with acceptable form/bole shape by species.

Table 27. Percentage of trees with acceptable form/bole shape by species

Species	% Trees with Good Form	Use Category
Schima khasiana	100%	1st timber
Cinnamomum bejolghota	86%	2nd timber
Persea clarkeana	80%	2nd timber
Daphniphyllum chartaceum	78%	Other use
Michelia doltsopa	78%	1st timber
Castanopsis hystrix	77%	2nd timber
Phoebe attenuata	75%	1st timber
Quercus lamellosa	72%	Quercus
Prunus cerasoides	67%	1st timber
Elaeocarpus lanceaefolius	63%	2nd timber
Quercus semiserrata	57%	Quercus
Betula utilis	50%	Other use
Lyonia ovalifolia	13%	Other use

Note: Trees with dbh > 29 cm were included.

There were no significant correlations between the percentage of trees with good form/bole shape and the number of stumps harvested in any time period during the past 30 years (0-4 yrs, 0-9 yrs, 0-19 yrs, and 0-29 yrs). When the species were combined by use category, a significant correlation was observed for trees in the category of “other use”, starting with the period of CF management (0-4 years), ($\tau = -.32$, $p < .05$), and continuing through later periods.

In a separate analysis, the percentage of trees with good form/bole shape was compared by harvesting intensity after separating the 36 plots into three categories of harvesting intensity:

- No harvesting for at least 30 years (twelve plots),
- Harvesting during past 30 years, but not during past ten years (14 plots), and
- Harvesting during the last ten years (ten plots).

There were no significant differences between the three harvesting categories for individual species or use categories.

5.1.7 Harvesting Intensity and Diameter Distribution

The relationship between harvesting intensity and diameter distribution was studied by comparing the diameter distributions of three categories of harvesting intensity:

- No harvesting for at least 30 years (twelve plots),
- Moderate harvesting during past 30 years, but limited during past ten years (14 plots), and
- Intense harvesting during past ten years (ten plots).

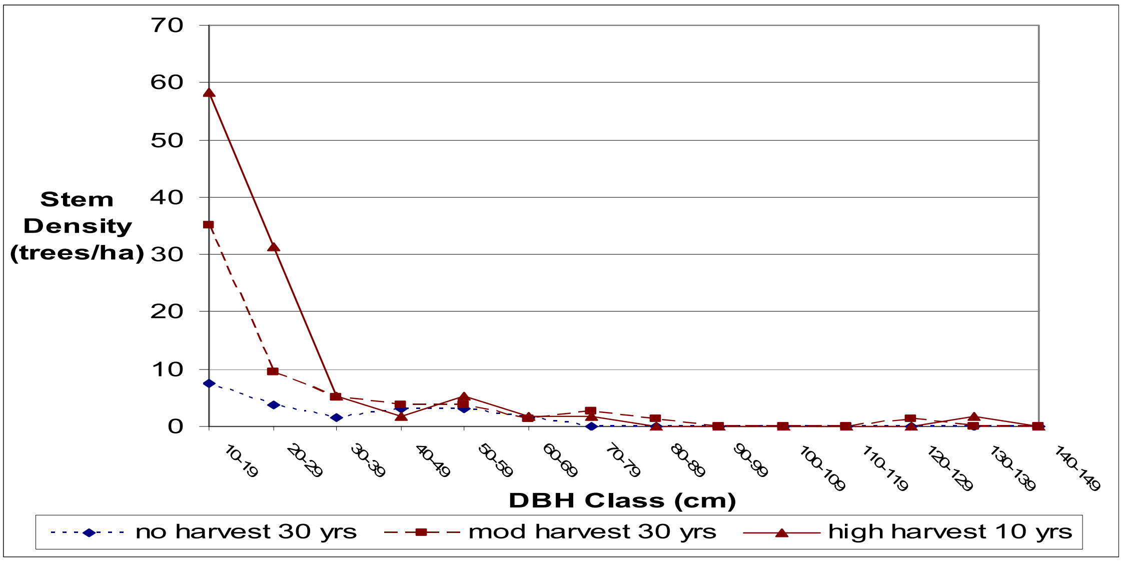
This analysis was carried out for the use categories and for individual species. The distributions of seedlings and seedlings/saplings were included in separate figures from the larger size classes, as the high numbers of seedlings/saplings made combined figures difficult to interpret.

5.1.7.1 1st Class Timber

The category of 1st Class Timber Species exhibited a strong “inverted J” (i-J) diameter distribution with steeper negative exponential curves in the plots with more logging, as can be seen in Figure 17. Diameter distribution of 1st class timber trees by harvesting intensity and Figure 18. Diameter distribution of 1st class timber seedlings and saplings by harvesting intensity.

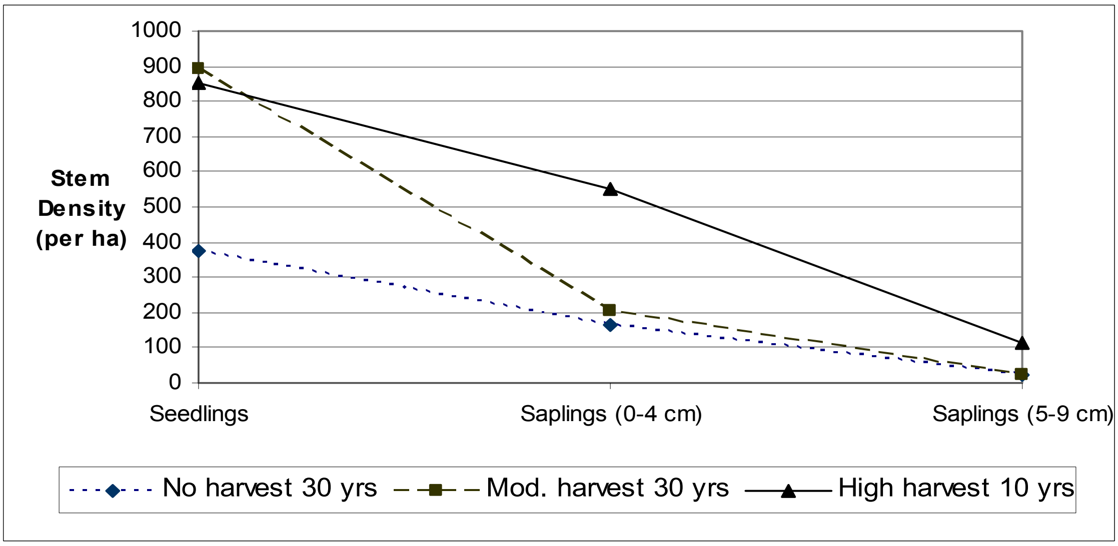
The diameter distribution of trees (all size classes except seedlings and saplings) in plots with high harvest during the past ten years was significantly different from the plots with no harvesting during the past 30 years, $Z = 2.26$, $p < .001$, and plots with moderate harvesting during the past 30 years, $Z = 1.13$, $p < .05$. The diameter distribution of trees in plots with no harvesting was also significantly different from the plots with moderate harvesting, $Z = 1.56$, $p < .001$.

Figure 17. Diameter distribution of 1st class timber trees by harvesting intensity



Note: Trees with dbh > 9 cm were included.

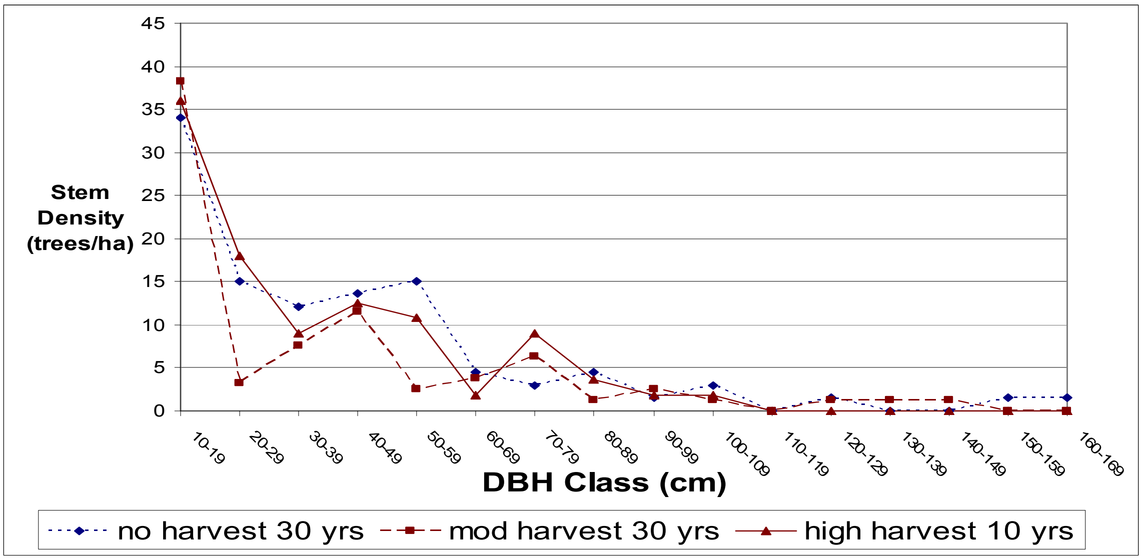
Figure 18. Diameter distribution of 1st class timber seedlings and saplings by harvesting intensity



5.1.7.2 2nd Class Timber

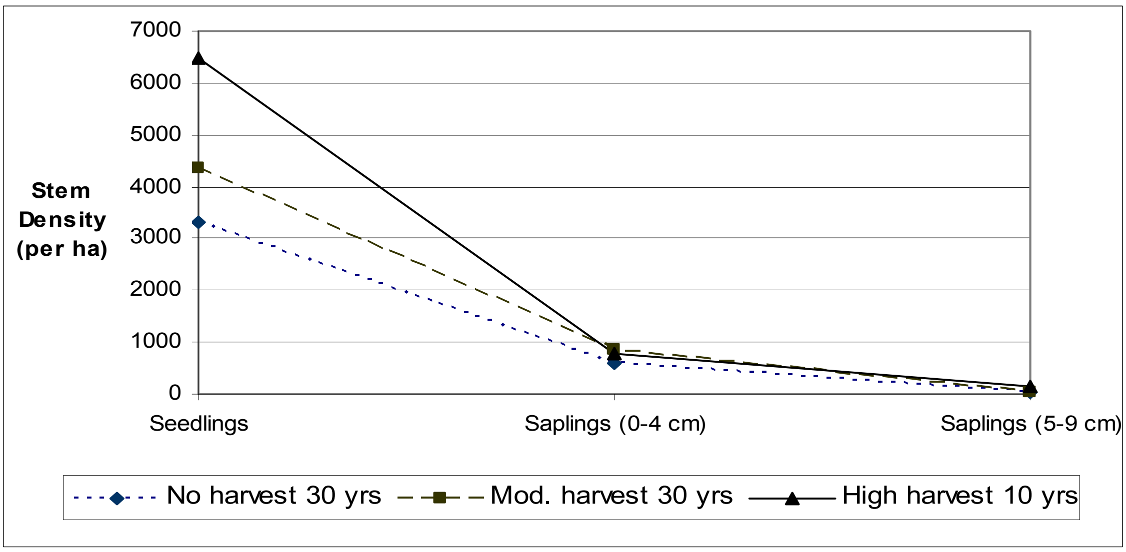
The diameter distribution of the 2nd class timber species was similar to the 1st class timber species, but with a less distinct i-J pattern, as can be seen in Figure 19. Diameter distribution of 2nd class timber trees by harvesting intensity and Figure 20. Diameter distribution of 2nd class timber seedlings and saplings by harvesting intensity. The diameter distribution of trees in plots with high harvest during the past ten years was significantly different from the plots with no harvesting during the past 30 years, $Z = 1.60$, $p < .005$, but not with the plots with moderate harvesting during the past 30 years. The diameter distribution of trees in plots with no harvesting was significantly different from the plots with moderate harvesting, $Z = 2.27$, $p < .001$.

Figure 19. Diameter distribution of 2nd class timber trees by harvesting intensity



Note: Trees with dbh > 9 cm were included.

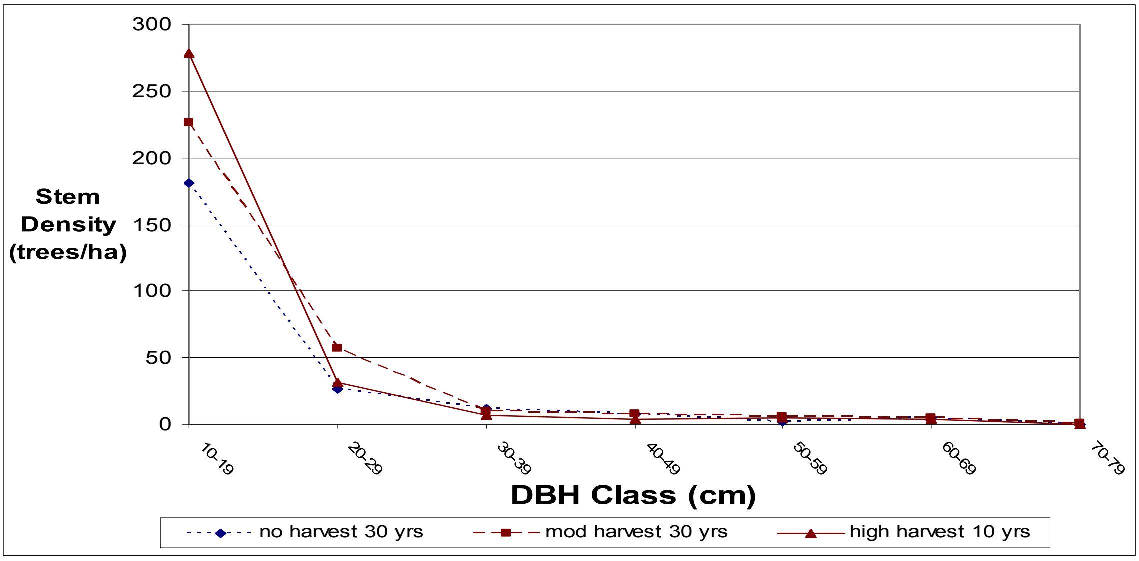
Figure 20. Diameter distribution of 2nd class timber seedlings and saplings by harvesting intensity



5.1.7.3 Other Use Trees

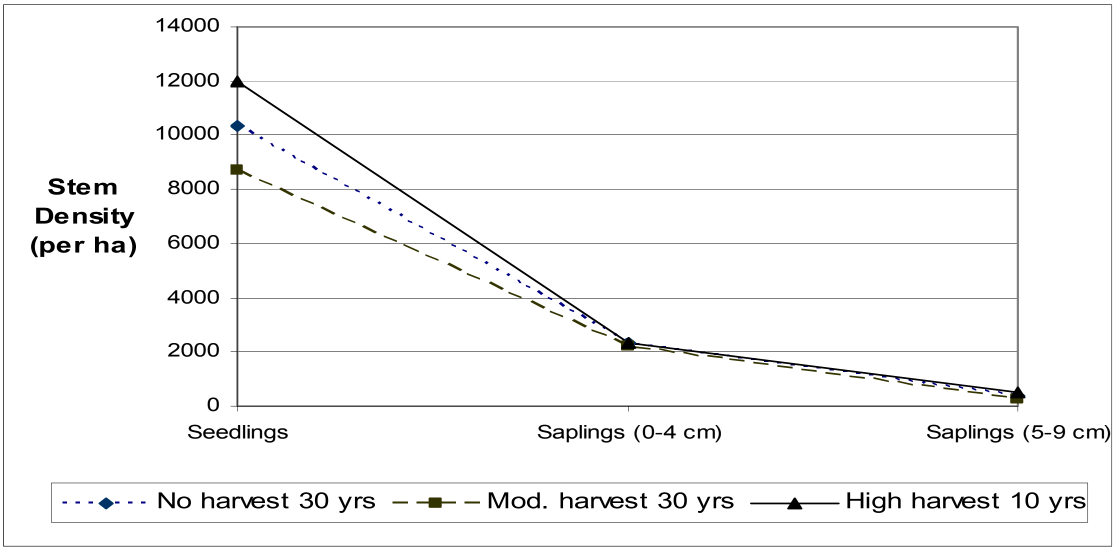
The “other use” category of trees, which had the highest number of trees, exhibited a strong i-J diameter distribution, as can be seen in Figure 21. Diameter distribution of "other use" trees by harvesting intensity and Figure 22. Diameter distribution of "other use" seedlings and saplings by harvesting intensity. The diameter distribution of trees in plots with high harvest during the past ten years was significantly different from the plots with no harvesting during the past 30 years, $Z = 1.11$, $p < .05$, and with the plots with moderate harvesting during the past 30 years, $Z = 2.04$, $p < .001$.

Figure 21. Diameter distribution of "other use" trees by harvesting intensity



Note: Trees with dbh > 9 cm were included.

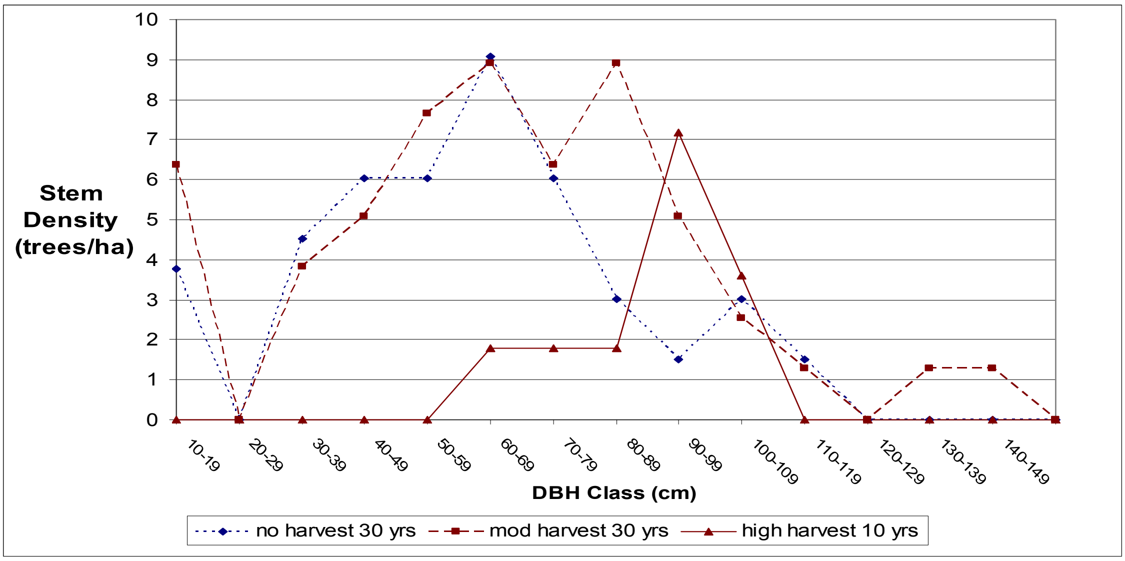
Figure 22. Diameter distribution of "other use" seedlings and saplings by harvesting intensity



5.1.7.4 Quercus

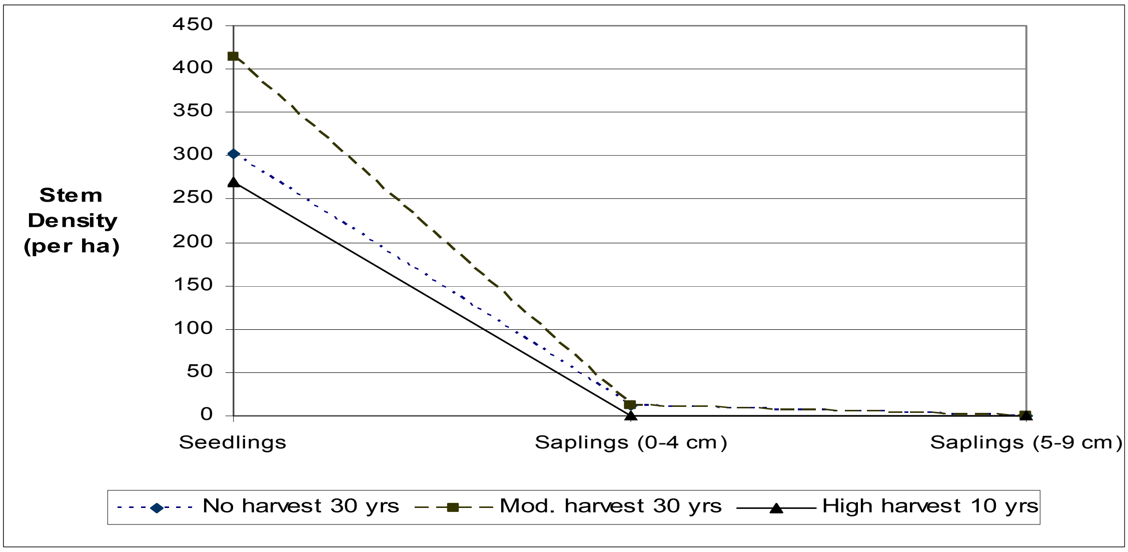
The stem density for the *Quercus* category (four species) was much lower than the three other categories, with no more than ten trees*ha^{-1} for any size class except seedlings. The distributions exhibited sporadic or bimodal patterns in all harvesting classes with very limited regeneration of seedlings and saplings, as can be seen in Figure 23. Diameter distribution of *Quercus* trees by harvesting intensity and Figure 24. Diameter distribution of *Quercus* seedlings and saplings by harvesting intensity. The diameter distribution of trees in plots with high harvest during the past ten years was significantly different from the plots with no harvesting during the past 30 years, $Z = 2.51$, $p < .001$, and the plots with moderate harvesting during the past 30 years, $Z = 2.64$, $p < .001$. The diameter distribution of trees in plots with no harvesting was significantly different from the plots with moderate harvesting, $Z = 1.15$, $p < .05$.

