# OAK FORESTS, LOPPING, AND THE TRANSFORMATION OF RURAL SOCIETY IN CENTRAL HIMALAYA, INDIA

by

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# PROLOGUE

## CONDUCTING ETHNOGRAPHIC RESEARCH IN TEHRI GARHWAL HIMALAYA, INDIA

### INTRODUCTION

The back portion of the TATA truck reeks of urine of previous hitch-hikers who did not manage to hit the roof of the driver's section hard enough to ask him to stop in time. Banging the roof with your fist is the only way to communicate with the driver once you have boarded the truck. If you were lucky, you got a truck that was transporting string beans or cauliflower which meant you were guaranteed a comfortable seat. However, if it was empty, you had to stand the entire ride hanging-on to the wooden sideboards. If you ever loosened your grip, you would be thrown to the other side of the truck every time the driver turned a corner on the narrow roads that wound around the Himalayan Mountains.

In 1993, the ride to Beli village took nearly two and a half hours from Mussoorie. The first hour was fairly comfortable since Tehri Road was paved. But once we reached Suhakholi and headed towards Tatyur, it became a dirt road. As we drove along, we would cover everything along the road with a cloud of dust.

Beli village is nested in the valley between two mountains. So it suddenly appears in front of you when you turn the corner. The houses are lined in neat rows above the road along the slope of the mountain. The walls of the houses are made of stone and sealed together by mud, and the roofs are made of slates of black shale. The second floor veranda is framed by ornately carved wooden arches and pillars. On the walls at each end of the veranda are small rectangular mirrors which face the front of the house. These mirrors are for decoration and reflect the sun as it rises above the mountain ridges.

When I returned to Beli village in 2006, some of the old ornate houses were abandoned and others were being torn down and replaced with brick and concrete houses with tin roofs. This visible difference in architectural preferences indicated a much deeper change that was occurring in the lives and attitudes of the people of Beli village that is intertwined with their relationship with the forests surrounding the village.

## CONDUCTING ETHNOGRAPHIC RESEARCH IN TEHRI GARHWAL

### Facilitating factors and barriers for conducting ethnographic research in a Himalayan village

There were five main facilitating factors for conducting research in the village. These factors were: (1) the existing trust between the villagers and myself that was developed during the summer of 1993 during the baseline data collection period. I returned to the village in 2000 to request permission to return again in 2006 and was granted the permission; (2) I am fluent in Hindi, one of the national languages of India and Nepali a vernacular very similar to the local Garhwali language. Being able to communicate directly with the people greatly facilitated the trust building process; (3) since I grew up in the region, I am familiar with the local culture and customs thereby reducing the chance of unconsciously doing anything disrespectful. In 1993, I made considerable effort to attend all the important religious ceremonies and greatly increased the trust and respect that the people had for me; (4) being a female researcher greatly facilitated the interview process since the fodder collection groups mainly consisted of females, it was socially acceptable for me to follow the women into the forest every day; and (5) being an Asian woman with black hair enabled me to physically blend in with the local population reducing the "foreignness" or outsider aspect.

There were five main barriers for conducting ethnographic research in the village. These were: (1) being a foreigner or outsider, I needed to ensure that trust was carefully built between myself and the villagers, and sensitive to any social customs or norms; (2) the region, being in close proximity to the Chinese and Nepali borders, is a sensitive area for the Indian military and prudence needed to be exercised to ensure that I did not take any action that drew unnecessary attention to my research activities; (3) there has historically been distrust of government representatives by the local people, and I needed to strike a balance between requesting information from the government representatives and ensuring that the village people saw me as a neutral figure; (4) most of the people in the village can not read and write, and it is easy for an outside researcher carrying a pen and paper to seem intimidating. It was very important for me to be sensitive to this perception and limit incidences where the villager may be required to write anything down such as consent forms and detailed maps; and (5) I needed to ensure that the research was conducted in such as way that it did not raise the expectations of the villagers for any immediate change in the management of the forest by the government.

The main factor in overcoming any of the barriers mentioned above was being extremely clear and consistent with my agenda and purpose in the village. I spent time explaining to as many people as possible in the community about the goals, objectives, and activities of the research. It was important to be transparent in every action that I took. Unless there was sensitive information contained in my notebooks, all written documents were made available for anyone in the village who was interested. Finally, the most important attitude that I needed when conducting this research was humility and the willingness to listen.

## The ethnographer

Though I am a Japanese citizen, I moved to India with my parents at the age of four in 1973. My parents moved to India nearly 40 years ago to pursue their passion of working with the rural poor and assisting them to become self-reliant through rural development activities and education. My father went on to found the College of Continuing and Non-Formal Education at the Allahabad Agricultural Institute Deemed University. My mother founded many primary schools in the Harijan[1] villages of Madhya Pradesh and also began a rural women leadership program along side my father. Growing up with parents who were immersed in rural development gave me early exposure to village life and its customs and culture. I was enrolled in a local school and acquired Hindi as my first foreign language. At the age of six my parents enrolled me in a small international boarding school located in the small town of Mussoorie in Tehri Garhwal Himalaya. The school is located at an elevation of 2,000 m in the foothills of the Himalayan Mountains. I stayed in the school until my graduation at the age of 18.

[1] Meriam-Webster dictionary definition: a member of the outcaste group in India

During the 13 years in Mussoorie, I took many hikes into the surrounding mountains and in high school participated in projects that visited rural villages organizing health clinics and local scholarship projects for the village children. It was on one of these volunteer trips into the rural areas when I that I noticed the peculiar poodle-like oak trees that surrounded the villages. I asked the medical doctor that I was assisting why the trees had such a peculiar appearance. He replied that the villagers were lopping or cutting the branches, causing the trees to gain their peculiar appearance, and that the villagers would eventually destroy the forest. However, his response raised another question in my mind, "Why would the villagers destroy something that their entire livelihood relies upon? Are they truly destroying the forest, or is that simply an outsiders' opinion?"

I was finally given the opportunity to pursue the answer to my question in 1992 when I began my Master's program. My upbringing and environment prepared me to work in Garhwal; I spoke Hindi, knew the village culture and customs, and had worked in Garhwali villages.

In this chapter I would like to share my experience as an ethnographer in Beli Village in Tehri Garhwal Himalaya. My experience may assist others, conducting research in rural Himalayan villages of India.

## Settling into Beli village

In 1993, I contacted an American missionary who was born in Kashmir and lived in Mussoorie off and on for over 60 years and had been conducting a rural community development project in Garhwal region for over 15 years. He knew the people and the

Garhwal region extremely well. I asked him if he knew of a village that met the criteria that I needed to conduct my research i.e. a village that had a forest that had been protected with a frequently disturbed forest at the same elevation. He mentioned that he knew of a village nearly two and a half hours away from Mussoorie that had a protected forest; however, he had neither visited it nor knew of anyone who had. He suggested that I go with his assistant who was a local Garhwali who could establish rapport with the villagers and then ask their permission for my stay.

On a Friday, his assistant and I traveled to Beli village in a jeep and a man came out to greet us on the dirt road. I found out later that the man, M. B., happened to be an opinion leader in the village and managed the ration store. The assistant introduced himself, and M. B. took us to his home. When we were seated, they started talking about the crops and how the harvest was that year. Then they discussed hunting and the wild animals in the forest, and the gentleman showed us his rifle. Meanwhile, I sat quietly for nearly two hours. In the last five minutes of the conversation, the assistant said as if in passing, "By the way this girl would like to live in your village and learn how you use the forest. Would that be possible?" The man immediately gave his content and the assistant asked him what I needed to bring and whether accommodations could be arranged. The gentleman said he would arrange a room and I could come whenever I wanted.

Thus, on Monday the following week, I arrived at Beli village alone with two *salwar kurtas*, a sleeping bag, plastic bucket, a cooking pot, a kerosene stove for cooking and some rice, *dal* lentils, salt and *masala*, tea and sugar. My room was located next to the primary teacher's room. She was about my same age and being a teacher, was respected by the villagers. I was able to establish rapport with her immediately.

Knowing the peoples' suspicions and distrust of outsiders, I made every effort to look like an Indian. In order that I do not look too foreign I dressed in *salwar kurtas* always keeping my chest covered with a *chunni or dupata.* I also spent two years growing my hair until it was waist length so that I would have the same length hair as the other girls my age. I was fortunate to have black hair and look Asian.

For the first three weeks of my four-month field season, I lived in the village alone. I did not collect any ecological data during those weeks but spent the time becoming more familiar with the people, lifestyles, customs, and culture. Since I am fluent in Hindi, I joined groups that were sitting around chatting and when they asked me what I was doing in the village, I would explain that I was there to learn from them about how they used the forest. I went to the agricultural fields and joined the forest fodder collection groups when I was invited.

Then, seven years later, during the summer of 2000, I returned to Beli village with a packet of more than one hundred photographs that I had taken during my stay in 1993. I wanted to request permission to return to the village sometime in the future to stay with them and learn more about the forest from them again. This visit and renewed contact paved the way for my return in 2006 for the second phase of my field work.

A crucial factor that enabled me to move into the village was that I was female. I was clearly told by the men in the village that they would have never permitted me to live in the village if I had been a man. My research entails following the villagers into the forest going to collect fodder everyday. Since most of the people in the groups were women and girls, it would have been extremely inappropriate for a man to go along.

There was a delicate balance that needed to be maintained between outsiders and the people who live in the village. Three incidents occurred during my field work in 2006 that confirmed the deeply grained distrust of outsiders and male outsiders in particular. The first incident was the enactment of new rule by the village *panchayat* or council that would require any outsider who stayed in the village to pay a tax of Rs. 500 per day. This was in response to the increasing popularity of the village for local Garhwali film crews to shoot movie scenes around the village due to its picturesque location. There were several reasons given for the enactment of the new tax. Some said that the entire village should benefit from the filming and not just the family that was providing room and board to the crew. Others explained that the tax was to discourage more film crews from coming to the village.

The second incident occurred in August 2006. It was when trenches were being dug along the road for new telephone lines. Nearly forty to fifty construction workers had arrived from Saharanpur, a city in the plains, and they were camped several kilometers from the village. They worked during the day digging the trenches for the wiring. However, several of the workers undressed and worked in their underwear briefs and undershirts, attire common in the plain regions. This upset the villagers who did not like the workers dressing so inappropriately in front of their women. One night, around 11 PM, nearly 40 village men proceeded down the road towards the workers' camp in order to beat up the workers. The incident was prevented when a local high school teacher intervened and mediated the dispute.

The third incident also occurred in August 2006, approximately four months into my stay at the village and two weeks before my departure from the village. By then, the villagers had gotten used to my presence and I was treated as an "insider" and people had gotten comfortable enough to confide village secrets with me. I had made every effort to build trust with the people; however, it was very difficult to fully comprehend the limits of boundaries up to which the researcher is permitted to encroach. I made an error in my judgment when I forgot that every foreigner was first considered an "*angraiz*" or a Britisher due to the history of colonialism in India. When I had arrived in the village, I had been very explicit of the fact that I was Japanese and not and "*angraiz*".

The incident occurred after I had been invited to my *alma mater* located in Mussoorie to give a presentation on my research to high school students. Several of the students expressed their interest in visiting the village and I agreed to show them around. In my previous stay in 1993, a female white American teacher had come to visit and they villagers had welcomed her, therefore, I had felt fairly confident that the villagers would permit outsiders into the village if they were introduced by me. However, the critical difference was that this time the teacher bringing the students was a white British male. When I proceeded to take the teacher and his students to one of the three village settlements, the *panchayat* leader came rushing up to me and commanded me to take them down to the road side and clearly indicated that outsiders were not permitted into the village above the road without first receiving permission from him. Considering the fact that I had been very close to the *panchayat* leader and his family, having been invited to his house for dinner several times, I was quite shocked at his reaction. Later, I asked the other villagers sitting around in the small "*dhaba*" or tea shop where I usually wrote my field notes, why he had gotten so upset. They all agreed that he had been right to be upset and that I should not have taken outsiders into the other areas of the village because it would give an impression that anyone could enter the village at their own will.

The attitude towards outsiders and the feeling of the need to protect the village from intruders had also intensified. I later found out that the main reason for the increased distrust of "*angraiz*" was due to an American male missionary who arrived in the village in 2003 and opened a Christian reading room in a rented room close to the road. He had tried to preach about Christianity to the local people. The villagers had welcomed him without knowing that his aim was to convert people to Christianity. Though the reading room was closed within a year, the people became increasingly suspicious of outsiders. Without knowing what had happened in the last few years, I misjudged the degree of protectiveness the people had developed for the village.

There were also distinct differences in 1993 and 2006. In 1993, the people had very limited exposure to the world outside their village. The road that ran along the village was opened in 1978 and only had one passenger jeep that made one round-trip a day from Mussoorie to Thyatur. I traveled from Mussoorie to the village by hitch-hiking on the back of trucks that carried produce from the villages to Dehra Dun. There was no phone or electricity supply. Therefore, there was no television and only few people owned radios.

The increase in economic disparity between families was clearly evident in 2006. By 2006, the road had been paved and there were about eight jeeps that made round-trips into town. There were people in the village who became wealthy enough to own jeeps and trucks which they rented out. When I visited families to interview, some had enough milk to sell and make *paneer* whereas others did not have enough milk to make tea. By the end of my four months in the village, I had been invited to eat at every single Rajput family home. However, in 2006, I was offered food in only a few homes. The *panchayat* leader also made a comment when I had taken the guests to the *chan* that illustrated the change in the degree of self awareness. He said I should not bring the visitors to the *chan* because “no one was dressed appropriately and did not want others to see how they lived.” Though I had been aware all along about how privileged I was to be permitted to live in the village and go deep into the forests with them every day, this reinforced the special exception that the villagers had granted me.

During the last week of August and a day before my departure, I requested that my parents and my assistant’s father to be permitted to visit the village and express their gratitude to the villagers for allowing their daughters to stay in the village. This was a way to demonstrate to them my sincerity and that I was not there to do any harm.

## Finding an assistant

Finding an assistant to conduct long-term field work in the village was extremely difficult due to the unique qualifications necessary. The critical factor for my research was that my assistant be a woman because, not only would the assistant and I be staying in the same room, but we would also be following the female villagers into the forest every day. It would not have been socially acceptable in the village for a male person to do either. However, there are very few women that fulfill the five main criteria necessary for a field assistant.

First, it was essential that the assistant was local so that she was aware of the local customs and culture. Being Garhwali, she would be able to develop trust with the villagers faster than someone from the plains with whom there was already a historically deeply engrained sense of distrust. Moreover, the main fodder collectors are women who mainly speak Garhwali and have a limited understanding of Hindi. Since I speak only Hindi and can somewhat understand Garhwali, the assistant needed to be able to speak both Garhwali and Hindi and be able to interpret when necessary.

Second, the Hindu caste (*jati*) of the assistant was important since most of the villagers are from the Rajput caste. Because my research involved visiting various families and at times eating with them, the assistant needed to be of a caste that would not offend the people if she ate with them.

Third, the assistant needed to be accustomed or willing to walking long distances in mountain terrain every day. The assistant also helped in setting up measurement plots in forests on extremely steep slopes. Therefore, the assistant needed to have the stamina to scramble up and down slopes.

Fourth, the assistant recorded all the ecological measurements that I conducted. Therefore, the assistant required at least an intermediate (High School) level of education. Yet, finding an educated assistant was very difficult because until recently, it was considered a negative factor for a local Garhwali girl to be "over-educated" or be educated at an intermediate level or above. The reason being that it would decrease the chances of her finding a husband since she would need to find someone who was just as well-educated, which was still rare in the villages. In addition, an "over-educated" girl was considered not useful as a wife because she was not capable of carrying out agricultural work or tended to dislike menial labor. My assistant in 1993 clearly demonstrated this issue. The assistant was an 18 year-old who had been educated to the intermediate level, and the daughter of an employee at my *alma mater*. The amount of salary I had provided her over the four months was enough to pay for a Bachelor level education at a local university. Therefore, I spent time explaining to her about how to open a bank account and save the money. Yet, in the following month, she used the entire amount to buy several new *salwar kameez* suits and she told me there was no point in getting any more education because she would not be able to find a husband if she did.

Fifth, in order to conduct my research, my assistant and I lived together in the village for nearly four months. Therefore, the assistant needed to be unmarried without family responsibilities and come from a family that would permit an unmarried girl to leave her family for an extended period of time without damaging her reputation. Yet, most local Garhwali girls tend to get married between the ages of 15 and 18. Therefore, it was very difficult to find local women who were old enough to leave home on their own and work with me, yet were unmarried and educated.

Both my assistants from 1993 and 2006 were introduced to me by persons currently implementing community development projects in the Garhwal region and familiar with the local customs. Without their help, I would not have been able to conduct any of my research.

**Managing the dynamics between the ethnographic team and the villagers**

In order to gain the trust necessary to gather accurate information, it was important to live in the village and eat and sleep in the same way the villagers do. This was also identified by Berreman (1993) in his research in the 50's and 60's:

"The only hope an outsider has of achieving acceptance is by establishing residence and, through social interaction, acquiring the status of a community-dweller; a slow process at best" (page xix).

I was the first outsider to be given permission to live in the village. And this put me in a unique position of developing trust with the villagers from scratch without having to worry about any preconceptions they may have developed from other researchers.

In 1993, I rented a room with a family. The family had also rented out another room to the local primary school teacher. My assistant and I cooked on a small kerosene stove, ate and slept in the same room. Our diet was very simple. We had rice and *dal* lentils three times a day with some mango pickles. The diet was sometimes supplemented with radish that the villagers gave us. Many times we were invited to the homes of families we went collecting fodder with and by the end of the four months field season I had eaten at every home in the village with the exception of the four Scheduled Caste families.

The floor of the room was made of three layers comprised of wooden boards covered with a thick bed of ferns and the top layer was a mixture made of *gobar*, clay and water. The top layer would become completely dry and needed to be re-applied about once a week. This type of floor kept the home cool during the summer and warm during the winter. It was also easy to clean when you spilt something. However, the problem was that it also provided a comfortable home for mice and fleas. By the end of the first month, my entire body was covered with small red flea bites and I came down with a fever. I later bought some insecticide from the Mussoorie bazaar and sprayed the room every other day.

In 1993, no house had toilet or bathing facilities. Since the village is surrounded by agricultural fields with very few bushes and rocks, it took me a month to figure out the time and place women went to the toilet. I woke at 4:30 AM every morning and went to a small gully behind the village. However, if I was slightly late, I would overlap into the time men would come out and would have to wait until I went into the forest with the village women. Because nearly every villager used the same area every morning, I could involuntarily keep track of the health of the entire village during the dry season before the rains washed all the fecal matter away. I also went for 10 days at a time not bathing and only bathed when I went into Mussoorie to replenish food supplies.

In my second field season in 2006, I rented a room on the second floor of a storage room located close to the road. The building was constructed using brick and cement. This time, the wife of the landlord remembered the difficulty I had had the first field season and offered to build a latrine for us below our room. By this time four households in the village had latrines attached to their houses. Inside our room, a raised ledge was also made in the corner of the room with a drainage hole in the wall so that we could take a bucket bath. Though our room did not have any electricity, by 2006 most houses had an electrical wire connected to them. However, electricity rarely flowed through them. Water was collected from two taps, one located right above the village and the other along the road, and a hand pump well recently built by the Government.

Another important factor that contributed to the people becoming friendly with me and accepting me in their community was the fact that I was extremely transparent in everything I did. I showed my notebooks to anyone who asked. I always gave the same response using the same terminology when I was asked about what I was doing in the village and what kind of research I was conducting. These actions were important to ensure that the same message was being transmitted to everyone in the village and when they checked with each other, they all corroborated. The attitude of humility was also extremely important. I made it clear that I was there to learn from them about how they used the forest. I was not there to teach or advise about anything. Therefore, throughout my entire stay in the village, I never voiced an opinion about the forest nor about their lifestyle. And because I communicated that I was there to learn, the children began coming to my room and calling me to join them on their trips into the forest to collect fodder. Soon, I was going every day into the forest with fodder collection groups and the people would even hand me their branches to be measured.

Being a foreigner, respecting local religious beliefs and being sensitive to the customs is extremely important. The purpose of my living in the village was not to change village customs or beliefs but to record their relationship with the forest and forest resources. The key was to adapt to the customs of my assistants who were both Rajputs. There were two instances which illustrated the delicate balance between my beliefs and being sensitive to the local religious customs. During my first field season in 1993, my field assistant and I had been setting up forest measurement plots in the forest starting at 7 AM in the morning, and by 4:30 PM we had run out of drinking water. As we were returning from the forest, we were very thirsty and were desperately looking for a spring.

We came across a small house at the edge of the *chan* and when an old woman came out of the house, we asked her if we could have some water. She put out both her palms and asked us, “I have water but can you drink from my hands?”  My assistant immediately understood that the old woman was from the Scheduled Caste and she responded, “No.” We thanked the woman and I quietly followed my assistant down the mountain path looking for another potential source of water. I was not in a position to determine whether what she did was right or wrong. These were the social rules that were practiced in the village and needed to be respected.

The second instance was when we were eating lunch in our room in the main village settlement. Since we did not have electricity our only source of light into the room was through the door, so we would sit on close to the door while eating. When we were in our room, it was common for the village children to come to visit and chat with us. One afternoon, several children came and were chatting with us when a 10-year-old girl joined us. Though she still took part in the conversation in a loud voice, she stood at the edge of the veranda, far away from the door. She only came to the door once we had finished eating. I had first wondered why she stood so far away, but realized that she was a Scheduled Caste girl and if she had stood at the doorway her shadow would have fallen into the room and may have touched my assistant’s plate of food, contaminating or polluting it. I let her stand there so that neither she nor my assistant would feel uncomfortable.

Another aspect that I needed to be careful about when collecting social data was as the first outsider to live in the village, the people would try to impress me in the beginning. Therefore, I kept my notes from the first month separate from my notes taken later to have a comparison of the facts that the people were telling me.

Finally, in order that I was not the only one taking information and learning from the villagers, as an expression of my gratitude, I took several boxes of *ladus* to the village when I first arrived and distributed the *ladus* to children in the primary school and others in the village. I also gave a copy of every picture I took of the people back to them as a gift. In 1993, when I left the village, I contacted an NGO who conducted health clinics in the region and asked them to visit the village and develop a health facility in the village if the villagers desired.

## CONCLUSIONS

As an outsider conducting research in a society that is very protective of its people, I needed to be very conscientious of the various barriers to acceptance that exist when entering the village. As Berreman (1993) also states, the researcher is judged by their own character and who they are associated with, including their assistant. Therefore, the selection of my assistant was of utmost importance. Moreover, I endeavored to associate with as many social groups in the village as feasible within the social norms of the society in order to get a wider perspective. Nevertheless, though I made every effort to facilitate building of trust between the people, the information that I collected is totally dependent on how much the people are willing to tell me.

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# ABSTRACT

## OAK FORESTS, LOPPING, AND THE TRANSFORMATION OF RURAL SOCIETY IN CENTRAL HIMALAYA, INDIA

by

Yuka Makino

Villagers are blamed for degrading the forest by lopping oak branches for fodder in the Central Himalayan region of India. Yet, research is lacking on the direct relationship between peoples' livelihood, lopping, and forest regeneration. In this 13-year study, I assess the effects of lopping *Quercus leucotrichophora* A. Camus and *Quercus floribunda* Lindley ex Rehder on forest composition, regeneration, and socio-economic conditions in Beli village, Tehri Garhwal Himalaya. Specific objectives were to determine: (1) the relationship between villagers and their use of the forest, (2) the lopping process, and (3) the influence of lopping on oak forest stands, their persistence and regeneration capacity.

In this study, data collected in 1993 and 2006 combine both ethnographic and ecological research methodologies to assess changes in the socio-economic conditions and in the forest. Face-to-face interviews and household surveys were conducted in 37 households out of 144 in Beli village. Method of fodder collection, type of branches and trees lopped, and amount of foliage collected were recorded for 49 collection trips. Data on physical site properties and on forest composition and regeneration were collected in 1993 and 2006 from a protected and a lopped forest.

The livelihood of the villagers is maintained by gender and age roles in households, availability of oak foliage, number and type of livestock, and type of agricultural production. The diameter of branches lopped in 2006 was significantly smaller, and weight of fodder bundles carried by females was significantly greater in 2006. Both effects reflect the villagers' strategies to adapt to decrease in oak foliage. They are increasingly sending their children to school and decreasing their reliance on agriculture for income.

The oaks have maintained their abundance, and pines have not become abundant or dominant in the overstory or ground-cover. Oaks accounted for 69.3% of the overstory stems in the lopped forest, whereas, pines only accounted for 1%. The greater number of oak stems regenerating in the ground-cover of the lopped forest compared to that of pine indicates that oaks continue to establish themselves. The oaks have the greatest coverage in the ground-cover of both the protected and lopped forests.

# CHAPTER I

# INTRODUCTION

The controversy between foresters and villagers over access to forests has existed in the Central Himalayan region of India for over 120 years. Conflict between the gradual "degradation" of forests and local villagers' need for fodder presents a major challenge for resource mangers. Using available research data, government foresters have assumed that the cause of forest degradation is largely due to the villagers' practice of lopping (i.e. cutting) branches of broadleaf evergreen oak species. The negative perspective of the foresters concerning the lopping practice is reflected in most of the literature on oak-pine forests in the Central Himalayas. The potential for "wanton destruction" of oaks was observed and recorded by Gorrie as early as 1937. He claimed that the "oaks everywhere in accessible Government forests have been so mutilated by continuous lopping that they are rapidly dying out" (Gorrie 1937). Later literature on forest use by the villagers also targeted lopping as the cause of the degradation of forests. Chaturvedi (1985) wrote that "the *banj* [*Quercus leuchotrichophora* A. Camus] forest and the water springs associated with the forest disappear."

Yet, the consistent supply of oak fodder for livestock is the key factor in the chain of interactions that sustains the livelihood of village communities of the Central

Himalayan Region (Negi 1977; Nautiyal *et al.* 1987; Moench 1989; Makino 1994; Rathore *et al.* 1995; Negi *et al.* 1997; Reddy & Chakravarty 1999). The livelihood of the these village communities is based upon income from agricultural production (Singh *et al.* 1984). The agricultural production is dependent on the availability of compost or *gobar* to fertilize the fields. *Gobar* is made by mixing dung and urine of buffalos, cows, and goats with dry oak or pine leaf litter from the forest floor. Therefore, the collection of fodder is the first step that turns the wheel of the agricultural economy of the village community (Makino 1994).

However, no systematic research on the effect of lopping and the dependency on the forest by the villagers has been conducted. There is limited understanding of the relationship between the practice of lopping and “forest degradation”. Forest degradation has been defined in the research in this area as the change in overstory composition from oak to pine and the inability of the oaks to return as the dominant overstory species.

In this 13-year study, I assess the effects of lopping *Quercus leucotrichophora* A. Camus and *Quercus floribunda* Lindley ex Rehder on forest composition, regeneration, and socio-economic conditions in Beli village, Tehri Garhwal Himalaya, Uttaranchal, India. Data were collected over two field seasons, one in 1993 and the second, in 2006. Specific goals of my research are to: (1) determine whether peoples’ dependency and forest use has changed since 1993 and, if so, the reasons for such a change; (2) gain insight into the lopping practice and how the trees are affected; (3) determine how lopping has changed the species composition and regenerative capabilities of the forest since 1993; and (4) ascertain how such changes affect the future regeneration of oaks and pines.