Figure 23. Diameter distribution of *Quercus* trees by harvesting intensity



Note: Trees with dbh > 9 cm were included.

Figure 24. Diameter distribution of *Quercus* seedlings and saplings by harvesting intensity



Q. semiserrata was the only species of *Quercus* with any seedling regeneration. Even though *Q. lamellosa* had the 2nd highest BA of the 39 recorded tree species, no stems under 10 cm dbh were found in any of the plots.

5.1.7.5 Individual Species

When the diameter distributions of individual species were analyzed, there were no significant differences between the three classes of harvesting intensity. Eight of the species exhibited i-J distribution patterns in most of the individual plots, while the other species exhibited sporadic distributions.

Schima khasiana, a first class timber species, exhibited an i-J distribution pattern in all 12 plots where it occurred. The i-J distribution pattern was the most distinct in the plots that had received high harvest levels during the past 10 years, but was also exhibited in plots which had not been harvested for 30 years, as can be seen in two representative plot examples in Figure 25. DBH distribution of *Schima khasiana* in a plot with no harvest for 30 years and Figure 26. DBH distribution of *Schima khasiana* in a plot with high harvest for 10 years

Figure 25. DBH distribution of *Schima khasiana* in a plot with no harvest for 30 years

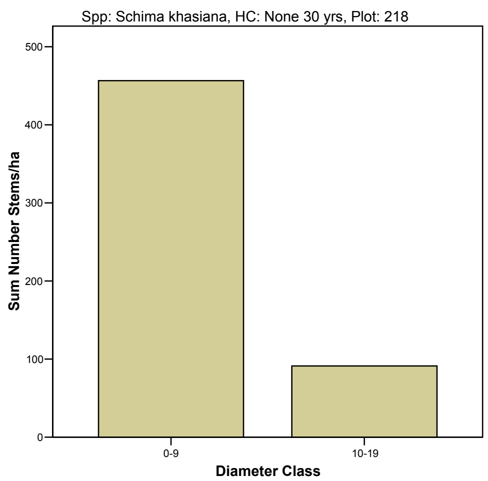
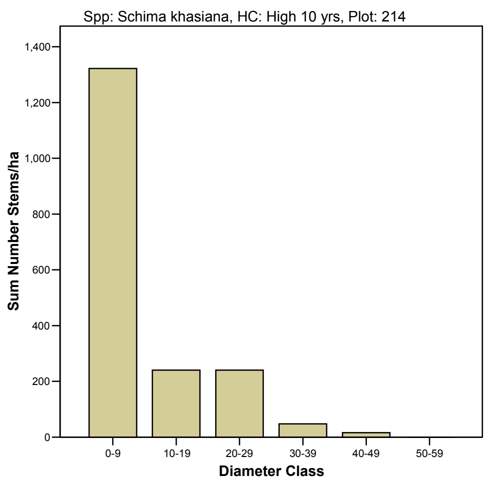


Figure 26. DBH distribution of *Schima khasiana* in a plot with high harvest for 10 years



Several 2nd class timber species followed the same pattern. *Cinnamomum bejolghota* exhibited an i-J distribution pattern in 20 of 24 plots where it occurred; while *Castanopsis hystrix* exhibited an i-J distribution pattern in 12 of 23 plots. *Cinnamomum bejolghota* tended to exhibit more distinct i-J distribution patterns in plots that had been harvested during the past 10 years, whereas *Castanopsis hystrix* followed the opposite pattern, as can be seen in Figure 27- Figure 30.

Figure 27. DBH distribution of *Cinnamomum bejolghota* in a plot with no harvest for 30 years

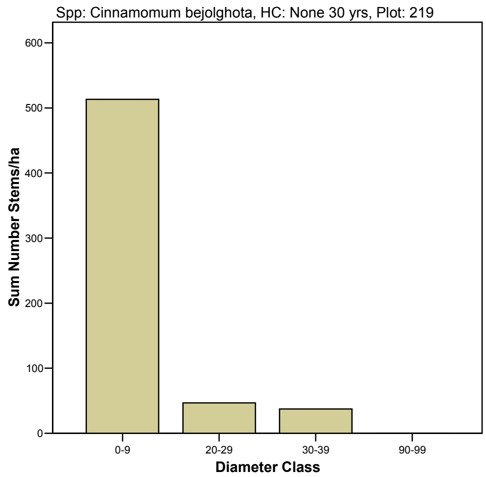


Figure 28. DBH distribution of *Cinnamomum bejolghota* in a plot with high harvest for 10 years

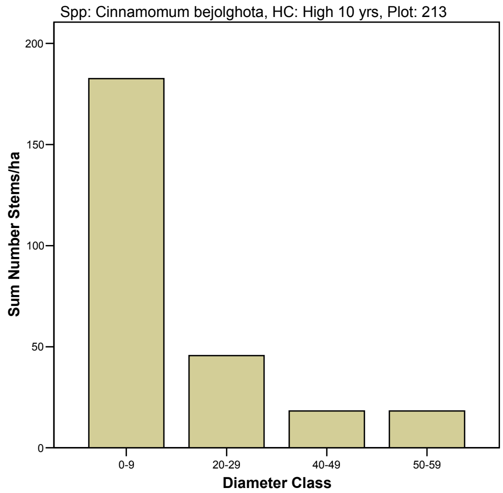


Figure 29. DBH distribution of *Castanopsis hystrix* in a plot with no harvest for 30 years

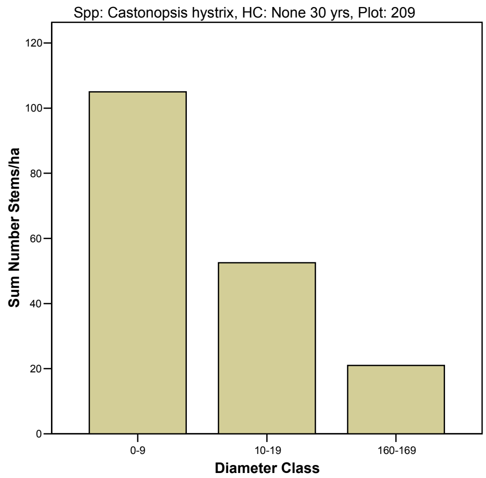
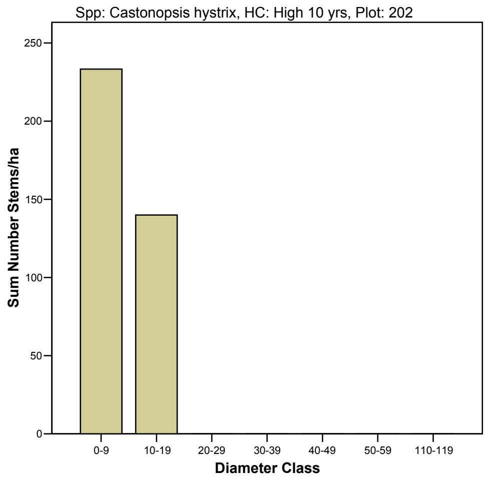


Figure 30. DBH distribution of *Castanopsis hystrix* in a plot with high harvest for 10 years



Five species in the "other use" category also exhibited i-J distribution patterns: *Daphniphyllum chartaceum, Maesa chisia, Neolitsea spp, Symplocos glomerata, and Symplocos ramosissima.* The diameter distributions of these species in representative plots can be seen in Appendix 9.

5.2 Household Survey of Three Community Forests

5.2.1 Socio-Economic Groups

The three CFs had an approximately equal breakdown of the different socio-economic groups, as can be seen in Table 28. CMFG members by wealth rank. The biggest exceptions were larger proportions of laborers in Shambayung and small farmers in Masangdaza.

Table 28. CMFG members by wealth rank

	All CFs		Yakpugang CF		Masangdaza CF		Shambayung CF	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Laborer	47	27%	31	27%	6	16%	10	44%
Small Farmer	56	32%	31	27%	20	54%	5	22%
Large Farmer	53	31%	40	35%	8	22%	5	22%
Salary Earner	17	10%	11	10%	3	8%	3	13%
Total	173	100%	113	100%	37	100%	23	100%

5.2.2 Indicators of Political Equity

Representation on Management Committee: The laborers were under-represented on management committees in relation to their proportion of the total members, whereas the large farmers were over-represented. The small farmers and salary earners were adequately represented. There was some variation from this pattern in the individual CFs, but in general rich as well as poor members were represented on the management committees of all three CFs, as can be seen in Table 29. Representation on management committee by socio-economic group and CF.

Table 29. Representation on management committee by socio-economic group and CF

	All CFs		Yakpugang CF		Masangdaza CF		Shambayung CF	
	% of committee	% of all members	% of committee	% of all members	% of committee	% of all members	% of committee	% of all members
Laborer	18%	27%	13%	27%	0%	16%	40%	44%
Small Farmer	32%	32%	33%	27%	50%	54%	20%	22%
Large Farmer	42%	31%	46%	35%	50%	22%	30%	22%
Salary Earner	8%	10%	8%	10%	0%	8%	10%	13%

The representation of women on management committees in all three CFs was close to their proportion of all members, as can be seen in Table 30. Representation of women on management committee by CF. However, men held the key positions of chairman and secretary in all three CFs.

Table 30. Representation of women on management committee by CF

All CFs		Yakpugang CF		Masangdaza CF		Shambayung CF	
% of committee	% of all members	% of committee	% of all members	% of committee	% of all members	% of committee	% of all members
58%	51%	58%	50%	25%	38%	70%	78%

Attendance at Meetings: 80% of the households had participated in the last CF meeting. There were no significant differences between the attendance of the socio-economic groups or male vs. female members in any of the CFs.

Knowledge of CF Administration: Only 18% of the respondents knew how much money was currently in the CF fund, and only 19% could explain how the fund was intended to be used. There were no significant differences between the socio-economic groups or male vs. female members in any of the CFs. Shambayung members were more likely than members of other CFs to know how much money was in the fund χ^2 (1) = 8.43, p < .05, OR 10.

5.2.3 Indicators of Economic Equity

5.2.3.1 Access to Timber Permits

The percentage of laborers receiving permits was higher than the average for all products, whereas the percentage of salary earners receiving products was lower or equal to the average for all products. The same general pattern was exhibited in all three CFs, as can be seen in Table 31. Percentage of members that received permits by socio-economic group and CF. The only indications of inequity were the generally high percentage of large farmers and the low percentage of small farmers that received permits for sawn timber.

Table 31. Percentage of members that received permits by socio-economic group and CF

CF	Size Class	Socio-economic Group				
		Average for CF	Laborer	Small farmer	Big farmer	Salary earner
All CFs	Sawn timber	35%	36%	29%	45%	24%
	Beams	14%	19%	13%	11%	12%
	Poles	12%	13%	13%	9%	12%
Yakpugang	Sawn timber	33%	26%	29%	43%	27%
	Beams	0%	0%	0%	0%	0%
	Poles	0%	0%	0%	0%	0%
Masangdaza	Sawn timber	19%	17%	20%	25%	0%
	Beams	14%	17%	15%	13%	0%
	Poles	22%	33%	20%	25%	0%
Shambayung	Sawn timber	74%	80%	60%	100%	33%
	Beams	82%	80%	80%	100%	67%
	Poles	52%	40%	60%	60%	67%

The laborers generally received more trees per household than the other three groups, whereas the salary earners generally received fewer trees than other groups. This same pattern was exhibited in all three CFs, as can be seen in Table 32. Average number trees per recipient by socio-economic group and CF. One exception was the high amount of sawn timber received by the salary earners in Shambayung.

Table 32. Average number trees per recipient by socio-economic group and CF

CF	Size Class	Socio-economic Group				
		Average for CF	Laborer	Small farmer	Big farmer	Salary earner
All CFs	Sawn timber	2.43	3.12	2.06	2.13	2.75
	Beams	19.46	34.56	8.86	13.17	7.50
	Poles	11.15	14.67	7.86	11.20	12.00
Yakpugang	Sawn timber	2.62	3.88	2.56	2.24	1.67
	Beams	-	-	-	-	-
	Poles	-	-	-	-	-
Masangdaza	Sawn timber	1.00	1.00	1.00	1.00	-
	Beams	4.20	2.00	5.67	2.00	-
	Poles	6.38	8.50	6.00	5.00	-
Shambayung	Sawn timber	2.59	2.63	2.00	2.20	6.00
	Beams	23.47	38.63	11.25	15.40	7.50
	Poles	14.33	17.75	10.33	15.33	12.00

A greater percentage of committee members received permits than regular members, and a greater percentage of female members received permits than male members. This pattern was generally exhibited in all three CFs, as can be seen in Table 33. Percentage of members that received permits by membership status and sex.

Table 33. Percentage of members that received permits by membership status and sex

CF	Size Class	Average for CF	Membership Status		Sex	
			Committee	Regular	Female	Male
All CFs	Sawn timber	35%	45%	33%	38%	33%
	Beams	14%	21%	12%	18%	9%
	Poles	12%	21%	9%	14%	9%
Yakpugang	Sawn timber	33%	38%	32%	30%	35%
	Beams	0%	0%	0%	0%	0%
	Poles	0%	0%	0%	0%	0%
Masangdaza	Sawn timber	19%	25%	18%	21%	17%
	Beams	14%	0%	15%	7%	17%
	Poles	22%	25%	21%	21%	22%
Shambayung	Sawn timber	74%	70%	77%	72%	80%
	Beams	82%	80%	85%	83%	80%
	Poles	52%	70%	38%	50%	60%

The number of trees per recipient was approximately the same for committee members vs. regular members (the committee members received more trees for sawn timber and beams, but fewer trees for poles). Female member received on average a greater number of trees of all size classes than male members. The same pattern was generally exhibited in all three CFs, as can be seen in Table 34. Number of trees per recipient by membership status and sex.

Table 34. Number of trees per recipient by membership status and sex

CF	Size Class	Average for CF	Membership status		Sex	
			Committee	Regular	Female	Male
All CFs	Sawn timber	2.43	2.47	2.41	2.45	2.39
	Beams	19.46	20.88	18.75	24.13	10.13
	Poles	11.15	10.63	11.50	11.83	10.13
Yakpugang	Sawn timber	2.62	2.67	2.61	2.65	2.60
	Beams	-	-	-	-	-
	Poles	-	-	-	-	-
Masangdaza	Sawn timber	1.00	1.00	1.00	1.00	1.00
	Beams	4.20	-	4.20	2.00	4.75
	Poles	6.38	1.00	7.14	7.33	5.80
Shambayung	Sawn timber	2.59	2.43	2.70	2.54	2.75
	Beams	23.47	20.88	25.36	25.6	15.50
	Poles	14.33	12.00	17.60	12.33	17.33

The laborers were more likely than other socio-economic groups to use the CF timber to build new houses, $\chi^2(1) = 16.41$, $p < .001$, *OR* 15.9. The small farmers were less likely to build new houses, $\chi^2(1) = 6.80$, $p < .01$, *OR* 11.2. The salary earners were more likely to renovate existing houses, $\chi^2(1) = 6.84$, $p < .05$, *OR* 10. The respondents who did not receive any timber permits explained that they had not requested permits for two reasons; either their existing house was in good condition or they lacked the cash or labor to undertake a renovation or construction activity. The laborers and small farmers were more likely than richer members to claim that they were short of cash or labor, whereas the large farmers and salary earners were more likely to claim that their house was in good condition, $\chi^2(1) = 4.941$, $p < .05$.

Only 6% of respondents had requested any timber permits from other national forests since the handover of their CF. In contrast, 30% of the members, all secondary members of Yakpugang CF, requested firewood permits from other national forests after the handover.

5.2.3.2 Location and Timing of Permits

The average time taken to reach a marked tree from the home of the recipient was 50 minutes, with timber trees being further (56 minutes) than firewood trees (42 minutes). There were no significant differences between the socio-economic groups or male vs. female members in any of the CFs. All of the permit recipients claimed that the permits were provided during the same year as the initial request.

5.2.3.3 Access to Firewood

Permits for live firewood trees were received by 40% of the users. The percentage of small farmers receiving permits was the lowest, followed by large farmers, laborers and salary earners. This pattern was generally consistent in the three CFs, as can be seen in Table 35. Percentage of members that received firewood permits by socio-economic group and CF.

Table 35. Percentage of members that received firewood permits by socio-economic group and CF

CF	Socio-economic Group				
	Average for CF	Laborers	Small farmers	Big farmers	Salary earners
All CFs	40%	47%	29%	42%	53%
Yakpugang	35%	36%	26%	38%	46%
Masangdaza	22%	33%	15%	25%	33%
Shambayung	96%	90%	100%	100%	100%

The number of trees per recipient over the three year period followed a slightly different pattern: it was lowest for laborers, followed by small farmers, large farmers and salary earners. This pattern was generally consistent in the three CFs, as can be seen in Table 36. Number firewood trees received by socio-economic group and CF.

Table 36. Number firewood trees received by socio-economic group and CF

CF	Socio-economic Group				
	Average for CF	Laborers	Small farmers	Big farmers	Salary earners
All CFs	2.46	2.23	2.44	2.64	2.67
Yakpugang	2.08	1.36	2.00	2.13	3.60
Masangdaza	1.38	1.00	1.33	2.00	1.00
Shambayung	3.55	3.56	3.80	4.40	1.67

A higher percentage of regular members than committee members received permits for firewood trees, and a higher percentage of female members received permits than male members. However, there was considerable variation among the three CFs, and can be seen in Table 37. Percentage of members that received firewood trees by membership status and sex.

Table 37. Percentage of members that received firewood trees by membership status and sex

CF	Average for CF	Membership Status		Sex	
		Committee	Regular	Female	Male
All CFs	40%	33%	68%	42%	38%
Yakpugang	35%	69%	31%	27%	42%
Masangdaza	22%	13%	55%	36%	13%
Shambayung	96%	33%	68%	94%	100%

The number of firewood trees per recipient was higher for committee members vs. regular members, and for female vs. male members. This varied between the three CFs, as can be seen in Table 38. Number firewood trees received by membership status and sex. The higher use of firewood trees from the CF by women was not related to a difference in consumption of firewood trees: the total harvesting of firewood trees (both inside and outside the CF) by female members was not significantly different from male members.

Table 38. Number firewood trees received by membership status and sex

CF	Average for CF	Membership Status		Sex	
		Committee	Regular	Female	Male
All CFs	2.46	2.78	2.30	2.70	2.19
Yakpugang	2.08	1.92	2.15	2.00	2.13
Masangdaza	1.38	2.00	1.29	1.20	1.67
Shambayung	3.55	3.90	3.25	3.76	2.80

Dry firewood, which did not require a permit or payment, was collected by 94% of the respondents. Dry firewood was collected exclusively inside the CF by 39% of respondents, exclusively outside the CF by 37%, and both inside and outside by 17%. No socio-economic group was more likely than other members to collect dry firewood inside any of the CFs.

The users tended to collect dry firewood and harvest live firewood trees in the same general location: the number of dry headloads collected in the CF was positively correlated with number of live firewood trees harvested in the CF; as were headloads outside the CF and live firewood trees collected outside the CF. These correlations were significant for Yakpugang CF but insignificant for the other two CFs, as can be seen in Table 39. Correlation between collection of dry firewood collection and firewood trees . There were no significant correlations between household size or number of workers and the total number of dry headloads or live firewood trees.

Table 39. Correlation between collection of dry firewood collection and firewood trees

CF	Dry headloads collected in CF and live firewood trees harvested in CF	Dry headloads collected outside the CF and firewood trees harvested outside CF
All CFs	$\tau = .29, p < .01$	$\tau = .50, p < .001$
Yakpugang	$\tau = .80, p < .001$	$\tau = .66, p < .001$

The small farmers collected a greater total amount of dry firewood than other socio-economic groups, but this was only significant in Yakpugang CF, as can be seen in Table 40. Comparison of dry firewood collection by socio-economic group.

Table 40. Comparison of dry firewood collection by socio-economic group

CF	Number of dry headloads collected		Significance
	Small farmers	Other socio-economic groups	
All CFs	$M = 10.9, SE = 1.52$	$M = 7, SE = 0.86$	$t(49) = 2.36, p < .05$
Yakpugang	$Mdn = 10$	$Mdn = 6$	$U = 39, p < .05$

Female respondents were more likely to harvest dry firewood inside the CF than males and collected more dry firewood in the CF, but this was generally not significant for individual CFs, as can be seen in Table 41. Comparison of female and male collection of dry firewood in CFs

Table 41. Comparison of female and male collection of dry firewood in CFs

CF	Odds of females collecting more dry firewood in CF than males	Quantity of harvest (headloads per month)		
		Female harvest of dry firewood in CF	Male harvest of dry firewood in CF	Significance
All CFs	*χ^2 (1) = 8.79, p < .01, OR 6.25*	Mdn = 4, M = 5.94	Mdn = 0, M = 2.11	*U = 167.1, p < .01*
Masangdaza	n.s.	*Mdn = 13, M = 13.6*	*Mdn = 5, M = 5.25*	U = 2.5, p < .05
Shambayung	*χ^2 (1) = 5.625, p < .05, OR 6.96*			n.s.