This is a three part multi-disciplinary research project. It combines ethnographic and ecological methods to examine the practice of lopping and its consequences to the rural society and composition of forest ecosystems.

In the first part, I examine the socio-economic aspects of forest use. This part examines how the interaction between individual households, forest use, livestock and agriculture maintain the socio-economic balance in the village. The research goal for the ethnographic study is to determine the sustainable and socially acceptable balance between utilization of the forest by the villagers and the provision of fodder resources by the forest ecosystem within the context of socio-economic change. The specific objectives are to determine: (1) the extent of peoples' dependence on the forest; (2) the underlying social, cultural, religious and economic basis of peoples' dependence on the forest; (3) forest change and its influence on village society; and (4) peoples' perspectives on forest management. The main tools used for data collection were informal observation, face-to-face interviews, and household surveys. Face-to-face interviews and household surveys were conducted in 37 households out of 144 residing in Beli village. The details of the methods and findings are found in Chapter II.

The second part of this research project examines the lopping process used to gather oak foliage from the forest used for fodder. The objectives are to examine factors that influence the lopping process, specifically: (1) fodder collection methods including lopping techniques and site selection; (2) lopping practices, including the tree species lopped, the diameter of the branches and trees lopped, and the weight of oak foliage bundles; and (3) socio-economic status of households and kinship relationships. Data on method of fodder collection, type of branches and trees lopped and amount of foliage collected were recorded for a total of 49 fodder collection trips in 1993 and 2006. The details of the method and findings are presented in Chapter III.

The third part examines the composition of the overstory layer in oak-dominated stands and how lopping of oaks affects the regeneration of the oak and pine species.

The objectives are to determine: (1) the abundance of oak species in the overstory, (2) the abundance of oak vs. pine regeneration, (3) the relative extent of oak and pine regeneration, and (4) changes in tree and ground cover species composition.

Baseline data on the site properties, regeneration, and overstory were collected in 1993 from both the protected and lopped forests. In 2006, data for the same variables were collected again using the same methodology used in 1993. In 2006, further data were also collected on terrain properties, overstory density, basal area, height and age of overstory trees, coverage, litter, seeds, soil and leaf nutrient content, and soil properties. The comparison of the data gives insight into the effect of lopping on the stand as well as the entire forest ecosystem. The details of the methods and results are presented in Chapter IV.

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# CHAPTER II

# OAK FOLIAGE, LOPPING AND THE TRANSFORMATION OF RURAL SOCIETY IN TEHRI GARHWAL HIMALAYA, UTTARANCHAL, INDIA

I sat in a narrow path in the forest with Devi, a diminutive woman who had been widowed a few years earlier. We were exhausted after climbing the slippery steep mountain slopes and hacking at the tough oak branches to gather a few twigs with foliage. Devi reached into the left breast pocket of her thin vest which all married women wore and pulled out a small packet of *beedis* and a wooden box of matches. She carefully placed a *beedi* between the tips of her thumb and forefinger made sucking sounds as she lit the *beedi*. As I watched her, my young college educated mind made a quick calculation and I suggested, “Do you know, if you stopped smoking for ten years, you could buy one buffalo and make more milk to sell.” Her response was quick and simple, “And who will feed the buffalo? I am one person; there is only so much I can carry. So let me enjoy my *beedi*.”

## INTRODUCTION

The controversy between government policies, foresters and villagers over the access to forests has existed in the Garhwal Himalaya, India since 1897 when the people of Tehri State who practiced shifting agriculture were forced to make permanent settlements (Ram 1988). The 1927 Forest Act codified the reservation of forests; placed boundaries around the forests; and prohibited the village people from cultivating forested land, lopping trees, or grazing livestock in the forest (Shiva & Bandyopadhyay 1986; Rawat 1989). The fundamental flaw in these laws and policies is that they fail to recognize that the consistent supply of fodder for livestock is the key factor in the chain of interactions that sustains the livelihood of the local village communities of Tehri Garhwal Himalaya, India (Negi 1977; Moench & Bandyopadhyay 1986; Nautiyal *et al.* 1987; Makino 1994; Rathore *et al.* 1995; Negi *et al.* 1997; Reddy & Chakravarty 1999; Awasthi *et al.* 2003).

Much of the literature of forest use in the Central Himalayas is written from the forester or government perspective who accuse the villagers of the "wanton destruction" of forests (Gorrie 1937; Tucker 1984; Chaturvedi 1985). Human use of the forest is sometimes characterized as disturbance and considered to have a negative impact on forest stands (Babu *et al.* 1984; Sundriyal & Sharma 1996; Dove *et al.* 2005). Other studies examine the people-forest interactions by analyzing the energy flow between the forest and agriculture (Pandey & Singh 1984; Singh *et al.* 1984; Datt 1993; Negi & Todaria 1993; Tripathi & Sah 2001).

The limitations of these studies are that they do not provide the perspectives of the villagers themselves. The disparity between the perceptions of the community and the forest department on the cause of forest degradation and the management strategy necessary to reduce degradation have been documented in social forestry research (Dove 1995). Yet, even much of the discussions on social forestry does not analyze the socio-economic underpinnings that drive forest use such as livelihood, kinship relationships, gender roles, peoples' perceptions of the forest, and the influence of the changing forest ecosystem.

In order to develop an effective management strategy appropriate to the livelihood needs of the local people and the regeneration capacity of the forest ecosystem, it is imperative to develop a deeper understanding of the intricate inter-relationship between the people and the surrounding forests. We need to closely examine peoples' perceptions on the forest, forest use, and changes in the village society over time.

This study was part of a three part longitudinal and multi-disciplinary research project that combined ethnographic and ecological methods to examine the practice of lopping and its consequences to the rural society and the forest ecosystems. The first part of the project examines the socio-economic aspects of forest use (Chapter II). The second part examines the lopping process used to gather oak foliage from the forest used for fodder. A detailed analysis of the lopping practice itself and the factors that influenced the process of lopping are presented. Data on method of fodder collection, type of branches and trees lopped and amount of foliage collected were recorded for a total of 49 trips in 1993 and 2006. The details of the method and findings are covered in Chapter III. The third part of the project examines how the forest ecosystem and the regeneration capacity of the forest are affected by the lopping of oaks. The impact on the forest ecosystems was determined by examining the overstory, understory, coverage, ground-cover, leaf-litter, and soil nutrients of the protected forest and the lopped forest. The details of the method and findings are covered in Chapter IV.

In this chapter, I document the first part of the research project and examine how the interaction between individual households, forest use, livestock, and agriculture maintain the socio-economic balance in the village. The research goal is to determine the sustainable and socially acceptable balance between utilization of the forest by the villagers and the provision of fodder resources by the forest ecosystem within the context of socio-economic change. The specific objectives are to determine: (1) the extent of peoples' dependence on the forest; (2) the underlying social, cultural, religious, and economic basis of peoples' dependence on the forest; (3) forest change and its influence on village society; and (4) peoples' perspectives on forest management.

## THE STUDY AREA

Beli village (pseudonym is used to protect the privacy of village) is located in the Jaunpur Range, Tehri Garhwal Himalaya, India (Figure 2-1). The village is situated in the temperate montane region of the Central Himalayas that ranges between 1,500 and 3,500 m in elevation. It is characterized by moist temperate mixed evergreen broadleaf and conifer vegetation. The average monthly rainfall from 1993-2006 was 581.4 mm, with the most rainfall occurring in July and August, 2,068.6 mm and 1,574.4 mm respectively (Division 2006b) (Figure 2-2 and Figure 2-3). Fires occur periodically in the conifer dominated region due to natural or human-made causes, particularly during the dry months between April and June (Division 2006a) (Figure 2-4). The vegetation of this region is dominated by *Q. leucotrichophora* A. Camus at the lower altitudes between 1,800 to 2,400 m and *Q. floribunda* Rehder at slightly higher altitudes, ranging from 2,000 to 2,700 m. The forests surrounding the village are classified as Reserve forests by the Forest Department and are not commercially logged.

The village is divided into three settlements, patterned after the historical and cultural transhumance lifestyle of the people in Garhwal before the 1800s (Ram 1988; Moench 1989; Berreman 1993). They migrated annually with their cattle from the plains to higher elevations for two to three months during the summer. Migration from one settlement to another occurs according to the cropping seasons. Living accommodations and fodder-collection cycles are adapted to the agricultural cycles. The main village settlement, referred to by the villagers as Beli, is located at an elevation of 1,854 m and supports 46 permanent houses. The lower settlement or *nadi* is situated in the Aglar river valley, approximately 17 km south from the main village settlement at an elevation of 500 m. The lower settlement is only used in the months of June and July during the potato harvesting and rice-transplanting season. The upper settlement called *chan* is located at an elevation of 2,110 m, approximately 0.70 km from the main village settlement. A road was built passing in front of the village in 1978 and connected Beli village to the nearby towns of Dehra Dun, Mussoorie, and Thyatur.

The village consists of 144 households, with a population of 892 people of which 46 are from the Scheduled Caste and 846 are from the Rajput Caste (Director of Census Operations Uttaranchal 2004). The occupations of the Scheduled Caste families consist of farmers, ironsmiths, and musicians. The people in the Rajput Caste are mainly farmers and merchants. The main source of income is agricultural production.

Beli village was selected because it is the only village in the region with a protected forest that the village community collectively decided to stop using approximately 40 years ago (Figure 2-1). The collection of fodder, grazing, and collection of fuelwood is forbidden in this forest. A forest where villagers lop branches is located diagonally above the northeast corner of the protected forest next to the *chan*. The forest is of similar aspect, elevation, and species composition. The forest is frequented throughout the year due to its close proximity to the *chan*. The presence of a protected forest and a lopped forest in the same vicinity and with similar geology and soil, provided the opportunity to analyze the influence of the people's use of the forest on forest composition and regeneration.

## METHODOLOGY

The data were gathered during the months of May-August in 1993 and 2006. The data collected in two field seasons, separated by 13 years, elucidates the dramatic transformation of the village society between 1993 and 2006 and its influence on community perceptions and forest use.

The methods used for data collection were informal observation, face-to-face interviews, and household surveys. Data sources also included census data, and administrative and land-use maps. The Chief Conservator of Forests for Uttaranchal, District Forest Officer and Agra Block Forest Guard were interviewed to determine current and past forest management practices and policies of the government of the region.

Informal observations were made during fodder collection trips and through my daily interactions with the villagers. They were used to develop a detailed record of individual forest use, and the information assisted in the formulation of the interview and survey questions. Face-to-face interviews and household surveys were conducted in 37 households out of 144 residing in Beli village. The entire population was divided into seven age groups and three females and three males were randomly selected from each age group. Each household was represented only once to avoid duplication of data. The names of the households were selected from the village ration list[2] from 1993, which was updated in 2006 (M. Singh, pers. comm.). The 2006 election register was not used because it did not contain a complete list of all the households in the village. All the males in the 71-80 age group were interviewed, and there were no males in the 81-90 age group. The following is the number of males and females interviewed in each age group: 20-30 (3 male, 3 female), 31-40 (3 male, 3 female), 41-50 (3 male, 3 female), 51-60 (3 male, 3 female), 61-70 (3 male, 3 female), 71-80 (2 male, 3 female), and 81-90 (2 female). Each of the interviews was recorded and their identities were coded to ensure confidentiality.

The aim of the interviews was to characterize the lives of each individual to the present, how they perceived it had changed over their lifetime, and their perception of how it may change in the future. Questions were related to specific time periods in the person's life that they would likely be able to remember, such as when they got married or when their child was born.

The first set of questions focused primarily on the dependency of the people on the forest and their change in behavior towards the forest over their lifetime. The questions were: (1) how many times they used to go into the forest, (2) where and how far they used to walk, (3) at what age they started collecting fodder, (4) what they used for cooking, (5) what fodder species they used to collect, (6) the extent of the edge of the forest at a particular age in their life, (7) what they believe about the forest and religious practices related to the forest, (8) how they used to manage the forest, (9) how many livestock people owned, and (10) the change in the extent of agricultural fields. I also

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[2] Ration cards are issued by the Government of India and is used for the procurement of essential commodities at a subsidized rates, and is also used as a form of identification.

asked each person for recommendations on managing the forest, taking into consideration their needs and the regenerative capacity of the forest (Appendix A).

The second set of questions focused on peoples' perceptions of the forest and its importance to their family and village; their emotional and religious relationship with the forest; and finally their concerns about the forest and their feelings about the future of the forest.

## DYNAMIC INTERACTION BETWEEN THE PEOPLE AND THE FOREST

The socio-economic balance of the people in Beli village is sustained through a complex interaction between each individual household, forest ecosystem, livestock and agriculture (Figure 2-5). The main source of livelihood of the people of Beli village is agriculture which is dependent on the consistent supply of *gobar* or manure to fertilize the fields. *Gobar* is produced by composting dung and urine from livestock with dry oak leaf litter from the forest floor. The livestock are either fed fresh oak leaves and grasses gathered from the forest, or they are grazed in the forest. Though the type and species of fodder collected changes according to the annual seasons, oak foliage is collected throughout the year. The number and type of livestock that a particular family can own is determined by the family composition. Since each member of the family has distinct household roles and responsibilities, the availability of people to collect fodder determines how much fodder can be collected in a day.

## Households

In Beli village, joint families[3] usually share one house and eat together in the kitchen. When a son gets married they stay in separate rooms with their wives and children. Therefore, kinship and gender roles and responsibilities are very important in maintaining the household (Table 1).

During various agricultural seasons the joint family is spread across the three settlements of Beli village. Most families have a member(s) living over extended periods of time in the main village settlement while other members move back and forth between the other settlements everyday or periodically. During the agricultural season between mid-March and October, some of the family members move to the *chan*. In families where the head of the family has two wives, one wife usually stays in the *chan* and the other wife stays in the main Beli village settlement. Each wife takes care of the livestock and agricultural fields in their settlement. The *chan* wife goes to higher elevations and walks greater distances to collect oak foliage and grass than the wife who lives in the main Beli settlement who tends to go to forests lower elevations closer to the village.

The cows are usually grazed in the lower elevations and are not taken to the higher elevations because of the limited availability of grass on the forest floor. Relatives sometimes share the responsibility of grazing each others' cows. Whoever is going out to collect fodder takes the cows with them and leave the cows in the forest. In the evenings, the cows return to the village and enter their stalls on their own. During the months of June and July when the rice is being transplanted, most of the joint family move down to

[3] A joint family is defined as "a patrilocal extended family under the leadership of the eldest active male" Berreman, G. D. (1993) *Hindus of the Himalayas : ethnography and change*. Delhi ; New York: Oxford University Press.

the *nadi* and help each other in transplanting rice. A few remain in the main Beli settlement to look after the buffaloes which are unable to walk down the steep mountain slopes.

The hierarchy of decision-making in the family is very clear. The eldest woman or the matriarch in the family decides what work needs to be done in the fields and what should be collected from the forest. One woman [40] explains,

"When there is a mother-in-law then we have to work. When she is around we are scared of her and work hard. …If I do not collect what is required [from the forest], I would be scolded. I would not go home without collecting anything because they would say I have spent all day outside and neither helped with the field work or brought back any fodder for the livestock."

The wives and daughter-in-laws are responsible for planting and harvesting the fields, threshing the wheat, taking care of the livestock, milking the cows and buffaloes, going into the forest to collect grass and oak foliage, cooking, spreading *gobar* (a mixture of cow dung and clay soil) on the floors and walls of the houses, and grazing cows. The first wife (in the case where there are two wives) is responsible for deciding what needs to be done that day and who will be responsible for carrying out the chores.

Daughters between seven and 10 years-old are responsible for looking after their younger siblings, fetching water from the stream or tap, grazing goats, gathering fuelwood and collecting leaf-litter from the forest floor. They are sometimes sent into the forest to collect grass because they are not yet able to climb trees with a sickle. The girls learn to climb trees and lop branches from the age of 10. Unmarried daughters between the ages of 10 and 18 are responsible for collecting oak foliage and grass for fodder, helping out in the fields, and cooking.

The husband is responsible for taking the produce to the market, running the store if they own one, plowing, sometimes helping out in tilling and harvesting the fields, and grazing goats. Before the road was built in 1978 between Tehri and Thatyur, the husbands used to leave at 4 AM to take the milk to a nearby town, Mussoorie, on a mule and return late at night. During harvesting season, the husband walked several days with a mule to take their produce down to the vegetable wholesale market located in the large town of Dehra Dun.

Sons between seven and 10 years-old are responsible for fetching water from the tap or stream, grazing the goats and cows, gathering fuelwood, gathering leaf litter, and collecting shrubs and grass for fodder. Many of the sons are sent to primary school in the mornings. Sons younger than 15 years-old also help in fetching water if their siblings are too young or if they do not have younger siblings. The sons between 10 and 18 years-old are responsible for collecting oak foliage from the forest.

Many parents begin taking their children into the forest when they turn four. Once I even accompanied a four-year-old girl who collected grass in a burlap sack and carried it on her head. On another occasion, I asked a mother why she brought her four-year-old son who could barely manage to carry a few branches, she replied, "You need to teach a child to work at a young age, then, they will learn the habit of working. Once they learn laziness, they will be lazy for the rest of their lives."

The responsibility of taking care of livestock is shared by the family members. Fodder in each household is usually collected by the unmarried sons, unmarried daughters, daughter-in-laws, mothers, and grand-mothers. The sons collect only oak foliage. The women alternate between grass and oak foliage depending on the seasons.

The grazing of cows is usually done by sons less than 10 years old. Grazing of goats and sheep is done by sons less than 10 years-old or by grandfathers. Therefore, the composition of the family determines the labor available for fodder collection and ultimately the number and type of livestock that the household can own.

**Peoples' dependence on the forest**

Beli village is unique in the region because the villagers have a heightened awareness of the importance of forests and trees. The village has protected their *panchayat* or village forest located immediately above the village since the early 1970s. After a particularly severe monsoon storm, a long and deep crevasse appeared in the forest, and the people feared that a landslide would wash the village down the mountain-side. A representative from each family gathered together and decided to establish a forest preserve in order to protect the village. The protected forest has been opened and closed several times after it was officially closed due to conflict which arose when some people "stole" fodder from the forest. The forest is also opened for one day in February or March if there is a shortage of fodder on a date determined by the *panchayat* or village council.

The theme of absolute dependence of the people on the forest for their survival was repeated throughout each of the interviews. The depth of the dependence and the powerful emotion that the forest evokes in the people is reflected by the words of each person:

"Our life is the forest. The forest is everything for us." [M-26][4]

[4] The letter denotes gender, M=male and F=female and the number denotes the age i.e. [gender, age]

“The forest is necessary. When there is forest, people will exist. Without forest what can we do? There are not many employed people, so we are all dependent on agriculture. Without forest we will be powerless and helpless. The forest is absolutely necessary. Without forest we will need to decrease the number of buffaloes.” [M-79]

“If there is no forest we will die. The forest is the foundation of our lives and without the forest we will all die. I wish that there will be more forest. I wish that we did not have to go into the forest and collect fodder, but what can our family do? To collect fodder is essential. So what can we do?” [F-62]

The main reason the forest is so important to the villagers is the demand for oak foliage for fodder. The important of the forest for their livelihood is reflected in what people are thinking of when they are collecting fodder. A 60 year-old woman replied,

“I am thinking about what I will plant in the fields. By collecting fodder, I am hoping that the animals will be healthy and provide milk. I am thinking about what I need to plant, harvest and other things I need to do on the field. I am not thinking about the forest at all.”

Oak foliage is collected for stall-feeding buffaloes and cows. Besides the oak foliage, the cows, goats, and sheep are also grazed in the forest. The dried branches from previous fodder collection trips and left over oak twigs after the livestock have eaten the foliage are used as fuelwood for cooking and heating during the winter.

The primary purpose for keeping the livestock is for their dung and urine to make *gobar*. *Gobar* is made by mixing leaf litter with dung, droppings, and urine of the livestock put in a pit for decomposing for three to eight months. The villagers prefer *gobar* from cows, followed by goats and then buffaloes. They claim that buffalo urine and dung are thicker in consistency than that of cows; therefore, it stays wet longer and decomposes slower, whereas, the cow dung and goat droppings are drier and decompose faster (Table 2-2). The composted matter is spread on the fields as fertilizer.

The villagers prefer to use compost from the livestock to the commercial fertilizers because the urine also acts as an insect repellant. They also insist *gobar* produces better harvest, healthier crops, and tastier vegetables [F-76, F-48]. Most importantly, the compost is free, whereas, both the fertilizer and additional pesticides must be purchased. The buffaloes and cows also provide a secondary source of income through their milk. The milk is sold as milk or used to make *paneer*, a type of cottage cheese. The *paneer* is sold to nearby towns such as Dehra Dun and Mussoorie. These practices were also observed in other villages in Garhwal by Moench *et al.* (1986) and Berreman (1993).

Fodder consists of fresh green oak foliage, green or dried grass from the forests, green grass from the agricultural fields, and dried wheat or rice stalks. The type of fodder collected throughout the year differs according to season (Table 2-3) and settlement (Table 2-4). The principal sources of foliage are low elevation oak *Quercus leucotrichophora* A. Camus or *banj* collected throughout the year, and high elevation oak *Q. floribunda* Rehder or *moru* collected during the summer months (Singh 1982; Singh & Naik 1987; Makino 1994) (See Chapter III for more detailed explanation of fodder collection). The villagers claim that the oak leaves are fed to the livestock simply to fill their stomachs and do not play a role to increase milk production [M-50]. *Moru* is fed to the livestock in the summer and not in the winter because it makes them "cold". Though *banj* is fed all year round, it is considered to be "warmer" than *moru*, and less is fed to the livestock in the summer. *Burans* (*Rhododendron arboreum)* makes the animal "warm," therefore, is sometimes fed to the livestock in the winter when nothing else available [M-41].

The favorite fodder for the cows and buffaloes is green grass, which is available in the forest during the monsoon months. The villagers believe that the animals produce more milk when they eat it. The women over 30 prefer to gather grass rather than oak fodder because they do not like climbing the trees, and the livestock can eat everything that is gathered. Males of any age do not gather grass and prefer to lop oak trees for foliage because it easier to climb a tree and get all the fodder at once.

The method the villagers use to collect the oak foliage is called lopping and involves a person climbing the tree and cutting off branches (Detailed explanation of the lopping practice and fodder collection is covered in Chapter III). The larger branches are left to dry and later collected as fuel wood, and the smaller twigs with the foliage are gathered into bundles and carried back to the village.

## Livestock

Each type of livestock has different feeding requirements. Therefore, the number and type of livestock that each household owns is dependent on the supply of fodder, which is determined by number of family members available for fodder collection.

Buffaloes are kept for both *gobar* and milk production, whereas, cows are kept mainly for *gobar*. Cows produce less milk than buffaloes. For example, in 1995-1996, each cow in the villages of Uttaranchal produced an average of 1.85 kg of milk per day in comparison to 3.13 kg from buffaloes (Singh & Tulachan 2002). Buffaloes are always stall-fed because they are heavy and cannot navigate the narrow and steep paths along the mountain-side. Cows are mostly grazed and sometimes stall fed, particularly in the winter. Some households prefer to keep buffaloes because many more cows will be necessary to provide the same amount of milk that one buffalo can provide. Others prefer to keep buffaloes because although cows can be grazed during the warmer months, owning more cows means more fodder needs to be collected and stored for the winter when the cows cannot be grazed in the forest. Bulls are grazed with the cows. They are used for pulling the yoke to plow the fields and always kept in pairs.

Goats and sheep are kept for *gobar* and cash flow. Since they are grazed all year round and by one person, they are less labor intensive to feed. The mules are fed grass, chickpeas, and sometimes *ghee* or clarified butter which is bought from the markets. The mules have been, until recently, the main source of transport to carry produce or milk to the markets.

## People and the forest

Though the people expressed the importance of the forest to their livelihoods, there was very little mention of spirits or gods in the forest in any of the interviews. Gods were mentioned only twice in relation to the forest. The gods were mentioned where a natural spring used for drinking water was designated as '*devta ka pani*' or 'god's water'. People had consecrated the area and the trees around it. Also, the cutting of grass or trees around it was forbidden. However, over time, peoples' reverence of the '*devta ka pani*' has decreased. The natural spring that existed in 1993 dried up by 2006, and the area around the spring was cleared and used as an agricultural field.

There are also *mandirs* or temples built by each *jat* or caste in the village in the surrounding forests. *Puja* is sometimes performed at these *mandirs* to call the rains, during particularly dry seasons. The land around the *mandir* is also considered sacred and people must enter the land barefooted.

In the past, the villagers believed in the presence of ghosts or *bhuts*. In the summer of 1993, a girl was possessed by a ghost recognizable by her eyes rolling back and incoherent speech. When asked about ghosts in 2006, the people replied that there were currently no ghosts in the village and that such incidents do not occur any more.

When asked about what they feared most in the forest, all of those interviewed replied that they were scared of wild animals such as bears (*Melursus ursinus*) and *bagera* (*Panthera pardus*). Some villagers have had their grazing goats and cows attacked or killed by the bears and *bagera* in the forest. Therefore, the villagers prefer not to enter thickly forested areas where the wild animals tend to reside.

Considering the fact the people have been going into the forest since their early childhood and for centuries, there are very few stories or legends that have been passed down from generation to generation about the forest. There is only one story told to children that is known by everyone in the village. It describes a bird cry heard during the *kaphal* (*Myrica esculenta* Buch-Ham ex D. Don) ripening season.

"*Kaphal pakka. Mai nahi chaka*"

(translation: the *kaphal* is ripe, but I did not eat it.)

"The story goes like this. A woman went into the forest and collected *kaphal*. She left the basket filled with *kaphal* in the sun in the morning and told her daughter not to eat it. But, when she came back in the evening, the basket was no longer full. She got mad and beat her daughter to death. At night, the dew fell on the *kaphal* and it swelled back to its original size. She realized that her daughter had not eaten it and she died of grief. So they now sing together." [F-55]

## CHAIN REACTION: THE TRANSFORMATION OF RURAL SOCIETY

In 2006, the fundamental interaction between the household, forest, livestock, and agriculture had not changed. However, there were significant differences in the composition of each of the components. The decrease of oak foliage was brought about fundamental changes in the villagers' sources of income and ultimately the roles and responsibilities of each family member.

The change was initiated by the construction of the road passing in front of Beli village in 1978 (Moench 1989). The road gradually brought with it easier access to markets and surrounding villages, exposure to new ideas and with it easier access of outsiders to Beli. With the construction of the road there was gradual increase in the traffic in the region. In 1993, there was only one jeep that transported both people and agricultural produce to the towns in a day. By 1995, there were jeeps running every 30 minutes starting from 7 AM until 3 PM. In 2006, a member of the village owned a truck that transported village agricultural produce directly to the Dehra Dun market. The villagers also began visiting the surrounding villages and began to be more aware of how the people lived in other villages [M-51]. In 2000, an electricity line was extended to the village. By 2005, a well had been dug and a hand pump for water was constructed beside the road. Therefore, the people no longer had to rely on natural springs for water. In the summer of 2006, a telephone line was also being drawn through the village.

Before the road was constructed, there was only a narrow path that connected the village to other villages in the region. There was very little exchange between the villages. Produce was transported on the backs of mules. Men would leave the village with their mules and potatoes at 5 AM in the morning and arrive in Dehra Dun located approximately 35 km away, at around 10 PM. They would stay overnight, sell the potatoes and return to the village the following day [M-67]. Therefore, after the advent of the road, the number of mules and horses in the village decreased.

Before the construction of the road, there also were very few varieties of agricultural produce that were planted in the fields. They were: potatoes, and grains such as *jangura* (*Echinochloa frumentacea*), *chaolai* (*Amaranthus frumentaceous*), *mandura* (*Eleusine coracana*) and wheat which were used to make flour for *roti*. The villagers were self-sufficient and produced everything they needed to eat. In the winter months, the villagers took their cows and buffaloes to Dehra Dun and sold milk there.

About a decade after the road was constructed, people began planting more wheat and vegetables such as radish, cabbage, cauliflower, bell peppers, string beans, and tomatoes. They also increased the quantity of potatoes they planted. Before the construction of the road, families produced an average of 30-40 kg of potatoes. After the road, they increased their production to 200-400 kg to be sold in the nearby markets. Ironically, however, the amount of agricultural land available was limited so the villagers had to decrease the production of their stables and began to purchase wheat, rice, and *dal* (lentils) because they did not produce enough to feed themselves. Until then, a man [51] explains, “The land provided everything we needed to eat.”

Ironically, the production of vegetables led to increased need for labor and bulls to plow the fields (Figure 2-6) [M-26]. A 50 year-old man explains, "Vegetables require more work…..We have to weed three to four times a year. Before, there was planting for one month then there was no work in the winter months. Now there is work up in the *chan* and then down here in the village."

The increase in agriculture also increased the demand for *gobar* and buffaloes to produce manure. Accordingly, the number of bulls surged from 112 in 1977 to 319 in 1993; and the number of buffaloes more than doubled from 82 in 1977 to 196 in 1992 (Statistics 1988; Nautiyal 1993; Rawat 1993) (Figure 2-6). More livestock meant heightened demand for fodder and an increase in the number of people going into the forest to collect fodder. The villagers state that the intensified demand for fodder led to a considerable decrease in the amount of fodder available from the forest by early 2000.

## Changes in the village society

The diversification of income sources has brought about greater income disparity and more individualistic behavior. This change is apparent most in the size of the groups that collect fodder. In 1993, the fodder collection groups consisted of up to 18 people. In 2006, people tended to either go with their kin or alone. The slow disintegration of the closely knit social infrastructure can also be demonstrated by the presence of three people with psychological problems, a problem that did not exist in 1993. The villagers explained that two women went "*pagal*" or insane with jealousy when their husbands left them for other women. One man went "*pagal*" when he was beaten by a wealthy man in the village because he had insulted his daughter.

A man [68] born and raised in the village who has two sons working in hotels in Punjab and two helping him with farming also perceives a change taking place in the relationships between people in the community,

"Before, people used to go together into the forest and people cooperated. Now, the same number of people still goes into the forest, but they do not go together anymore. People were more peaceful. Now people are more interested in making money and have become colder to each other. People have become more individualistic and some want to go now, some want to come back earlier or later. So they are all going separately."

A woman [47] who began collecting fodder 33 years ago commented,

"When I lived in the *chan*, I used to go so far away because 30-40 people used to go together. Now we don't go in large groups anymore. There is much less love and camaraderie as we used to have. The young people have changed. The world has changed."

In order to have fodder available close to the settlement during the winter when it is difficult to go far into the forest, some families have claimed some of the forest land surrounding their fields as their own and forbid others from lopping there. This practice began nearly over 30 years ago but increased about 15 years ago.

Nevertheless, the village society still sticks together when it involves the good of the village as a whole. There were several examples of this when I was living in Beli. One was the night trips into the mountains organized by 14 young males to illegally collect gravel for building the walls of a new high school the villagers want built close to the village. Another was the attempted assault by 40 villagers on scantily dressed road construction laborers from the plains. The villagers considered the manner of dress disrespectful to the women of the village. The assault was prevented by teachers intervening and mediating the conflict.

Interestingly, the Scheduled Caste people whose main occupation are ironsmiths, have gotten richer faster than others in the village due to their marketable skills. Their increase in wealth has brought about subtle changes in their position in the village society. In 1993, Rajputs did not use the tap close to the Scheduled Caste households due to the religious principle of contamination by the lower caste. Young Scheduled caste children were taught not to stand in doorways so that they would not cast a shadow into the room where higher caste people are eating and mistakenly contaminate their food. However, in 2006, not only did the Scheduled Caste family own a ration shop which sold food; they also offered tea when I visited their home. When I visited the Scheduled Caste families, they openly offered tea and snacks to me, something which never occurred in 1993. My assistant, who was a Bandhari *jhat* of the Rajput caste also drank tea and ate biscuits that were offered without hesitation. A Rajput man also told me that sheep, which were considered unclean and were previously only owned by the Scheduled Caste, were now being owned by Rajputs because sheep wool and selling mutton are good sources of instant cash income.

### Change in forest and oak foliage

The fundamental use of the forest has not changed over the years. Every person, from the 20 year-olds to the eldest 82 year-old person interviewed stated that there was no difference in what they currently obtain from the forest and what they obtained in their childhood. They still brought oak foliage, grass, and fuelwood from the forest as they did when they first started going into the forest. They mentioned that the only difference is that they no longer depend upon the forest for medicinal plants such as *karui*. It is used for stomach ailments, and *kingori* used to treat eye ailments, because the road has made it easier to purchase medicine from nearby towns.

Most of the people between the ages of 20 and 82 also noted that the forest boundary surrounding the main Beli village settlement has not changed since their childhood. In other words, the forest extent remains the same as it was over 70 years ago. The construction of the road, however, did destroy many agricultural fields and removed many trees that were previously used for fodder. A 76 year-old woman who has been living in the village for nearly 60 years remarked,

"I used to cut around here. When the road was built, all the trees that I used to lop have been cut down…..Once the cars started coming, the forest foliage started decreasing…..Now many people come to our village from above…..People cut the leaves and wood and carry it off in their vehicles…..Bears used to come up to the agricultural fields, but stopped coming since the road was built."

On the other hand, in the *chan* area, many observed that there were new fields and houses built in the last 15-20 years. Some of the fields are on the land title register and others are not. Since it is illegal to make fields in the government forest, many were reluctant to respond to the question of whether there was a change in the number of fields. A 66 year-old woman who began collecting fodder when she got married and moved to the village at the age of 14 and continues to go into the forest to collect fodder stated,

"When I got married the forest used to come close to the *chan*. Now there are many more fields. The *ban* and *moru* were close by and we did not have to go as far away to collect fodder. The trees and leaves have decreased because the number of livestock owned by the villagers has increased. But from now on the number of livestock will slowly decrease in the village."

However, those interviewed all remarked that though the number of trees has not decreased, the amount of foliage available on each tree has decreased. The villagers have observed that fewer and fewer leaves are growing back and those that do are infested with pests [F-82].

This trend in decreasing foliage appears to have begun in the 1990s. A 40 year-old woman who began collecting fodder at the age of 16 said,

> "When I was younger I only needed to lop one tree and I would get enough [foliage] to take home. Now I have to lop four and still not get enough to take home."

Another 55 year-old woman who began collecting fodder when she was 11 remarked,

> "I used to go into the forest three to four times a day because there were plenty of leaves close by and we used to bring a little at a time. Now there are not enough leaves close by so we do not go often [we have to go further on longer trips]."

Many of those interviewed think the reason for less foliage in the forest is due to a combination of peoples' lopping practice, the increase in the number of livestock, and decrease in rainfall. Also, they state that more people are cutting off the tops of the trees than before and stunting the growth of the trees, causing a decrease in leaf production. They also say that people are becoming more wasteful, lop off more branches than they need, and leave the foliage behind on the forest floor. Most blame the decrease in foliage to the increase in population, and the corresponding increase in the number of livestock and agricultural fields. The census data also supports their observations and shows that the number of households in Beli has increased from 89 in 1981 (Payal 1993), to 110 in 1991 (Payal 1993) and 144 in 2001 (Director of Census Operations Uttaranchal 2004). A 55 year-old man explained, "The leaves are decreasing because the number of people collecting the leaves has increased. Where there used to be 10 people collecting and now there are 50 people collecting from the same tree. How much can one tree provide?  Where will the leaves come from?"

## Change in households

The adaptation of Himalayan mountain communities to the changing availability of resources and the important role that households and kinship plays in the maintaining the household economy has been documented in Nepal as well. The household and joint families as an important source of labor has been described in the Tamang and Gurung societies. Each family member performs their duties for the greater good of the entire household (Macfarlane 1976; Fricke 1986).

The steady decrease in the availability of oak foliage meant that there was less fodder available to support stall-feeding of livestock. The decrease in fodder brought about the decrease in the number of livestock and ultimately, the decrease in the availability of compost. Without compost, the agricultural fields decrease in productivity, and in turn decrease the income of families. The decrease in compost has forced families to increasingly rely on chemical fertilizers and pesticides, putting a strain on the cash flow of families. Though there are no statistics on the consumption of fertilizers specific to Beli village, this trend is apparent in the rest of the State of Uttaranchal as well. The amount of urea consumption in the State of Uttaranchal increased from 169,040 tons in 2000-2001 to 170,910 tons in 2001-2002 (India 2000-2001; India 2001-2002).

Since agriculture has become unreliable as a source of income, villagers are exploring other sources of income. Such explorations have resulted in households sending both their sons and daughters to school to prepare them for employment outside the village. Ironically, however, more children going to school means that there are fewer people available to collect fodder from the forest. Therefore, there is a further decrease in the amount of fodder collected from the forest, forcing families to decrease the numbers of cows and buffaloes. This chain reaction has brought about gradual and some dramatic changes in the way the villagers interact with each other and how they relate to the forest.

In Beli village in 1993, there were 96 households, 92 of which were Rajputs and four were Harijans in Beli village (Makino 1994). Each family depended on farming and agriculture as their main source of income. Three Rajput males worked for the Public Works Department (PWD) in maintaining the road that was built in 1978. There was a small shop that provided basic supplies such as cigarettes, matches, and soap. The village agricultural produce was collected in one store and taken to the Dehra Dun vegetable wholesale market. One man collected milk from the other villagers and sold the milk in Mussoorie. Out of the four Scheduled caste families in the village, two were musicians and the other two were ironsmiths. Receiving a formal education was not considered important to the lifestyle of the people, and there was only one primary school from kindergarten to fifth grades managed by one teacher. The only high school in the region was located in Thyatur, a town in the Aglar valley nearly two and a half hours walk from the village. A 16 year-old girl, when asked why she left school after class 2, replied, “I go into the forest every day; what is the use of learning to read and write?”

In 2006, a substantial change had taken place on the villagers’ reliance on agriculture as their main source of income, and consequently their attitude towards education. Villagers were exploring ways to diversify their sources of income. One strategy was to open new stores in the village. Compared to the one small shop in 1993, in 2006, there were four ration stores. One was an agricultural produce collection center and another was a milk collection center. Also there were three *chai* or tea stalls and two tailor shops. The Scheduled Caste ironsmith was still there and his son had opened a new ration store next to his iron workshop. Those who were wealthier were buying jeeps and trucks which they rented out.

A man explains that as people continued to have more and more children, agriculture alone could not sustain the family. So 10-15 years ago they started searching for employment outside the village [M-51]. The response to declining agriculture has been has been more young people leaving the village to earn wages or whole families are permanently emigrating to low lands or cities. Though families are yet to emigrate from Beli, more than 50 young males are working in hotels in Punjab and Rajasthan and remitting their income to their families. Some youth live in Dehra Dun valley and learning how to type in order to qualify for government clerk positions.

The parents, apprehensive about relying on agriculture as the main source of income, began to focus on providing their children with skills other than farming. Therefore, they began sending both their male and female children to school in order to prepare them for other forms of employment outside the village. The interest in education increased considerable when the road passing in front of the village was black-topped in 2002, making outside access to and from the village easier. This exposed the village to outside media and recently, Beli village has become a popular filming location for local Garhwali films. A 57 year-old man states that,

"A big change has happened where the children are now literate. When I was young, we did not learn to read and write. Only two or three children learned to read and write."

This focus in education has been manifested in the increase in the number of schools in the village vicinity from one in 1993 to five in 2006. By 2006 there were two primary schools (Government Primary Basic classes 1-5, established in 1962; Renuka Shushi Mandir classes 1-5 established in 1997), one nursery in *chan* (established in 2005), one Junior high school (classes 6-8 established in 1996), and one Kastura Gandhi Girls boarding school (established in 2005). The village donated the land for the Kastura Gandhi Girls boarding school and in exchange, the government paved the dirt path that runs through the village.

Another striking change from 1993 was that, whereas in 1993 most girls dropped out of school at grade two, in 2006 there were several girls who had graduated from high school. One of the interviewees was a 21 year-old woman who had rarely collected fodder and could not identify the tree species found in the forest. The establishment of Kasturba Gandhi School, a boarding school for girls, also demonstrates the significant change in the peoples' attitude towards the education of girls.

This focus on education has also brought about change in the role of women in the village. As the village community is being exposed to outsiders, it is also exposed to working women, such as the women who work in the film crews or the woman "*madams*" who teach at the schools. As a result, the people began to consider the possibility that both girls and boys have equal potential of finding employment. Some also believe that if girls learn to read and write, they will be able to teach their children to read and write.

The census data also supports this trend of increasing focus on literacy and the increase in women being educated (Figure 2-7). In 1981, 30 % of the male and none of the females were literate and in 1991, the number of literate men were 47 % and females were four people or 1% (Payal 1993). Only 10 years later in 2001, the male literate population increased to 71%, and the females increased remarkably to 87 people or 19 % (Director of Census Operations Uttaranchal 2004) .

Intriguingly, girls going to school has also influenced the age in which they get married. Based upon the interviews, women who are currently over 50 were married between the ages of 10 and 16. Women below the age of 50 tended to get married between 15 and 19. However, in 2006, there were two women who had both been educated up to high school level who were unmarried at the age of 21. Yet, as the shift in attitudes is occurring, there is also an internal dilemma within the families because sending the girls to school may make it difficult for them to get married. As one man [41] commented,

"The educated girls have a hard time getting married because then they need to give more dowry. The uneducated girls can get married easily. The girls who are educated also have a hard time getting married because they do not know how to do field work and housework as well as the girls who have not gone to school. The girls who go to school cannot climb trees and are not good at agricultural work. They are also not strong enough to carry the loads."

On the other hand, education is seen as a way to move ahead in society as one woman [40] commented,

"I send my children to school so that they can marry into good families so that they will not have to depend on agriculture for income. If you are illiterate, you cannot become anything. You are forced to do agriculture."

A man [31] also commented that because many boys are getting educated, they do not want to take an uneducated girl as a wife, and the opposite can also be true. The parents of an educated girl would not want her to get married to an uneducated boy. One of the youngest women aged 21 interviewed personifies the sentiments expressed by the others. She is in her last year in intermediate level i.e. 12th class and is unmarried. She has rarely been into the forest or done farm-work, and her dream is to become a school teacher. Most of her family's fields have been leased out to others to cultivate. She states,

"If I have to cut grass and *banj*, then all my studying will go to waste. So what would have been the use of all my studying?"

Interestingly, there has been no change in the ages of men getting married, which is 18 to 24 years-old.

The sentiment that the current generation of children will no longer rely on agriculture as a source of income, raise cows or buffaloes, or go into the forest to collect fodder is repeatedly expressed by the majority of the people interviewed. A man [51] who sends all of his children to school commented,

"I have a feeling that my children will no longer do agriculture because the situation will not be agreeable for doing agriculture. For agriculture you need *gobar*, you need goats, you need buffaloes….. For agriculture you need to get into the mud and get dirty. But the children nowadays say they do not want to do agriculture."

Another man [51] remarked,

"I want my children to have employment, whether small or big. I want my children to be literate. If they can bring income from outside it will help our agriculture."

One man [45] with a son in 9th class and a daughter in 6th class clearly stated, "I am sending them to school because my children cannot raise cows or buffaloes. Nor will they do any agriculture….. My children do not know how to climb a tree….. My children will not continue after me."

### Change in oak foliage and livestock

The decision to send children to school has not surprisingly led to further decrease in oak foliage in the forests immediately surrounding the village. When both daughters and sons go to school, there are fewer children between the ages of seven and 10 who have time to graze livestock or collect fodder. Also, when children attend school in the morning it means that they can only collect fodder in the afternoons after school. This in turn means that children living in the *chan* can no longer collect the higher elevation oaks in the summer because it takes an entire day to collect fodder from these oaks. Therefore, the children can only go to the forests within one to two kilometers from the *chan* and collect lower elevation oak foliage in the afternoons. This arrangement increases pressure on the oak forests which are closer to the settlements because they are not given time to re-sprout, which is traditionally available over the summer.

As children go to school, the number of people available to go into the forest to collect fodder or graze livestock has decreased in each household. This situation has brought about change in the type and number of livestock that a household can feed. Without the children, the responsibility for grazing and collecting oak fodder falls upon the wife or daughter-in-law(s) in the household. However, since the women are getting married later, the first wives need to wait longer before they can get help from the daughter-in-laws. Thus, some families are selling all their cows or replacing the cows with goats, which can be grazed by the older men. Though the livestock census has not been conducted in Beli yet, the statistics from the rest of Tehri Garhwal reflect the same trend. Villagers are reducing the number of cows and buffaloes, whereas the number of goats stays relatively the same (Table 2-5). A man [68] stated,

"When I was younger we had 15-20 cows, two bulls, two buffaloes, two mules and 15-20 goats. We kept so many cows because they provided *gobar* and milk. We made *paneer* for 10-15 years and sold it in Dehra Dun during the six months of winter. The goats are good because they have many kids throughout the year and can be sold. We do not keep so many livestock anymore because of the decrease in fodder available from the forest. There are also no people to go into the forest."

"Before girls did not go to school so they grazed the cows and goats….Now the girls are going to school so there is no one to graze the animals" [M-80]

Most of the people interviewed foresee that there will eventually be a decrease in the number of livestock owned by the people in the village because there will no longer be people available to go and collect fodder.

"As I see the foliage decreasing from the forest, I wonder where my children will go to collect fodder. Our livelihood depends on the forest, but one day our children will not be able to keep livestock." [M-68]

The reduction in livestock has again resulted in a decrease in the supply of compost, and exacerbating the villagers' need to buy fertilizer and pesticides and cash income. Use of chemical fertilizers began 15-20 years ago because the supply of *gobar* was not enough for the increased production [M-68]. There was a large increase about five years ago when people started keeping less livestock because of the decrease in fodder supply from the forest and fewer people available to collect fodder [F-76, F-48].

## FUTURE: MANAGEMENT OF THE FOREST

An interesting finding from the interviews is that though the people strongly feel that the existence of the forest determines their survival, they do not feel strongly about their role in ensuring that the forest continues to provide oak foliage. There is a collective sense that it is not their responsibility to look after the forest, but that it is the responsibility of the Forest Department. They feel it is the responsibility of the government to decide how to manage the forest since it is owned by the government. There was an attempt in 2002-2003 by the government to set up a *ban panchayat* or forest management council in the village consisting of 15-20 members from the village to monitor the use of the forest. However, the council is no longer active. One 41 year-old man explained,

"The department is paid to look after the forest. Unless we get paid, we cannot look after the forest. It should be a type of employment. There was a committee made by *panchayat*, but the committee cannot do anything by itself. It needs people to do the work and they need to be paid."

Many felt that since it is the government forest, the government should plant fodder trees and if they want trees to be planted in the forest, they need to pay for the labor. Also, villagers cannot spend time planting trees because they need to do their field work and sell their produce. One 57 year-old man mentioned the need to plant trees and look after the forest, but stated that "someone needs to provide the saplings because we are poor; we cannot buy them." They also feel that it is the forest guard's job to check that the trees are lopped properly, and they complain that the guards only come about twice a year and do not oversee the lopping process properly.

A sense of powerlessness is also reflected in the words of a 36 year-old man. By 2006, his family had sold all three of their buffaloes, 12 goats, and reduced the number of cows from 16 to 13.

"Before, I used to think that there was a lot of forest and no shortage. Now the forest area decreased. What is going to happen in the future? There is less forest left and less leaves. People are not into protecting the forest. What can we do? No one listens. People cut down trees and lop off the top of the tree, so now we have less leaves and a shortage. What is there that I can do? How will I feed my livestock? Will I need to change? But there is nothing that I can do." [M-36]

When asked about the best way to ensure that the forest continues to re-sprout and grow, all of those interviewed mentioned that the trees should be lopped only from the bottom, and the tops of trees should be left uncut. They state that if the tops of the trees are left intact, the trees will continue to grow, but if they are cut off then the tree will grow only a few leaves and will eventually die.

"Do not cut the trees from the top. Next year there will be no new leaves if the top is cut off. We need to tell our children that you can lop the leaves but do not cut the tree so that we will continue to have leaves the next year." [M-80]

"The problem is that younger children are cutting the small trees down from the bottom. Some also cut off the tops of trees. Everyone knows it's bad but they cut it off anyway. If the tree was on their agricultural land, they would take care of it like their child, but they don't care in the forest." [F-55]

There was a broad spectrum of views on how the forest should be managed. The views did not differ greatly between those aged 20 and 40. It is important to note that all of them saw the forest as part of their livelihood and recognized that changes would need to be made in their lifestyle if the amount of foliage in the forest was to increase.

Many felt the only way to regenerate the forest was to stop lopping the branches. They stated that in order for them to stop lopping the forest, the people would either need to stop keeping cows and buffaloes or reduce the number they own. Their strategy would be to send their children to school to learn to read and write so that they will eventually not need to go into the forest to collect fodder or graze their animals. They felt that the people would eventually reduce the number of livestock to supply just enough milk for their own needs because it would get easier to purchase what they need from the shops.

Some suggest that sections of the forest be closed off for one to five years to allow the trees to regenerate and periodically rotate the areas of these closed sections. A guard should be assigned to the forest, and if someone is caught lopping they should be fined Rs. 500 [F-21]. One person felt that the villagers should decide what forests to close off for one to two years at a time. However, he stated the difficulty would be to monitor the lopping because everyone moves between settlements throughout the year [M-32]. Some felt it would not be feasible to close off sections of the forest because people go everywhere in the forest to collect fodder or graze their livestock. One woman [47] suggested that the *pradhan* (village elected head) or the *panchayat* employ a guard and the closing of the forest be decided by everyone in the village to prevent anyone from becoming upset. A 68 year-old man expanded her opinion and stated,

“We need to close off some part of the forest for some time and rotate the lopping in a five year cycle. It should be managed by the villagers - the *panchayat* should make the decision. The delineation of the forest should be decided by the *panchayat*. The idea should be raised by the *pradhan* and the elders of the village.”

The villagers say that if they could afford it they would prefer to switch to gas for cooking and reduce the need to go into the forest to collect fuelwood. But many of those interviewed said they still preferred fuelwood in the winter because it kept them warm.

On the other hand, there were notions that nothing could be done by the village to help regeneration of the forest. This was expressed by a 41 year-old woman,

"No one thinks about saving the forest. What can the village do? No one can do anything. People think about it but don't do anything about it. The only thing we can do is to decrease the number of livestock. Even if someone wants to decrease forest use, someone else will go into the forest and collect fodder. So there is nothing we can do."

A new sentiment arose in the persons interviewed between the ages of 51 and 70. There was more of a feeling of ownership of the forest. A 56 year-old man, born and raised in the village and who relies on agriculture and his employment at the Public Works Department (PWD) for income, expressed his thoughts,

"The forest is for everyone. The government can only think about itself. The use of the forest is for us, not the government. The government can't do anything. It is our forest."

A 51 year-old man expresses his dissatisfaction with the way the government is trying to approach reforestation,

"The government recently had a reforestation project. It is government money. It is useless money. It is not money from my bones. If the forest was ours, then the forest would still exist. We would keep it for our children and descendents…..The problem with the forest now is that the government is spending crores of money planting trees in places where forests did not exist before. The places where nature or God did not give trees, they are trying to plant trees. They are only planting trees because they get money…..Forest will only grow where we listen to nature."

A 62 year-old woman born and raised in the village expresses her frustration with working with the government and the conflict of ownership and access,

"We would like to cooperate with the foresters and forest guards, but they interfere with our lives. They close off the forest and prevent us from using the forest. They stop us from living our lives – they keep telling us that this is theirs and we can't use it. We can't do anything with the government."

Another 63 year-old man complains that the people need to think more about the future and the forest. What is reflected in his opinion is also the fact the parents and children are no longer going to collect fodder together because the women go collecting in the morning and the children go in the afternoons after school. Therefore, the traditional lopping practices that had been previously passed down from parent to child are no longer happening.

"We need to think of the people who will use it in the future – fodder, leaf litter etc. What we need to do is think. The people are not thinking anymore. Such as do not cut the tip of the tree. If they leave it, the tree will still continue to grow…..Have a meeting with the Forest Department in the village, including the daughters and women and teach about how to use the forest because they are the ones who go into the forest. We need to use the forest for livelihood, so we need to use the forest resources, but we need to learn how best to collect fodder to prevent destruction. How best to lop the trees. They don't know the best collection method."

When I asked an 82 year-old woman born and raised in Beli whether she had any suggestions for the government concerning forest management, her response shed some light on the status of women in the village and the limited role they have been given in decision-making in the village,

"I don't want to ask the government anything. The government do not come and talk to women. They only talk to the men. Or they talk to some women who are literate not to us who cannot read or write. What is the purpose of the meetings? Nothing. All they do is talk and decide then nothing happens. They smoke *beedi*….."

# CONCLUSIONS

Forest ecosystem management in Garhwal Himalaya cannot be considered in isolation from the livelihood of the local people due to their total dependence on the forest. The livelihood of the people is maintained by complex interactions among households, availability of oak foliage from the forest, livestock, agricultural production and income. Forest use is governed by traditional gender roles that determine how much foliage is collected from the forest. Therefore, any change in forest composition, health, or management brings about a transformation in the individual lives of people and eventually the village society as a whole.

The interaction between the villagers and the forest is a dynamic process and constantly varies over time. The construction of the road in 1978 began a gradual series of change in agricultural practices that intensified the use of oak fodder from the forest eventually leading to a decline in oak foliage. Consequently, the villagers began to perceive agriculture as an unreliable source of income in the future. Therefore villagers began to diversify their income sources and searched for employment outside the village. Accordingly, parents began to send their children to school to prepare them for future employment. Thus, the number of people and the group composition going into the forest has changed, decreasing the degree of dependence on the forest. Ultimately, the villagers do not see traditional agriculture as an important aspect of their children's lives and thus less reliance on the forest.