Male respondents were more likely than females to harvest dry firewood exclusively outside the CF and to request DFO permits for firewood trees outside the CF, but this was generally not significant for individual CFs, as can be seen in Table 42. Comparison of female and male collection of dry firewood outside CFs.

Table 42. Comparison of female and male collection of dry firewood outside CFs

CF	Odds of males collecting more dry firewood outside CF than females	Odds of males requesting more DFO permits for firewood trees outside CF than females
All CFs	*χ^2 (1) = 6.61, p < .05, OR 5.36*	*χ^2 (1) = 5.68, p < .05, OR 4.50*
Yakpugang	*χ^2 (1) = 5.40, p < .05, OR 5.68*	n.s.

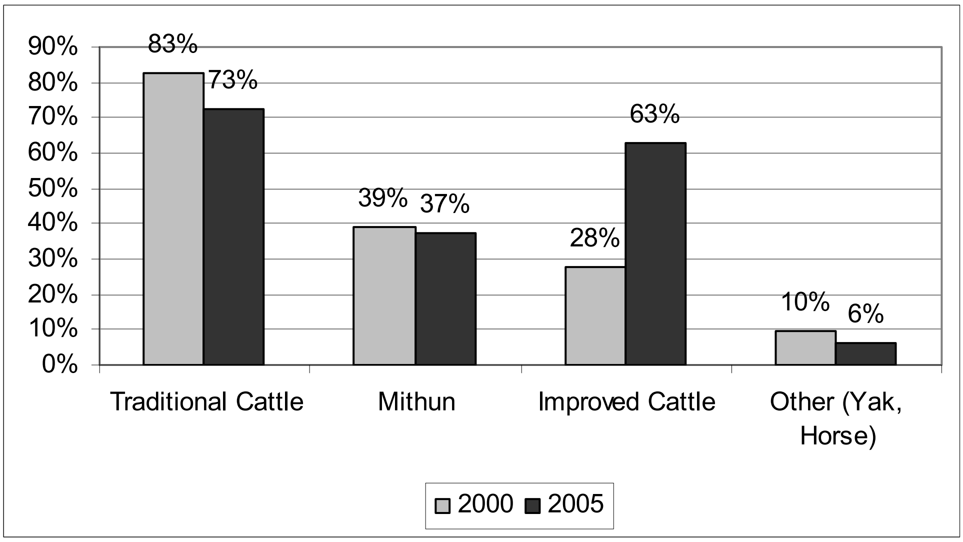
5.2.3.4 Access to Forest Grazing

Almost all members of the three CFs owned livestock and practiced forest grazing in the CF or in other national forests. For the purpose of this study, livestock were classified as traditional cattle, improved cattle, mithun (*Bos frontalis* - a bovine species indigenous to the south-eastern Himalayas (PHANCHUNG and RODEN 1996), and “others” (horses or yaks).

Livestock Holdings

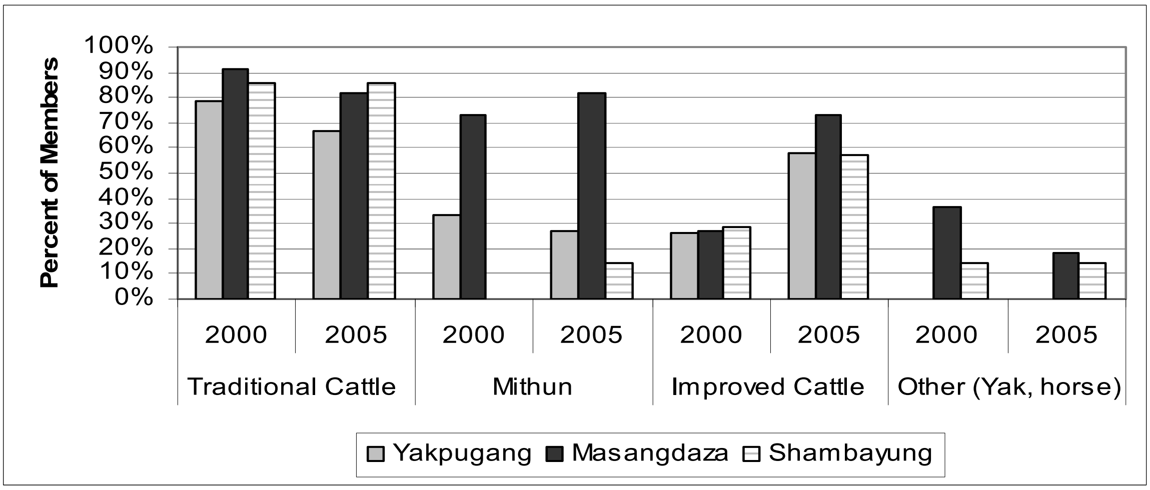
The percentage of respondents owning improved cattle increased between 2000 and 2005, while the percentage owning other types of livestock decreased, as can be seen in Figure 31. Percent of members owning livestock (combined CFs).

Figure 31. Percent of members owning livestock (combined CFs)



These trends were observed in all three CFs, as can be seen in Figure 32. Percent of members owning livestock by CF.

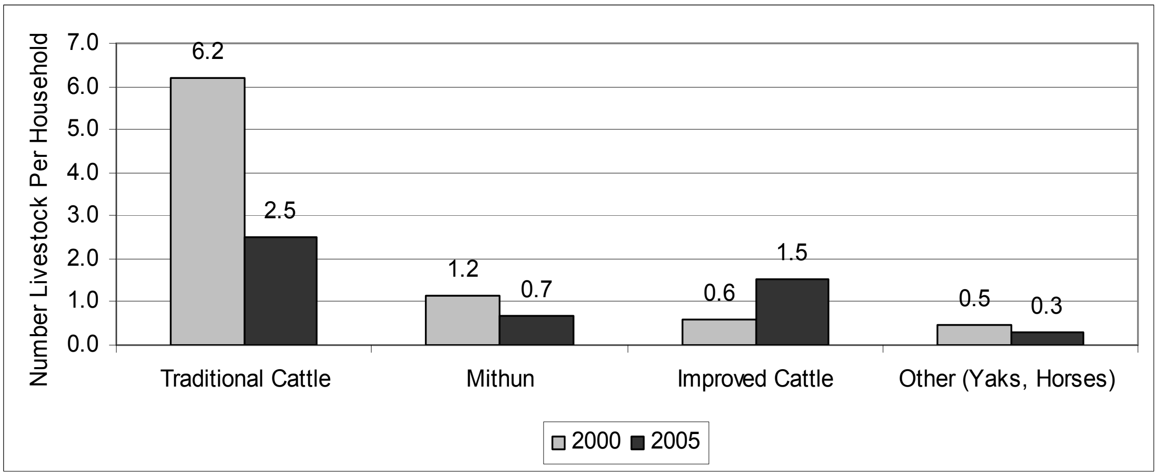
Figure 32. Percent of members owning livestock by CF



There was no significant difference between the percentage of male and female users owning livestock. There was only one significant difference in current holdings between the socio-economic groups: the laborers were seven times less likely to own mithun than other groups, χ^2 (1) = 5.82, $p < .05$, OR 7.29.

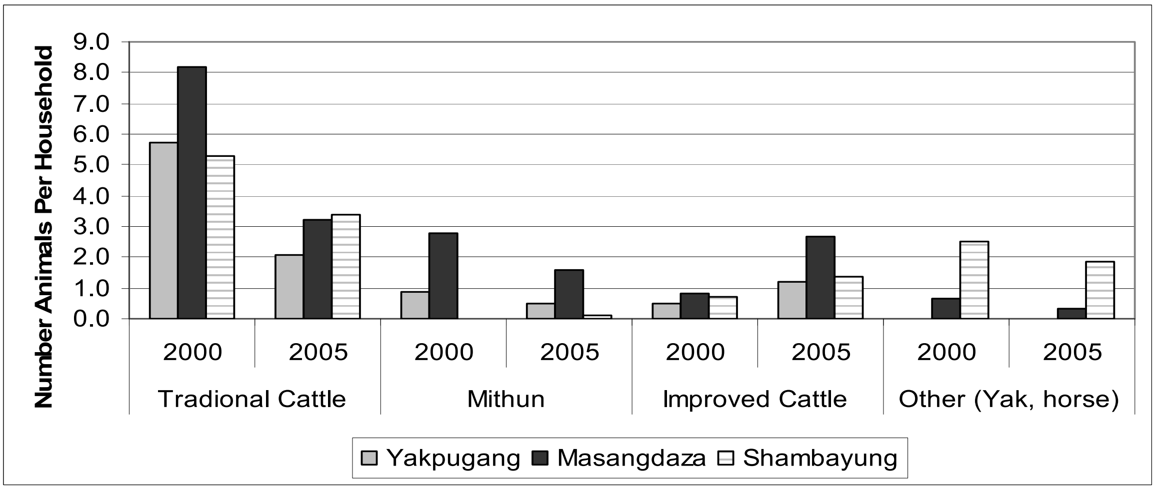
Overall, there was a substantial decrease in the number of livestock during the five year period: 70% of the respondents reported decreased livestock holdings. The general trend was to reduce the number of local cattle and replace them with a smaller number of improved breeds (Jersey Cross and Swiss Brown Cross), as can be seen in Figure 33. Average household livestock holdings.

Figure 33. Average household livestock holdings (combined CFs)



These trends were observed in all three CFs, as can be seen in Figure 34. Average household livestock holdings by CF.

Figure 34. Average household livestock holdings by CF



The decrease in livestock holdings per household was significant for the combined CFs and for all individual CFs except for Shambayung. The number of improved cattle increased significantly, but was countered by a larger reduction in the numbers of local cattle, as can be seen in Table 43. Significant changes in number of livestock owned per household from 2000 to 2005.

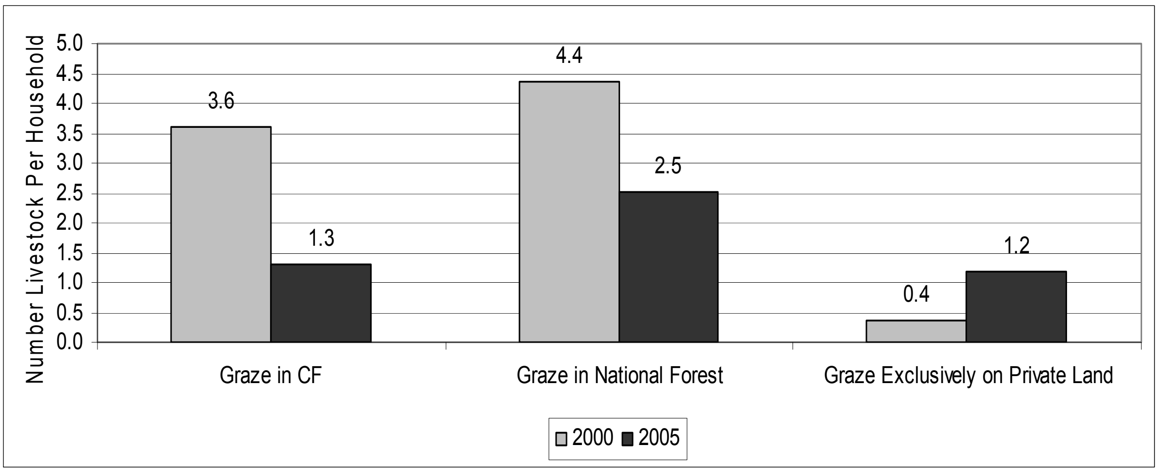
Table 43. Significant changes in number of livestock owned per household from 2000 to 2005

CF	Size Class	Mdn livestock/ household		M livestock/ household		Significance
		2000	2005	2000	2005	
All CFs	Total livestock	7	4	*8.4*	5.0	*T = 125.50, p < .001*
	Local cattle	5	2	6.2	2.5	*T = 34.50, p < .001*
	Improved cattle	0	1	0.6	1.5	*T = 34.50, p < .001*
Yakpugang	Total livestock	7	3	7.1	3.8	*T = 38.00, p < .001*
	Local cattle	6	2	5.7	2.1	*T = 10.05, p < .001*
	Improved cattle	0	1	0.5	1.2	*T = 15.00, p < .01*
Masangdaza	Total livestock	11	6	12.5	7.8	*T = 3.25, p < .05*
	Local cattle	7	2	8.2	3.2	*T = 1.50, p < .01*
	Improved cattle	0	2	0.8	2.7	*T = 0, p < .05*

Grazing Location

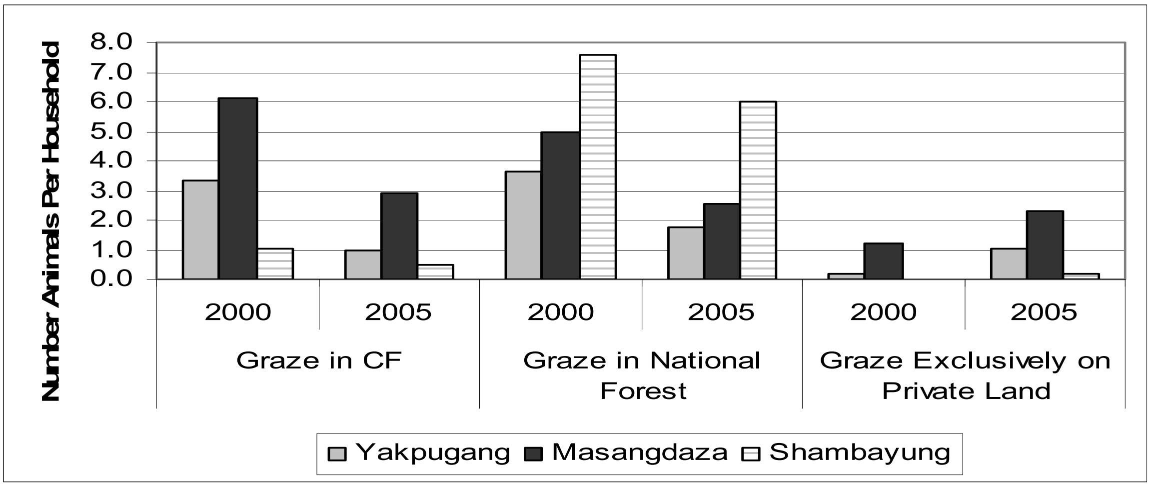
The reduction in livestock numbers reduced the grazing pressure both inside and outside of the CFs, as can be seen in Figure 35. Number of livestock per household by grazing location. The increased grazing on private land also contributed to less grazing pressure inside and outside of the CFs.

Figure 35. Number of livestock per household by grazing location (combined CFs)



These trends were observed in all three CFs, as can be seen in Figure 36. Number of livestock per household by grazing location by CF.

Figure 36. Number of livestock per household by grazing location by CF



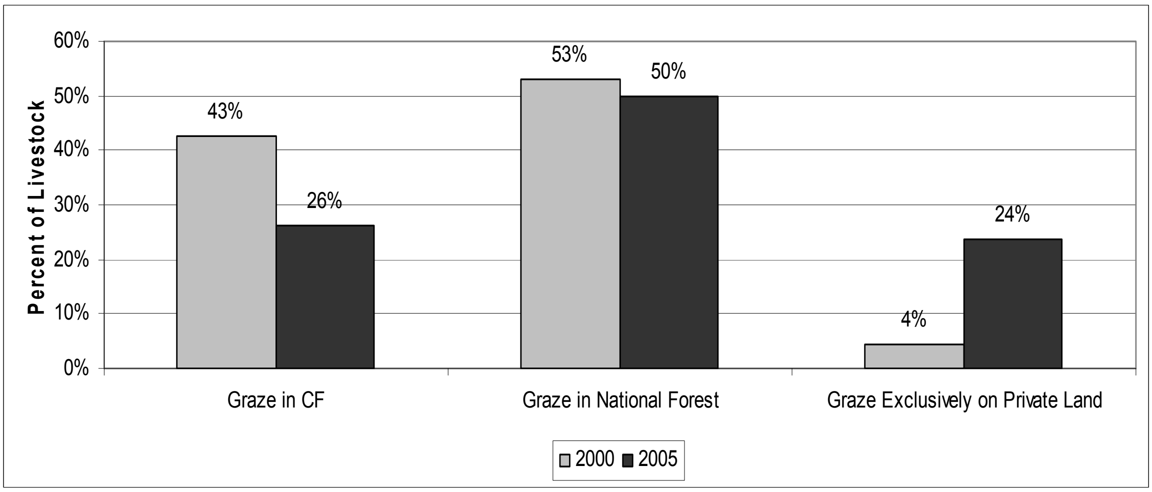
The trends in grazing were significant for the combined CFs and for all individual CFs except for Shambayung, as can be seen in Table 44. Significant changes in grazing location from 2000 to 2005

Table 44. Significant changes in grazing location from 2000 to 2005

CF	Grazing Location	Mdn livestock/ household		M livestock/ household		Significance
		2000	2005	2000	2005	
All CFs	CF	2	0	3.6	1.3	*T = 19.00, p < .001*
	Other National Forest	4	0	4.4	2.5	*T = 28.00, p < .001*
	Private Land	0	0	0.4	1.2	*T = 31.50, p < .001*
Yakpugang	CF	1	0	3.3	1.0	*T = 8.50, p < .05*
	Other National Forest	0	0	3.6	1.8	*T = 8.50, p < .01*
	Private Land	0	0	0.2	1.0	*T = 3.50, p < .001*
Masangdaza	CF	5	1	6.1	2.9	*T = 0, p < .05*
	Other National Forest	5	0	5.0	2.6	*T = 0, p < .05*

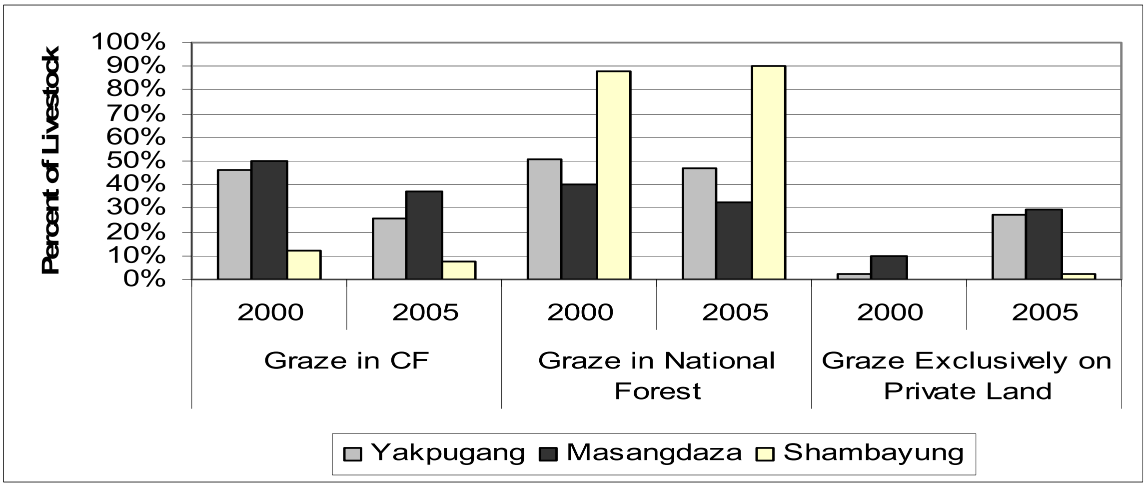
When the same data is expressed as a percentage of total livestock, it can bee seen that the percentage of livestock grazing in national forests remained close to 50% over the five year period, while the increased percentage grazing in private land contributed to the reduced percentage grazing in the CF, as can be seen in Figure 37. Percent livestock in different grazing locations (combined CFs).

Figure 37. Percent livestock in different grazing locations (combined CFs)



These trends were observed in all three CFs, as can be seen in Figure 38. Percent livestock in different grazing locations by CF.

Figure 38. Percent livestock in different grazing locations by CF



The reduced number of animals grazing in the CF (which was significant for Yakpugang and Masangdaza CFs) resulted in a reduction in the grazing intensity per hectare, as can be seen in Table 45. Grazing Intensity in the CFs in 2000 and 2005.

Table 45. Grazing Intensity in the CFs in 2000 and 2005

CF	Yakpugang	Masangdaza	Shambayung	All CFs
CF Area (ha)	260	87	46.5	393.5
Number members	113	37	23	173
M Livestock/household in CF 2000 (livestock*ha^{-1})	3.3	6.1	1.0	3.6
M Livestock/household in CF 2005 (livestock*ha^{-1})	1.0	2.9	0.5	1.3
M Grazing Intensity 2000 (livestock*ha^{-1})	1.4	2.6	0.5	1.6
M Grazing Intensity 2005 (livestock*ha^{-1})	0.4	1.3	0.2	0.6

Choice of Grazing Location

The respondents that grazed livestock in other national forests were asked why they preferred this location to the CF. They gave three main answers:

- They lived close to a national forest with good grazing areas.
- They used a private tsamdro, which they either owned or rented from others.
- The CF did not have open areas which are good for grazing, so they preferred other national forests.

Almost half (44%) of the respondents reported that their grazing location had not changed since 2000, even though the numbers of livestock have been reduced. However, an equal number reported a change, which was generally to areas closer to home. They gave several reasons for this change, the most important two reasons being:

- They had fewer animals and adequate food sources closer to home (23%).
- They no longer could find a watchman to stay with the animals (10%). This was generally because more children were in school and that the cost of hiring a watcher had increased as villagers switched to more profitable off-farm labor.

There were no significant differences in these responses between the socio-economic groups or male vs. female members in any of the CFs.