The very fabric of the rural agricultural society is being modified by the decrease in oak foliage. The socio-economic situation in the villages is changing, and the entire economy is gradually moving away from agriculture as the main source of income. Finally, the complex relationship between the people, forest, livestock and agriculture that has maintained the livelihood of the people no longer holds true. The concern of the foresters that the villagers will gradually degrade the forest beyond its ability to regenerate may eventually become irrelevant.

**Figure 2-1** Location of the main settlement of Beli Village showing the protected forest directly above the village and the adjacent lopped forest to the right of it. Beli village Jaunpur Range, Tehri Garhwal Himalaya, India.

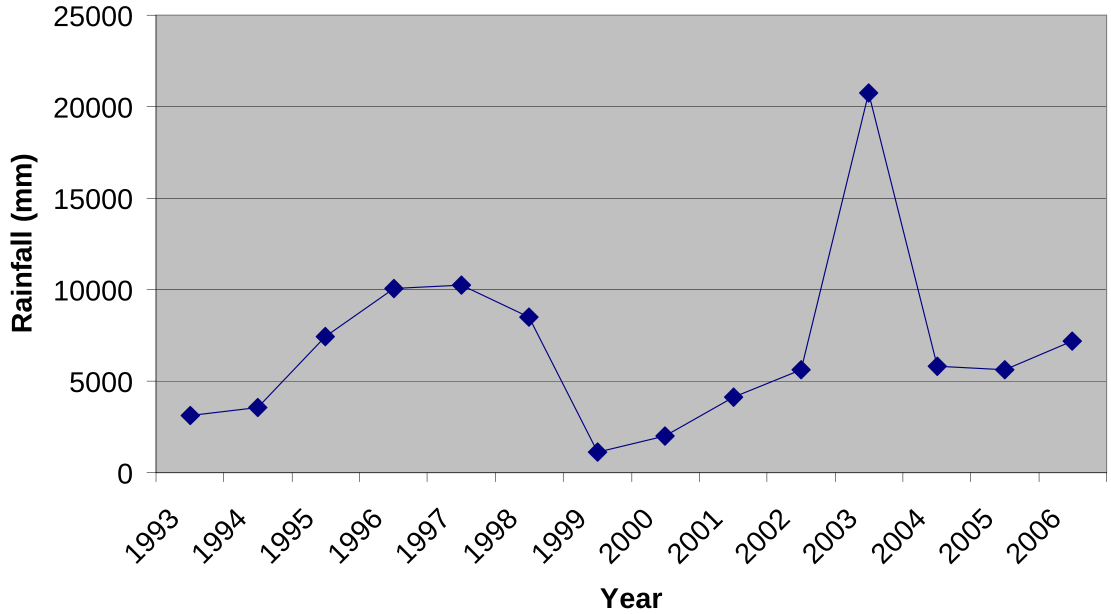


**Figure 2-2** Diagram of the average annual rainfall, Jaunpur Range, Mussoorie Forest Division, Garhwal, Uttaranchal, India. Source: Rainfall register, Jaunpur Range, Mussoorie Forest Division (2006).

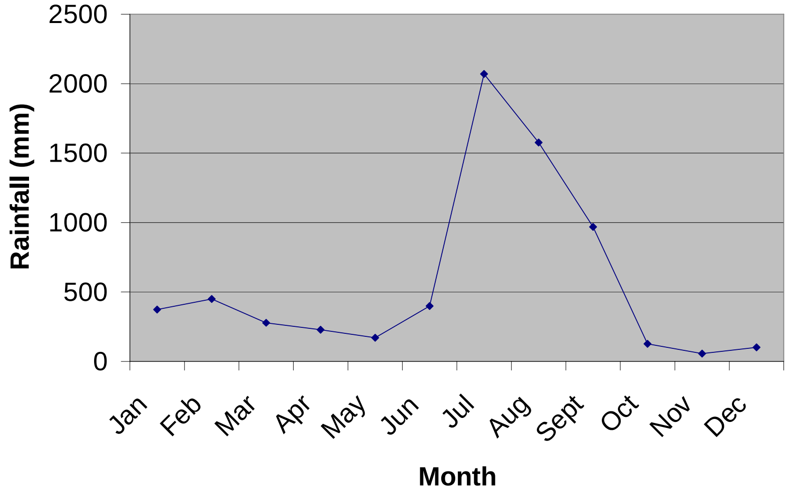


**Figure 2-3** Diagram of the average monthly rainfall (1993-2006) Jaunpur Range, Mussoorie Forest Division, Garhwal, Uttaranchal, India. Source: Rainfall register, Jaunpur Range, Mussoorie Forest Division (2006).

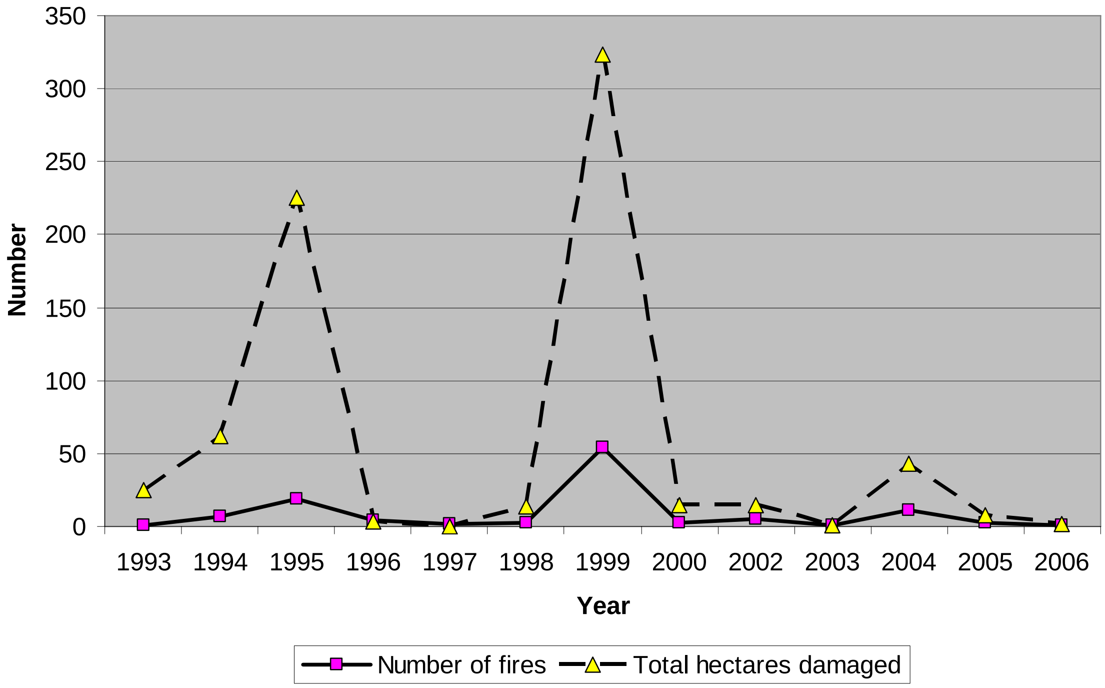


**Figure 2-4** Diagram showing the number of fires per year (□) and the number of hectares (Δ) damaged by fire from 1993 to 2006. Source: Fire register, Jaunpur Range, Mussoorie Forest Division (2006).

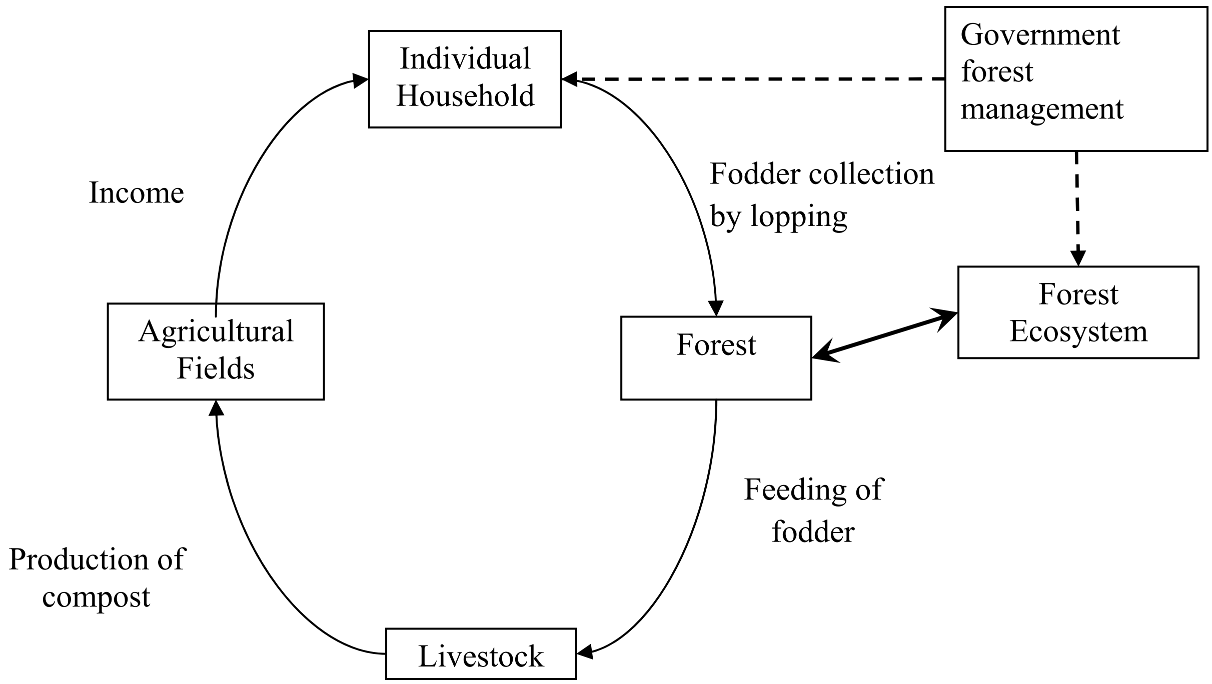


**Figure 2-5** Conceptual model of the complex interactions between the people and the forest in Beli village, Tehri Garhwal Himalaya, India.

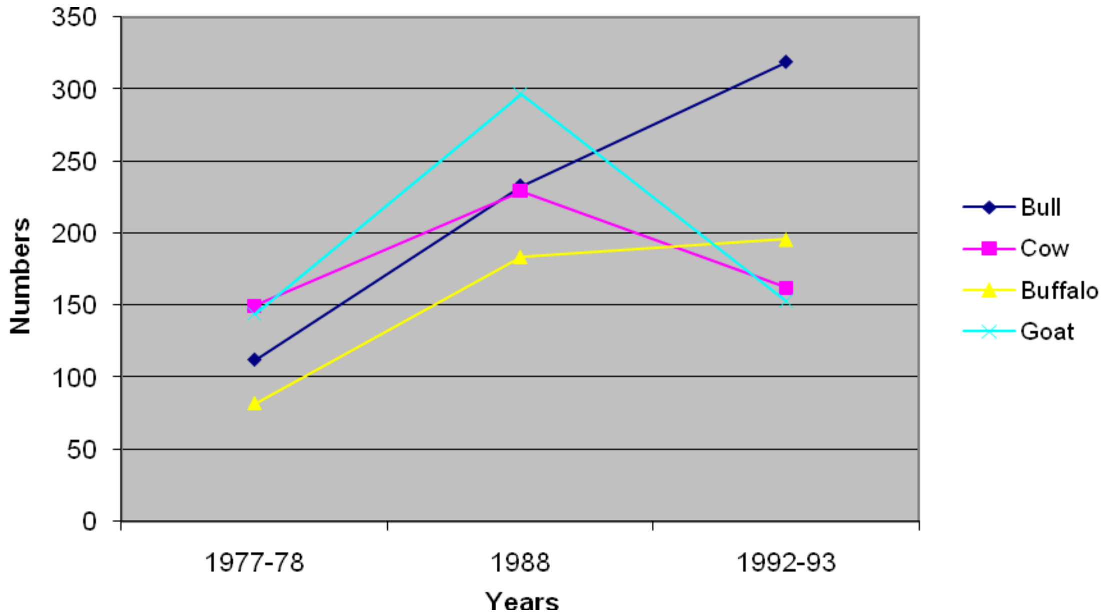


**Figure 2-6** Changes in the number of bulls, cows, buffaloes, and goats in Beli village from 1977 to 1993.

Sources: Nautiyal HM: Livestock Census 1977-78. Tahsil, Dhanolti, District Tehri Garhwal U. P., 1993; Livestock Census 1988. District Tehri Garhwal U. P., Block Development Office, 1988; Rawat GS: Livestock Census 1992-1993. District Tehri Garhwal U. P. , Revenue Office, 1993.

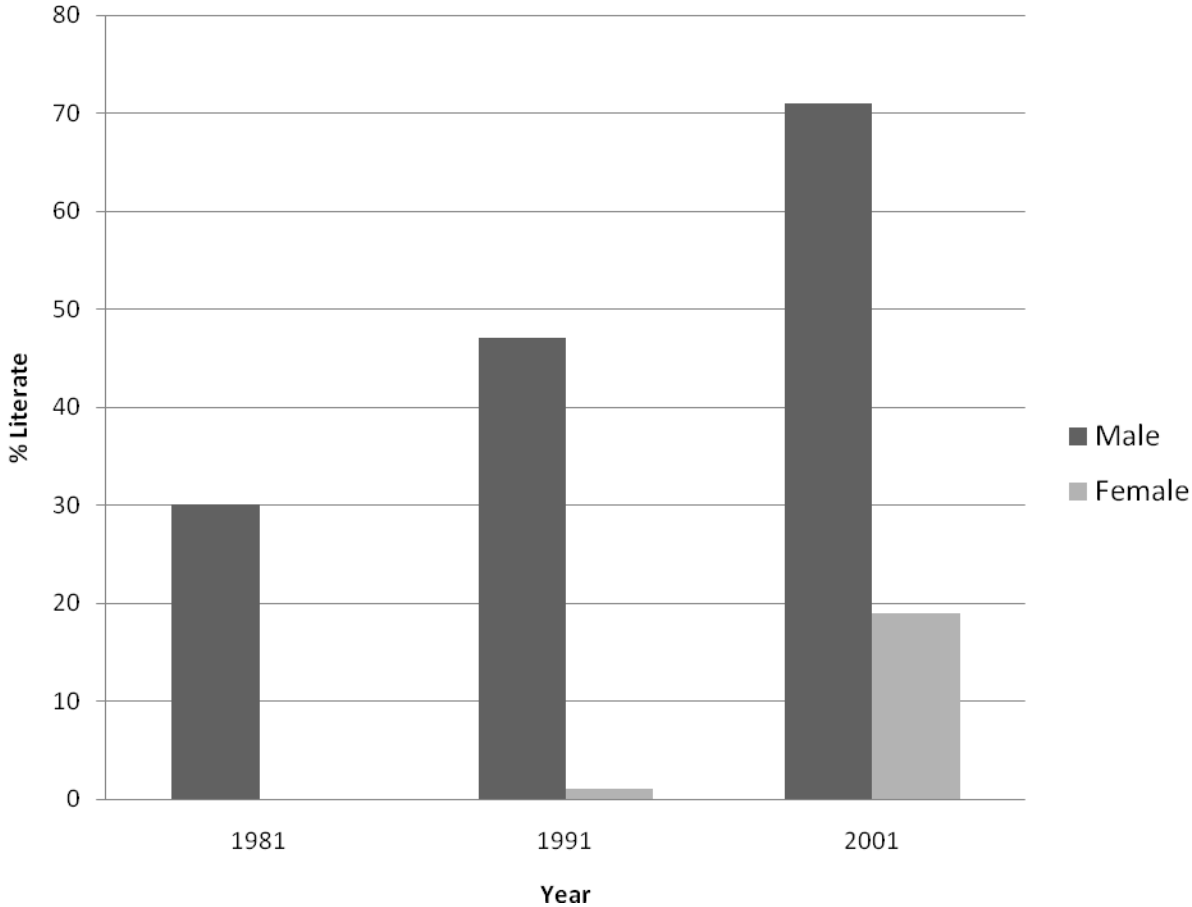


**Figure 2-7** Comparison of the literacy rate of females and males for 1981, 1991, and 2001 in Beli village, Jaunpur Range, Tehri Garhwal, India

Sources: Payal BS: Census of Tehri Garhwal U. P. 1981, 1991. 1993; Vijayan Unni M. 1999. *Uttar Pradesh district profile, 1991*. Delhi, Controller of Publications; Director of Census Operations U, India. 2004. *Census of India, 2001. Series 6*. Delhi, Controller of Publications.

**Table 2-1** The traditional roles and responsibilities of females and males in each household according to their age in Beli Village, Tehri Garhwal, India.

| Age | Role and responsibility of females |
|---|---|
| 4 | Follow mother into forest and pick up twigs<br>Begin gathering grass |
| 7 | Look after younger siblings<br>Fetch water |
| 10 | Graze cattle<br>Gather fuelwood and leaf litter from the forest |
| 11-12 | Begin climbing trees and lopping branches |
| 15-18 | After marriage – collect fodder, cook, do field work<br>May graze cows and goats while collecting fodder |
| 40 + | After eldest son is married, usually stop collecting fodder and daughter-in-law takes over. If not, will continue to collect fodder until unable to carry heavy loads. |

| Age | Role and responsibility of males |
|---|---|
| 4 | Follow mother into forest and pick up twigs<br>Gather grass |
| 5 - 15 | Some attend school. |
| 7 | Those children not in school gather grass<br>Begin grazing goats<br>Fetch water |
| 10 | Graze cattle<br>Gather fuelwood and leaf litter from the forest |
| 12-15 | Begin climbing trees and lopping branches |
| 15-20 | Those who continue to intermediate stop going into the forest.<br>Those who quit school collect fodder |
| 20 | After marriage – looks after young child and stops going into forest<br>Plow fields, harvesting and other field work<br>Some find employment outside the village or open a shop<br>Graze cows, bulls and goats<br>May continue collecting fodder if owns lots of agricultural fields |
| 50 | May graze goats |

**Table 2-2** Comparison of the quantity of dung and urine excreted by different animals in India in kilograms.

| TYPE OF ANIMAL | QUANTITY EXCRETED PER DAY | | TYPE OF ANIMAL | AVERAGE WEIGHT | QUANTITY EXCRETED AT NIGHT (15 HR) | |
|---|---|---|---|---|---|---|
| | Dung | Urine | | | Dung | Urine |
| Horse | 16.1 | 3.6 | Cow (Cultivators) | 172 | 2.8 | 1.31 |
| Cattle | 23.5 | 9 | Bullock (Govt. Farm) | 279 | 3.8 | 1.4 |
| Sheep | 1.13 | 0.6 | Breeding Bull (Govt.Farm) | 530 | 7.7 | 4.5 |
| Pig | 2.7 | 1.5 | She-buffalo | 374 | 5.3 | 2.2 |
| Poultry | 0.04 | - | He-buffalo | 617 | 7.7 | 4.4 |

Source: Agricultural Research Data Book, 2001. IndiaStat.com

**Table 2-3** Different fodder types collected or fed to livestock during the various seasons of the year for both 1993 and 2006 in Beli Village, Tehri Garhwal, India.

| **Livestock** | **Seasons** | | | |
|---|---|---|---|---|
| | **Winter (January to mid-March)** | **Summer (mid-March to mid-June)** | **Monsoon (mid-June to August)** | **Fall (September-October)** |
| **Buffalo** | Dried grass<br>Dried wheat/rice stalk<br>*Quercus leucotrichophora* | *Quercus leucotrichophora*<br>*Quercus floribunda* | *Quercus leucotrichophora*<br>Grass | *Quercus leucotrichophora* |
| **Cow/Bull** | Dried grass<br>Dried wheat/rice stalk<br>*Quercus leucotrichophora* | Graze on forest grass | Graze on forest grass | Graze on forest grass |
| **Goat** | Graze on forest grass | Graze on forest grass | Graze on forest grass | Graze on forest grass |

**Table 2-4** Comparison of the number of fodder collection trips in 1993 and 2006 during the summer and monsoon months in Beli Village, Tehri Garhwal, India.

| **Village settlement** | **Year** | |
|---|---|---|
| | **1993** | **2006** |
| **Main Beli village settlement** | 7:30 AM -1:00 PM<br>*Quercus floribunda* or grass<br>3:00 – 8:00 PM<br>*Quercus leucotrichophora* | 8:00 – 11:00 AM<br>*Quercus leucotrichophora* |
| **Chan or upper settlement** | 7:00 – 9:00 AM<br>*Quercus leucotrichophora*<br>7:30 AM- 1:00 PM<br>*Quercus floribunda* or grass<br>2:00 – 6:00 PM<br>*Quercus leucotrichophora* | 8:00 AM – 1:30 PM<br>*Quercus floribunda* or grass<br>2:00 – 6:00 PM<br>*Quercus leucotrichophora* |

**Table 2-5** Comparison of the change in the number of animals in Tehri Garhwal in 1997 and 2003.

| Year | Animals | | | | | |
|---|---|---|---|---|---|---|
| | **Cattle** | **Buffalo** | **Sheep** | **Goat** | **Mule** | **Dog** |
| **1997** | 169,000 | 121,000 | 24,000 | 103,000 | | |
| **2003** | 123,160 (-27.1%) | 115,050 (-4.9%) | 14,811 (-38.3%) | 101,981 (-1.0%) | 3,571 | 14,409 |

Sources: 16th Indian Livestock Census 1997, Department of Animal Husbandry and Dairying, Ministry of Agriculture, Government of India. 17th Livestock Census 2003, Department of Animal Husbandry and Dairying, Ministry of Agriculture, Government of India.

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# CHAPTER III

# LOPPING OF OAKS: THE LINK BETWEEN THE GARHWALI PEOPLE AND THEIR FORESTS

## SUMMARY

The practice of lopping used by villagers to collect fodder in rural villages of the Central Indian Himalaya has existed for centuries. Yet, there have been no studies on the lopping practice and its inherent relationship with the livelihood of the people. I examined the relationship among the socio-economic factors such as gender roles and responsibilities, household composition together with lopping practice such as the diameter of branches lopped and the weight of foliage bundles removed from the forest. Data were collected in 1993 and 2006 to determine how lopping practices changed over 13 years. The results indicate that lopping practice is not static. Though the physical method of lopping and the location for fodder collection has not changed over the years, the intensity of lopping has changed from 1993 to 2006. A marked increase in intensity was initiated by the construction of the road that altered the socio-economic situation of each individual household in the village. Under intense lopping, the people noticed that the foliage of forest trees began to decrease. This initiated a reconsideration of the entire

village society on their current absolute dependence on the forest as their principal source of livelihood.

## INTRODUCTION

The practice of lopping or the cutting of branches and twigs of oak trees has been a constant source of conflict between forest managers and the villagers in the Central Himalayas of India. The 1927 Forest Act codified the reservation of forests; placed boundaries around the forests; and prohibited the village people from cultivating forested land, lopping trees, or grazing livestock in the forest (Tucker 1984; 1986; Rawat 1989). Yet, this Act ignored a fundamental aspect of the lives of the rural people – that their livelihood is entirely dependent on the availability of oak foliage.

The negative perspective of the foresters concerning the lopping practice is reflected in most of the literature on oak-pine forests in the Central Himalayas. The potential for "wanton destruction" of oaks was observed and recorded by Gorrie as early as 1937. He claimed that the "oaks everywhere in accessible Government forests have been so mutilated by continuous lopping that they are rapidly dying out" (Gorrie 1937). Later literature on forest use by the villagers also targeted lopping as the cause of the degradation of forests. Chaturvedi (1985) wrote that "the *banj* [*Quercus leuchotrichophora* A. Camus] forest and the water springs associated with the forest disappear." Human use of the forest is sometimes characterized as disturbance and considered to have a negative impact on the forest stand (Babu *et al.* 1984; Sundriyal & Sharma 1996; Dove *et al.* 2005). More recent studies have begun to examine the people-forest interactions by analyzing the energy flow between the forest and agriculture (Pandey & Singh 1984; Singh *et al.* 1984; Datt 1993; Negi & Todaria 1993; Tripathi & Sah 2001). Yet, these studies do not systematically examine the key link between humans and the forest – the lopping practice itself (Moench & Bandyopadhyay 1986; Mahat *et al.* 1987; Negi *et al.* 1999).

The practice of lopping is what brings the village people in direct contact with the forest. It is the method used by villagers to collect oak foliage which is fed as fodder to their water buffaloes, cows, and bulls. Fodder consists of fresh green oak foliage, green or dried grass from the forests, green grass from the agricultural fields, or dried wheat or rice stalks (Singh & Naik 1987; Makino 1994; Singh & Bohra 2005). Pandey *et al.* (1984) found that up to 87% of the fodder requirement was met by the forest in villages of the Kumaon Division of Central Himalaya.

The consistent supply of fodder for livestock is the key factor in the chain of interactions that sustains the agricultural livelihood of the rural village communities of Garhwal Himalaya, India (Negi 1977; Nautiyal *et al.* 1987; Singh & Naik 1987; Rathore *et al.* 1995; Negi *et al.* 1997; Reddy & Chakravarty 1999). Historically, in this Himalayan region, the availability of oak foliage from the forest determines the agricultural productivity of the village (Moench & Bandyopadhyay 1986; Moench 1989; Makino 1994). Therefore, lopping practice is the link between the health and persistence of the forest ecosystems and the livelihood of the village people. Without a detailed understanding of lopping, we can neither resolve the threat to the forest ecosystems nor the threat to the livelihood of the rural village society. It is not sufficient just to state that lopping affects the forest; but it is imperative to understand both the physical process of lopping, as well as, the socio-economic factors that drive the lopping practice.

The objectives of the study were to examine factors that influence the lopping process, specifically: (1) fodder collection methods including site selection and lopping techniques; (2) lopping practices including the tree species lopped, the diameter of the trees and branches lopped, and weight of oak foliage bundles; and (3) socio-economic status of households and kinship relationships.

## METHODS

### Study area

Beli village (pseudonym) is located in the Jaunpur Range, Tehri Garhwal Himalaya, India (Figure 3-1). The village is divided into three settlements, patterned after the historical and cultural transhumance lifestyle of the people before the 1800s (Ram 1988; Moench 1989; Berreman 1993). They migrated annually with their cattle from the plains to higher elevations for two to three months during the summer. Migration from one settlement to another occurs according to the cropping seasons. Living accommodations and fodder-collection cycles are adapted to the agricultural cycles. The main village settlement is at an elevation of 1,854 m; it supports 46 permanent houses. The lower settlement or *nadi* is situated in the Aglar river valley, approximately 17 km south of the main village at an elevation of 500 m. This settlement is only used in the month of July during potato harvesting and in the rice-transplanting season. The upper settlement, called *chan,* is located at an elevation of 2,110 m, approximately 0.70 km from the main settlement.

In 2006, the village consists of 144 households, with a population of 892 people of which 46 are from the Scheduled Caste and 846 are from the Rajput Caste (Director of Census Operations Uttaranchal 2004). The occupation of the Scheduled Caste families consists of farmers, ironsmiths, and musicians. The people in the Rajput Caste are mainly farmers and merchants. The main source of income is agricultural production.

Beli village is situated in the temperate montane region of the Central Himalayas that ranges between 1,500 and 3,500 m in elevation and is characterized by moist temperate mixed evergreen broadleaf and conifer vegetation. The average monthly rainfall from 1993-2006 was 581.4 mm, with the most rainfall occurring in July and August with 2,068.6 mm and 1,574.4 mm respectively (Division 2006b) (Figure 3-2 and Figure 3-3). Fires occur periodically in the conifer dominated region due to natural or man-made causes, particularly during the dry months of April and June (Division 2006a) (Figure 3-4). The vegetation of this region is dominated by *Quercus leucotrichophora* A. Camus at the lower altitudes between 1,800 to 2,400 m and *Quercus floribunda* Rehder at slightly higher altitudes, ranging from 2,000 to 2,700 m. The forests surrounding the village are classified as Reserve forests by the Forest Department of Uttaranchal and are not commercially logged.

Beli village was selected because it is the only village in this region with a protected forest that the village community collectively decided to stop using approximately 40 years ago. The collection of fodder, grazing, and collection of fuelwood is forbidden in this forest. A lopped forest of similar aspect, elevation and species composition is located diagonally above the northeast corner of the protected forest. The forest is frequented throughout the year since it is located immediately next to the *chan*. The presence of a protected forest and a lopped forest in the same vicinity provided the opportunity to analyze the influence of the villagers' use of the forest on forest composition and regeneration.

## Multi-disciplinary research approach

This study was part of a multi-disciplinary study that combined ethnographic and ecological methods to examine the practice of lopping and its consequences to the rural society and the forest ecosystem. The ethnographical methods were used to analyze the roles of age, gender, and kinship in fodder collection (The details of the method and findings are presented in Chapter II). The impact on the forest ecosystems was determined by examining the overstory, understory, coverage, ground-cover, leaf-litter, and soil nutrients of the protected forest and the lopped forest (The details of the method and findings are presented in Chapter IV).

In this study, I examined the practice of lopping and the factors that influenced it. In order to determine the long-term consequences of lopping on the rural society and the forest ecosystems, the data were collected during the months of May-August in 1993 and 2006. Twenty-two fodder collection trips were made in 1993, and 27 trips were made in 2006. Data on method of fodder collection, type of branches and trees lopped and amount of foliage collected were recorded for each trip. Specifically, these data included: (1) informal observations on the lopping method; number, gender, and age composition of the fodder collection group, distance and time traveled; location and area of forest lopped by the entire group; and elevation and aspect of the collection site; (2) diameter of each tree and branch lopped per person including name of each individual, gender, age, and species. The diameter of every branch lopped was measured at its attachment to the bole of the tree; and (3) weight of oak foliage bundles, including name of collector, gender, and age. The weight of every individual was recorded on a scale during a rest stop on the way to the collection site. The individuals were weighed again on the return trip along with their bundles. The bundle weight was calculated by subtracting the body weight from the total weight.

The data were analyzed using Pearson correlation and multiple linear regression analysis. Univariate ANOVA was used to compare the diameter of branches lopped per tree, DBH of tree, and the number of branches lopped between 1993 and 2006. I set the Type I error rate at 0.05.

## RESULTS

### Fodder collection

There are several closely related factors that determine the particular part of the forest where the people go to collect fodder (Table 3-1, Table 3-2). The season, agricultural cropping cycle, time during the day the collection takes place, the settlement from which the fodder collection group departs from, and the composition of the group all influence the location of fodder collection. The climatic season determines what species of fodder is available in the forest. Since each type of fodder is located at different elevations, the location is automatically rotated throughout the year. The season also determines the cropping cycle and the amount of work required in the fields. Therefore, during the harvest season, the people tend to go to the closer forests to collect fodder.

The purpose of fodder collection is to feed livestock (Figure 3-5). The water buffalo are stall-fed all year round, most cows and bulls are grazed during the summer (March-June) and monsoon (June-August) months, and the goats are grazed all year round (Table 3-1). The livestock, stall-fed during the summer, are fed the foliage of *Quercus floribunda* and *Quercus leucotrichophora*. When the monsoon rains begin, grass is gathered from the forest and agricultural fields. In the winter (January-March) the villagers feed the grass which they collected and dried in October and November along with dried wheat and rice stalks from that year's harvests. *Q. leucotrichophora* foliage is also collected and fed during the winter when there is no snow on the ground.

The fodder collection for *Quercus floribunda* begins in May and continues for two months (Table 3-1). The summer months are warmer and more time is available for the long trips because it falls between the harvest seasons. The number of people collecting fodder decreases in July when the rice transplanting season begins in the Aglar valley, and many families take their livestock with them. At the end of July they return to the main village settlement and *chan* for the potato harvest season. Since the villagers are occupied with harvesting, the fodder consists mainly of grass from the fields and *Quercus leucotrichophora*.

The oak trees chosen for lopping depend on the amount of foliage available on the branches. In order to reduce the necessity of climbing many trees, the people tend to select trees with a large amount of foliage. The foliage is collected by lopping the branches off the trunk at the point of attachment with a sickle (Figure 3-6). The thickness of branches lopped depends on the strength and weight of the individual. A large individual tends to lop branches that do not hold their weight as they climb the tree. Traditionally, people leave some foliage at the very top of the tree because they believe that leaving the foliage will prevent the tree from dying. The smaller twigs with foliage are removed from the larger branches and gathered into bundles. The larger branches are collected the following year when they are dry enough to be used for fuelwood. The bundles of foliage are tied together using the fibrous bark of *Wikstroemia carescens* Meissn. or *Viburnum cotinifolium* D. Don. The females carry the foliage bundles on their heads, and the males pierce them with a stick or *sweti* and carry them on their backs. Lopping is sometimes a family effort. When someone finds a tree that has more foliage than they need, they invite others to gather the fallen foliage. Those who are 10-12 years-old and still inexperienced at climbing trees gather foliage that has been cut for them by others.

Fodder collection is usually done in groups consisting of kin or in case of children, school friends. Who goes into the forest each day from individual households is determined by the matriarch of the family. She determines whether oak foliage, grass, fuelwood or leaf litter needs to be collected based upon the number and type of livestock owned by the family.

### *Quercus floribunda collection trips*

Since *Quercus floribunda* collection occurred during the months of May-June when the schools were on summer vacation, the fodder collection groups were large and consisted of 12 to 32 people (Table 3-3). The composition of the groups ranged from four to14 females and four to 12 males. The ages of females collecting fodder ranged from 12 to 50 and the ages of males ranged from eight to 20.

Each morning during the summer months in 1993, a group from the main settlement and another group from the *chan* went to collect *Quercus floribunda* in the morning (Figure 3-7). The forest they lopped was about 3 km away at an elevation of 2,450 m. The two groups met at a rest stop on the way to their destination. The destination was usually decided by the oldest females of the group. The young people in the group preferred to go as far as they could because the trees further away from the main village settlement and *chan* have a higher probability of not being previously lopped. The females over 40 years-old preferred not to go too far because it meant a long return trip with heavy loads. However, the distance traveled to collect *Q. floribunda* got progressively further during the subsequent trips during the month because the trees closer to the settlements were already lopped.

In 2006, only one group from the *chan* went to collect *Quercus floribunda* in the morning (Table 3-2) (Figure 3-7). No group left from the main settlement. During the summer until the beginning of the monsoon season, the fodder collected alternated between *Q. floribunda* on one day and grass the next. *Q. floribunda* collection ended once the monsoon season began and the potato and radish harvesting season began. The location for fodder collection was decided by consensus while they are walking in the forest. Groups traveled from 1 to 2.8 km to reach the *Q. floribunda* site located at around 2,450 m in elevation (Figure 3-7). Once the group reached their destination, they spread out and found trees that they preferred to lop within an area up to 640 $m^2$. The number of people in a group ranged from two to 10, which is considerably less than 1993 (Table 3-3). The number of females in a group ranged from two to 8, whereas, there were only one to four males in the group. The ages of females collecting fodder ranged from 12 to 53, and the ages of males ranged from 15 to 25. The decrease in the number of males was due to the fact that all the young children were now going to school during the day, and only the children who no longer go to school collect fodder in the mornings.

### *Quercus leucotrichophora* collection trips

In 1993, *Quercus leucotrichophora* collection trips left from both the main settlement and the *chan*. In the main settlement, during the months of July and August, *Q. leucotrichophora* was collected only in the afternoon (Table 3-2). The groups would walk along the road towards another village and climb up the numerous goat paths above the road (Figure 3-7). The lopping sites were approximately 2 km from the main Beli village settlement. The groups consisted of approximately four to eight people and were considerably smaller in size than the *Q. floribunda* collection groups (Table 3-3). The groups were composed mainly of females between the ages of 13 to 17 and males between the ages of eight to12. The primary reason for the small group was because many families move to the lower settlement in the Aglar valley for rice transplanting and take their livestock with them. Families that were large enough to have some members stay behind in the main village or those families who did not own land in the valley sent their children to the forest to collect fodder.

In 1993, two *Quercus leucotrichophora* trips left from *chan*, one in the morning and another in the afternoon. The lopping site was located 0.8-1.3 km from *chan* and toward the neighboring village in the opposite direction from the *Quercus floribunda* collection sites at an elevation of 2,083 m (Figure 3-7). The fodder collection trips were made in early in the morning and afternoon to allow time for potato harvesting. The groups consisted mainly of kin who helped each other collect fodder. The morning consisted only of females between the ages of 13 to 50, because the males around the ages of 8 to 14 were attending school (Table 3-3). The afternoon trips were made by the males who came back from school and females of the ages of 40-50. The other *females* were busy harvesting potatoes. Both the forests that were lopped for *Q. leucotrichophora* had been previously lopped.

There was a marked difference in 2006 in comparison to 1993 in the number of trips, group composition, and the number of people in the *Q. leucotrichophora* fodder collection groups (Table 3-3). The fodder collection from the main village settlement took place in the mornings by single individuals, rather than by groups. The females were aged between 21 and 26, and consisted mainly of daughter-in-laws while the mother-in-law worked in the fields. The males were between 12- and 18-years-old and were no longer going to school. The fodder collection sites were the same as in 1993 and were located along the road towards Mugra at elevations of 1,854-2,010 m (Figure 3-7). The villagers traveled between 0.2-2.5 km from the village, and they reached their destinations within an hour after leaving the village.

In 2006, only one trip was made from the *chan* to collect *Quercus leucotrichophora* in the afternoons, and the groups consisted of children who attended school in the morning (Table 3-2). No trips were made in the mornings in contrast to 1993. The ages of the both the females and males ranged from 11 to 16 (Table 3-3). The number in a group ranged from 2 to 9 people. The fodder collection sites were located between 0.74-2.3 km from the *chan* at an elevation of 2,083 m (Figure 3-7). Most of the trees in the forest had been previously lopped.

## Comparison of lopping practices between gender and ages

### *Diameter at breast height (DBH) of trees lopped*

In 1993, the average DBH of trees lopped by females was 21.9 cm, whereas in 2006, the average was 20.6 cm (Table 3-6). In contrast, for males in 1993, the average DBH of lopped trees was 27.4 cm, and the average in 2006 was 27.8 cm.

There was no significant difference between the DBH of tree lopped between 1993 and 2006 by females at the average age of 20.3 (p=0.61) (Table 3-4 and Table 3-5). There was no significant difference between the DBH of trees lopped between 1993 and 2006 by males at the average age of 14.9 (p=0.31).

For both 1993 and 2006, the body weight of males and their age (were good predictors of the DBH of trees they lop (Table 3-3). However, for females the body weight and age are not significant predictors (Table 3-3 and Table 3-4).

### *Number of branches lopped per tree*

In 1993, the average number of branches lopped by females was 44, whereas in 2006, the average was 63 (Table 3-6). In contrast, for males in 1993, the average number of branches lopped was 58, and the average in 2006 was 75 (Table 3-6).

For females, there was no significant difference in the number of branches lopped between 1993 and 2006 (p=0.13) at the average age of 20.3 (Table 3-3 and Table 3-4). For males, there was no significant difference in the number of branches lopped between 1993 and 2006 (p=0.19) at the average age of 14.3 (Table 3-3 and Table 3-4).

For the 2006 data, age was a good predictor of the average number of branches lopped per tree for both females (p=0.01) and but not for males (p=0.48) (Table 3-4).

### *The diameter of branches lopped*

In 1993, the average diameter of branches lopped by females was 1.6 cm (Table 3-6). The variation in the diameter of branches lopped was greater in females below age 20 (Figure 3-8). However, as they grew older, there was a slight negative but not significant trend in diameter beginning around the age of 25, and the variation in the diameter of branches get smaller. In 2006, the diameter of the branches lopped by females was 0.99 cm (Table 3-6). There is a slight but not significant increase in the diameter of branches lopped with age (p=0.08) (Table 3-3) (Figure 3-9). There was a significant difference between the years at the average age of 20.03 (p=0.0003). The diameter of branches lopped by females in 1993 was significantly greater than 2006 at the ages below 25. But the difference between the ages becomes insignificant at after age 30 (Figure 3-8).

In 1993, the average diameter of branches lopped by males was 1.75 cm (Table 3-6). There is a significant (p=0.02) increasing trend in the diameter of branches lopped as the age increased (Table 3-3) (Figure 3-9). The regression equation used to estimate the diameter of branches lopped overestimates for ages above 22 and above because of the lack of data (Table 3-3) (Figure 3-9).

In 2006, the average diameter of branches lopped by males was 0.89 cm (Table 3-6). There is a slight but significant increase in the diameter of branches lopped with increase in age (p=0.01) (Figure 3-9). Again, the regression equation used to estimate the diameter of branches lopped overestimates for ages over 25 because of limited data. There was significant difference in the diameter of branches lopped between the years 1993 and 2006 at the average age of 14.9 (p=0.00008). The diameter of branches lopped by males in 1993 was significantly greater than those lopped in 2006. The difference tends to get greater as the age increases (Table 3-4) (Figure 3-9).

### ***The weight of the bundles carried out of the forests***

In 1993, the average weight of bundles carried out of the forest by females was 29.3 kg (Table 3-6). The weight of bundles carried by females gradually increased until age 25 when the weight of the bundles gradually decreased (Figure 3-10). In 2006, the average weight of bundles was 29.5 kg. In 1993, the average weight of bundles carried by males was 28.6 kg (Table 3-6). In 2006, the average weight of bundles carried by males was 22.2 kg. The male data have a more linear relationship compared to the females until the age of 30 (Figure 3-11).

In comparing the weight of bundles carried out of the forest in 1993 with 2006, the univariate analysis of variance test showed that there is a significant year effect for both males and females at the average age. For the females, the average bundle weight carried in 1993 at the average age of 24.2 years-old was 28.17 kg while in 2006 females carried an average of 31.57 kg. The bundle weight carried by females in 2006 is significantly greater than in 1993 at p=0.02, and differs by 3.4 kg. However, for males, the average bundle weight carried in 1993 (n=18) at the average age of 15.6 years-old was 29.97 kg, which is significantly more than 21.87 kg carried in 2006 (n=24) (p=0.0004). The trend of females carrying heavier bundles by males in 2006 compared to 1993 is consistent from a young age (Figure 3-10). The bundle weight carried in 2006 is significantly less at all the ages (Figure 3-11). Since there is no interaction between the curves, the tendency for the two years is the same.

# DISCUSSION

## Relationship between lopping and socio-economic situation in the village

The significance of this research is that the rural society is not static; it responds and adapts to resource availability. In Beli village, the villagers realized the decrease in oak foliage in the forest and adjusted their entire lifestyle and livelihood base to decrease their dependence on oak foliage.

The importance of the practice of lopping cannot simply be explained as the cutting off of branches. The practice of lopping is a reflection of the entire socio-economic situation in the rural society. It helps determine the entire social behavior of the community. Therefore, by examining the lopping practice over-time, it is possible to discern the changes that the rural society has undergone and continues to undergo.

The rural society of Garhwal is dependent on agriculture for their livelihood (Figure 3-3). However, this paradigm is undergoing a fundamental shift to seeking outside income from employment (Moench & Bandyopadhyay 1986; Berreman 1993; Guha 2000). This paradigm shift is due to a complex interaction between the people and the forest ecosystem (Figure 3-3). The change from agriculture to employment is exemplified in the lopping practice of the villagers (Figure 3-12).

In order to understand the shift it is important to understand the agricultural system of the village (Figure 3-3). Agriculture is supported by input of compost which is produced by mixing livestock manure with dry leaf litter from the forest (Pandey & Singh 1984). Livestock is kept for the production of manure and the production of milk is only a by-product of keeping livestock. The villagers prefer compost over commercial fertilizers because the urine acts as a natural pesticide and is free. The purpose for lopping is to collect oak foliage for fodder to feed the livestock (Figure 3-5) (Macfarlane 1976; Moench & Bandyopadhyay 1986; Guha 2000). Therefore, any increase in the demand for compost translates to the increase in livestock and greater demand for foliage from the forest (Figure 3-12). However, the amount of oak foliage that can be collected from the forest is constrained by the composition of each household and the amount of foliage available in the forest. Therefore, examining the gender roles and age differences in lopping and how they have changed between 1993 and 2006 indicates the shifting priorities of the households that have been induced by the change in foliage availability.

Five things stayed the same in the interaction between the people and the forest from 1993 and 2006. The people were still dependent on the forest for oak foliage as fodder to feed their livestock and made daily trips into the forest. The Reserve forests surrounding the village used in 1993 were the same forests used in 2006 as the source for fodder. Also lopping technique and tools used for lopping had not changed. The people continued to use a sickle to cut the branches off trees and remove the smaller twigs with foliage to be carried back to the village. The same oak species, *Quercus leucotrichophora* and *Quercus floribunda* were collected for fodder and rotated according to the annual seasons (Makino 1994; Singh & Bohra 2005) (Table 3-1 and Table 3-2). However, there was a distinct decrease between 1993 and 2006 in the number of trips into the forest, and the number of people collecting fodder.

The roots of the transformation began in 1978 when the road connecting the village to nearby towns was constructed (Moench 1989). Before the existence of the road, the agricultural produce in Beli village was wheat, rice, and potatoes which could be transported easily by mules. The ability to use trucks enabled the production of cash crops such as radish, cabbage, capsicum, and cauliflower. Yet, these vegetables required high input of compost, thus increased the need to keep more livestock and collect more fodder. According to the villagers, the increase in livestock continued until early 2000s when the villagers noticed a marked decrease of the foliage on the lopped oak trees. This perception by the villagers is also supported by Singh et al. (2005) who reported a 19% deficit in green fodder in the mid-altitude Himalayan hills in 2001. The dramatic increase in the number of livestock also has been observed in other villages in Uttaranchal (Singh & Tulachan 2002). The villagers began to modify their fodder collection and lopping practices. The decrease in the number of trips being made daily into the forest from five in 1993 to three in 2006 indicated that less fodder was being collected from the forest. There was not a considerable decrease in the number of people in each fodder collection group but a change in the age composition of the group. The groups in 2006 were composed of males and females who no longer went to school (Figure 3-13).

The shift in focus of the villagers from agriculture as the main source of income to outside employment meant that the villagers needed to learn to read and write to be employable. The relationship between the availability of forest resources and its greatest impact on the poorest people in the village has also been documented by Reddy *et al.* (1999). Therefore, instead of the few children being sent to school in 1993, all the children were being sent to school in 2006 (See chapter II). With more children being sent to school, there was again, a decrease in the number of people available to go into the forest to collect fodder. This inevitably places greater burden on the females in the household to collect enough fodder. This trend was reflected in the lopping practice.

## Lopping practice

There were significant differences in the diameter branches and weight of foliage bundles that being carried out of the forest between 1993 and 2006 (Figure 3-8, Figure 3-9, Figure 3-10, Figure 3-11). The differences clearly reflect the socio-economic changes that occurred in the village since 1993 as well as the changes that occurred in the forest ecosystem. The data, segregated by gender and age, allow a detailed analysis of the changing lopping practices concomitant with gender and age changes in the village society. Through understanding the effects of differences in age and gender on the diameter of branches collected and the bundle weight, one can estimate the degree in which the group will impact the tree and the forest.

No significant differences in the diameter of trees that were lopped in 1993 and 2006 indicate that the forest density and growth have largely stayed the same over the 13 years. Yet, there is a significant difference in the diameter of branches that were lopped by both the females and males. This difference may signify that the villagers are lopping more epicormic sprouts in 2006 in comparison to 1993 i.e. sprouts on the bole of a tree due to physiological stress from a poor crown. This trend also supports the villagers' perception that the forest is providing progressively less foliage.

The importance of comparing the relationship between age and gender and the diameter of branches lopped is that it determines how quickly the tree will assume the "poodle" like appearance that is characteristic of lopped trees (Figure 3-6). The positive correlation between the thickness of the branches lopped and age is most likely due to the increase in body weight and strength as the collector grows older. As body weight increases, it also becomes increasingly difficult and dangerous to go further out on a branch to lop the smaller twigs or climb higher in a tree. Therefore, the stronger people tend to lop the entire branch and remove the smaller twigs from it once it is on the ground. Likewise, the young females tend to have greater variation in the diameter of branches that they lop because of their greater variation in their size and weights. However, the variance disappears in the females above 30 years-old because they tend to be smaller in size, and weaker, but also prefer to lop smaller branches which are easier to bundle.

The relationship between age and gender and the weight of fodder bundles gives an insight on the need for fodder in the particular family. The person or the number of persons sent out from the family is likely to be directly related to the number of livestock that are stall-fed. Therefore, by simply observing the composition of fodder collection groups, one can estimate the amount of fodder collected from the forest by the entire village.

The relationship between age and fodder bundle weight appears to be the similar for both females and males (Figure10, Figure 3-11). The initial part of the curvilinear trend of bundle weights carried is expected because as age increases, the bundle weight a person can carry also increases as a function of strength. However, after a certain age, one begins to carry lighter loads. However, the regression equation tends to over-estimate the fodder bundle weights for males over the age of 25 yrs. There is limited data on males after the age of 25 because most males stop collecting fodder at the age of 20 and very few carry on until the age of 30. This is because males get married at the age of 19 to 20 yrs, and once they are married, it becomes the wife's responsibility to collect the fodder. If the male comes from a small joint family[5] or owns a large amount of livestock, he may continue to go collecting after marriage. However, once their child reaches the age of 10 yrs, the child takes over the responsibility, and the father stops collecting.

The foliage bundle weight of males decrease significantly and the bundle of weight of females increase from 1993 to 2006. This change in bundle weight is a reflection of the social trend where the females have had to take the responsibility of collecting more fodder due to the decrease in labor available because the children are now going to school. The decrease in available labor has forced a decrease in the number of livestock a family can keep, thereby, decreasing the amount of compost available to apply on the fields. As a result, the people have become increasingly reliant on chemical fertilizers and pesticides which require cash to purchase whereas, fodder was cost free. Accordingly, more people need to leave the village to seek outside employment, again decreasing the amount of labor available in the household for fodder collection.

Finally, the importance of these findings is that it demonstrates previous studies have largely ignored the role of females in fodder collection even though they are the main fodder collectors. Though Mahat et al. (1987) studied peoples' perceptions of the forest, they only interviewed the heads of the family who were mostly males, except two females. Negi *et al.* (1999) also interviewed villagers but they focused on the heads of the family or the oldest member in the family. Yet, most males stop collecting fodder when

[5] A joint family is defined as "a patrilocal extended family under the leadership of the eldest active male" Berreman, G. D. (1993) *Hindus of the Himalayas : ethnography and change*. Delhi ; New York: Oxford University Press.

they marry between the ages of 18 to 20. Moreover, due to societal constraints, it is extremely difficult for outside males to live in villages for extended periods of time and observe the daily lives of the people (Berreman 1993).

## CONCLUSIONS

The rural society is not static, but adapts to resource availability. The people in Beli village continued to collect fodder daily; varied species collected and rotated the location of lopping throughout the year of in 2006 as they did in 1993. Yet, the practice of lopping had undergone some fundamental changes between 1993 and 2006. The changes were initiated when the villagers' noticed that the amount of oak foliage available in the forest was gradually decreasing. Therefore, they realized that they could no longer rely entirely on the forest for their livelihood. In order to reduce their reliance on agriculture as their main source of livelihood, the villagers' strategy was to educate their children in preparation for future employment. This strategy resulted in changing the lopping practice that had continued for centuries. The age and gender composition of fodder groups changed; the number of fodder collection trips that were made into the forest changed; and ultimately, the number and type of livestock that each household owned changed. These changes were reflected in the type of branches that were lopped and the weight of the foliage bundles that were brought out by individuals. In other words, the villagers implemented their own form of forest management that adapted to changes in oak foliage.

The practice of lopping and fodder use is unequivocally driven by the interaction of complex socio-economic and ecological factors. The lopping practice is based upon embedded knowledge passed down from generation to generation. Household composition, age, and gender roles determine the type of impact the lopping practice has on the individual tree and ultimately the forest ecosystems. Due to the complexity of interactions, forest-use cannot be examined in isolation from the livelihood of the villagers. As the source of livelihood of the villagers change, the intensity of forest use also changes. Therefore, in order to understand forest use and management in the villages of Central Himalaya, it is essential to understand the socio-economic changes that are also occurring.

**Figure 3-1** Location of the main settlement of Beli Village showing the protected forest directly above the village and the adjacent lopped forest to the right of it. Beli village, Tehri Garhwal.

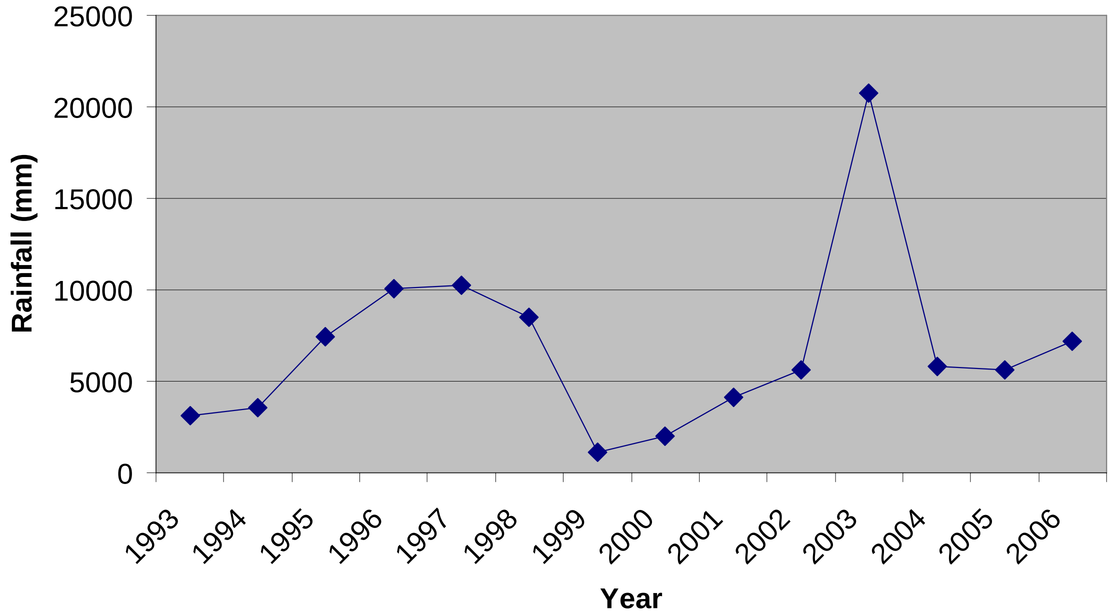



**Figure 3-2** Diagram of the average annual rainfall, Jaunpur Range, Mussoorie Forest Division, Garhwal, Uttaranchal, India. Source: Rainfall register, Jaunpur Range, Mussoorie Forest Division (2006).