5.2.3.5 Access to NWFP Collection

Most members (65%) collected NWFPs, either inside the CF (35%) or in other national forests (42%). The most common NWFPs collected were ferns, mushrooms, wild vegetables and bamboo. Most members collected NWFPs for home consumption, but 12% of the members sold NWFPs collected in their CF and 10% sold NWFPs collected in other forests. None of the respondents reported this as a major source of income.

No socio-economic group was more likely than other groups to collect NWFPs inside the CF. This applied to the combined CFs and to all three individual CFs. Female members were not more or less likely than male members to collect NWFPs in any of the CFs. The laborers were less likely than other socio-economic groups to collect NWFPs, χ^2 (1) = 4.8, p < .05, OR 4.1, but this did not apply to collection inside the CF.

People tended to collect NWFPs where they grazed their animals and harvested firewood trees. People who collected NWFPs inside the CF grazed more animals inside the CF (Mdn = 2) than other members (Mdn = 0), U = 171, p < .01; and harvested more firewood trees (Mdn = 3) than other members (Mdn = 0), U = 201, p < .05. Conversely, people who collected NWFPs outside the CF grazed more animals outside the CF (Mdn = 2) than others (Mdn = 0), U = 213, p < .05.

Male members were more likely than females to harvest NWFPs outside of the CF, $\chi^2(1) = 4.56$, $p < .05$, OR 3.9. The Yakpugang primary members were the most dependent on the CF for NWFP collection: they were more likely than other members to collect NWFPs inside the CF, $\chi^2(1) = 12.2$, $p < .001$, OR 10; and less likely to collect outside the CF, $\chi^2(1) = 11.9$, $p < .001$, OR 25.1.

5.2.3.6 Perception of Personal Benefits from the CF

Most of the respondents (69%) reported that their household had already benefited directly from the CF. The most important benefit, which was mentioned by 60% of the beneficiaries was the simpler process for obtaining timber permits. There were no significant differences between the socio-economic groups or male vs. female members in any of the CFs.

However, there were differences between the CFs. The Yakpugang primary members were more likely than other members to have personally benefited from the CF, $\chi^2(1) = 9.14$, $p < .01$, OR 1.7; whereas the Yakpugang secondary members were less likely to have benefited, $\chi^2(1) = 25.21$, $p < .001$, OR 53.

Almost all of the respondents (96%) could explain how they expected to benefit from the CF in the future. There were no differences between the socio-economic groups in any of the CFs. Female respondents were more likely to consider future access to all forest products as the primary future benefit of the CF, whereas males were more likely to focus exclusively on timber, $\chi^2(1) = 9.63$, $p < .01$, OR 5.4.

5.2.4 Equity of Members vs. Non Members

Focus group discussions in the adjacent villages to each CF did not indicate that any traditional users from other villages had been excluded from the user groups. The use of the CF area by residents of adjacent villages was very limited, and they did not feel excluded or inconvenienced by the establishment of the CF. However, the views of the three adjacent villages about community forestry were quite different. The villagers living adjacent to Shambayung CF did not express any concerns about the future availability of forest products due to the rapid natural regeneration of bluepine in their village, and they did not seem to have any interest in establishing their own CF.

The villagers living adjacent to Yakpugang, on the other hand, mentioned that firewood and timber were becoming increasingly scarce near their village and that they now had to use inferior species. They were fully aware of the benefits of having a CF, especially in regard to avoiding the long process for obtaining timber permits. But they claimed that the forest adjacent to their village was too degraded to be a CF, and that the DOF would not allow them to establish a CF in the nearby FMU. So even they would like to establish a CF, they did not expect to be able to. They claimed that forest quality in the Yakpugang CF had improved since the handover while the other adjacent national forests in the area had become more degraded. The latter was a general trend that was not related to the establishment of the CF.

The villagers living adjacent to Masangdaza were also well aware of the benefits of having a CF, as many of them were related by marriage to Masangdaza CF members. They claimed that they had used the CF for resin tapping in the past, but that they had given up this practice before the establishment of the CF. They did not consider themselves to be traditional users of the CF because it was outside of their traditional village boundary, which they still observed for forest grazing. They were interested in establishing their own CF in order to avoid the lengthy process for obtaining permits and to be able to generate income for their village fund, but they had not yet identified a specific forest area for a CF. They were not currently facing problems for timber and firewood products as the quality of national forests has been steadily improving in recent years due to the ban on shifting cultivation and the resulting reduction in forest fires. However, they were facing an increasing shortage of cane and bamboo, which used to be available near their village, but has been heavily exploited by outsiders for the past 10 years. The recent construction of a forest road in the adjacent FMU accelerated commercial exploitation of cane and bamboo by outsiders with permits from the DOF. They have raised this issue with the DOF and the district government.

5.2.5 Community Forestry Policy

During the design of the community forestry program, the government of Bhutan was able to learn from the experience of other countries in Asia and other parts of the world. As a result, the government was able to develop a community forestry policy which provides strong support to CF user groups. When Bhutan's community forestry policy, as outlined in the Forest and Nature Conservation Rules (MOA 2000, 2006b) and the Community Forestry Manual (DOF 2004a), is assessed in relation to the attributes of successful user groups identified by McKean (2000), the policy environment appears to be highly conducive for the development of successful user groups, as can be seen in Table 46. McKean's attributes of successful user groups in relation to studied CFs. When the three CFs were assessed in relation to the attributes of successful user groups, they were found to have most of the positive attributes.

Table 46. McKean's attributes of successful user groups in relation to studied CFs

Attributes of successful user groups (McKean 2000)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
1. User groups need the right to organize or at least no interference in their attempt to organize.	Yes, the government fully supports the CF program and has given clear legal standing to CF user groups	Yes, the users were aware of their legal standing, which was also acknowledged during interviews with government officials and neighboring communities.
2. The boundaries of the resources must be clear.	Yes, the boundary of the CF must be surveyed and marked.	Yes, all boundaries were clearly marked, and members were aware of the boundaries.
3. Criteria for membership in the user group must be clear.	Yes, all traditional users of the forest must be allowed to join.	Yes, membership was open to all residents of the villages near the CFs. Interviews in adjacent villages did not reveal any indications that traditional users from other villages had been excluded.
4. Users must have the right to modify their use rules over time.	Yes, the management plan can be revised as necessary.	Yes, the Yakpugang users were in the process of revising their management plan to: a) include additional areas for firewood collection, and b) adjust the rules for primary and secondary members. Masangdaza CF had already adopted the rules to allow users who missed work days to provide additional labor rather than paying cash fines.
5. Use rules should be environmentally conservative to provide a margin for error.	Yes, the harvesting limits are based on a forest resources assessment.	Yes, harvesting limits were based on forest resources assessments, and were conservatively calculated to maximize sustainability of production.

Attributes of successful user groups (McKean 2000)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
6. Use rules must be clear and easily enforceable.	Yes, the management plan must include a detailed set of rules for use of the CF, including clear harvesting limits for trees expressed in terms of number of trees rather than wood volume.	Yes, all three plans included detailed rules for harvesting which were understood by the user groups.
7. Infractions of rules must be monitored and punished.	Partially, the CF management committee has the right to impose fines, but the DOF does not insist that the fines are actually imposed.	Yes, two of the three CFs had imposed fines on members for unauthorized harvesting or grazing, or for lack of attendance at work days.
8. Decision making and distribution of benefits need not be egalitarian, but must be viewed by the members as "fair"	Partially, the DOF insists that user groups follow a detailed process for issuing permits for CF products, and the user groups must submit reports on annual harvesting using a standard monitoring format.	Yes, the CF members generally believed that the distribution of products had been fair. However, in Yakpugang CF the awareness of many members about CF administration and financial management was very limited, which could lead to inequitable distribution in the future.
9. Inexpensive and rapid methods are needed for conflict resolution	Yes, the management plan must include a section on conflict resolution.	No experience yet, although the Yakpugang members decided to replace their management committee after three years because they were not considered to be sufficiently available to perform duties such as issuing permits and marking trees on a timely basis.
10. Institutions for managing very large systems need to be layered with devolution of authority to small components to give them flexibility and control over their fate.	Not specifically, but so far there have not been any expressions of interest in establishing a very large community forest in Bhutan. In terms of area, the largest CF at present is 300 ha. In terms of users, the largest user group at present has 126 members.	Irrelevant: all three studied CFs are small in area and number of users.

When assessed in relation to Ostrom's attributes of successful user groups (Ostrom 1999), the policy did not address all of the attributes, but still the three CFs possessed most of the attributes, as can be seen in Table 47. Ostrom's attributes of successful user groups in relation to studied CFs.

Table 47. Ostrom's attributes of successful user groups in relation to studied CFs

Attributes of successful user groups (Ostrom 1999)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
1. Users should be dependent on the resource for a major portion of their livelihood or other variables of importance to them.	Partially, the FNC Rules stipulate that the user group members must be traditional users of the forest.	Yes, most user group members were dependent on the CFs for all of their timber, and most of their forest grazing and collection of non-wood forest products. The exception was the secondary users of Yakpugang CF, who generally only utilized the CF for timber.
2. Users should have a shared image of the resource and how their actions affect each other and the resource.	Yes, the procedure for preparing management plans requires the users to collaborate in a lengthy planning process and agree on the objectives of the CF.	Yes, the users were found to have strong awareness about the condition of the forest and how it had changed since handover to community management. Most users could articulate how they expected to benefit from the CF in the future.
3. Users should have a sufficiently low discount rate in relation to future benefits to be achieved from the resource.	Yes, community forestry policy provides the users with a secure bundle of property rights to the forest, which increases the confidence of the users that they will benefit from any investments in the forest, thus lowering their discount rate in relation to future benefits.	Yes, the users were aware of their legal standing, which was also acknowledged during interviews with government officials and neighboring communities. Furthermore, the users have lived in the area for a long time, and generally assume that their children and grandchildren will continue to live there, which may further lower their discount rate in relation to future benefits.
4. Users with higher economic and political assets should be similarly affected by a current pattern of use.	Not directly addressed by the policy.	Yes, the different socio-economic groups generally were equally affected by the current pattern of land use, and generally utilized the forest in similar ways, despite some minor differences (e.g. less collection of non-wood forest products by laborers). Most users from all socio-economic groups were primarily interested in having a sustainable supply of timber from the CFs.

Attributes of successful user groups (Ostrom 1999)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
5. Users should trust each other to keep promises and relate to one another with reciprocity.	Not directly addressed by the policy.	Partially, the level of trust and cooperation within the user groups appeared to be high, despite the general lack of awareness of many members about the administration and financial management by the management committees. There were no allegations of misuse of funds, and almost all members reported that they were willing and able to provide the required voluntary labor. Distribution of benefits from the CF was highly equitable, with poorer members benefiting equally if not more so than the richer members.
6. Users should be able to determine access and harvesting rules without external authorities countermanding them.	Partially, the policy allows the users to determine the harvesting rules as long as the total harvesting level can be justified as being sustainable based on the forest resources assessment.	Yes, the three CFs have considerable flexibility in determining harvesting rules, but the DOF provides oversight to ensure that harvesting does not exceed the amount determined to be sustainable by the forest resources assessment.
7. Users should have learned at least minimal skills of organization through participation in other local associations or learning from neighboring groups.	Partially, the management planning process involves some skill development for the users.	Partially, the organizational skills of the users were generally quite poor, despite considerable amounts of training provided by DOF during the management planning process and after the handover. The lack of awareness of many CF members about CF administration and finances opens the door for misuse, even though there have not been any such allegations to date.

The policy also addressed the attributes that Ostrom (1999) found were related to successful community forests, as can be seen in Table 48. Ostrom's forest attributes of successful user groups in relation to studied CFs.

Table 48. Ostrom's forest attributes of successful user groups in relation to studied CFs

Attributes of forests of successful user groups (Ostrom 1999)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
1. The forest should not be so degraded that it is useless to organize, or so underutilized that there is little advantage from organizing.	Yes, the policy states that where possible CFs should be composed of approximately 50% degraded forest and 50% well-stocked forests.	Yes, all three CFs were well stocked, but regularly utilized by the members, who were concerned that degradation would cause them problems in the future.

Attributes of forests of successful user groups (Ostrom 1999)	Enhanced by Bhutan's community forestry policy?	Assessment of Yakpugang, Masangdaza and Shambayung CFs
2. Reliable and valid information about the general condition of the resource should be available at reasonable costs.	Yes, DOF developed a cost effective methodology for conducting a forest resources assessment as part of the management planning process.	Yes, even before the resource assessment the CF members were intimately familiar with the forest, which they used regularly for forest grazing and harvesting timber and non-wood forest products. Awareness about changes in the condition of the CFs was generally high, with the exception of the Yakpugang secondary users, who only utilized the CF for timber.
3. The availability of resource units should be relatively predictable.	Not directly addressed by the policy.	Yes, there was minimal year-to-year variation on the supply of products from the three CFs.
4. The resource should be sufficiently small, given the transportation and communication technology in use, so that users can develop accurate knowledge of external boundaries and internal microenvironments.	Yes, the CF policy states that CFs should be limited to approximately 2.5 ha per user household.	Yes, the areas of the three CFs were close to the national guideline of 2.5 ha per user household. The users could reach any part of their CF by foot in one hour, and most users were very familiar with the boundaries and species composition in the different blocks of their CFs.

6 Discussion

6.1 Impact of Selection cutting in Broadleaved Community Forests

6.1.1 Introduction

The study detailed the high diversity of cool broadleaved forests in Bhutan: 39 tree species were recorded in the research plots, representing 22 families and 32 genera. Moist temperate forests in Asia are well known for their high diversity, containing on average 2.9 times the number of species found in eastern North America and 5.9 times the number found in northern, central and eastern Europe, probably due to historical and evolutionary factors rather than present day ecological interactions (BARNES et al. 1998).

The Yakpugang CF contained eight species considered by the CF members to be first class timber, which contributed 11.6% of the total BA. However, the CF members utilized almost all of the species in the forest. They only classified six of the 39 species as having no use, and these species combined contributed less than 2% of the total BA. They harvested a wide range of size classes, with the largest number of stumps in the 10-14 cm dbh class. Stumps of 19 species were found in the study area. In terms of BA, the most harvested species were *Castanopsis hystrix* (shingles), *Persea clarkeana* (timber), *Quercus lamellosa* (shingles and firewood) and *Cinnamomum bejolghota* (timber), representing 68% of the total BA harvested. In terms of number of stumps, the most common genus was *Symplocos* (two species), which was harvested in smaller dbh classes for fence posts.

6.1.2 Harvesting Levels and Annual Allowable Cut

The comparison of harvesting levels and AAC in Yakpugang CF did not reveal any indications of over-harvesting, as has been reported in CFs in other countries (WHITE and MARTIN 2002). Harvesting in the studied forest averaged 4.6 m^3*ha^{-1}*$year^{-1}$ since the establishment of the CF, which was significantly lower than the calculated AAC of 5.59 m^3 * ha^{-1}. Even when the rotation period was increased from 100 to 150 years, the harvested volume of timber trees and all other use categories was significantly lower than the AAC.

The annual harvest in Yakpugang was close to the AAC of 4.46 m^3*ha^{-1}*$year^{-1}$ planned for the adjacent Korilla FMU, which was based on a total AAC of 8,375 m^2 and a net operable area of 1,877 ha for the hardwood working circle (CHAMLING and PUSHPARAJAH 1993). The volume harvested in Yakpugang was also comparable to the actual or planned volume*ha^{-1}*$year^{-1}$ in broadleaved forests in other mountainous countries: 4.6 m^3 for single tree selection of broadleaved forest in the Appalachian Mountains of USA (SCHULER 2004); 4.2 m^3 for hardwoods in northeast USA (HOWARD et al. 2005); 4.4 m^3 for mixed forests on alpine farms in Austria (SEKOT 2000); 3-10 m^3 in the Kilimanjaro region of Tanzania (FAO 1981).

The lack of over-harvesting in Yakpugang may be largely attributable to the strong support and monitoring from the forestry extension service. The community forestry program is supported by an intensive forestry extension program. The ratio of forestry extensionists to rural residents in 2000 was approximately 1:4,000, based on a cadre of 117 forestry extension staff (DOF 2002b) and a rural population estimated to be 69% of the total population of 672,425 (RGOB 2005). In Nepal, comparable figures are not available, but the ratio of technical forestry staff to rural population is 1:11,000, based on a cadre of 1,900 technical staff and a rural population estimated to be 85% of the total population of 25 million (POKHAREL 2007). When all Bhutanese technical forestry staff are considered, the ratio of technical forestry staff to rural population is approximately 1:500 (DOF 2002b), which is more than 20 times higher than in Nepal.

The forestry extension agent responsible for Yakpugang lived within a few km of the CF, and met with the CF Management Committee on a regular basis. During the field research it was observed that the extension agent knew the names of all of the committee members and many of the general members. He helped the user group develop guidelines for harvesting expressed in terms of numbers of trees of different size classes rather than cubic meters in order to be more easily understood by the members. This may have helped the CF avoid the problems documented in Nepal, where many members did not understand the forest inventory process (MAHARJAN 2001) and some user groups set harvesting targets with little concern for long term sustainability (KELLERT et al. 2000).

The stump study proved to be a useful methodology for analyzing the history of harvesting in the CF. The stumps were well-preserved, making it possible to identify the species and estimate the approximate year of harvest. Stump studies have been used in industrial plantations to assess timber harvests, determine volume loss resulting from illicit cuttings, and trace the history of cutover stands (CORRAL-RIVAS et al. 2007; KHATRY CHHETRI and FOWLER 1996). However, the Yakpugang study appears to be the first time that stump studies were used to assess the ecological sustainability of harvesting practices in a CF. The approach is highly appropriate for studies of CFs, because it allows the quantification of harvesting levels in the absence of reliable baseline data, which are often not available for CFs. However, the analysis required the use of non-parametric tests (which are available in statistical software but not Excel) because the stump data exhibited non-normal diameter distributions when separated by species or species category.

6.1.3 Forest Development 2000 - 2005

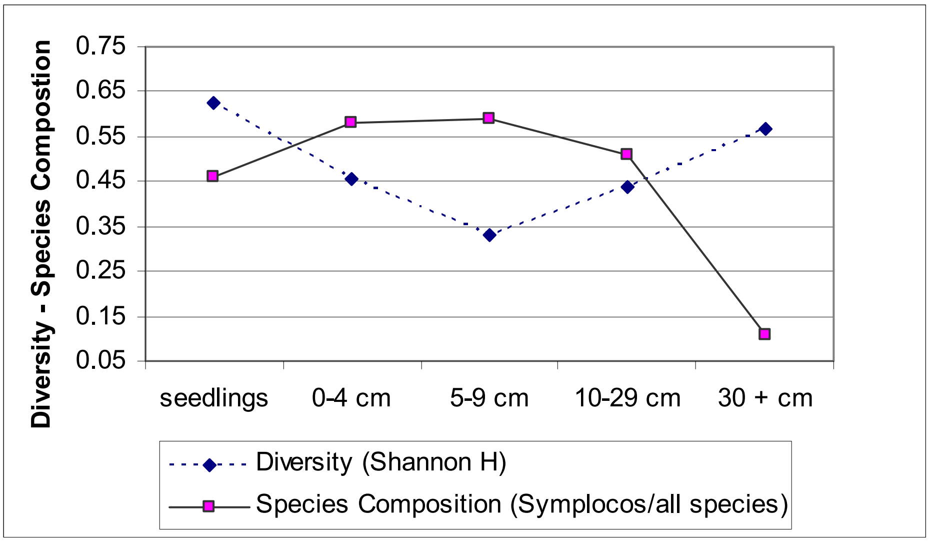
The comparison of the 2005 and 2000 inventories did not reveal any significant differences between the total N, V or BA of standing trees, which indicated that harvesting had not exceeded the annual increment. However, there were indications that natural regeneration increased during the period of CF management. The numbers of seedlings and saplings were significantly greater in 2005. There were also indications that the species mix changed during the five year period: the number of saplings of timber species increased, as did the percentage of saplings of timber species (in comparison to saplings of all species). These findings contrasted with the findings in the adjacent Korilla FMU, where the percentage of seedlings of timber species declined after harvesting while the percentage of non-timber species increased (DAVIDSON 2000).

6.1.4 Harvesting Intensity and Diversity

The analysis of diversity (Shannon *H*) of different size classes revealed an inverted humped pattern, with diversity highest for seedlings (.63), decreasing for small saplings (.59) and large saplings (.33), and increasing again for small trees (.44) and large trees (.57).

Since the greatest numbers of seedlings were found in plots with the most disturbance, the pattern of diversity partially reflects the process of stand development described by Oliver and Larson (1996): diversity is generally high during the initial stage of stand initiation when many seedlings invade the disturbed area; diversity decreases during the stage of stem exclusion as some stems and species are excluded; and diversity increases again during the stages of understory reinitiation and old growth due to the increased variation in horizontal and vertical structure. However, a more important factor in the diversity pattern in Yakpugang may have been the distribution of *Symplocos*, which dominated natural regeneration in Yakpugang. The two species of *Symplocos* contributed 45% of all seedlings, 58% of small saplings and 59% of large saplings even though they only contributed 11% of the trees with dbh over 30 cm. As can be seen in Figure 39. Diversity and percentage of stems of Symplocos/all stems by size class, the distribution of diversity was the inverse of the distribution of *Symplocos.* The size class where Symplocos was most dominant - large saplings (5-9 cm) - exhibited the lowest diversity.