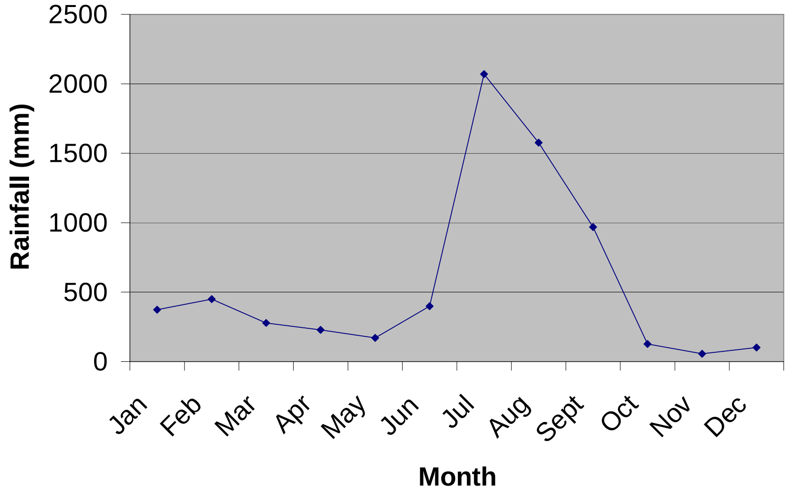



**Figure 3-3** Diagram of the average monthly rainfall (1993-2006) Jaunpur Range, Mussoorie Forest Division, Garhwal, Uttaranchal, India. Source: Rainfall register, Jaunpur Range, Mussoorie Forest Division (2006).

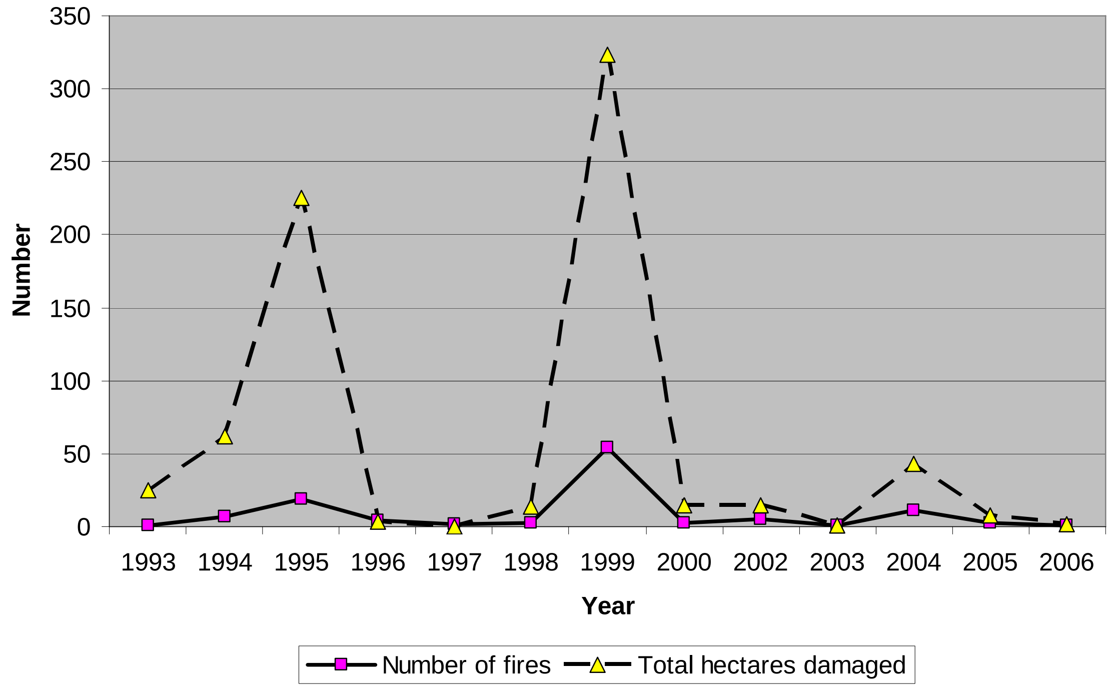



**Figure 3-4** Diagram showing the number of fires per year (□) and the number of hectares (Δ) damaged by fire from 1993 to 2006. Source: Fire register, Jaunpur Range, Mussoorie Forest Division (2006).

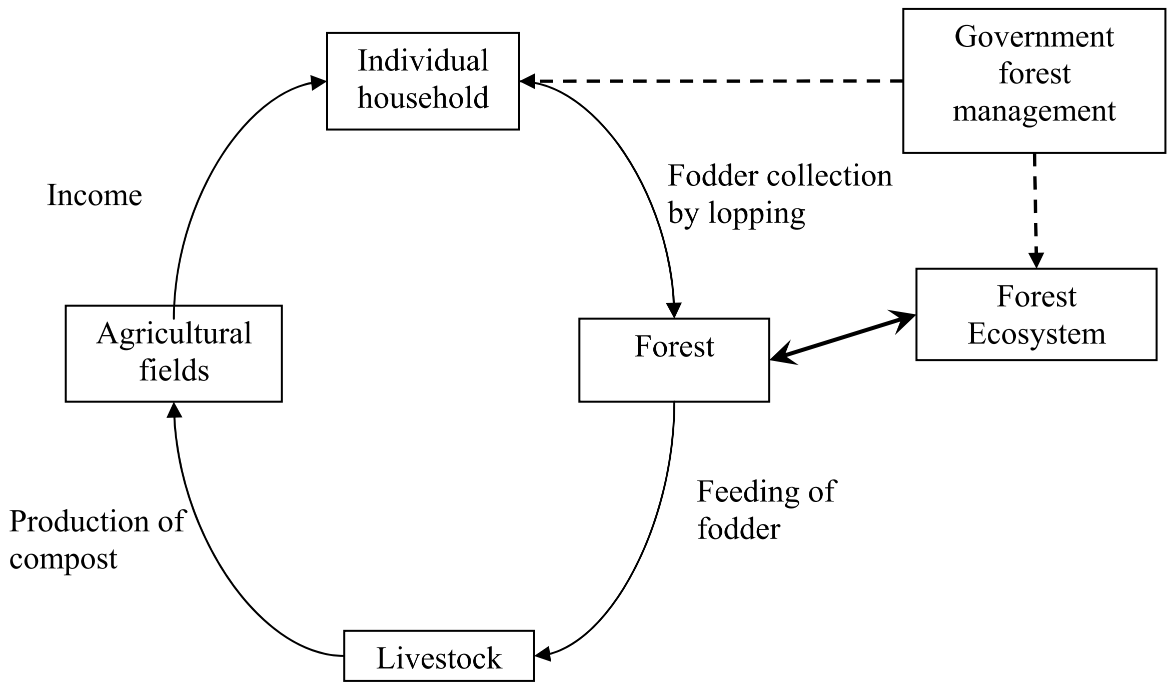
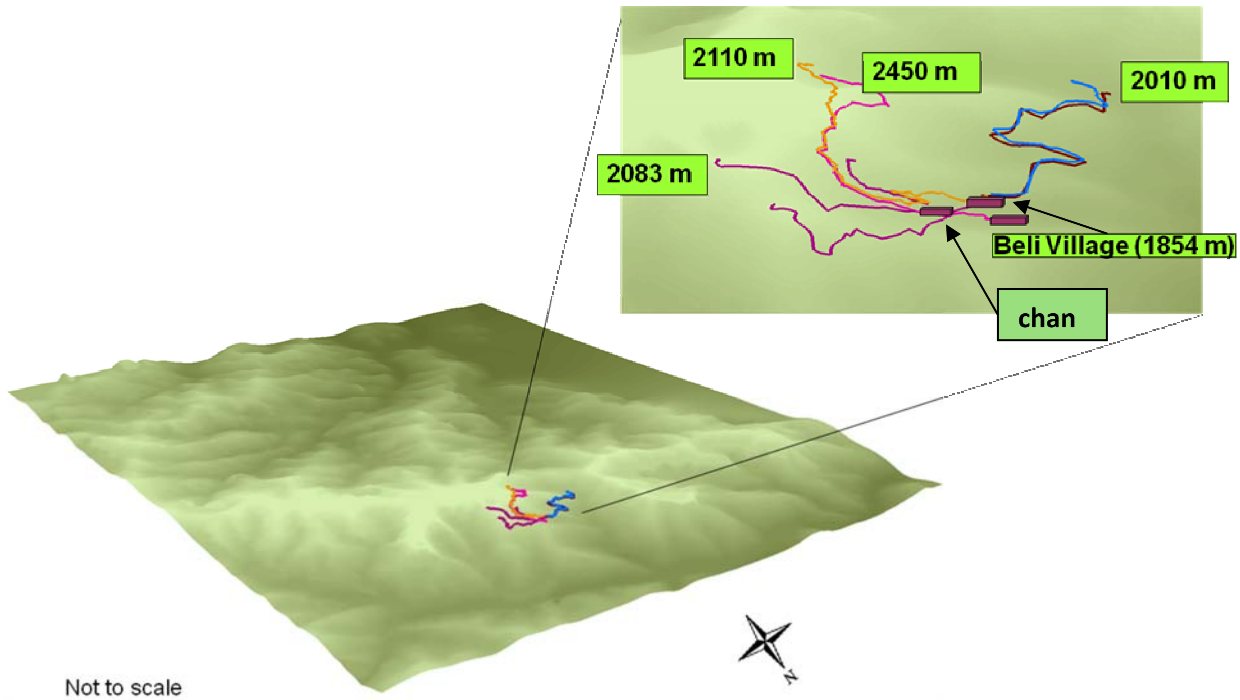



**Figure 3-5** Conceptual model of the complex interactions between the people and the forest in Beli village, Tehri Garhwal Himalaya, India

a) b)

**Figure 3-6** Comparison of a Quercus leucotrichophora tree before a) and after b) lopping. The lower branches have been lopped and the top has been left. Lopped forest near Beli village, Tehri Garhwal.




**Legend**

Quercus leucotrichophora route from *chan*

Quercus leucotrichophora route from Main Village

**Quercus** floribunda route from *chan*

Grass route from *chan*

Grass route from Main Village

**Elevation**

**Value**

High : 2806

Low : 650

**Figure 3-7** Map showing the relative location of fodder collection sites for 2006 according to oak species or grass collected around Beli village, Tehri Garhwal.

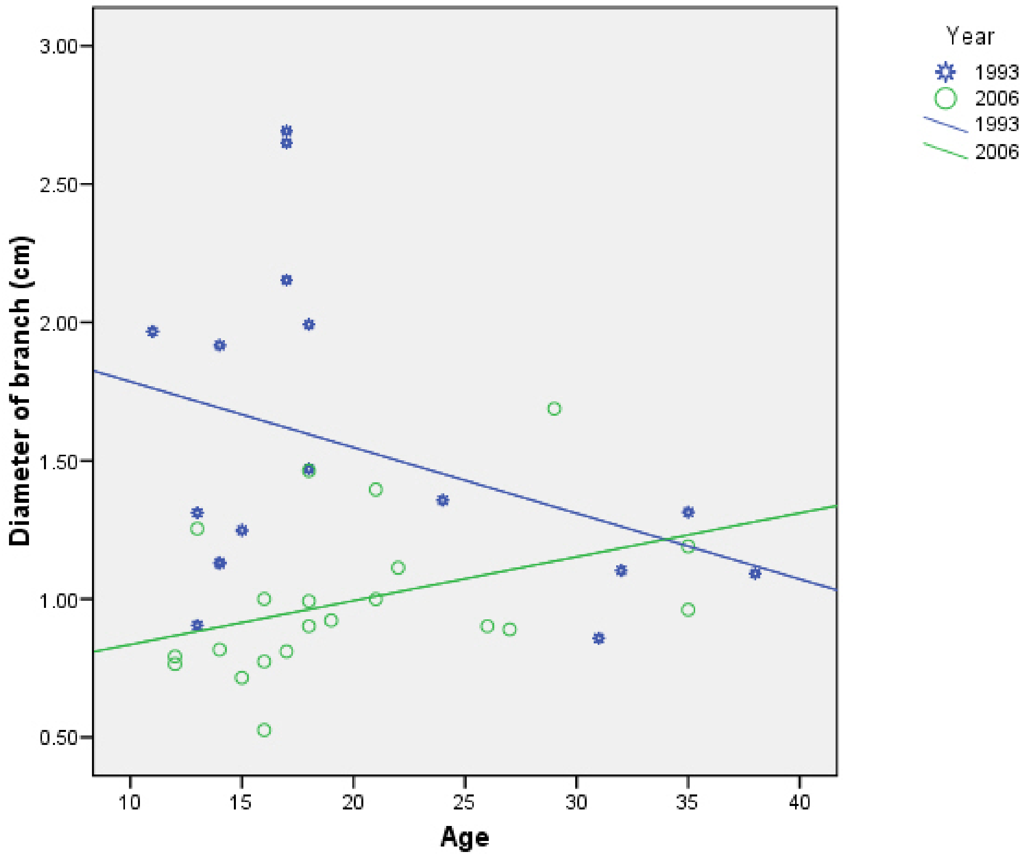



**Figure 3-8** Comparison of the average diameter of oak tree branches lopped by females Average in 1993 and 2006 in Beli village, Tehri Garhwal.

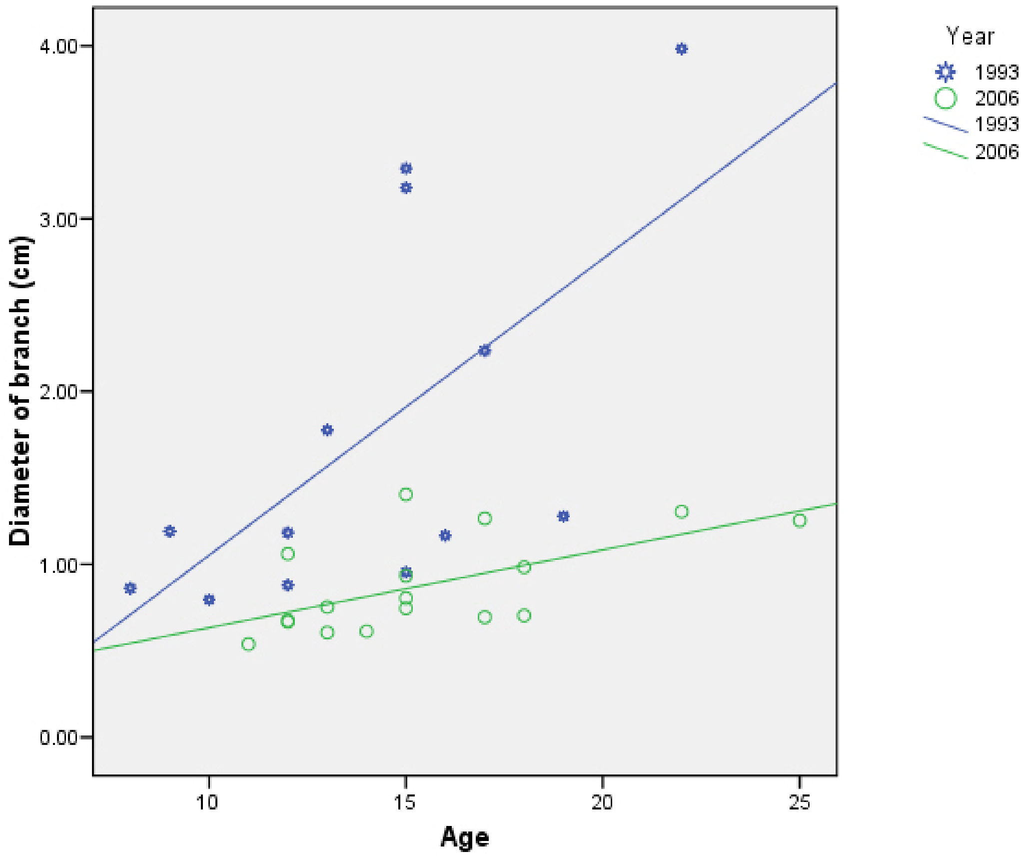



**Figure 3-9** Comparison of average diameter of oak tree branches lopped by males in 1993 and 2006 in Beli village, Tehri Garhwal.

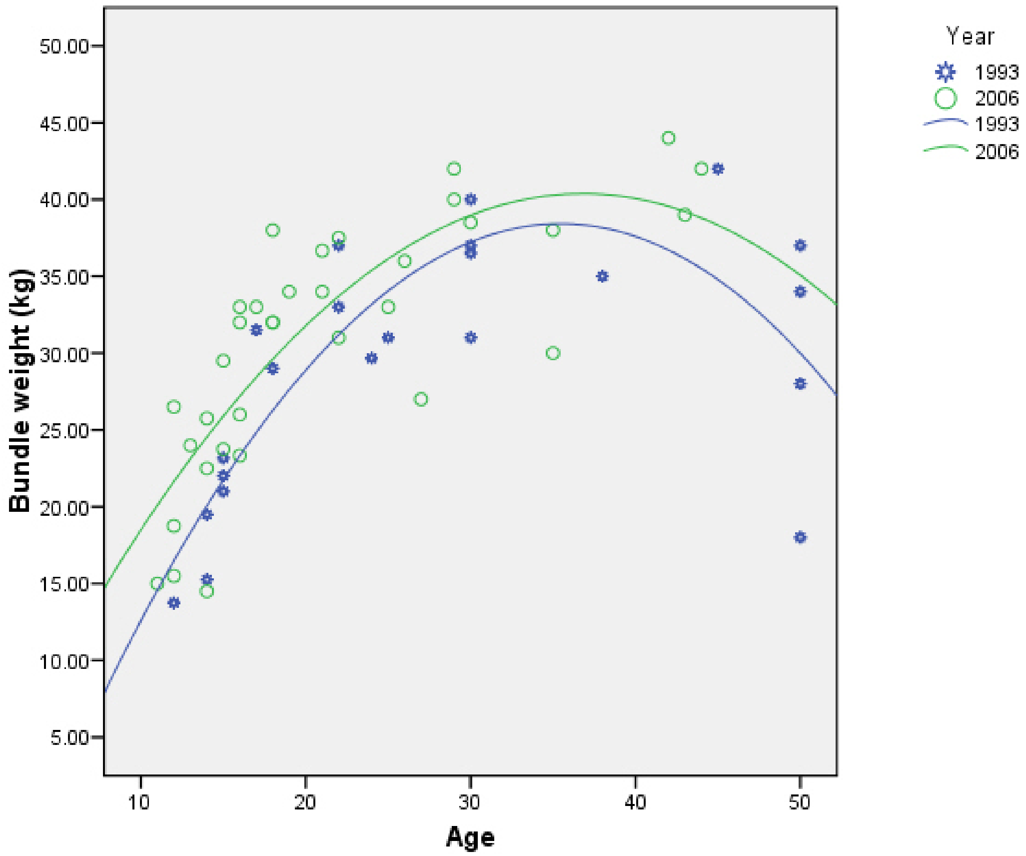



**Figure 3-10** Comparison of the weight of fodder bundles carried out of the forest by females in 1993 and 2006 in Beli village, Tehri Garhwal.

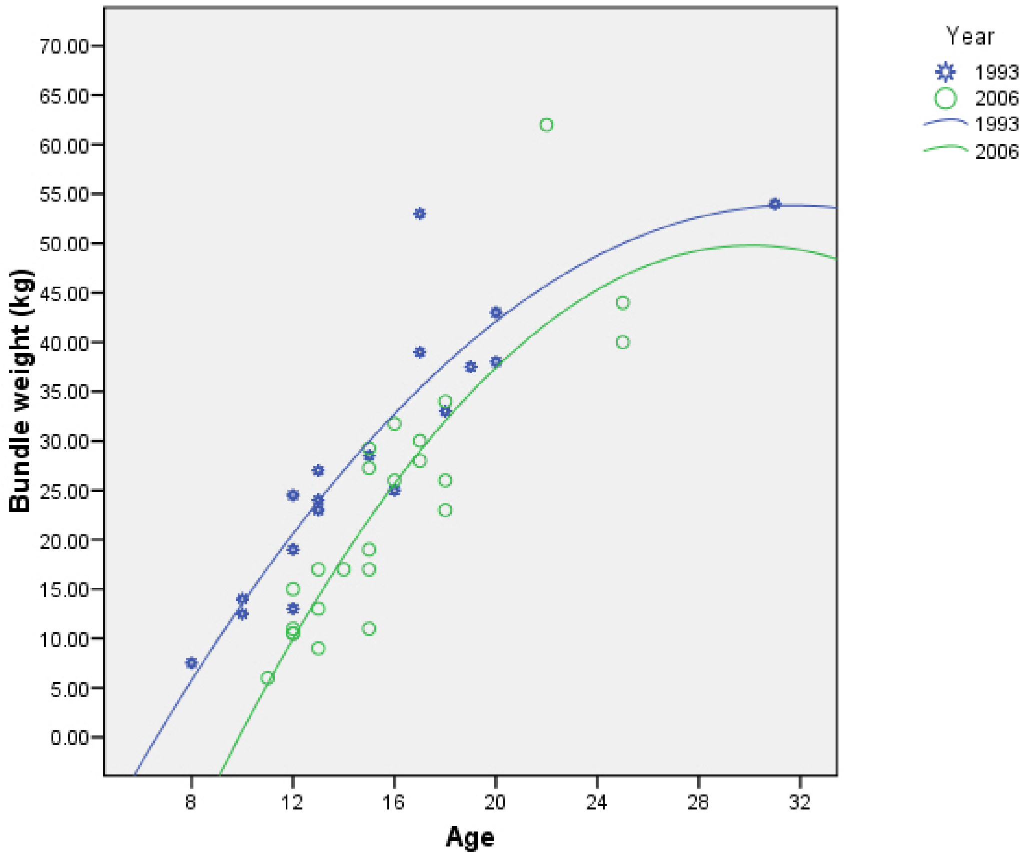



**Figure 3-11** Comparison of the weight of fodder bundles carried out of the forest by males in 1993 and 2006 in Beli village, Tehri Garhwal.

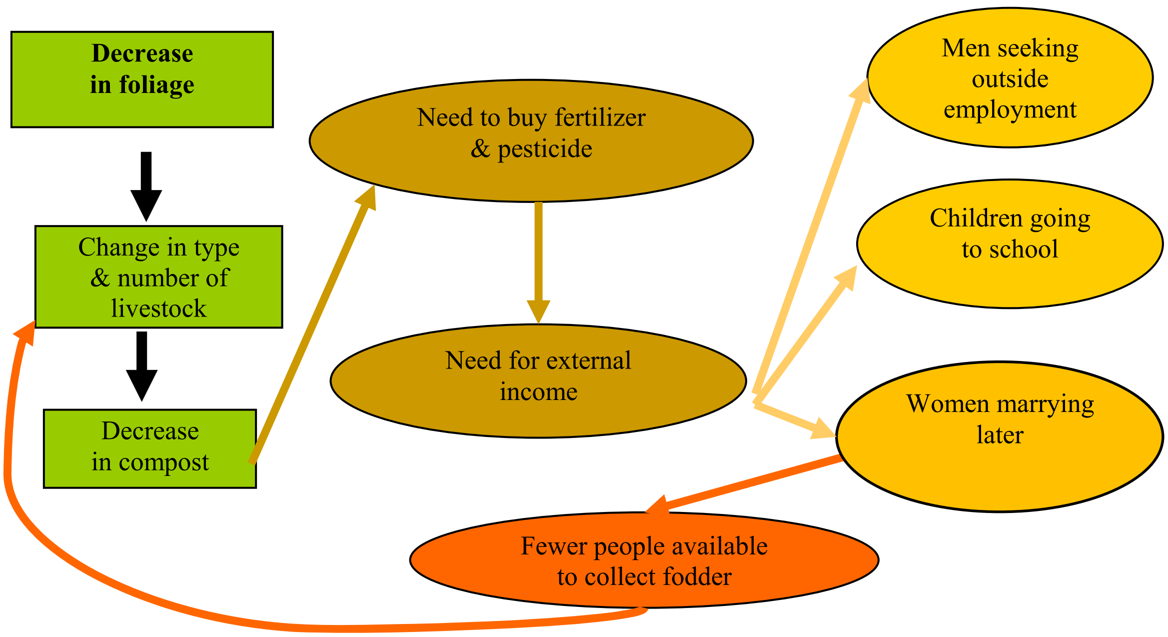



**Figure 3-12** Diagram illustrating the interaction between people and the forests to show the changes brought about in the Beli village, Tehri Garhwal due to the decrease in foliage (2006).

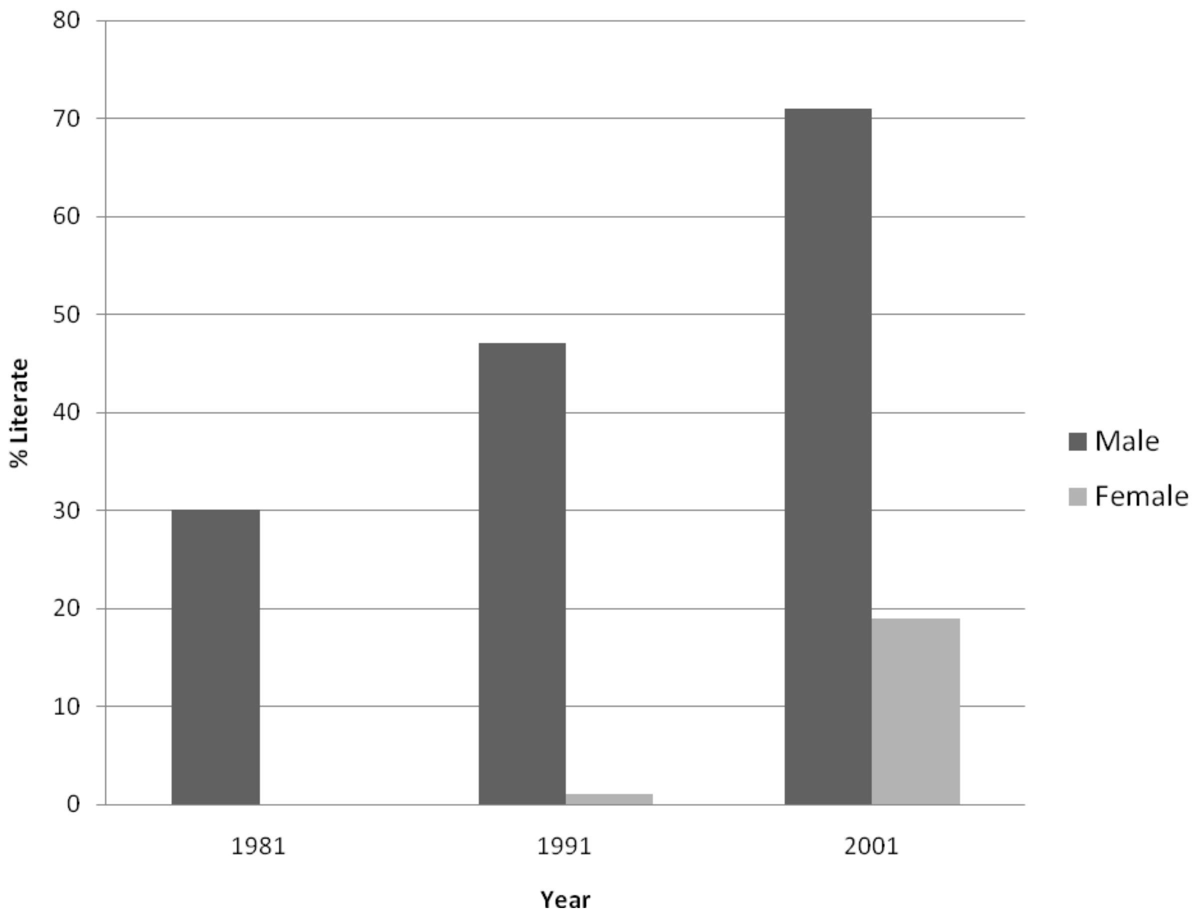



**Figure 3-13** Comparison of the change in literacy rates of males and females for 1981, 1991 and 2001 in Beli village, Tehri Garhwal.