Figure 39. Diversity and percentage of stems of Symplocos/all stems by size class



Note: The indicators for diversity and species composition use the same scale.

Timber harvesting appeared to have a positive impact on diversity: the diversity of seedlings and all size classes up to 30 cm dbh was positively correlated with increased intensity of harvesting. There were no indications of any impact on the diversity of the larger size classes. These findings agree with several studies which reported that selective logging did not reduce tree diversity (CANNON et al. 1998; DEKKER and DE GRAAF 2003; MONTAGNINI et al. 1998; WEBB and PERALTA 1998).

The data also appeared to support the intermediate disturbance hypothesis (IDH) by exhibiting a humped relationship between diversity and disturbance, indicating that diversity was highest with an intermediate level of disturbance as predicted by (CONNELL 1978). Three indicators of disturbance were assessed: frequency of disturbance, time since disturbance, and intensity of disturbance. All three disturbance indictors exhibited significant quadratic relationships with diversity, with intensity of disturbance exhibiting the strongest humped relationship. The sample size was too small to be conclusive, but the approach appears promising to address this controversial issue.

Two major studies have attempted to test the application of the IDH to diverse rain forests with conflicting results. Molino and Sabatier (2001) found strong support for the IDH in Guiana, with results that agree with the Yakpugang data. Hubbel et al. (1999) found that natural treefall gaps in Panama did not result in increased diversity. Sheil and Burslem (2002) concluded that the findings of both studies were consistent with the IDH because of the “species decline paradox”: disturbances at different successional stages can lead to either increased or decreased diversity, even though all disturbances help prevent the ultimate decline in diversity associated with the final stage of succession. They pointed out that the forest studied by Hubbell et al. was still undergoing succession as a result of disturbances 150 years ago, so new disturbances would not necessarily lead to increased diversity. Jenkins and Parker (1998; 2001) reported similar findings in a broadleaved forest in the USA still undergoing succession: single tree selection reduced diversity by favoring shade tolerant species whereas clear cuts resulted in higher levels of diversity by favoring shade intolerant species.

The approach of estimating disturbance in Yakpugang based on an inventory of stumps enabled the assessment of three different indicators of disturbance, and appeared to be a promising method of addressing the research question. Hubbell et al. (1999) used canopy height as an indicator of disturbance, while Molino and Sabatier (MOLINO and SABATIER 2001) used the percentage of heliophilic stems. Sheil and Burslem (2002) discussed the difficulty in selecting an appropriate indicator of rainforest disturbance, and noted that the biological significance of the canopy height is not clear while the percentage of heliophilic stems suffers from analytical pitfalls (SHEIL and BURSLEM 2002).

6.1.5 Harvesting Intensity and Natural Regeneration

Harvesting intensity appeared to have a complex impact on the natural regeneration of seedlings and saplings. The total number of seedlings in the plots was positively correlated with indicators of harvesting intensity (N/V/BA of harvested trees), which was expected since release of growing space generally allows the germination of new plants (OLIVER and LARSON 1996). The impact of tree harvesting on the number of seedlings appeared to only last for a few years: the total number of seedlings was positively correlated with the number of trees harvested during the previous four years, but not with the number of trees harvested during earlier periods.

Harvesting did not appear to have an impact on the total number of saplings. There were no significant correlations between the total number of saplings and the indicators of harvesting intensity. Furthermore, the number of saplings in plots that had not been harvested for 30 years was not significantly different from the number of saplings in recently harvested plots. Even the plots that had never been harvested contained dense regeneration of saplings. This finding was not expected, and will be discussed later in this section.

However, harvesting intensity appeared to have a strong impact on the species composition of saplings. The percentage of saplings of timber species was significantly correlated with indicators of harvesting intensity (N, V harvested trees). Analysis of individual species revealed similar relationships: seven species exhibited significant correlations between the percentage of their saplings/all saplings and harvesting intensity. These correlations were consistently positive, indicating that higher levels of harvesting promoted the growth and survival of saplings, except in the case of the two species of *Symplocos,* which exhibited higher percentages of its saplings/all saplings in plots with lower harvesting intensity.

These findings are consistent with other studies which have reported that germination of both shade tolerant and intolerant species are triggered by disturbance, even when the disturbance releases soil growing space and does not affect the amount of available sunlight (LUTZ 1945). The number of species is generally highest in the initial years after a canopy disturbance but decreases as the species compete for limited growing space in the next stage of stem exclusion (OLIVER and LARSON 1996). Many factors affect which species will survive after a gap is created, such as gap size, shape, orientation, and timing, and periodicity: for example, “after equal time periods, a site affected by a single large treefall may be dominated by shade-intolerant canopy trees, whereas a site affected by multiple small treefall gaps totaling the same area would be expected to be dominated by more shade-tolerant canopy trees” (VEBLEN 1992, p 170). The latter situation is common in Yakpugang: most plots contained several stumps of trees harvested in different years.

When the Yakpugang species were aggregated by species category, the timber trees exhibited positive correlations with harvesting intensity, while the low preference category exhibited negative correlations with harvesting intensity. This is largely the effect of the rankings and priorities of the user group members, but it was interesting to observe that harvesting operations appeared to have a positive impact on the regeneration of species preferred by the user group despite the lack of any silvicultural interventions to reduce the density of low preference species.

The timing of harvesting was influential: the intensity of harvesting 0-4 years earlier was significantly correlated with the total number of seedlings. The timing of harvesting did not affect the total number of saplings, but it did affect species composition. The percentage of numbers of saplings of timber species/all species and high preference species/all species were strongly correlated with harvesting intensity 5-9 years earlier, and somewhat less strongly correlated with harvesting intensity 10-19 years earlier. Saplings of species in the low preference category exhibited correlations with the same time periods, but the correlations were negative instead of positive. When the same tests were conducted for individual species, six species exhibited significant correlations with harvesting intensity during different timber periods. Once again, the significant correlations were generally positive except for *Symplocos*, but this time the results for *Symploco*s varied: *S. ramosissima* exhibited two positive correlations, while *S. glomerata* and combined results for the genus were negative.

Light availability exhibited the same relationship with natural regeneration as harvesting intensity. A significant increasing trend with decreasing canopy cover was observed for the number of saplings of timber species and their percentage of all saplings. The same relationships existed for saplings of preferred species, and the opposite relationships were observed for saplings of low preference species such as *Symplocos*.

Unfortunately the results of the more detailed study of light availability with hemispherical photography were inconclusive, probably due to the limited number of plots with useable data (23 of 36 plots). The correlations between GSF and the numbers/composition of seedlings and saplings were consistent with the relationships described above for upper canopy cover, but the findings were only significant for one-sided tests.

The findings suggest that harvesting operations promoted the development of a new cohort of seedlings which affected the number of seedlings and subsequently the species composition of saplings. However, the new cohort of seedlings did not appear to affect the future number of saplings. This unexpected finding may be largely due to the influence of *Symplocos,* which dominated natural regeneration of seedlings and saplings in Yakpugang. The distribution in the adjacent Korilla FMU appeared to be similar: Davidson (2000) and Chamling and Pushparajah (1993) did not provide figures for *Symplocos* seedlings/saplings, but mentioned that its regeneration was profuse.

Symplocos has been classified as a pioneer in Bhutan (DAVIDSON 2000, p 72; NORBU 2000, p 52), which would normally be characterized by dependence on large openings for germination and high mortality in the shade (CLARK and CLARK 1992). However, the Yakpugang data suggest that *Symplocos* is actually well adapted for growth in undisturbed forests. *Symplocos* exhibited an i-J diameter distribution in all plots, including those that had never been harvested. Furthermore, *Symplocos* achieved the highest percentage of its seedlings/all seedlings and its saplings/all saplings in plots with the densest canopy cover. Thus the regeneration mode of *Symplocos* can best be categorized as continuous regeneration, which includes shade-tolerant understory trees that do not require gaps for either germination or growth to reproductive capacity if the canopy is not too dense (DENSLOW 1980; VEBLEN 1992).

Symplocos appeared to have established permanent seedlings banks which could produce large numbers of saplings even in the unharvested plots. In a study of seedling banks in beech forests in Poland, Szwagrzyk et al. (2001) reported that permanent seedlings banks could be formed in stands with light intensities of 9-15% due to the proximity of canopy gaps, while in denser stands seedling banks were ephemeral and did not develop into saplings. Yakpugang's upper canopy was relatively open and never exceeded 80%, even in plots that had never been harvested. Sapling regeneration of *Symplocos* in the plots with low or no harvesting was so profuse that the total number of saplings in these plots matched the number of saplings in the harvested plots, despite the larger number of seedlings in the harvested plots.

These findings contrast with the findings in the adjacent Korila FMU where the percentage of seedlings of timber species decreased after cable crane logging operations, and the percentage of seedlings of timber species was the highest in the smallest openings (DAVIDSON 2000). These contradictory findings can partially be understood in the context of life history trade-offs between conflicting costs and benefits of traits. The first tradeoff is gap regeneration vs. forest regeneration, in which shade tolerators can survive under dense shade but may not be able to respond quickly to new canopy gaps (CANHAM 1988). This tradeoff explains why *Symplocos* saplings dominated in the unharvested plots, while saplings of the timber species dominated in the harvested plots. The second tradeoff is palatability vs. competitive ability, which "lies at the heart of herbivore effects on plant community structure" (CRAWLEY 1986, p 89). *Symplocos* may grow slower than the more palatable timber species, but its unpalatability becomes a considerable advantage when grazing pressure is high.

The results in Yakpugang suggest that grazing pressure was below the threshold where the faster growth of the timber species would become less important than the unpalatability of *Symplocos*. The results in Korilla, on the other hand, suggest that the grazing pressure must have been high enough to make palatability the key factor affecting survival. These findings point to the complexity of selecting appropriate silvicultural options to promote the natural regeneration of preferred species in this forest type.

6.1.6 Harvesting Intensity and Bole Shape and Form

There were no indications that selection cutting had a negative impact on the bole shape and form of remaining trees, as has been reported in broadleaved forests in the USA (CLATTERBUCK 2006; NYLAND 2006a; OLIVER and LARSON 1996) and in national forests in Bhutan where selection cutting is practiced (DAVIDSON 2000).

This can be attributed largely to improved marking of trees by the CF management committee. Before a member can harvest a tree, a member of the CF management committee has to mark the tree with the official CF marking hammer. The management committee only allowed harvesting in certain blocks of the forest, and the locations were changed periodically depending on the amount of prior harvesting. Several respondents mentioned that the management committee had refused to grant permits for trees close to the village and had required them to harvest trees in denser stands. While this added to the workload, all of the respondents appeared to understand the rational, and many specifically mentioned that the quality of the forest was improving due to greater discipline in marking and harvesting. They contrasted the new marking practices with the situation before the establishment of the CF when DOF was responsible for marking: the rangers were often too busy to respond to all marking requests and as a result the villagers generally harvested in the most convenient location. This long-standing problem with marking by DOF rangers has been documented in other areas of the country (DOF 1996). As a result, villagers with urgent needs for timber sometimes harvested trees illegally rather than wait for marking by DOF (WANGCHUK 1998).

Another factor which may have contributed to the lack of high-grading in Yakpugang was the lack of road access in the CF, which could have encouraged concentrated harvesting near the roads as has been reported in Korilla FMU (DAVIDSON 2000). The topography of the CF may have also been a factor, as the steep slopes facilitated transportation of logs and timber from most parts of the CF, whereas some other CFs include areas with topographical features (slopes, rivers, gullies) that makes transportation wood products more difficult.

6.1.7 Harvesting Intensity and Diameter Distribution

The analysis of the diameter distribution of the different use categories found that harvesting appeared to have a positive impact on the diameter distribution of preferred timber trees. The diameter distribution is generally considered to be "balanced" when it exhibits an i-J distribution, which indicates that: "the abundance of smaller or younger individuals allows for continued recruitment into large or older classes, so that the frequency distribution remains constant (VEBLEN 1992, p 159). In uneven aged rain forests, the i-J distribution can be affected by various factors including timber harvesting, so diameter distributions are often analyzed to assess the disturbance effect within forests (HITIMANA et al. 2004).

The category of first class timber trees in Yakpugang exhibited an i-J diameter distribution with a steeper negative exponential curve in plots that were more intensively harvested, indicating a high regeneration density in these plots. Trees with i-J distribution in Bhutan regenerate continuously under closed canopies and include both shade tolerant climax trees and understory species of climax forest (OHSAWA 2002).The categories of 2nd class timber trees and "other use" trees also exhibited i-J diameter distributions, but there were no significant differences between the three harvesting categories.

When the diameter distributions of individual species were examined, there were no significant differences in the distribution of trees in three classes of harvesting intensity. This is probably because of the relatively small sample size. Eight of the species, including four timber species, exhibited i-J distribution patterns in most of the plots where they occurred, while the other species exhibited sporadic distributions. All eight of these species exhibited i-J distribution patterns in both recently harvested plots and plots that had not been harvested for 30 years, which suggested that harvesting did not have a major impact on the diameter distribution.

These findings were in contrast to the situation in the adjacent Korilla FMU, where logging and grazing were reported to have altered the forest structure so that only non-palatable *Symplocos*, *Daphniphyllum* and *Rhododendron* species exhibited i-J distributions while the timber species tended towards bell-shaped size class distributions (DAVIDSON 2000).

Interestingly the differences between the diameter distributions of the three harvesting categories were largely in the lower size classes, with more small trees in the heavily harvested plots. One might have expected to see reduced numbers of larger trees in the harvested plots, as was observed after selective logging in the adjacent Korilla FMU (CHAMLING and PUSHPARAJAH 1993) and after selective logging in Australian rainforests (KARIUKI et al. 2006). However, the number of large trees in the logged plots in Yakpugang was not significantly lower than in the unlogged plots, and the same was true for the BA and V of trees. The only significant differences between the plots were the higher BA and V of stumps in the logged plots. This suggested that the more rapid growth in the harvested plots was able to compensate for the amount of extracted wood. It also supported the view that the unlogged stands of broadleaved forests in Bhutan have reached a late successional stage where increment is low (DAVIDSON 2000).

There were indications that harvesting had a negative impact on the diameter distribution of the *Quercus* species. All three harvesting categories of *Quercus* exhibited sporadic or bimodal distributions with very limited regeneration. The plots with high harvest during the past ten years had a significantly different diameter distribution than the other two harvesting categories, with fewer trees in the smaller diameter classes.

The successional status of Quercus in the Himalayan region is still debated. Ohsawa (2002) noted that the sporadic diameter distribution is common for *Quercus* in Bhutan following gap disturbance. Metz (1997) hypothesized that *Quercus* in Himalayan broadleaved forests are long lived early successional species that require catastrophic disturbances from fire or landslides to regenerate and establish forests like those presently in place. Furthermore, the regeneration dynamics of *Quercus* are complex: Tashi (2004) documented the complex regeneration dynamics of *Quercus*, and reported that canopy openness was negatively correlated with the survival of *Q. semecarpifolia* seedlings but positively correlated with the growth of small saplings, offering challenges for management. The number of *Quercus* trees in the Yakpugang research plots was too low for the findings to be conclusive, but there were indications that the harvesting of *Quercus* combined with forest grazing may have affected the diameter class distribution in a way that would reduce future productivity, even though the annual harvest of *Quercus* was significantly less than the AAC during the past 50 years. This issue requires further study with a larger sample of *Quercus*.

The collection of data on the age distribution of the forest, which was not possible during this study, would provide valuable supplementary information. Size is a better indicator than age of reproductive capacity and the ability to contribute to the next generation of canopy trees, but size data alone can only be used to predict the future of a stand, while the combination of age and size data allows a reconstruction of the history of stand development (VEBLEN 1992).

6.2 Impact of Forest Grazing in Broadleaved Community Forests

The average cattle holdings per household in Yakpugang CF as well as the two studied conifer CFs decreased significantly between 2000 and 2005 as traditional cattle were replaced with smaller numbers of improved breeds (Brown Swiss or Jersey Cross). According to the user group members, the main reason was a shortage of labor due to increased school attendance and greater availability of seasonal employment for adults on government construction projects. Similar trends have been observed in Nepal and the Indian Himalayas (TULACHAN and NEUPANE 1999) as well as in other parts of Bhutan (SPIERENBURG 2003). The total number of cattle in the three CFs also decreased. This was the case in the Indian Himalayas but not in Nepal, where cattle numbers continued to increase as the human population increased, despite a reduction in per capita holdings (TULACHAN and NEUPANE 1999).

The overall reduction in livestock holdings and the shift to improved breeds contributed to a significant reduction in grazing intensity in Yakpugang CF. This was because the improved breeds were generally stall fed or kept on private pastures in the village, although they were occasionally grazed in the forest. The number of improved breeds grazing on private land increased six-fold during the five year period. The number of traditional cattle grazing on private land also increased as the owners found it more convenient to keep their reduced livestock holdings closer to home. The estimated grazing intensity applied to the entire CF and not specifically to the research area, but the occurrence of livestock trails throughout the CF suggested that the research area was representative of the entire CF area in terms of grazing intensity.

The changes in livestock holdings and grazing patterns applied equally to all socio-economic groups, and to both male and female members. There were no indications of favoritism in terms of access to the CF for forest grazing, as has been reported in Nepal (PANDIT and THAPA 2004).

The number of animals belonging to CF members that were grazed in other national forests decreased significantly during the five year period, so there was no evidence that the users protected their own CF by increasing the utilization of other national forests. Some authors believe that this is the case in Nepal (CHHETRY et al. 2005; NURSE et al. 2003). However, the status of forest grazing in CFs is quite different in the two countries: most CFs in Nepal impose a strict ban on forest grazing in order to protect plantings and/or promote the growth of fodder grass, a highly desired commodity which the members pay royalties to harvest. In Bhutan, on the other hand, CFs allow forest grazing except in reforestation areas, and members are not charged fees for the collection of fodder grasses.

These different practices can probably be attributed to the higher amount of forest in Bhutan, the lower intensity of livestock, and the ongoing reduction in livestock holdings in Bhutan. Nepal's livestock population is one of highest in the world in relation to the amount of arable land (TULACHAN and NEUPANE 1999) and was estimated to be 13 times higher than the carrying capacity of temperate rangelands in the mid hills (PARIYAR 1995). The decision in Nepal to prohibit grazing in the CFs undoubtedly contributed to the positive ecological impact of the community forestry program, which included increased forest cover (GAUTAM et al. 2002; GAUTAM and WATANABE 2004; SAKURAI et al. 2004) and increased stem density and natural regeneration (BRANNEY and YADAV 1998; YADAV et al. 2003). However, the impact on livelihood has been questioned: the increased forest cover in the CFs may have actually reduced the availability of forage for livestock and forced many user group members in Nepal to reduce their cattle holdings (DHAKAL et al. 2005). Bhutan, on the other hand, is in the enviable position of having a small population and a high percentage of forest cover. Bhutan's forest cover is estimated at 72.5% (DOF 2002a) and its population at 672,425 (RGOB 2005). There were no indications that the establishment of the studied CFs influenced members to reduce their livestock holdings.

During the same five year period, the frequency of seedlings and saplings in Yakpugang CF significantly increased. The frequency of saplings of timber species, which are generally highly palatable to livestock (DAVIDSON 2000), also increased. These findings agree with the opinion of the Yakpugang CF members: 89% responded that the condition of the CF had improved during the five year period, and none claimed that the forest condition had worsened.

The increased natural regeneration in Yakpugang CF did not appear to be the result of recent changes in harvesting intensity. The volume and BA of trees harvested during the five year period were not significantly different than any other five year period. The forest had been harvested at levels below the AAC during the past 20 years. Furthermore, the comparison of the 2000 and 2005 forest inventories did not reveal any significant change in the number, volume, or BA trees with dbh ≥ 10 cm. Therefore the increased natural regeneration appeared to be primarily due to reduced grazing intensity.

Grazing intensity of 0.4 $LU*ha^{-1}$ appeared to be below the threshold of sapling recruitment of the preferred species in the broadleaved forest of Yakpugang CF. This finding agreed with estimated carrying capacity of 0.54 $LU*ha^{-1}$ for temperate rangelands in Nepal associated with oak, mixed broad leaf, *Quercus,* or bluepine (PARIYAR 1995). The only genus in Yakpugang that did not exhibit adequate sapling recruitment was *Quercus.* This was consistent with the findings of controlled grazing studies in Denmark, where *Quercus* was suppressed at summer/winter grazing levels of 0.28/0.57 $LU*ha^{-1}$ while other species were only suppressed at a higher grazing levels of 0.4/0.8 $LU*ha^{-1}$ (HESTER et al. 2000). Other studies in Bhutan have noted the limited regeneration of *Quercus* in forests used for grazing (MIEHE and MIEHE 2002).

The findings of this study suggested that cool broadleaved forests like Yakpugang can be managed for timber with moderate levels of forest grazing (0.45 $cattle*ha^{-1}$) without negative impacts on natural regeneration. The findings also supported the policy of allowing grazing in CFs in Bhutan, and were in agreement with other studies which have concluded that forest grazing can be ecologically sustainable as long as grazing intensity is controlled (ADAMS 1975; KRZIC et al. 1999; KRZIC et al. 2001; PATRIC and HELVEY 1986; RODER et al. 2002).

6.3 Equity in Community Forests

6.3.1 Political Equity

The assessment of three indicators of political equity found a moderate level of equity, as can be seen in Table 49. Summary of political equity indicators.

Table 49. Summary of political equity indicators

Indicator of Political Equity	Equity Between Socio-economic Groups	Equity Between Men and Women
Representation on management committees	Medium	Low
Attendance in CF meetings	High	High
Knowledge about CF finances	Medium*	Medium*

Note: * Equity was high, but general level of knowledge was very low.

The level of political equity in Bhutan was only marginally higher than what has been reported in Nepal. Malla et al. (2003) found that the lowest income groups were under-represented on CF committees in Nepal, while the richest group had the largest representation. Khanel and Kandel (2004) found only 24% representation of women on management committees in Nepal. The low representation of poor and female members on committees in both countries may have been partially due to the requirement in both countries that committee members be literate and able to maintain CF records. The 2004 adult literacy rate was 48.6% in Nepal and 47% in Bhutan (UNDP 2006), while the literacy rate for women was 34.9% in Nepal (UNDP 2006) and 34% in Bhutan (CIA 2007).

The three user groups in Bhutan exhibited a remarkable lack of knowledge about CF administration: very few respondents knew the current value of the CF funds or how they were intended to be used. Although there were no indications of corruption in the three CFs, such a high lack of awareness opens the door for manipulation by the management committees. Corruption by management committees in Nepal has been linked to the members' lack of awareness about CF finances (POUDEL 2002).

The level of participation of the user groups, when assessed according to the four categories of participation described by Lawrence (2006) ranged from the lowest level of "consultative" to the highest level of "transformative", but generally could best be described as "collaborative", whereby the center and the local people collaborate in deciding what is needed and both contribute expert knowledge.

- The participation of general members vis-à-vis the management committees was generally "collaborative", but occasionally attained the highest level of "transformative": for example, the members of Yakpugang CF decided to replace the original management committee after one year because the committee members were often not available to perform marking duties on a timely basis. This was the only indication that collaboration in the CF may have transformed the power relationships in the user group.
- The participation of women vis-à-vis the management committees best fit the 2nd level of "functional": the center (management committee) made decisions and then involved the local actors (women) to help implement their decisions. Although women were well represented on the management committees, the key positions of chairman and secretary were always held by men.
- The participation of the user group vis-à-vis the DOF appeared to be gradually shifting from "functional" to "collaborative". DOF and the management committee collaborated in deciding which blocks of the forest should be harvested each year and which activities should be implemented each year, and the management committee appeared to be

assuming greater responsibility each year. During the initial management planning process the participation of the user group was limited to the 1st level of "consultative": the user groups simply contributed information and DOF made all of the policy decisions.

6.3.2 Economic Equity

The level of economic equity was very high in Bhutan, as can be seen in Table 50. Summary of economic equity indicators. There were no signs of domination by wealthier members in terms of receiving permits for timber, the CF's most valuable resource. In fact, the poorest members received more timber permits than average members for all size classes. During the interviews, no respondent suggested that the distribution of benefits had been inequitable. These findings contrasted sharply with the many reports of inequitable distribution of benefits in Nepal (ADHIKARI et al. 2004; CHHETRY et al. 2005; MALLA et al. 2003; NIGHTINGALE 2003; POKHAREL and NURSE 2004) and India (AGARWAL 2001; VARALAKSHMI 2002), as well as in other countries around the world (CARTER 2005).

Table 50. Summary of economic equity indicators

Indicator of Economic Equity	Equity Between Socio-economic Groups	Equity Between Men and Women
Access to permits for timber and firewood trees.	High	High
Distance to marked trees	High	High
Access to dry firewood collection	High	High
Access to collection of NWFPs	High	High
Access to forest grazing	High	High
Perception of personal benefits from the CF	High	High

Considering the low level of political equity and modest participation of disadvantaged groups and women, it was surprising that the level of economic equity was so high in Bhutan. Some authors have argued that political equity within user groups is a prerequisite for equitable distribution of benefits (ADHIKARI 2005; AGRAWAL and GUPTA 2005). Yet the user groups in Bhutan appear to have achieved a high level of economic equity with a low level of political equity.

6.3.3 Factors Supporting Equity in Bhutan

The high level of economic equity in Bhutan was attributed to supportive government policy, which was affected by Bhutan's environmental conditions, socio-cultural conditions, and strong extension support.

Supportive Government Policy

Bhutan's community forestry policy provides strong support for CF user groups. The policy directly addressed three of the four attributes that Ostrom (1999) found were associated with successful CFs, and the three studied CFs were found to exhibit all four of the attributes. Perhaps the most important of Ostrom's forest attributes is that the forest should not be so degraded that it is useless to organize or so underutilized that there is little advantage from organizing. All three of the studied CFs were well stocked and regularly utilized by the members, who were concerned about potential degradation in the future.

Bhutan's policy of handing over well-stocked forests for community forestry is unusual: governments in many countries have only been willing to hand over degraded forests for community management (CARTER 2005; MENZIES 2002), as has generally been the case in India and Nepal (HOBLEY 2005). Initially Bhutan's community forestry program was intended to be only implemented on degraded land, but in 1992 DOF decided to give villagers a stronger incentive to participate by stipulating that CFs should be approximately 50% well-stocked and 50% degraded (CHHETRI 1992; UPADHYAY 1992). This provision was included in the 2000 and 2003 versions of the FNC Rules (MOA 2000, 2003). It may have enhanced the equity of CFs, since the more powerful members may be more likely to postpone demanding their share of timber until they actually needed it.

The community forestry policy in Bhutan was certainly affected by the abundance of forest resources: although Bhutan has only 60% as much per capita agriculture land as Nepal and 46% as much of India, the country has eight times the per capita forest land of Nepal and more than 22 times the per capita forest land of India (WRI 2007). However, the policy probably reflected a genuine willingness by the DOF to give up control of some forests in order to promote economic development at the village level. In Nepal the DOF has been less willing to give up control of valuable timber resources: the new forest policies since 2000 have restricted the handover of well-stocked forests in the Terai/Churia regions while continuing to promote the handover of relatively low value forests in the mid-hills (AGRAWAL and OSTROM 2001; BHATTARAI 2006). In India, the Forest Department also reportedly retained control of the most productive forest land and allocated fragmented and degraded patches for community management (AGRAWAL and OSTROM 2001).

The community forestry policy of Bhutan also addressed most of the attributes of successful user groups listed by McKean (2000) and Ostrom (1999). The assessment of the three CFs found that the user groups exhibited all of McKean's positive attributes and all but two of Ostrom's positive attributes, which were partially exhibited. Not surprisingly, the two partially exhibited attributes had direct linkages with political equity:

- The users should trust each other and relate to one another with reciprocity.
- The users should have learned at least minimal skills of organization though participation in other local associations or learning from neighboring groups.

Socio-cultural Conditions

The socio-cultural conditions in rural Bhutan may have enabled the CFs to exhibit so many of these positive attributes. Each of the three studied user groups was ethnically homogenous, shared a common language and did not observe the caste system. In Nepal, on the other hand, ethnic heterogeneity has been identified as the main cause of conflict in community forestry (UPRETY 2006), and there are many reports of ethnic heterogeneity contributing to inequity (ADHIKARI et al. 2004; BUFFUM and CHETTRI 2000; CHHETRY et al. 2005; MALLA et al. 2003; NIGHTINGALE 2003).

The status of women in Bhutan may have also been a positive factor. More than half (51%) of the members of the three studied CFs were female. This contrasted with the situation in Nepal and India, where female membership in the studied user groups was 3.5% and 10% respectively (AGRAWAL and OSTROM 2001), and where cultural norms discouraged women from participating in CF meetings (SPRINGATE-BAGINSKI et al. 2003). The female respondents in Bhutan were observed to have strong views on forest management and be comfortable expressing their views during group meetings, even though men held most of the influential positions in the CF management committees.

Women in Bhutan tend to be actively involved in forestry issues (NAMGAY and SONAM 2006; TFDP 2000) and participate actively in community meetings (UNESCO 2006). Several studies of the role of Bhutanese women in natural resources management reported that women and men had almost equal roles in forestry, and that cultural or educational barriers did not inhibit direct interaction between women and male extensionists (TFDP 2000). This may be due to inheritance practices: daughters traditionally inherit the family home and farm, whereas the sons are expected to move to their wives' homes after marriage (UNESCO 2006). As a result, women take greater responsibility for house maintenance, taking the lead in deciding when timber was needed for house repairs or construction (DUBA et al. 1998).

Forestry Extension

Another important factor affecting equity in Bhutan was the intensive forestry extension program. The three forestry extension agents responsible for the studied CFs lived within a few km of the sites and had regular contact with the user groups. They provided strong support during the management planning phase, which relied heavily on participatory rural appraisal (PFA) exercises to increase the involvement and awareness of the users. The development of a standard set of monitoring formats for use by CFs enabled the users to monitor their own compliance with the rules, which has been identified as being a key attribute of successful user groups (GIBSON et al. 2005).

Many authors have stressed the importance of strong extension support for community forestry programs. Menzies (2002, p. 26) analyzed six reviews of community based forest management around the world and noted the importance of "crafting and building community institutions which can ensure equitable, inclusive and just governance with mechanisms to counter the possibility of corruption and elite domination." Nurse et al. (2003) highlighted the importance of extension support in Bhutan during the management planning process in order to avoid subsequent equity problems. Agrawal and Gupta (2005, p 1104) also noted the importance of extension support: "government officials often decide about the objectives of the community-level groups, the obligations of members, and the benefits they receive. Careful initiatives can reduce costs of local collective action substantially. Ill-designed interventions can undermine all possibility of widespread participation"

7 Summary and Conclusions

This research addressed three specific concerns related to community forestry:

- The harvesting approach of selection cutting utilized by CF user groups may not be ecologically sustainable in diverse broadleaved forests.
- The use of CFs for forest grazing as well as timber production may have negative impacts on the natural regeneration of preferred tree species.
- The distribution of benefits from CFs may not be equitable, and may even exacerbate inequality.

7.1 Sustainability of Harvesting in CFs

The ecological sustainability of harvesting in CFs has rarely been addressed by research: a recent review of participatory forest management (PFM) concluded that: “perhaps the most conspicuous absence from the PFM literature is a thorough analysis of forestry itself, the technology of intervention in a forest ecosystem to provide a reliable supply of the products and benefits required by the users (LAWRENCE 2007, p 2). Other studies have reported that foresters have not yet devoted adequate attention to the development of more productive silvicultural systems for natural forests under community management (CARTER 2005; DONOVAN 2001; VICTOR 2001).

While experience with the plenter system in Central Europe has demonstrated that selection cutting can be highly sustainable (O'HARA and GERSONDE 2004; O'HARA et al. 2007), the use of simpler systems of selection cutting in the USA is widely reported to have a negative impact on the form, bole shape and species composition of residual stands (NYLAND 2006b; OLIVER and LARSON 1996). With the rapid expansion of community forestry in developing countries, it is important to assess the ecological sustainability of CF harvesting practices, which are generally based on indigenous knowledge and traditional practices of selection cutting. If these harvesting practices are not sustainable, then there is an urgent need for technical assistance and training.

Studies of CF management to date have only assessed simple indicators of forest quality, such as number of stems and amount of forest cover (GAUTAM et al. 2002; YADAV et al. 2003). This research attempted to conduct a more thorough study of selection cutting in CFs by assessing six indicators of ecological sustainability.

This research component concluded that the selection cutting approach used in Yakpugang is ecologically sustainable and appropriate for the cool broadleaved forests of Bhutan. Harvesting by the user group was well below the AAC, and did not appear to affect the standing volume of the forest, the species composition, or the form/bole shape of remaining trees. The impact on natural regeneration of valuable timber species appeared to be positive, in contrast to the experience in the adjacent Korilla FMU. These findings can be attributed to two main factors, both of which were enhanced by strong support from the forest extension service:

- Harvesting did not exceed the AAC because the management plan provided clear guidance on harvesting limits of different size classes and the user group developed a simple yet effective system for monitoring harvesting. The ability of the users to exclude outsiders from harvesting trees in the CF was also important.

- The improved marking and discipline by the user group spread out the harvesting in different forest stands, which reduced the effect of high-grading and avoided the creation of large openings which would attract livestock,. The resulting irregular pattern of harvested trees created a wide range of light conditions which increased the quantity and diversity of natural regeneration.

7.2 Sustainability of Forest Grazing in CFs

The ecological sustainability of forest grazing in CFs has not been the focus of much research to date, despite the importance of forest grazing to the livelihoods of many farmers around the world (RODER et al. 2002). The impact of forest grazing in general has been extensively studied (GRATZER et al. 1999; MAYER et al. 2006; PALMER et al. 2004; VANDENBERGHE et al. 2007), and several studies have investigated the impact of forest grazing after logging in commercially managed forests (DARABANT et al. In Press; KRZIC et al. 2001; TSHERING 2005; VAN IJSSEL 1990), but the literature search did not locate any studies investigating the impact of forest grazing and logging in a CF. Lawrence (2007) also observed the lack of silvicultural guidelines for forests managed by communities for forest grazing and other non-wood forest products

This research component concluded grazing intensity of 0.4 cattle*ha^{-1} was below the threshold for sapling recruitment in Yakpugang, and that cool broadleaved CFs in Bhutan can be sustainably managed for timber and non-wood forest products in combination with moderate levels of forest grazing. The findings agreed with other several studies which have concluded that forest grazing can be ecologically sustainable as long as grazing intensity is controlled (ADAMS 1975; PATRIC and HELVEY 1986; RODER et al. 2002)

7.3 Equity of Community Forestry

The equity of community forestry has been the focus of considerable attention around the world since equity emerged the weakest aspect of generally successful community forestry programs (CARTER 2005; HOBLEY 2005; SCHRECKENBERG et al. 2006). However, this issue has not yet been addressed in depth in Bhutan. A study of local perceptions of equity was conducted (NAMGAY and SONAM 2006), but the current research was the first time that the actual distribution of products from Bhutanese CFs was assessed. Bhutan's unique socio-cultural conditions offer a new context to understand the issues affecting the equity of community forestry programs.

This component of the research concluded that the distribution of benefits in the three studied CFs was highly equitable. There were no indications that disadvantaged groups had been discriminated against, as has been widely reported in neighboring countries. The user groups exhibited all of the attributes of successful user groups which were identified in two previous studies. This was attributed to a combination of supportive government policy (willingness to handover well stocked forests to user groups), environmental factors (the high amount of per capita forest), socio-cultural factors and strong support from the forestry extension service. The level of political equity (participation in decision making) in Bhutan was moderate, but was higher than what has been reported in neighboring countries.

7.4 Policy Implications

The research findings have several policy implications for Bhutan and other countries:

- The initial field experience in Bhutan suggests that user groups can manage CFs in an ecologically sustainable manner and distribute the produce equitably.
- The selection cutting approach used in Yakpugang CF appears to be ecologically sustainable and appropriate for the cool broadleaved forests of Bhutan. Selection cutting appears to avoid some unresolved silvicultural problems of cable crane logging operations related to the promotion of natural regeneration of preferred species.
- The existing policy of allowing forest grazing in community forests in Bhutan appears to be appropriate: the findings of this study suggest that moderate levels of forest grazing and timber harvesting can be combined on an ecologically sustainable basis. However, the

long term effect of grazing on natural regeneration of *Quercus* species needs further study.

- The policy of handing over forests to communities that are approximately 50% well stocked appears to be appropriate, as it allows the user groups to obtain some immediate benefits while they invest in the improvement of the degraded portions of the CFs.
- The policy of actively involving CF user groups in the process of forest resource assessments by developing simple inventory methodologies (e.g. replacing volume calculations with the number of trees of different size classes) appears to have a positive impact on the subsequent ability of the user group to manage harvesting operations.
- User groups require intensive and ongoing institutional strengthening, especially in the area of record keeping. Even though the forest management activities and distribution of forest products in the three CFs was satisfactory, the standard of record keeping was unacceptable and could lead to equity problems in the future.

7.5 Effectiveness of Research Methodology

The interdisciplinary approach of combining ecological and social research methodologies proved effective in addressing the research questions. The social and ecological research approaches were highly synergistic: the interaction with user group members in the forest during the ecological studies provided many valuable insights for the equity study; while the household surveys and focus group discussions provided an opportunity to discuss findings from the ecological study with a wider group of users. The study on selection cutting required social research to supplement the ecological research, and the study of forest grazing required roughly equal amounts of both types of research. Many studies of equity in CFs have been approached exclusively with social research, but it was valuable to also understand the ecology of the forest, since social conflicts are likely in CFs that cannot provide a steady flow of products and services.

The research involved two commonly used research methodologies (forest inventory and household survey) along with a less common methodology (study of harvested trees to analyze the history of forest management) which may not have been previously applied to the study of CFs. This approach proved to be highly effective, and is recommended for future studies. It allowed an assessment of the sustainability of harvesting levels, and also permitted the study of several aspects of forest development in the absence of detailed baseline data from an earlier forest inventory.