Sources: Payal BS: Census of Tehri Garhwal U. P. 1981, 1991. 1993; Vijayan Unni M. 1999. *Uttar Pradesh district profile, 1991*. Delhi, Controller of Publications; Director of Census Operations U, India. 2004. *Census of India, 2001. Series 6*. Delhi, Controller of Publications.

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# CHAPTER IV

# THE IMPACT OF LOPPING ON LONG-TERM FOREST COMPOSITION AND REGENERATION IN TEHRI GARHWAL HIMALAYA, INDIA

## INTRODUCTION

Lopping of oak branches is the method used by the villagers to collect foliage fed to livestock (Moench & Bandyopadhyay 1986; Makino 1994). However, the practice of lopping oak branches for fodder has been blamed by foresters for causing extensive degradation of the forests in the Central Himalayan region of India. Yet, the consistent supply of fodder for livestock is the key factor in the chain of interactions that sustains the livelihood of the village communities (Negi 1977; Nautiyal *et al.* 1987; Rathore *et al.* 1995; Negi *et al.* 1997; Reddy & Chakravarty 1999). The livelihood of these village communities is based upon income from agricultural production (Singh *et al.* 1984a). In turn, the agricultural production is dependent on the availability of compost or *gobar* to fertilize the fields. *Gobar* is made by mixing dung and urine of buffalos, cows and goats with dry oak or pine leaf litter from the forest floor. Therefore, the collection of fodder is the first step that turns the wheel of the agricultural economy of the village community (Makino 1994).

Fodder consists of fresh green oak foliage, green or dried grass from the forests, green grass from the agricultural fields, and dried wheat or rice stalks. Although the type of fodder fed to the livestock varies according to the yearly seasons, oak foliage is fed all year round. The principal sources of foliage are the lower elevation *Quercus leucotrichophora* A. Camus[6] collected throughout the year, and the higher elevation *Quercus floribunda* Rehder collected during the monsoon months (Singh 1982; Singh & Naik 1987; Makino 1994). The oak foliage is collected by climbing the tree and lopping the branches. The larger branches are then left to dry on the forest floor for later collection as fuel wood and the smaller twigs with the foliage gathered into bundles and carried back to the village.

The lopping practice has long been a source of friction between government foresters and the villagers, as voiced in 1907 by Garhwal Deputy Commissioner Nair in a note on forest administration for his successor, "forest administration consists for most part in a running fight with the villagers (Shiva & Bandyopadhyay 1986)." Most of the literature approaches lopping from the perspective of its impact on forest trees and stands. As early as 1937, Gorrie (1937) wrote of the potential for "wanton destruction of this valuable fodder resource." He claimed that the "oaks everywhere in accessible Government forests have been so mutilated by continuous lopping that they are rapidly dying out" (Gorrie 1937). Later literature on forest use also asserts that lopping was causing "the *banj* forest and the water-springs associated with the forest [to] disappear" (Chaturvedi 1985). Though regeneration ecology of oak and pine in the temperate montane regions of the central Himalayas between 1,500 and 3,500 m has been

[6] All Latin names follow Gaur, R. D. (1999) *Flora of the District Garhwal Northwest Himalaya (with ethnobotanical notes)*. Srinagar (Garhwal). India: TransMedia.

documented since 1921, research on forest use by the village communities gained attention only in the 1980s (Troup 1921; Moench & Bandyopadhyay 1986; Rao & Singh 1989; Tripathi & Sah 2001; Awasthi *et al.* 2003). These studies on people-forest interactions focused on energy and biomass flows between forest and agriculture (Pandey & Singh 1984; Singh *et al.* 1984a; Datt 1993; Negi & Todaria 1993; Tripathi & Sah 2001). Since 2001, there are studies documenting changes of land-use and land-cover over several decades using GIS information (Rao & Pant 2001; Sen *et al.* 2001). Further studies compare the regeneration under varying degrees of anthropogenic disturbance (Babu *et al.* 1984; Sundriyal & Sharma 1996; Kumar & Ram 2005). Kumar *et al.* (2005) studied eight forests varying in disturbance frequencies in the state of Uttaranchal, Central Himalayan Region. The limitation of the Kumar *et al.* (2005) study is that they defined the level of disturbance based on the distance of the forest from the village settlement. This definition is flawed in that the villagers rotate the forest stands, distance they travel, and species of fodder they utilize according to the annual season (Makino 1994).

## Disturbance in the Himalayas

As recognized in other landscape ecosystems, disturbance is an integral part of the mountain ecosystem and landscape. Both the natural and human disturbances have created "patch-mosaics" within the landscapes by altering the availability of light, nutrients, and favoring the survival of certain species (Turner *et al.* 2001).

Many of the natural disturbances that occur in the mountain landscapes of Beli village are directly related to the climate of the region. Though there is some precipitation from Jan-May, 75% of the rainfall occurs during the monsoon or rainy season which begins around June or July and ends in mid-September. There is very little precipitation for the rest of the year (Kandari & Gusain 2001). The severe monsoon rains can cause debris flow in the valleys, landslides, and wind throw of mainly pine trees.

On the other hand, during the dry season, all the forests are under drought conditions and the pine forests are susceptible to fires. There are fires reported every year. The number of fires range from one in 2003 to 53 in 1999. The number of fires is directly correlated to the amount of rainfall that year (personal comm., forest ranger Jaunpur range 2006). 63% of these fires are intentionally or accidentally lit by the villagers (Semwal & Mehta 1996). The main reasons given by the villagers is that the pine needles make the paths slippery for the livestock to graze and the pine needles have no use to the villagers. The fire can also be spread from agricultural fields that are burnt after wheat harvest in the dry months of summer or from a discarded lit cigarette or *bidi,* a locally made tobacco. Other human-caused disturbances besides fire are the extensive agricultural development into the forests, the practice of terrace farming on steep slopes, grazing of livestock in the forests, and lopping of oak foliage for fodder. There is very limited literature on the presence of pests in this region. There was only one article that mentioned an outbreak of Gypsy moth in 1979 in Himachal Pradesh, a state west of Garhwal (Verma *et al.* 1979).

The impact caused by these disturbances on the mountain landscape is dependent on: (1) the frequency, intensity, severity, size, and return interval of each disturbance (Turner *et al.* 2001), (2) type of land-use and forest composition, and (3) the predominately clay loam texture of the soil and limited soil horizon development.

The most severe and intense disturbances that occur in a short period are fire, landslides, and wind throw. Most of the fires in Garhwal are surface fires or low intensity fires and very seldom become crown fires. The fire travels down or up the slope of the mountain (Semwal & Mehta 1996). Fire favors the regeneration of fire resistant species such as pine and reduces the survival of less resistant species such as oak. Therefore, forests dominated by pines tend to remain pine dominated. In mixed forests, fire may favor the regeneration of pine species and reduce the regeneration of oak. Tiwari et al. (1985-1986) found that fire in the mixed forests of Garhwal increased the number of pine and shrub seedlings while decreasing the number of oak seedlings (Tiwari *et al.* 1985-86). This may be also due to the ability of pines to persist under the shade of oak for a longer time than it can under a dense shade of pine even though it is shade intolerant (Troup 1921). Sharma et al. (1997) found that after a wild fire in a forest dominated by broadleaf species, the barks of oaks was the least affected in comparison to the other species. Regeneration of saplings was observed for all the tree species through sprouting. However, oak trees with DBH<40 cm were susceptible to fires and did not resprout (Sharma & Rikhari 1997).

Landslides are frequent on the mountain-sides of Garhwal Himalaya and have varying intensities, severities and size. They can range from small landslides on agricultural terraces to extremely large landslides that wash away entire sections of the mountain-side taking with it roads and sections of villages. Landslides are usually triggered by extensive rainfall over a short period of time. The extent of the landslide is influenced by geology and steepness of the slope. Creep occurs where a mass of soil is sitting on top of bedrock. It develops over an extended period of time as the soil becomes slowly saturated with water and the entire soil mass begins to slide. Debris flow usually occurs when the soil from several landslides agglomerate in a drainage basin and flow down the mountain side or river basin. Large landslides cause the most extensive change in the forest ecosystem.

Wind throws are infrequent and tend to affect tall, shallow rooted pine trees. Entire trees fall down the mountain side creating gaps in the canopy. The gaps permit the pine or oak saplings in the ground-cover and understory access to light and grow (Troup 1921).

A natural disturbance that affects forests over the long-term is drought. Drought tends to affect the higher elevation oaks more than the lower elevation pines and oaks that are better adapted to drier conditions. *Q. leucotrichophora* has leaves that are dull green and glabrous above and densely white tomentose beneath (Troup 1921). The leaves of *Q. floribunda* are green on both surfaces but have adapted to drought by flushing their leaves close to the rainy season. In severe water shortages, *Q. floribunda* lower their osmotic water potential enabling them to extract more water from the soil and keep their buds closed even when the first season leaves die (Singh *et al.* 2000).

The frequency and severity of landslides can be aggravated by human land-use practices as well. The steepness of the slope of agricultural terraces can encourage runoff and cause erosion of limited top soil, exposing the coarse rocky soil immediately underneath. Deforestation of areas prone to creep reduces the amount of moisture transpired by plants and encourages seepage of water into soil resulting in landslides. As villagers expand their agricultural terraces into surrounding forests, the edges of forests become exposed and compacted with frequent livestock traffic. This is particularly a problem in higher elevations where the soil texture is predominantly clay loam. Once this soil is compacted, it reduces the water holding capacity of the soil, inhibits plant rooting, and makes the area prone to erosion (Brady & Weil 1996).

The most frequent human-made disturbances covering large areas are lopping of oak foliage and grazing of livestock in the forest. The livestock consist mainly of goats, sheep and cows. However, the key to understanding this type of disturbance is to determine where the villagers are going for lopping oak foliage, how frequently the site is visited, what time of year they are lopping, and how that affects the regeneration of the oak. However, there has not been a comprehensive study concerning the impact of lopping on regeneration (Zobel 1987).

## Regeneration ecology of oaks and pines

Regeneration and forest composition are important in understanding the impact of lopping because both are directly related to the availability of optimum conditions for oak seed production and seedling establishment. The three main species found in the region of my research, Tehri Garhwal Himalaya are *Quercus leucotrichophora* (range 1,800 to 2,400 m), *Quercus floribunda* (range 2100 to 2800 m), and *Pinus roxburghii* (range 1,200 to 2,400 m). Therefore, the regeneration ecology of each species is important in determining the impact of lopping on the forest ecosystem.

*Quercus leucotrichophora* is found mainly on well-drained sites (Mehta 1989). It is sensitive to drought and tends to die in hot, dry conditions (Troup 1921). It tolerates shady conditions as a juvenile and becomes moderately shade tolerant as an adult. The formation of young shoots, flowering, fertilization and the maturing of acorns spans a period of two years. *Q. leucotrichophora* takes 24-27 months from pollination to seed dispersal. The dispersal of the acorns begins in February until July in time for the second year rainy season when soil-water is available to facilitate germination. Acorns germinate early in the rainy season (July - August) or after the early showers immediately preceding the monsoons. Germination is best in the slight depressions that are covered with leaf litter; germination do not occur in direct sunlight (Troup 1921; Moench 1989).

*Quercus floribunda* takes only 16-18 months from pollination to the dispersal of acorns, a much shorter time period in comparison to *Quercus leucotrichophora* (Troup 1921). The flowering, pollination, and flushing of leaves take place slighter earlier in *Q. leucotrichophora*, most likely due to the temperature increasing sooner in the season at the lower elevations than at the higher elevations.

Though the fertilization in both oaks take place at a similar time around March of the second season, the key difference between *Quercus floribunda* and *Quercus leucotrichophora* lies in the timing in which the acorns mature and are dispersed (Troup 1921). The acorns of *Q. leucotrichophora* take nine months to mature and are dispersed 11 months after fertilization. However, the acorns of *Q. floribunda* take only five months to mature and are dispersed almost immediately after they have become mature. Furthermore, the acorns of *Q. floribunda* are dispersed after the rainy season and not before, as in the case of *Q. leucotrichophora*. Since *Q. floribunda* is found in higher altitudes in comparison to *Q. leucotrichophora*, the soil is less likely to lose its moisture as rapidly as in the lower altitudes. Whereas, *Q. leucotrichophora* located at lower altitudes with warmer and consequently drier climate, needs to rely on the rains to provide water for germination.

*Pinus roxburghii* is found in lower elevations similar to *Quercus leucotrichophora* with drier and warmer sites and has a similar life cycle to *Q. leucotrichophora* (Troup 1921). Pollination, fertilization and dispersal of seeds occur at the same time. It takes 26-27 months from pollination to the dispersal of seeds. Seed dispersal occurs before the start of the rainy season, and germination occurs immediately after dispersal during the rainy season. Both *P. roxburghii* seedlings and trees are highly light-demanding or shade intolerant (Troup 1921). It was found that *P. roxburghii* studied in Nepal has high dehydration tolerance levels (Shrestha *et al.* 2006). Its strategy to survive drier sites is to maintain high wood water content and shed leaves during the dry season when developing their cones.

Landscape ecosystems are constantly undergoing change. Understanding the type of disturbances in Himalayan landscapes and its impacts is important when determining the natural and human-induced changes of the landscape. It is only when we have this understanding can we consider whether or not any intervention is necessary.

## Purpose of study

This study examines the lopping practice itself, its relationship with the socio-economic circumstance of the people, and its implications on forest composition and regeneration over time. Lopping practice can potentially effect oak regeneration and overstory composition by: (1) decreasing the amount of leaf litter reaching the forest floor, thereby, decreasing the potential for acorn germination and seedling establishment; (2) decreasing the number of acorns dispersed and available for establishment; (3) decreasing the amount of leaf litter and consequently, nutrients returned to the soil and available for the trees; (4) changing the amount of sunlight reaching the forest floor by varying canopy density; (5) changing the abundance of oak versus pines; (6) increasing the presence of pioneer species and changing the species composition of forest stands; (7) causing death to trees; and (8) maintenance or persistence of dominant overstory trees.

The term "degradation" has been defined very loosely, and the meaning is slightly different in every study that focuses on forest disturbance. In some studies, the perceived change of species composition from oak- to *Pinus Roxburghii* Sarg.-dominated forest is the assumed as proof that the forest community is being degraded (Gorrie 1937; Reddy & Singh 1993; Rathore *et al.* 1997; Singh 1998; Samant *et al.* 2000). This assumption of degradation is based upon the successional dynamics of pines and oaks. The pine, a light-requiring early-successional species, it more effective in regenerating in large openings than the shade mid-tolerant oaks (Barnes *et al.* 1998). Therefore, in locations where gaps are created by lopping, the pines are able to effectively regenerate and become established. However, around the temperate world, pines and oaks grow together, and the natural successional sequence is that the pines, which establish first on the disturbed landscape, are succeeded by oaks, which grow up in the forest understory and replace the pines (Mohns *et al.* 1988; Barnes *et al.* 1998; Dobrowolska 2006). Once the oaks are dominant, only major disturbances such as large fires, clear-cutting and regeneration failure will restore pines again to dominance.

The purpose of this study is to determine the impact of oak lopping on forest composition and regeneration. These characteristics were examined through comparing the data from the protected forest with that of the lopped forest. This study was conducted in two stages. Baseline data on the status of regeneration and the forest ecosystem, forest use and the lopping practice was collected in 1993. A second set of data on physical site factors, vegetation, forest use by the villagers, lopping practices, and the developments in the socio-economic status of the people were collected in 2006. The data from the two years are compared to determine the changes in the forest stand structure and its implications on the lives of the village people. The objectives are to determine whether (1) oaks are maintaining themselves in the forest overstory and in seedling regeneration, (2) if so, what is their abundance, and have they increased from 1993 to 2006, and (3) if not, what is the amount and size of oak regeneration that is present.

## STUDY AREA

Beli village is located in the Central Himalayan region of Tehri Garhwal, Uttaranchal, India. The village is divided into three settlements – an upper elevation settlement or *chan*, the main Beli village settlement and a lower elevation settlement or *nadi* in the Aglar valley. The vegetation surrounding the village is classified as Broadleaf temperate forest and is dominated by *Quercus leucotrichophora* at the lower altitudes between 1,800 to 2,400 m, and *Quercus floribunda* at slightly higher altitudes ranging from 2,000 to 2,700 m (Kandari & Gusain 2001). The forests surrounding the village are not commercially logged and are classified as Reserve Forests by the Indian Forest Department.

The geographical area of Tehri Garhwal was chosen as the study site because of the relative absence of research about the people and forests of Tehri Garhwal in comparison to those of the Kumaon Himalaya region. Beli was selected for this study because it is the only village in the region where the villagers have designated part of their *panchayat* or village forest as protected. The villagers forbade the collection of fodder, grazing, and collection of fuelwood in the protected forest stand approximately 40 years ago. The protected forest stand is located immediately above the village (Figure 1). All the forests immediately surrounding the protected forest stand are lopped. The lopped forest stand, or area that I sampled is located diagonally above the northeast corner of the protected forest next to the *chan*. The lopped forest is frequented throughout the year due to its close proximity to the *chan*. The presence of both a protected forest and a heavily disturbed forest in the same vicinity allowed me to study the effects of the people's use of the forest on forest composition and regeneration in versus that in the protected forest. The dominant species in both the forests are *Quercus leucotrichophora* and *Pinus roxburghii*.

## METHODS

Baseline data on the site properties, regeneration, and overstory were collected in 1993 in both the protected and lopped forests. In 2006, data on site properties and vegetation were collected again using the same methodology that was used in 1993. In

2006, further detailed data were also collected on terrain properties, overstory crown density, basal area using BAF10 prism, height and age of tallest overstory trees, coverage, leaf litter, oak acorns and female pine strobili, soil and leaf nutrient content, and soil properties.

In 1993, two forest stands were identified as "protected" and "lopped" through visual determination of the crown position of the trees and the degree of lopping most of the trees appeared to have received. The protected forest covers an area of approximately 21.5 ha and is located immediately above the main Beli settlement. It ranges in elevation from 1,852 m to 2,018 m. The lopped forest is situated adjacent to the *chan* at elevation ranging from 2,100 m to 2,310 m. It is diagonally adjacent to the protected forest with one corner overlapping it. Forests at the same elevation with differing degrees of lopping were not sampled because the land surrounding the protected forest has been completely converted into agricultural fields. Nevertheless, the range of 1,852 m to 2,310 m still falls within the range of *Q. leucotrichophora* (Kandari & Gusain 2001). The protected forest has an aspect range from southwest-west, and the lopped forest has a range of aspect from southwest-northwest.

## Field sampling methodology

The plot sampling methodology was systematic sampling with a random start (Magurran 1988; Krebs 1989). Six plots, each 15 m x 30 m, were located in each forest type. The plots were placed in pairs at the similar elevations (Appendix B). The 30 m side of the plot was placed in a north-south direction and the 15 m side was placed in the east-west direction, on the contour. The plots in 2006 were established in the same location as in 1993 with the exception of two plots. In 2006, two plots in the lopped forest had been converted into agricultural fields. Therefore, two new plots were established at a different location in the lopped forest at the same elevation as those two 1993 plots.

Four 1 m x 1 m ground-cover subplots were located at each corner of each 15 m x 30 m plot. Two 5 m x 10 m subplots were established in the center of each 15 m x 30 m plot to measure coverage and ground cover.

### *Site properties*

The following parameters were recorded for each plot: (1) plot number; (2) aspect; (3) percent slope; (4) slope position:  1- summit or the highest point of the land form; 2- upper slope; 3- midslope; 4- lower slope; 5- bottom of slope; and 6- level terrain; (5) exposure class: 1- wind; 2 – insulation; 3 - frost; 4 - cold air drainage; and 5 - other; (6) site surface shape: 1 - concave; 2 - convex; and 3 - straight; (7) ecological moisture regime: 1 - very xeric; 2 - xeric; 3 - dry-mesic; 4 - mesic; 5 - wet-mesic; 6 - wet; (8) soil drainage: 1 - excessively drained; 2 - somewhat excessively drained; 3 - well drained; 4 - moderately well drained; 5 - somewhat poorly drained; 6 - poorly drained; 7 - very poorly drained; (9) topographic position diagram; (10) McNab's terrain shape index: calculated by using elevation measurements taken at 20 m from the center of the plot in north, east, south and west directions (McNab 1989); (11) elevation using a hand-held GPS; (12) evidence of erosion: 1-none; 2-light; 3-moderate; 4 - severe; 5 - extreme; and (13) soil characteristics: texture, pH, depth, and color of upper horizon. A soil pit was excavated at approximately 30 cm in depth adjacent to each of the plots, and a soil profile description was made according to Natural Resource Conservation Service measures (Staff 1975). The soil texture was determined by the texture-by-feel analysis method (Thien 1979). The rooting depth was measured using a ruler. The percent coarse fragments were estimated on a scale from abundance: 0-2% (very few), 2-10% (few), 10-20% (common), 20-50% (many), 50-90% (abundant) and >90% (very abundant). The pH was measured with a Hillege-Truog Soil Reaction/pH Test Kit. The soil color was determined according to the Munsell Soil Color Charts.

Soil samples were collected from the A horizon of each soil pit and transported to the lab in sealed plastic bags. The soil samples were air dried and then ground into fine powder using a ball mill. The powder was oven dried for 24 hours at 60°C. The samples were analyzed for Carbon and Nitrogen content using NC 2500 Elemental Analyzer (CE Elantech Lakewood NJ).

### *Litter*

Litter of the forest floor was sampled as follows: (1) the 15 m x 30 m plot was divided into nine 5 m x 10 m subplots. One litter sample was taken from each of the top three and bottom three subplots; (2) depth of Oi, Oe, Oa horizons were measured 15 cm above the 15 cm x 15 cm litter frame used to collect litter samples; and (3) Oe and Oa horizons were collected by using a knife to cut around 15 cm x 15 cm litter frame at the center of each subplot. Samples were put in Ziploc plastic bags for transport to the village. Later, the samples were air dried and the dry weights were measured. A pilot study was conducted to determine the length of time the litter would need to be thoroughly dried. Three samples were taken and weighed every day until the weight did not change. Results showed that samples became dry after three days. Living plant foliage from *Quercus leucotrichophora*, *Quercus floribunda,* and *Pinus roxburghii* were collected from each plot. The living plant foliage samples were air dried and then ground into fine powder using a ball mill. The powder was oven dried for 24 hours at 60°C. The samples were analyzed for Carbon and Nitrogen content using NC 2500 Elemental Analyzer (CE Elantech Lakewood NJ).

### ***Vegetation***

Data were recorded for several layers of vegetation in both the protected and lopped forest plots. The layers were: overstory and ground cover. Coverage was also estimated for species of the ground-cover. To facilitate comparisons of the 1993 and 2006 data of tree species composition, I combined all trees with DBH of 1.5 cm and greater into one layer, termed the overstory. The term regeneration is defined as seedlings and basal sprouts found in the ground cover; stems < 1.5 m tall.

#### *Overstory*

The following information were recorded for each plot for trees in the overstory: (1) species; (2) DBH for trees >1.5 cm in DBH to the nearest 0.01 cm (includes understory 1.5-5.0 cm); (3) crown position of trees with DBH >5.0 cm: 1 - dominant; 2 - codominant; 3 - intermediate; and 4 - suppressed categories; (4) tree condition: 1- dead or

2 - live; and (5) extent of lopping: 1 – not lopped; 2 - lower 1 to 20% of the tree lopped; 3 - lower 21 to 40% lopped; 4 - lower 41 to 60% lopped; 5 - lower 61 to 80% of the tree lopped; and 6 - 81 to 100% of the tree lopped. The height and age were determined for the two largest individuals. The height was measured using a clinometer, and the age was determined by taking core samples at breast height using an increment borer.

Determinations of basal area by tree species were made with data from the plots and using a BAF-10 prism in two 5 m x 10 m subplots. Estimated relative light intensity in the plot was measured using a densiometer. Three readings were taken in each 5 m x 10 m subplot located along the center of the plot.

Using the DBH measurements of each tree in a plot, the relative density and relative dominance were determined for each species. Relative density is the number of individuals of a given species sampled divided by the total number of individuals sampled. This value is multiplied by 100 to express relative density as a percentage. Relative dominance is the sum of the basal area of the individuals of a given species divided by the total basal area of all the species sampled. This value is multiplied by 100 to express relative dominance as a percentage.

*Vegetation below the overstory layer*

Two kinds of subplots were established:

1. As in 1993, ground cover was sampled by preparing 1 m x 1m ground-cover subplots in each corner of the plot, and recording the following data: (1) height of

woody species < 1.5 m high; (2) seedling or seedling-sprout, (3) lopping extent; and (4) number of acorns, aborted acorns, and strobili.

2. Only in 2006, two adjacent 5 m x 10 m subplots (i.e. 100 $m^{2)}$ were established in the central strip of each plot. Two attributes were sampled:

a) The areal coverage of all vascular species < 1.5 cm DBH was estimated. Coverage was also measured for bare soil, grass, woody debris, moss, fern and rocks. A sampling frame representing 0.1% (1000 $cm^2$) of the sample area was used for ocular calibration in standardizing coverage estimates. All vascular plants were identified to species (Walker *et al.* 2003).

b) The stem count, lopping extent, sprout, top cut, and height of all woody species <1.5 m.

**Statistical analysis**

First, site properties, overstory, and regeneration of the protected and lopped forests were compared for 1993 and 2006. Then data for the 1993 protected forest were compared with the 2006 protected forest, and the 1993 lopped forest were compared with the 2006 lopped forest, in order to determine whether there were changes over time for selected variables in each of the forests.

The basic premise of this study is that comparisons are being made between forests with similar physiographical properties, site conditions, and dominant oak-pine species composition with the only difference between the two forests being the degree of oak tree lopping. Therefore, it is important to first establish that the physiographic properties of the site are similar and that they only differ in their degrees of lopping.