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9 Appendix

9.1 Map of Forest Management Units and Protected Areas

9.2 Organogram of Ministry of Agriculture

9.3 List of Approved CFs in Bhutan

9.4 Additional Research on Bhutan

9.5 Map of Yakpugang Community Forest

9.6 Questionnaire for Household Survey

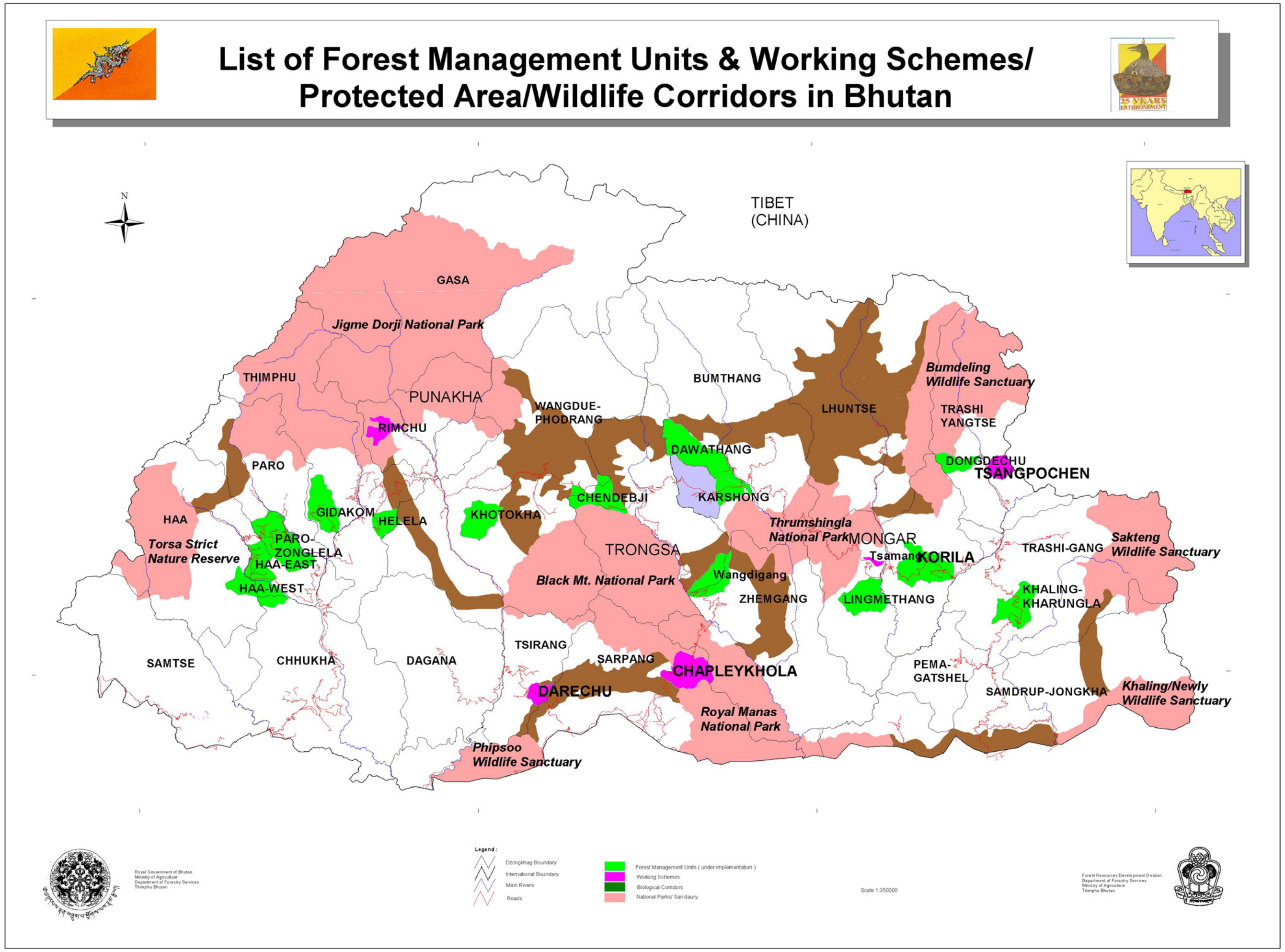
9.7 Format for Focus Group Sessions

9.8 Results of Selected Statistical Analyses

9.9 Diameter Distribution of Selected Species

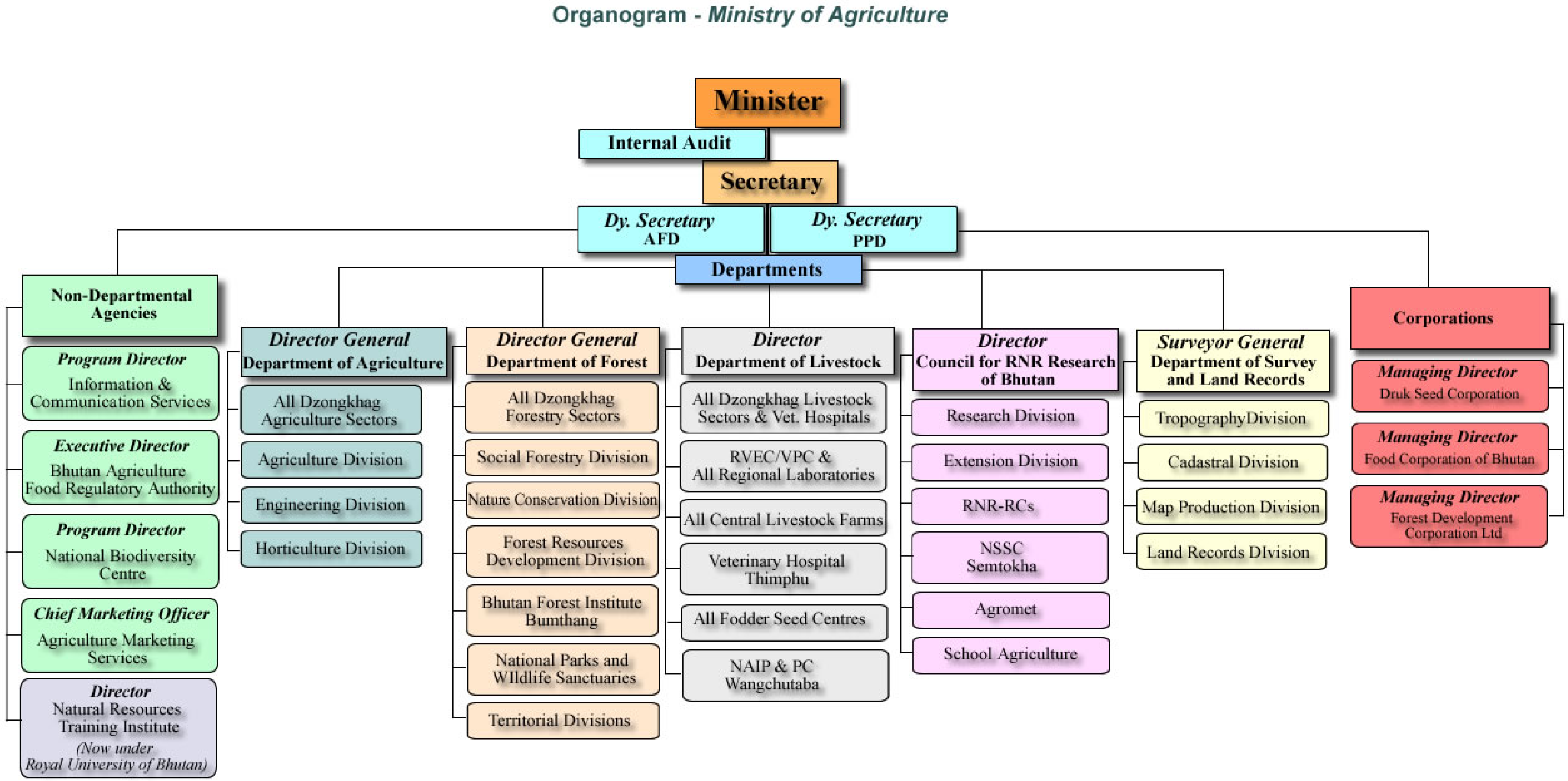
9.10 CV

9.1 Map of Forest Management Units and Protected Areas



Source: Department of Forests, Ministry of Agriculture, Bhutan

9.2 Organogram of Ministry of Agriculture



Source: Ministry of Agriculture (MOA 2007b)

9.3 List of Approved CFs in Bhutan

	CF Name	Geog	District	Area (Ha)	No. Members	Year Approved	Forest Type
1	Dozam	Drametse	Mongar	300	109	1997	Chirpine
2	Yakpugang	Mongar	Mongar	260	103	2001	Broadleaf
3	Masangdaza	Saling	Mongar	87	37	2002	Chirpine/broadleaf
4	Gayzor	Zobel	P/Gatshel	20.9	29	2001	Broadleaf
5	Joensham Lamdoksa	Khaling	Trashigang	132	126	2002	Broadleaf
6	Salibagar	Sumar	P/Gatshel	10	56	2002	Chirpine
7	Ngangney	Jarrey	Lhuntse	10	33	2002	Mixed
8	Merculing	Gangzur	Lhuntse	71	29	2003	Broadleaf
9	Tshokpethang	Membee	Lhuntse	48	36	2003	Chirpine
10	Lekcha	Khoma	Lhuntse	18	17	2003	Bamboo
11	Gakey	Jarrey	Lhuntse	58	28	2004	Broadleaf
12	Namtongphung	Jamkhar	Trashiyangtse	13	60	2002	Chirpine
13	Ompuri	Orong	S. Jongkhar	81	39	2003	Broadleaf
14	Shambayung	Tang	Bumthang	46	23	2003	Mixed
15	Siptangzur	Ura	Bumthang	75	30	2003	Mixed
16	Tshapay	Usue	Haa	95	33	2003	Mixed
17	Dungkarling	Bhur	Sarpang	115	62	2004	Broadleaf
18	Lamjithang	Thedtsho	Wangdue Phodrang	240	86	2004	Mixed
19	Lobneykha	Chapcha	Chukha	195	81	2004	Conifer
20	Norzin Choling	Ngala	Zhemgang	105.44	84	2004	Broadleaf
21	Willing	Nubi	Trongsa	29.52	12	2004	Broadleaf
22	Tshangkha	Tshangkha	Trongsa	42.54	25	2004	Broadleaf
23	Yoesel -Pelri	Nangkhor	Zhemgang	42.91	21	2004	Broadleaf

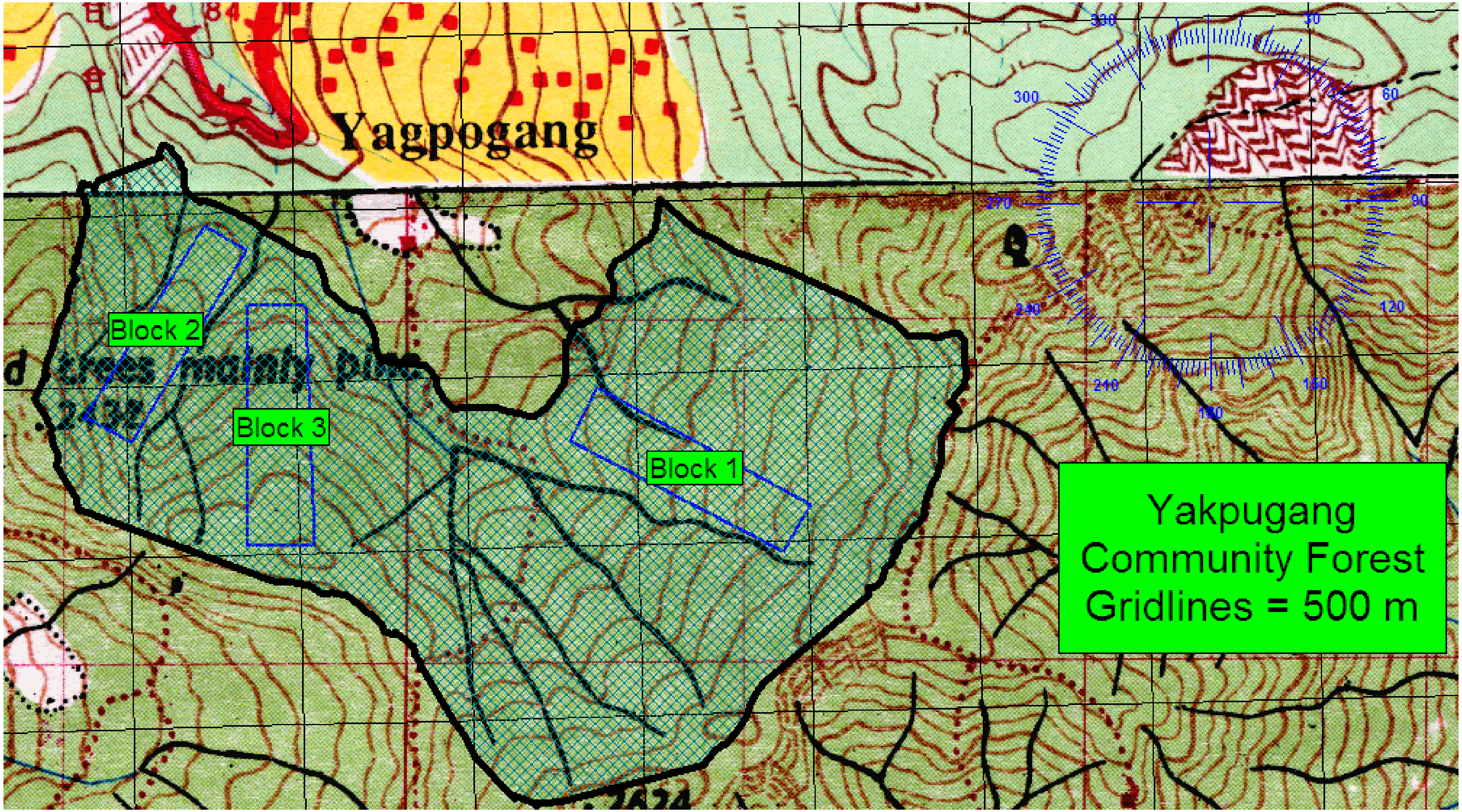
	CF Name	Geog	District	Area (Ha)	No. Members	Year Approved	Forest Type
24	Woku-Damchi	Kabjisa	Punakha	75.5	42	2005	Broadleaf
25	Lumsum	Limbukha	Punakha	60	29	2005	Broadleaf
26	Yargay	Lumbukha	Punakha	15	20	2005	Plantation
27	Mangi Zingkha	Talo	Punakha	41.34	17	2005	Plantation/natural forest
28	Zhasela	Menji	Lhuntse	33.48	14	2005	Mixed
29	Pipla Management	Nangkhor	Zhemgang	38.28	107	2004	Pipla
30	Chalibadeb	Tshenkhar	Lhuntse	26.8	27	2005	Conifer
31	Samdrup	Patale	Tsirang	363	145	2006	Chirpine/Broadleaved
32	Norbuling	Bartsham	Trashigang	47.5	19	2006	Chirpine
33	Sangtseree	Phangkhar	Zhemgang	14.76	20	2006	Barren
34	Masepokto	Gase Tsho-Gom	Wangdue Phodrang	21	19	2006	Chirpine
35	Bali CF plan	Chubu	Punakha	37.6	22	2006	Chirpine
36	Tshang Chhu	Jigme Chholing	Sarpang	44	24	2006	Broadleaved
37	Kumbu	Gangtey	Wangdue Phodrang	43	21	2006	Bluepine
38	Tashi-Phuntsho-Jong	Guma	Punakha	60.82	47	2006	Broadleaved
39	Wamanang Bamboo	Bumdeling	Trashiyangtse	321.4	97	2007	Bamboo
40	Tsentof	Tenstog	Paro	87.25	36	2007	Blue pine/Quercus
41	Ganju	Nyesho	Wangdi	20	20	2007	Degraded
42	Lhenkebji	Kashi	Wangdi	25.9	17	2007	Chirpine/broadleaf

9.4 Additional Studies on Bhutan

In addition to the studies mentioned in the Literature Survey in Section 2, several other relevant studies have been conducted in Bhutan.

- Fischer (1976) wrote one of the first descriptions of the forests of Bhutan, focusing on conifer forests but with some information about broadleaved forests.
- Sargent et al. (1985) inventoried forests in 63 locations throughout the country and described broadleaved and conifer forests, using LANDSAT 2 imagery to prepare the sampling stratification and plot the distribution of defined vegetation types after sampling and analysis.
- Biswas (1986) provided an early description of Bhutan's forestry sector.
- Karan (1987) discussed the land use and population in Bhutan with special reference to mountain hazards in the broadleaved forests of Trongsa and Mongar districts.
- Hara (1991a; 1991b) compared the seedling stages and regeneration properties of seven species of Fagaceae (*Quercus* and *Castanopsis*) and studied the floristic composition, vertical stratification, size structures and regeneration characteristics of five broadleaved stands ranging in elevation from 1,800m to 2,910m.
- Gurung et al. (1999; MIEHE et al. 1999) studied natural cypress stands and concluded that cypress is a light demanding pioneer which initiates primary or secondary succession in broadleaved forests after landslides or episodic fires.
- Ohsawa et al. (2002) studied secondary succession and soil development in tseri-farming systems in Shemgang, and concluded that the twelve year cycle was critically balanced to maintain soil fertility with limited labor inputs due to rapid forest growth during the fallow period.
- Schindele conducted a number of studies, including forest function maps for three broadleaved forests in the Punakha-Wangdi valley (2002a; 2002b; 2002c) and development of the national forest resources potential assessment, which reported that only 10% of the national forests were suitable for commercial harvesting (2004).

9.5 Map of Yakpugang Community Forest



9.6 Questionnaire for Household Survey

The following formats were used in the Household Survey:

- Form 1. A two page format that was applied to all respondents.
- Form 2. If they received timber permits from the CF.
- Form 3. If they received timber permits from other national forests.

Form 1. General questionnaire

CF MEMBER		CF	
Wealth Ranking		Village	
Person interviewed		Distance from CF?	
Relation to member		Interview Date	
Age		Committee Member?	
Size of HH		Number of workers in HH?	
Taken timber permit in CF?		If no, why not?	(Coded answers)
Taken firewood permit in CF?		If no, why not?	(Coded answers)
Taken DFO permit outside CF in last 3 years?		How much time to get DOF permit?	
Year house built?		Year last renovation?	
When will build new house?		When next renovation?	
Will request timber next year inside CF?		Size class and number	
Will request timber next year from DFO?		Size class and number	
How many firewood trees per year in CF with permit? Species?		How many head-loads dry firewood per year in CF? Species?	
How many firewood trees per year outside CF with DFO permit? Species?		How many head-loads dry firewood per year outside CF? Species?	
What NWFPs harvest inside CF? How much?		What NWFPs harvest outside CF? How much?	
CF permit needed?		DFO permit needed?	
CF produce for sale?		DFO produce for sale?	
LIVESTOCK NOW	Number	No. grazing inside CF now? Where in CF?	No. grazing outside CF now. Where?
Traditional cattle:			

Mithun:			
Improved breed:			
Other:			
LIVESTOCK 5 YRS AGO	Number	No. grazing inside CF then? Where in CF?	No. grazing outside CF then. Where?
Traditional cattle:			
Mithun:			
Improved breed:			
Other (horse, mule, etc):			
Why change in numbers of cattle?	(Coded answers)	Why change in location of grazing?	(Coded answers)
Has quality of grazing in CF changed in 5 yrs?		If Y, how?	(Coded answers)
Has quality of grazing outside CF changed in 5 years?		If Y, how?	(Coded answers)
Number of stall fed only cattle now?		Number of stall fed only five years ago?	
How many non CF members graze in CF now?		From what villages?	
How many cattle?		How many non CF members grazed in CF 5 years ago?	
How many cattle?		From what villages?	
Did a member of your HH attend last CF meeting?		How much money in CF account?	
What is the CMFG fund used for?		Has your HH already benefited from the CF?	
If Y, how?	(Coded answers)	How do you expect your HH to benefit in the future?	(Coded answers)
Has the CF increased your workload? Explain.		Has forest condition in CF changed from 5 yrs ago? If Y, how?	(Coded answers)
Has forest condition in other national forests changed from 5 yrs ago? If Y, how?			

Other comments?

Form 2. Information about each Timber Permit issued within CF

CF:		Date of Survey:	
Name		No.	
Hamlet		Year of Permit	
Size Class		Quantity	
Use?		Had to wait for permit?	
Species		Preferred Species?	
Location		Minutes from house?	
Harvested? Why not? When will?		Constructed? Why not? When will?	
Harvest/Process Method		By whom?	

Form 3. Information for each Timber Permit Issued by DFO Outside the CF

CF:		Date of Survey:	
Name		Already harvested?	
Hamlet		Month/year of permit	
Size Class		Quantity	
Location		Use	
Species		Why not from CF?	

9.7 Questionnaire for Focus Group Interviews

Form 4. FOCUS GROUP INTERVIEW IN ADJACENT VILLAGE	
Date:	Village:
Persons interviewed (Name and village)	
Did you harvest products in the CF before the estab of the CF? If yes, what products?	
If yes, where do you now harvest the same products?	
If Y, is the new location more or less convenient? Explain?	
How many timber permits from DFO in last 3 years? What species?	
How many firewood permits in last 3 years? What species?	
Will you request timber next year from DFO?	
Will request firewood next year from DFO? Species?	
What NWFPs harvest?	
For sale or home consumption? DFO permit needed?	

Livestock Type	No. 2005	No. grazing in CF	No. grazing outside CF
Mithun			
Traditional cattle			
Improved cattle			
Other			
Livestock Type	No. 2000	No. grazing in CF then	No. grazing outside CF
Mithun			
Traditional cattle			
Improved cattle			
other			

Why change in numbers of cattle?	
What change in grazing pattern?	
Has quality of grazing inside the CF changed in 5 yrs? How/why?	
Has quality of grazing outside CF changed in 5 years? How/why?	
Has the quality of the forest in the CF increased in 5 years? How/why?	
Has the quality of the other national forests improved in 5 years? How/why	
How has the CF benefited from the CF? How?	
Would you like to establish a CF? Explain?	

Any other comments?

9.8 Results of Selected Statistical Analyses

A. Harvest compared with AAC by use category (combined blocks)

Use Category		Period of Harvest					
		0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
1st Timber	Harvest/Yr (*Mdn*)	0	0	0	0	0	0
AAC = 0.27 m3/yr (*Mdn*) 0.65 m3/yr *(M)*	Statistic	T= 59.5, p< .001, r= - .52	T= 61, p< .01, r= - .49	T= 33.5, p< .001, r= - .60	T= 0, p< 001, r= - .74	T= 26, p< 001, r= - .63	T= 28, p< 001, r= - .65
2nd Timber	Harvest /Yr (*Mdn*)	0	0	0	0	0	0
AAC = 1.70 m3/yr (*Mdn*) 2.02 m3/yr *(M)*	Statistic	T= 98.5, p< .001, r= - .57	T= 56, p< .001, r= - .71	T= 118, p< .01, r= - .51	T= 113, p< 001, r= - .55	n.s.	n.s.
Other Use	Harvest /Yr (*Mdn*)	0	0	0	0	0	0
AAC = 0.58 m3/yr (*Mdn*) 0.79 m3/yr *(M)*	Statistic	T= 9.5, p< 001, r= - .84	T=101, p< 001, r= - .59	T=23.5, p< 001, r= - .81	T=0, p< 001, r= - .86	T=0, p< .001, r= - .86	T=56.5, p< 001, r= - .67
Quercus	Harvest /Yr (*Mdn*)	0	0	0	0	0	0
AAC = 1.02 m3/yr (*Mdn*) 2.03 m3/yr *(M)*	Statistic	T=12, p< 001, r= - .51	T= 8, p< 001, r= - .62	T=9, p< 001, r= - .72	T=0, p< .001, r= - .72	T=0, p< .001, r= - .63	T=1, p< .001, r= -.62
No Use	Harvest /Yr (*Mdn*)	0	0	0	0	0	0
AAC = 1.02 m3/yr (*Mdn*) 0.10 m3/yr *(M)*	Statistic	T=0, p< .01, r= - .42	T=0, p< .01, r= - .42	T=0, p< .01, r= - .42	T=0, p< .01, r= - .42	n.s.	T=0, p< .01, r= - .42

Note: n.s. = not significant. Rotation = 100 yrs.

B. Harvest compared with AAC by block (combined use categories)

		Time Period of Harvest					
		0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
Block 1	Harvest (*Mdn*)	0	0	1.0	0	0	.70
AAC = 5.85 m3/yr (*Mdn*) 6.42 m3/yr *(M)*	Statistic	n.s.	T=9, p< 05, r= -.39	T=12, p< .05, r= -.35	T=12, p< .05, r= -.35	n.s.	T=6, p< .01, r= -.43
Block 2	Harvest (*Mdn*)	0	0	0	0	0	1.0
AAC = 5.20 m3/yr (*Mdn*) 5.03 m3/yr *(M)*	Statistic	T=0, p< .001, r= - .51	T=12, p< 05, r= -.35	T=7, p< .05, r= -.41	T=0, p< .001, r= -.51	T=5, p< .01, r= -.45	T=1, p< .05, r= -.45
Block 3	Harvest (*Mdn*)	0	0	0	0	0	0
AAC = 4.62 m3/yr (*Mdn*) 5.28 m3/yr *(M)*	Statistic	n.s.	T=12, p< .05, r= -.35	T=0, p< .001, r= -.51	T=0, p< .001, r= -.51	T=6, p< .01, r= -.43	n.s.

Note: n.s. = not significant. Rotation = 100 yrs.

C. Harvest compared with AAC by use category and block

			Time Period of Harvest					
			0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
Block 1	1st Timber	AAC (*Mdn*)	.11	.11	.11	.11	.11	.11
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	n.s.	n.s.	n.s.	T=0, p< .01, r= -.73	T=0, p< .01, r= -.73	n.s.
	2nd Timber	AAC (*Mdn*)	.50	.50	.50	.50	.50	.50
		Harvest (*Mdn*)	.23	0	0	.12	0	0
		Statistic	n.s.	T=9, p< .05, r= -.73	n.s.	n.s.	n.s.	T=11, p< .05, r= -.63
	Other Use	AAC (*Mdn*)	.59	.59	.59	.59	.59	.59
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	T=2.5, p< .01, r= -.78	n.s.	T=79, p< .01, r= -.72	T=0, p< .001, r= -.85	T=0, p< .001, r= -.85	n.s.
	Quercus	AAC (*Mdn*)	4.17	4.17	4.17	4.17	4.17	4.17
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	n.s.	T=0, p< .01, r= -.81	T=0, p< .01, r= -.81	T=0, p< .01, r= -.80	n.s.	T=0, p< .01, r= -.81
Block 2	1st Timber	AAC (*Mdn*)	.33	.33	.33	.33	.33	.33
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	T=0, p< .01, r= -.81	n.s.	T=2.5, p< .01 r= -.74	T=0, p< .01, r= -.81	n.s.	T=0, p< .01, r= -.81
	2nd Timber	AAC (*Mdn*)	2.78	2.78	2.78	2.78	2.78	2.78
		Harvest (*Mdn*)	0	0	0	0	0	.38
		Statistic	T=0, p< .001, r= -.85	T=12, p< .05, r= -.61	n.s.	T=9, p< .05, r= -.68	n.s.	n.s.
	Other Use	AAC (*Mdn*)	.59	.59	.59	.59	.59	.59
		Harvest (*Mdn*)	0	.85	0	0	0	0
		Statistic	T=2, p< .00, r= -.84	n.s.	T=2, p< .001, r= -.84	T=0, p< .001, r= -.88	T=0, p< .001, r= -.88	T=12, p< .05, r= -.61
	Quercus	AAC (*Mdn*)	.29	.29	.29	.29	.29	.29
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	T=0, p< .05, r= -.64	T=0, p< .05, r= -.64	T=0, p< .05, r= -.64	T=0, p< .05, r= -.64	T=1, p< .05, r= -.63	T=0, p< .05, r= -.64

			Time Period of Harvest					
			0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
Block 3	1st Timber	AAC (*Mdn*)	.30	.30	.30	.30	.30	.30
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	n.s.	*T*=0, *p*< .01, *r*= -.73	*T*=0, *p*< .01, *r*= -.51	*T*=0, *p*< .01, *r*= -.51	*T*=0, *p*< .01, *r*= -.51	*T*=0, *p*< .01, *r*= -.51
	2nd Timber	AAC (*Mdn*)	1.89	1.89	1.89	1.89	1.89	1.89
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	*T*=8.5, *p*< .05, *r*= -.63	*T*=0, *p*< .001, *r*= -.85	*T*=2, *p*< .01, *r*= -.80	*T*=9, *p*< .05, *r*= -.62	n.s.	n.s.
	Other Use	AAC (*Mdn*)	.59	.59	.59	.59	.59	.59
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	*T*=0, *p*<.001, *r*= -.88	*T*=0, *p*< .001, *r*= -.88	*T*=0, *p*< .001, *r*= -.88	*T*=0, *p*< .001, *r*= -.88	*T*=0, *p*< .001, *r*= -.88	*T*=0, *p*< .001, *r*= -.88
	Quercus	AAC (*Mdn*)	.95	.95	.95	.95	.95	.95
		Harvest (*Mdn*)	0	0	0	0	0	0
		Statistic	n.s.	n.s.	*T*=0, *p*< .01, *r*= -.73	*T*=0, *p*< .01, *r*= -.73	*T*=0, *p*< .01, *r*= -.73	n.s.

n.s. = not significant. Rotation = 100 yrs.

D. Harvest compared with AAC by species (combined blocks)

		Time Period of Harvest					
		0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
Cinnamomum bejolghota	AAC (*Mdn*)	.20	.20	.20	.20	.20	.20
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=23, *p*< .001, *r*= -.58	*T*=0, *p*< .001, *r*= -.70	*T*=54, *p*< .01, *r*= -.49	*T*=70, *p*< .01, *r*= -.45	n.s.	*T*=37, *p*< .001, *r*= -.51
Daphniphyllum chartaceum	AAC (*Mdn*)	.03	.03	.03	.03	.03	.03
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=0, *p*< .001, *r*= -.57	*T*=12, *p*< .01, *r*= -0.45	*T*=0, *p*< .001, *r*= -0.57	*T*=0, *p*< .001, *r*= -0.57	*T*=0, *p*< .001, *r*= -0.57	*T*=15, *p*< .01, *r*= -0.43
Persea clarkeana	AAC (*Mdn*)	.28	.28	.28	.28	.28	.28
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=9, *p*< .01, *r*= -0.49	*T*=9, *p*< .01, *r*= -0.45	n.s.	n.s.	n.s.	n.s.
Michelia doltsopa	AAC (*Mdn*)	.28	.28	.28	.28	.28	.28
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	n.s.	*T*=0, *p*< .01, *r*= -0.44	n.s.	*T*=0, *p*< .01, *r*= -0.44	*T*=0, *p*< .01, *r*= -0.44	n.s.
Symplocos glomerata	AAC (*Mdn*)	.44	.44	.44	.44	.44	.44
	Harvest (*Mdn*)	0	0	0	0	0	0

		Time Period of Harvest					
		0-4 yrs	5-9 yrs	10-19 yrs	20-29 yrs	30-39 yrs	40-49 yrs
	Statistic	*T*=60, *p*< .05, *r*= -.40	*T*=0, *p*< .001, *r*= -.70	*T*=0, *p*< .001, *r*= -.35	*T*=0, *p*< .001, *r*= -.35	*T*=0, *p*< .001, *r*= -.35	*T*=0, *p*< .001, *r*= -.35
Castanopsis hystrix	AAC (*Mdn*)	.02	.02	.02	.02	.02	.02
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=53, *p*< .01, *r*= -.49	*T*=25, *p*< .001, *r*= -.64	*T*=62, *p*< .01, *r*= -.45	*T*=35, *p*< .001, *r*= -.59	*T*=74, *p*< .01, *r*= -.43	n.s.
Schima khasiana	AAC (*Mdn*)	.07	.07	.07	.07	.07	.07
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=5, *p*< .01, *r*= -.44	n.s.	*T*=8, *p*< .05, *r*= -.41	*T*=5, *p*< .01, *r*= -.44	*T*=0, *p*< .001, *r*= -.51	*T*=0, *p*< .001, *r*= -.51
Quercus lamellosa	AAC (*Mdn*)	.46	.46	.46	.46	.46	.46
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=18, *p*< .01, *r*= -.49	*T*=0, *p*< .001, *r*= -0.60	*T*=0, *p*< .001, *r*= -.60	*T*=0, *p*< .001, *r*= -.60	*T*=18, *p*< .01, *r*= -.49	*T*=19, *p*< .01, *r*= -.45
Elaeocarpus lanceaefolius	AAC (*Mdn*)	.61	.61	.61	.61	.61	.61
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=13, *p*< .05, *r*= -.38	*T*=0, *p*< .001, *r*= -.51	*T*=0, *p*< .001, *r*= -.51	*T*=0, *p*< .001, *r*= -.51	n.s.	*T*=13, *p*< .05, *r*= -.38
Symplocos ramosissima	AAC (*Mdn*)	.49	.49	.49	.49	.49	.49
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	n.s.	n.s.	n.s.	*T*=33, *p*< .001, *r*= -.58	*T*=0, *p*< .001, *r*= -.71	*T*=23, *p*< .001, *r*= -.60
Quercus semiserrata	AAC (*Mdn*)	1.28	1.28	1.28	1.28	1.28	1.28
	Harvest (*Mdn*)	0	0	0	0	0	0
	Statistic	*T*=20, *p*< .001, *r*= -.53	*T*=21, *p*< .001, *r*= -.55	*T*=0, *p*< .001, *r*= -.65	*T*=0, *p*< .001, *r*= -.65	*T*=2, *p*< .001, *r*= -.65	*T*=0, *p*< .001, *r*= -.65

n.s. = not significant. Rotation = 100 yrs.

E. Regression Results for Diversity and Disturbance

```
MODEL 1: Frequency of Disturbance (all plots)
Dependent variable.. ShH_AllStems          Method.. LINEAR
Listwise Deletion of Missing Data
Multiple R           .38714
R Square             .14988
Adjusted R Square    .12487
Standard Error       .20440
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      1         .2504428        .25044285
Residuals      34        1.4205351        .04178045
```

```
F =       5.99426       Signif F =  .0197
-------------------- Variables in the Equation --------------------
Variable                    B         SE B       Beta          T  Sig T
NumberCl              .074422     .030397    .387141     2.448  .0197
(Constant)            .579740     .047171               12.290  .0000

Dependent variable.. ShH_AllStems          Method.. QUADRATI
Listwise Deletion of Missing Data
Multiple R           .53780
R Square             .28923
Adjusted R Square    .24615
Standard Error       .18971

            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      2         .4832913        .24164567
Residuals      33        1.1876866        .03599050
F =       6.71415       Signif F =  .0036
-------------------- Variables in the Equation --------------------
Variable                    B         SE B       Beta          T  Sig T
NumberCl              .223173     .064931   1.160942     3.437  .0016
Number_1             -.040068     .015753   -.859137    -2.544  .0158
(Constant)            .516566     .050335               10.263  .0000
Abbreviated  Extended
Name         Name
Number_1     NumberClassWithBAS_3_5**2
NumberCl     NumberClassWithBAS_3_5

MODEL 2: Frequency of Disturbance (excluding plot 201)
Dependent variable.. ShH_AllStems          Method.. LINEAR
Listwise Deletion of Missing Data
Multiple R           .49705
R Square             .24706
Adjusted R Square    .22417
Standard Error       .19559
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      1         .4128318        .41283178
Residuals      33        1.2581432        .03825366
F =      10.79195       Signif F =  .0024
```

```
-------------------- Variables in the Equation --------------------
Variable                   B         SE B       Beta          T  Sig T
NumberCl             .122412     .037263    .497052      3.285  .0024
(Constant)           .543580     .048428                11.224  .0000

Dependent variable.. ShH_AllStems          Method.. QUADRATI
Listwise Deletion of Missing Data
Multiple R           .54243
R Square             .29423
Adjusted R Square    .24997
Standard Error       .19231
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      2         .4916572        .24582861
Residuals      32        1.1793177        .03698140
F =       6.64736       Signif F =  .0039
-------------------- Variables in the Equation --------------------
Variable                   B         SE B       Beta          T  Sig T
NumberCl             .259478     .100779   1.053606      2.575  .0149
Number_1            -.057025     .039060   -.597433     -1.460  .1541
(Constant)           .509909     .052907                 9.638  .0000
Abbreviated  Extended
Name         Name
Number_1     NumberClassWithBAS_3_5**2
NumberCl     NumberClassWithBAS_3_5

MODEL 3:  Time since disturbance
Dependent variable.. ShH_AllStems          Method.. LINEAR
Listwise Deletion of Missing Data
Multiple R           .42828
R Square             .18342
Adjusted R Square    .15941
Standard Error       .20033
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      1         .3064949        .30649486
Residuals      34        1.3644831        .04013186
F =       7.63720       Signif F =  .0092
-------------------- Variables in the Equation --------------------
Variable                   B         SE B       Beta          T  Sig T
```

```
NumberCl           -.022342     .008084   -.428278    -2.764  .0092
(Constant)          .796615     .059767               13.329  .0000

Dependent variable.. ShH_AllStems          Method.. QUADRATI
Listwise Deletion of Missing Data
Multiple R           .57774
R Square             .33378
Adjusted R Square    .29340
Standard Error       .18367
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      2         .5577367        .27886833
Residuals      33        1.1132413        .03373459
F =       8.26654       Signif F =  .0012
-------------------- Variables in the Equation --------------------
Variable                  B        SE B       Beta         T  Sig T
NumberCl            .056320     .029762   1.079628     1.892  .0672
Number_1           -.007222     .002646  -1.556965    -2.729  .0101
(Constant)          .709004     .063508               11.164  .0000
Abbreviated  Extended
Name         Name
Number_1     NumberClassSinceLastBAS_35**2
NumberCl     NumberClassSinceLastBAS_35

MODEL 4: Intensity of Disturbance
Dependent variable.. ShH_AllStems          Method.. LINEAR
Listwise Deletion of Missing Data
Multiple R           .46706
R Square             .21815
Adjusted R Square    .19515
Standard Error       .19602
            Analysis of Variance:
               DF   Sum of Squares      Mean Square
Regression      1         .3645175        .36451754
Residuals      34        1.3064604        .03842531
F =       9.48639       Signif F =  .0041
-------------------- Variables in the Equation --------------------
Variable                  B        SE B       Beta         T  Sig T
BASrep10            .006264     .002034    .467061     3.080  .0041
(Constant)          .532741     .052578               10.132  .0000
```

Dependent variable.. ShH_AllStems Method.. QUADRATI

Listwise Deletion of Missing Data

Multiple R	.51770
R Square	.26801
Adjusted R Square	.22365
Standard Error	.19252

Analysis of Variance:

	DF	Sum of Squares	Mean Square
Regression	2	.4478398	.22391990
Residuals	33	1.2231382	.03706479

F = 6.04131 Signif F = .0058

-------------------- Variables in the Equation --------------------

Variable	B	SE B	Beta	T	Sig T
BASrep10	.015455	.006447	1.152427	2.397	.0223
BASrep_1	-.000186	.000124	-.720826	-1.499	.1433
(Constant)	.471192	.065968		7.143	.0000

Abbreviated Name	Extended Name
BASrep_1	BASrep100**2
BASrep10	BASrep100

9.9 Diameter Distributions of Selected Species

Figure 40. DBH distribution of *Daphniphyllum chartaceum* in a plot with no harvest for 30 years

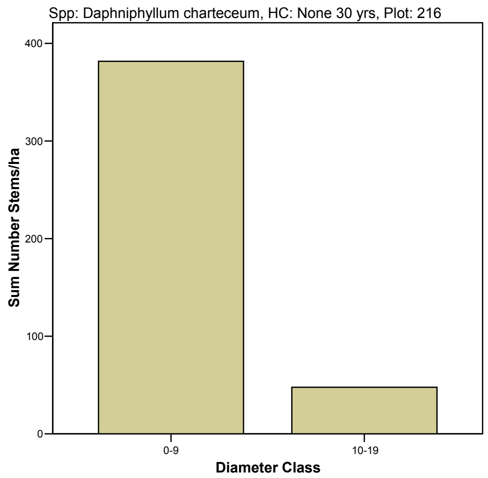


Figure 41. DBH distribution of *Daphniphyllum chartaceum* in a plot with high harvesting for 10 years

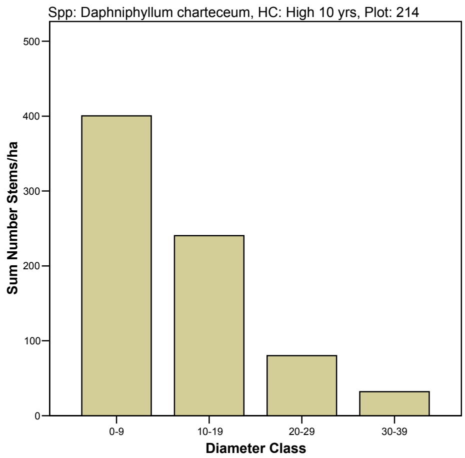


Figure 42. DBH distribution of *Maesa chisia* in a plot with no harvest for 30 years

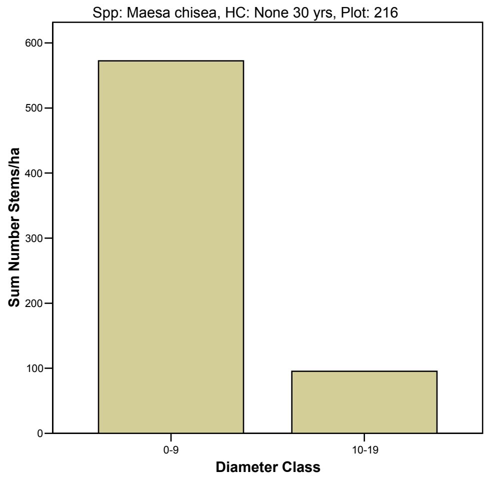


Figure 43. DBH distribution of *Maesa chisia* in a plot with high harvesting for 10 years

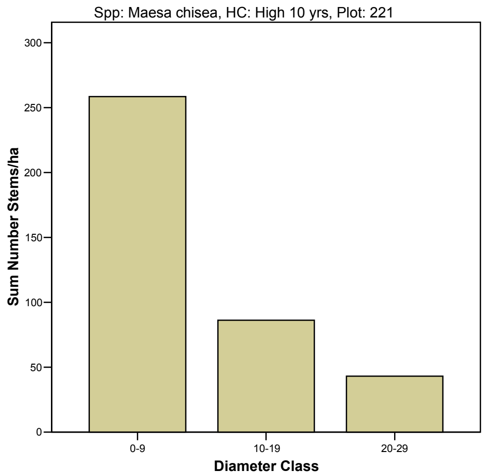


Figure 44. DBH distribution of *Symplocos glomerata* in a plot with no harvest for 30 years

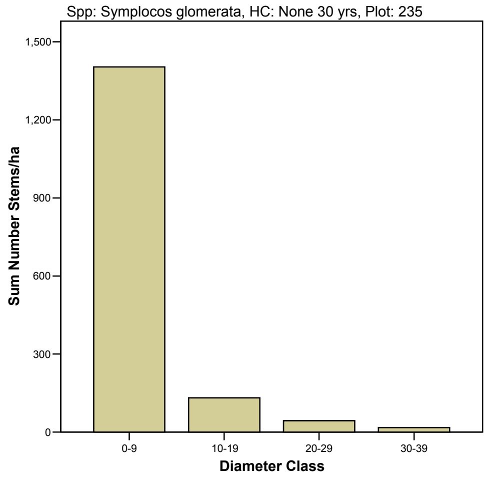


Figure 45. DBH distribution of *Symplocos glomerata* in a plot with high harvest for 10 years

Figure 46. DBH distribution of *Symplocos ramosissima* in a plot with no harvest for 30 years

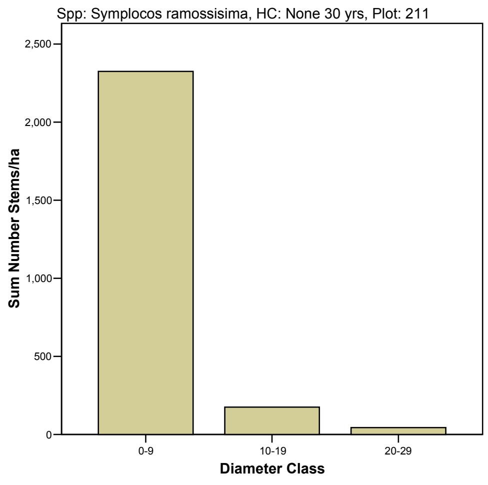


Figure 47. DBH distribution of *Symplocos ramosissima* in a plot with high harvest for 10 years

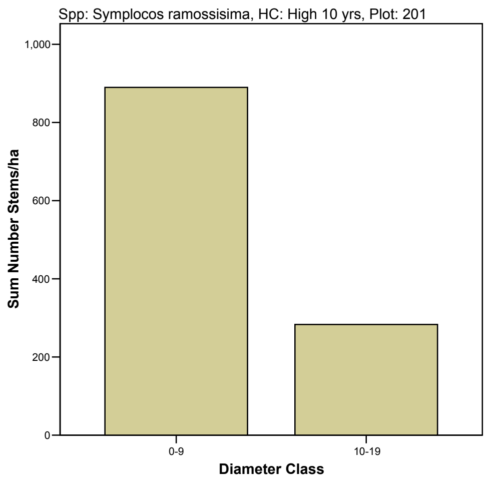
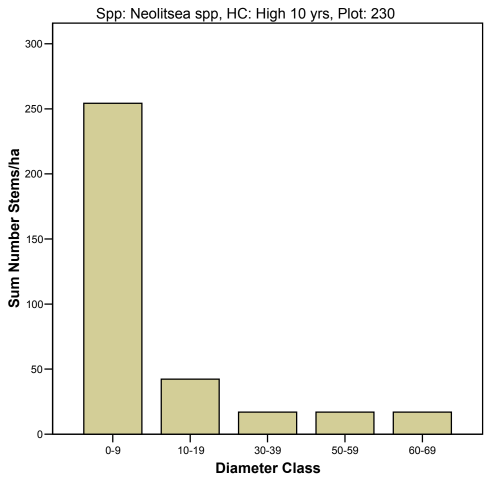


Figure 48. DBH distribution of *Neolitsea* in a plot with no harvest for 30 years

Figure 49. DBH distribution of *Neolitsea* in a plot with high harvest for 10 years



9.10 CV

Personal data

Name	William Buffum
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	Forestry Consultant, 1996 - 2000
	Protected Area Management Specialist, Indonesia Biodiversity Conservation Project, Chemonics International Inc. 1994 - 1996
	Social Forestry & Curriculum Advisor, Nepal Institute of Forestry Project, International Resources Group, 1993 - 1994
	Assistant Country Director, Nepal, CARE International, 1988 - 1993
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	Agroforestry Extension Advisor, Haiti Agroforestry Outreach Project, Pan American Development Foundation, 1982 - 1985
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Kingston RI, USA	24 October 2007