The overstory, understory, and site property data of the protected forest and the lopped forest were analyzed using One-way Analysis of Variance (ANOVA) ($\alpha$ =0.10) and where normality was violated, nonparametric statistic Mann-Whitney Test was used. Comparison of the degree of lopping, basal area ($m^2$ $ha^{-1}$), and the number of stems $ha^{-1}$ were made between the overstory and understory of the forests.

Since my overall focus is on the effects of lopping, a comparison was made between the degrees of lopping for *Quercus leucotrichophora* and *Quercus floribunda* in the two forests. Stem and species count data were analyzed using the Poisson Regression Model, and the presence/absence of species was tested using the Fisher's exact test (when the numbers are very small) or the Pearson Chi-square test ($\alpha$ =0.10).

Both the overstory data and the regeneration data were analyzed for the degree of aggregation using Variance-Mean Ratio (VMR); and species diversity was analyzed using Species richness, Shannon Index H', Simpson's Index and Whittaker's Measure (Magurran 1988).

Ground cover data were analyzed in three ways: (1) Count data i.e. number of stems, were analyzed using the Poisson Regression Model with Generalized Estimating Equations (GEE), test statistic: Wald Chi-square; (2) Presence/Absence of variable was analyzed using the Logistic Regression Model with GEE, test statistic: Wald Chi-square; and, (3) the mean heights of ground-cover woody species were analyzed using the Linear Mixed Model, test statistic: F-test. For all the analysis $\alpha$ = 0.10 to allow for the high degree of variability in natural forested ecosystems. For results where $0.10 < \alpha \leq 0.15$ the result is considered marginally significant.

## RESULTS

### Physiographic properties of site

#### *Comparison of protected and lopped forests for 1993*

There was no significant difference in the slope position (p=1.00), surface shape (p=1.00), moisture regime (p=1.00), and drainage class (p=1.00) (Table 4-1 and Table 4-2). There was significant difference in the exposure class (p=0.002) with all of protected forest having wind exposure, whereas the lopped forest was mostly insulated. The elevation of the plots in the lopped forest was significantly greater than the plots in the protected forest (p=0.002). The percentage slope in the protected forest ranged from 53.3% to 100% and 53.3% to 90.0% in the lopped forest.

#### *Comparison of protected and lopped forests for 2006*

There was no significant difference in the slope position (p=1.00), exposure class (p=0.73), surface shape (p=0.63), moisture regime (p=0.45), drainage class (p=0.45) and the extent of surface erosion (p=0.95) (Table 4-1 and Table 4-2). However, there was significant difference in the average elevation of the forests (p=0.001). The plots in the lopped forest were located at a higher elevation than the protected forest. The percentage slope in the protected forest ranged from 18% to 100% and 14% to 102% in the lopped forest. A comparison of the McNab's Terrain Index indicates that there was no significant difference in the terrain shape between the protected and lopped forests (p=0.45) (McNab 1989).

### *Comparison of leaf and soil nutrient content and soil properties of protected and lopped forests in 2006*

The parent material for both the forests was sandstone with high clay content (J. Blum, personal communication). There was no significant difference in the N% or C:N ratio between the soil of the protected and lopped forests (p=0.35) (Table 4-3). There was also no significant difference in the N% or C:N ratio in the *Pinus roxburghii* needles of the protected and lopped forest (p=0.50). However, there was significantly greater N% in the *Quercus leucotrichophora* leaves of the lopped forest than in the protected forest (p=0.02). Therefore, it follows that the C:N ratio was a significantly greater in the *Q. leucotrichophora* leaves of the protected forest in comparison to the lopped forests (p=0.01).

There was a significant difference in the average pH of the A horizon between the protected and lopped forests (p=0.02) with the lopped forest having a higher pH (Table 4-4). Accordingly, there was significantly higher average pH in the C horizon of the lopped forest in comparison to the protected forest (p=0.02). The pH of the C horizon in both the protected and lopped forests were acidic in comparison to the A horizon.

There was a significantly deeper rooting in the lopped forest in comparison to the protected forest ($p=0.002$) (Table 4-4). There was no significant difference in the percentage of coarse fragments present between the protected and lopped forests ($p=0.18$). However, there tended to be larger coarse fragments in the protected forest in comparison to the lopped forest.

### *Comparison of depth of Oi and Oe horizons of protected and lopped forests in 2006*

There was significantly deeper Oi horizon in the lopped forest in comparison to the protected forest, $F(1,10) = 5.86$, $p=0.04$ (Table 4-4). Due to the presence of many zero values in the Oe depth (42% in the protected forest and 25% in the lopped forest), a comparison was made of the proportion of subplots with Oe present in the lopped vs. protected forest, using a Wald chi-square test. A significantly higher proportion of subplots had Oe present in the lopped forest than in the protected forest, $\chi^2$ (1,N=78) = 6.00, $p=0.01$. The mean Oe depth was also compared in an analysis that excluded zero as a value when no Oe was present. In this analysis, there was no significant difference in the depth of Oe horizon, $F(1,11)=0.26$ $p=0.62$.

### *Comparison of dry weight of Oi and Oe horizons of protected and lopped forests in 2006*

There was no significant difference in the dry weight of the Oi horizon between the protected and lopped forests, $F(1,10)=0.01$ $p=0.91$ (Table 4-4). There was no significant difference in the dry weight of the Oe horizon between the protected and lopped forests with the lopped forest having heavier dry weight, $F(1,10)=2.11$ $p=0.18$. There was also no significant difference between the dry weights of Oe in the protected and lopped forests, $F(1,4)=1.79$ $p=0.26$ when the mean dry weights were compared excluding the zero values when there was no Oe present.

## Forest cover

### *Protected forest in 1993*

#### *Protected forest overstory in 1993*

The overstory trees found in the protected forest were *Quercus leucotrichophora* A. Camus, *Lyonia ovalifolia* (Wallich) Drude, *Pinus roxburgii* Sarg., *Rhododendron arboreum* Sm., *Benthamidia capitata* (Wallich ex Roxb.), *Ficus hipsida* Linn., and *Prunus cornuta* Wall. *Q. leucotrichophora* and *P. roxburghii* had the greatest number of stems/ha$^{-1}$ with 544.4 and 233.3, respectively. The relative dominance of *Q. leucotrichophora* and *P. roxburghii* were 27.2% and 64.7% respectively (Table 4-5) and the relative densities were 58.8% and 25.5%.

The average DBH of the trees found in the protected forest was 10.60 cm and the average basal area was 2.23 m$^{2}$ ha$^{-1}$(Table 4-5). The crown position of the trees with DBH> 5.0 cm ranged from suppressed to codominant positions. The degree of lopping of the branches ranged from no lopping in *Prunus cornuta* to completely lopped in *Ficus* *hipsida* (Table 4-5). The lopping of *Quercus leucotrichophora* was between 30 to 50% of the lower branches. *Pinus roxburghii* had very little lopping of its lower branches.

*Protected forest ground cover, 1 m x 1 m subplots in 1993*

The species regenerating in the protected forest were *Quercus leucotrichophora*, *Pinus roxburghii, Benthamidia capitata*, *Cedrus deodara*, and *Pyrus pashia* (Table 4-6). The species with the fewest number of regenerating stems were *Cedrus deodara*, and *Pyrus pashia* with 2,500/ha. The species with the greatest number were *Q. leucotrichophora* with 48,333/ha. *Q. leucotrichophora* also had the greatest amount of growth with an average height of 0.62 m.

The analysis of the number of stems regenerating in the protected and lopped forest showed that there was a significantly greater amount of regenerating stems in the lopped forest (p=0.002). Accordingly, the number of stems of *Quercus leucotrichophora* regenerating in the protected forest was significantly less than that in the lopped forest (p=0.02). However, there was no significant difference in the number of *Pinus roxburghii* regenerating stems between the two forests (p=0.68).

***Lopped forest in 1993***

*Lopped forest overstory in 1993*

The species composition of the lopped forest included *Quercus leucotrichophora*, *Quercus floribunda*, *Lyonia ovalifolia*, *Pinus roxburghii*, *Rhododendron arboreum*, *Benthamidia capitata*, and *Ficus hipsida* Linn (Table 4-7). *Q. leucotrichophora* and *Q. floribunda* had the greatest number of stems/ha with 700 and 163.0 respectively. The relative dominance of *Q. leucotrichophora* and *Pinus roxburghii* were 25.9% and 3.8% and the relative densities were 58.2% and 4.3 % respectively.

The average DBH of the trees found in the lopped forest was 14.1 cm, and the average basal area was 3.7 $m^2$ $ha^{-1}$(Table 4-7). The crown position of the trees with DBH> 5.0 cm ranged from intermediate to suppressed positions. The degree of lopping of the branches ranged from lower 1 to 20% lopped in *Benthamidia capitata* to 81 to 100 % of the tree being lopped in *Quercus leucotrichophora* and *Quercus floribunda* (Table 4-7). Several trees in the lopped forest also had their tops cut off (Table 4-7).

*Lopped forest ground cover, 1 m x 1 m subplots in 1993*

The species that were regenerating in the lopped forest were *Quercus leucotrichophora*, *Quercus floribunda*, *Lyonia ovalifolia*, *Pinus roxburgii*, *Rhododendron arboreum*, *Benthamidia capitata, Ficus hipsida*, and *Prunus cornuta* (Table 4-8). The species with the greatest number of regenerating stems were *Q. leucotrichophora* and *Rhododendron arboreum* with 131,667/ha and 114,167/ha respectively.

### ***Protected forest in 2006***

#### *Protected forest overstory in 2006*

Of the overstory trees found in the protected forest 98.7% were live trees (Table 4-9). There were 17 species of overstory trees found in the protected forest in 2006 (Table 4-10). *Quercus leucotrichophora* and *Lyonia ovalifolia* had the greatest number of stems per hectare with 1,944.4 and 355.6 respectively. The number for *Pinus roxburghii* was 77.8. The relative densities of *Q. leucotrichophora* and *P. roxburghii* were 72% and 4% respectively (Table 4-11). The mean DBH of *Q. leucotrichophora* was 9.73 cm and that for *P. roxburghii* was 17.48 cm (Table 4-12). The mean height of the tallest *Q. leucotrichophora* was 9.02 m and the mean age was 81.5 years (Table 4-13). The mean height of the tallest *P. roxburghii* was 12.68 m and the mean age was 53.2 years-old. The mean basal area measured by prism was 59.44 $ft^2$/acre for *Q. leucotrichophora* and 7.22 $ft^2$/acre for *Pinus roxburghii* (Table 4-14).

#### *Protected forest ground cover 1 m x 1 m subplots in 2006*

There were four species present in the ground cover of the protected forest (Table 4-15). The species only present in the protected forest and not in the lopped forest were

*Quercus floribunda* and *Rhus wallichii*. The relative density of *Quercus leucotrichophora* was 42% and for *Pinus roxburghii* was 17% (Table 4-16). The mean height of all the plants present in the ground-cover was 44.67 cm (Table 4-17). The mean height of *Q. leucotrichophora* was 65.50 cm and for *Pinus roxburghii* was 56.67 cm (Table 4-18).

The mean number of acorns present in the protected forest was 3.21 per $m^2$ and the mean number of strobili was 9.67 per $m^2$ (Table 4-19).

### ***Lopped forest in 2006***

#### *Lopped forest overstory in 2006*

Of the overstory trees present in the lopped forest, 95% were live trees (Table 4-9). There were 18 tree species in the lopped forest in 2006 (Table 4-20). *Quercus leucotrichophora* and *Quercus floribunda* have the greatest number of stems per hectare with 596.8 and 434.9 respectively, and that for *Pinus roxburghii* being 14.9. The relative densities of *Q. leucotrichophora*, *Q. floribunda* and *P. roxburghii* were 46%, 32%, and 2% respectively (Table 4-21). The mean DBH of *Q. leucotrichophora* was 13.00 cm and *P. roxburghii* was 10.10 cm (Table 4-12). The mean height of the tallest *Q. leucotrichophora* was 11.61 m and the mean age was 102 years (Table 4-13). The mean height of the tallest *P. roxburghii* was 8.53 cm and the mean age was 27 years. The mean basal area measured by prism was 34.76 $ft^2$/acre for *Q. leucotrichophora* and 2.38 $ft^2$/acre for *P. roxburghii* (Table 4-14).

*Lopped forest ground cover, 1 m x 1 m subplots in 2006*

There were 13 species present in the ground cover of the lopped forest (Table 4-15). The relative density of *Quercus leucotrichophora* was 19% and for *Pinus roxburghii* was 10% (Table 4-16). The mean height of all the plants present in the ground-cover was 63.32 cm (Table 4-17). The mean height of *Q. leucotrichophora* was 62.30 cm and for *P. roxburghii* was 25.50 cm (Table 4-18).

The mean number of acorns present in the protected forest was 1.29 per $m^2$, and the mean number of pine female strobili was 2.18 per $m^2$ (Table 4-18).

### ***Comparison between the protected and lopped forests for 1993***

*Comparison of overstory of protected and lopped forests for 1993*

The degree of lopping was significantly different ($p<0.001$) between the protected and the lopped forest (Table 4-5 and Table 4-7). The lopped forest had trees with significantly greater degree of lopping than in the protected forest. Lopping of *Quercus leucotrichophora* trees was also significantly greater in the lopped forest ($p=0.005$).

There was significantly greater total basal area ($m^2$ $ha^{-1}$) ($p=0.08$) in the lopped forest but no significant difference in the number of stems >5 cm in DBH ($p=0.52$) between the two forests (Table 4-5 and Table 4-7). Though the protected forest had significantly less *Pinus roxburghii* overstory trees than the lopped forest ($p=0.01$), there was no significant difference in the number of *Q. leucotrichophora* trees ($p=0.57$).

The overstory of the protected and lopped forest had similar highly clumped spatial patterns with Variance Mean Ratio for protected and lopped forest 103.46 and 104.02 respectively (Table 4-22). The regeneration of the two forests had similar clumped spatial patterns, and there was no difference in the degree of aggregation or patchiness (Table 4-8).

The overstory species richness of the protected and lopped forests was both seven species (Table 4-23). The overstory species diversity of the two forests was significantly different ($p<0.05$). The Shannon Index showed that the lopped forest was more diverse than the protected forest for the overstory composition.

There was significantly greater *Quercus leucotrichophora* with tops in the protected forest than the lopped forest, $F(1,10)=9.12$ $p=0.01$ but no significant difference in the percentage of live stems, $F(1,10)=0.02$ $p=0.89$ (Table 4-5 and Table 4-7). Also, there was no significant difference in the percentage of live *Pinus roxburghii* stems, $F(1,10)=0.08$ $p=0.79$. There were no significant differences in the other species that were present (Table 4-5 and Table 4-7).

*Comparison of ground cover, 1 m x 1 m subplots of protected and lopped forests for 1993*

There was significantly greater relative density of *Quercus floribunda* ($p=0.07$), *Lyonia ovalifolia* ($p=0.002$), *Rhododendron arboreum* ($p=0.002$), *Viburnum cotonifolium* ($p=0.02$) and *Rhamnus persica* ($p=0.02$) in the lopped forest in comparison to the protected forest and no significant difference in the other species (Table 4-6 and Table 4-8).

There was no significant difference in the heights of *Quercus leucotrichophora* and *Pinus roxburghii* between the protected and lopped forests (Table 4-18).

There was significantly more lopping of *Quercus leucotrichophora* in the lopped forest in comparison to the protected forest, $\chi 2=(5,N=216)$ $p<0.001$ (Table 4-6 and Table 4-8). There was no significant difference in the sprouting of *Pinus roxburghii* between the protected and lopped forests $\chi 2=(1,N=30)=0.24$. There was no significant difference in the basal sprouting of *Q. leucotrichophora* between the protected and lopped forests $\chi 2=(1,N=216)$ $p=0.58$ (Table 4-6 and Table 4-8).

The species richness of the regeneration in the two forests was significantly different ($p<0.05$) (Table 4-15 and Table 4-24). The Shannon Index showed that the lopped forest was more diverse than the protected forest.

### *Comparison of the protected and lopped forests for 2006*

#### *Comparison of overstory of protected and lopped forests for 2006*

The overstory density of the protected forest ranged from 16% to 90% with the mean being 68% (Table 4-11). The overstory density of the lopped forest ranged from 14% to 82% with the mean being 47% (Table 4-21). Using the Mixed Model analysis, taking into account both within-plot and between-plot variance, the protected forest has significantly greater overstory density compared to the lopped forest $F(1,11)=3.74$ ($p=0.08$). The intraclass correlation was 0.72. Therefore, the overstory density was very similar within a given plot and most of the variability was between plots.

The mean basal area for prism data of all the species combined were compared between the protected and lopped forest and there was no significant difference in the means ($p=0.28$) (Table 4-14). The basal area of *Quercus leucotrichophora* was compared using the mixed model analysis and there was significantly greater basal area, $F(1,37)=5.54$ $p=0.02$ in the protected forest in comparison to the lopped forest.

There were 17 species of trees in the protected forest and 18 species of trees in the lopped forest out of which 11 were found in both forests (Table 4-10 and Table 4-20).

The Wald Chi-square, based on the Generalized Estimating Equations (GEE) analysis comparing forest types, adjusting for clustering within plots was used to determine the probability of finding any trees. There was a higher probability of finding any trees in the lopped than in the protected forest, $\chi2$ (1, *N*=130) = 4.36, $p=0.04$ where 23% of subplots in the protected forest had trees and 34% of the subplots in the lopped forest had trees.

There was significantly greater percentage of live *Lyonia ovalifolia* in the protected forest in comparison to the lopped forest, $F(1,8)=3.20$ $p=0.11$ (Table 4-10 and Table 4-20). There was no significant difference in the percentage of live stems of *Quercus leucotrichophora*, $F(1,11)=0.48$ $p=0.25$ or *Pinus roxburghii*, $F(1,5)=0.86$ $p=0.40$ between the protected and lopped forests (Table 4-10 and Table 4-20). There were significantly fewer stems of *Q. leucotrichophora* with tops in the lopped forest, $F(1,11)=47.56$ $p<0.01$. There was fewer stems of *Quercus floribunda* with tops in the lopped forest, $F(1,7)=8.53$ $p=0.02$.

The DBH of the overstory trees were compared between the protected and lopped forests (Table 4-10 and Table 4-20). There was no significant difference in DBH of

*Benthamidia capitata,* $F(1,26)=2.49$ ($p=0.13$); *Pyrus Pashia*, $F(1,17)=2.83$ ($p=0.11$); *Pinus roxburghii*, $F(1,23)=3.78$ ($p=0.06$); *Quercus floribunda,* $F(1,145)=0.93$ ($p=0.34$); *Rhododendron arboreum,* $F(1,10)=0.01$ ($p=0.91$); *Rhamnus Persica,* $F(1,4)=0.33$ ($p=0.60$); *Pinus roxburghii,* $F(1,2)=0.23$ ($p=0.68$); and *Viburnum Cotinifolium,* $F(1,42)=2.84$ ($p=0.10$). The DBH of *Lyonia ovalifolia* and *Quercus leucotrichophora* was significantly greater in the lopped forest compared to the protected forest $F(1,125)=40.03$ $p<0.001$ and $F(1,711)=74.76$ $p<0.001$ respectively.

The trees that were measured for height and age were compared (Table 4-13). There was marginally significantly greater DBH, $F(1,10)=2.54$ $p=0.14$ and height, $F(1,8)=3.28$ $p=0.11$ of *Pinus roxburghii* trees in the protected forest. There was no significant difference in age, $F(1,10)=1.17$ $p=0.30$ or crown position, $F(1,10)=0.68$ $p=0.43$ of the *Pinus roxburghii* trees. There was no significant difference in DBH, $F(1,25)=0.49$ $p=0.49$; age, $F(1,25)=1.91$ $p=0.18$; or crown position, $F(1,25)=0.18$ $p=0.67$ of the *Quercus leucotrichophora* trees. However, there was a significant difference in the height of the trees, $F(1,25)=4.44$ $p<0.05$, with the trees in the lopped forest being taller.

### ***Comparison of ground cover of protected and lopped forests for 2006***

#### *Ground cover in 1 m x 1 m subplots*

Only *Indigofera cassioides*, *Pinus roxburghii*, and *Quercus leucotrichophora* were common in the ground cover between the protected and lopped forests (Table 4-15). There was no significant difference in the number of stems or relative density of any of the species (Table 4-7 and Table 4-16). There was no significant difference in the mean heights of *Indigofera cassioides*, *P. roxburghii*, and *Q. leucotrichophora* between the protected and lopped forests (Table 4-25).

There was no significant difference in the lopping of *Quercus leucotrichophora* between the protected and lopped forests, $\chi 2=(3,N=18)=0.28$. There was significantly more basal sprouting of *Q. leucotrichophora* in the lopped forest in comparison to the protected forest $\chi 2=(1,N=18)=0.14$.

The mean number of acorns in the protected was marginally significant greater than in the lopped forest at $\chi^2$ (df=1, N=52) = 2.35, p=0.13 (Table 4-18). There was significantly higher probability of finding any acorns in the protected than in the lopped forest, where 42% of the subplots in the protected forest had acorns and 25% of the subplots in the lopped forest had acorns, $\chi^2$ (1, *N*=52) = 3.15, p=0.08. There was no significant difference in the number of aborted acorns between the protected and lopped forests, $\chi^2$ (df=1, N=52) = 0.27, p=0.61. There was a higher probability of finding aborted acorns in the protected than in the lopped forest where 33% of the subplots in the protected forest had aborted acorns and only 14% of the subplots in the lopped forest had aborted acorns, $\chi^2$ (1, *N*=52) = 3.33, p=0.07. There was significantly greater mean number of female pine strobili in the protected than in the lopped forest, $\chi^2$ (df=1, N=52) = 6.11, p=0.01. There was no significant difference in the probability of finding any pine strobili in either the protected or lopped forest (0.33 vs. 0.39), $\chi 2$ (1, *N*=52) = 0.13 p=0.72.

*Ground cover in 5 m x 10 m subplots*

There were 12 species present in the 5 m x 10 m subplots of the protected forest whereas there were 25 species present in the lopped forest (Table 4-26). There were significantly more stems of *Quercus leucotrichophora* and marginally significant number of stems of *Rhododendron arboreum* in the 5 m x 10 m subplots of the protected forest than the lopped forest (Table 4-27). There were significantly more stems of *Pyrus pashia* (p=0.02) and *Viburnum cotinifolium* (p=0.01) in the ground cover of the lopped forest.

There was significantly greater lopping (p=0.002) and tree tops that had been cut off (p<0.001) in the lopped forest in comparison to the protected forest in the 5 m x 10 m subplots (Table 4-28). There was significantly more lopping of the *Quercus leucotrichophora* in the lopped forest in comparison to the protected forest (p=0.01) (Table 4-29). There was significantly more *Quercus leucotrichophora* with tops cut off in the lopped forest in comparison to the protected forest (p<0.001). There was no significant difference in the lopping of *Quercus floribunda* between the protected and lopped forests because of the small sample size of *Q. floribunda* present in the protected forest due to elevational differences.

In the protected forest there was significantly greater number of basal sprouts occurring (p<0.001). When only *Quercus leucotrichophora* was compared, there was no significant difference in the amount of basal sprouting of *Q. leucotrichophora* between the protected and lopped forests (p=0.71) (Fisher's Exact Test) (Table 4-30). There was significantly greater sprouting in the protected forest of *Cotinus coggygria* (p=0.03) and *Lyonia ovalifolia* (p=0.02). There was marginally significant sprouting of *Pinus* *roxburghii* p=(0.11), and *Rhus punjabensis* (p=0.13) in the protected forest. On the other hand there was significantly greater sprouting of *Viburnum cotinifolium* ($p<0.001$) in lopped forest.

There was no significant difference in the height of the plants between the protected and lopped forests (p=0.85). The mean heights of *Benthamidia capitata*, *Quercus leucotrichophora*, *Rhododendron arboreum*, and *Rhus punjabensis* were greater in the protected compared to the lopped forest (Table 4-31). The mean heights of *Pyrus pashia* and *Viburnum cotinifolium* were smaller in the protected forest in comparison to the lopped forest. There was no significant difference found in the mean heights of *Lyonia ovalifolia*, *Pinus roxburghii*, and *Quercus floribunda* between the protected and lopped forests.

## *Comparison of ecosystem properties between 1993 and 2006 in the protected and lopped forests*

### *Comparison of physiographic properties of site in protected forest in 1993 and 2006*

There was no significant difference in the slope position (p=0.59), surface shape (p=0.70), moisture regime (p=1.00), and drainage class (p=1.00) in the protected forest between 1993 and 2006 (Table 4-1 and Table 4-2). However, there was significant difference in the exposure class (p=0.015). The exposure class in the protected forest changed from wind in 1993 to insulated in 2006.

*Comparison of physiographic properties of site in lopped forest in 1993 and 2006*

There was no significant difference in the slope position (p=0.63), exposure class (p=0.23), surface shape (p=1.00), moisture regime (p=0.45), and drainage class (p=0.45) in the plots sampled in the lopped forest in 1993 and 2006 (Table 4-1 and Table 4-2).

*Comparison of overstory of protected forest in 1993 and 2006*

There was no significant difference in the relative dominance of *Benthamidia capitata* and *Lyonia ovalifolia*. The relative dominance of *Pinus roxburghii* in 1993 was significantly greater than 2006, F(1,10)=5.99 p=0.03. The relative dominance of *Quercus leucotrichophora* in 2006 was significantly greater in 2006, F(1,10)=6.59 p=0.03.

There was a significant increase in the basal area of *Q. leucotrichophora* in 2006 compared to 1993 (p=0.01) (Table 4-32). There was no significant difference in the average DBH of any of the species (Table 4-12).

There was a significant increase in the relative density of *Quercus leucotrichophora* in the protected forest in 2006 in comparison to 1993, F(1,10)=5.02 p=0.05 (Table 4-11). There was a significant decrease in the relative density of *Pinus roxburghii* in the protected forest in 2006 in comparison to 1993, F(1,10)=11.67 p=0.001. There was a significant increase in the relative density of *Viburnum cotinifolium* in the protected forest in 2006 in comparison to 1993, F(1,10)=5.12 p=0.046 (Table 4-11).

The crown position ($p=0.10$) and lopping extent ($p=0.07$) of *Quercus leucotrichophora* in the protected forest was significantly greater in 1993 in comparison to 2006.

### *Comparison of overstory of lopped forest in 1993 and 2006*

The relative dominance of *Quercus floribunda* significantly increased in 2006 in comparison to 1993 $F(1,41)=194.31$ $p<0.001$. The relative dominance of *Q. leucotrichophora* also significantly increased in 2006 in comparison to 1993 $F(1,105)=91.10$ $p<0.001$. There was also no significant difference in *Pinus roxburghii* $F(1,4)=0.75$ $p=0.44$. The relative dominance of *Lyonia ovalifolia* significantly increased in 2006 in comparison to 1993 $F(1,21)=4.69$ $p=0.04$.

There was a significant increase in the relative density of *Q. floribunda* in the lopped forest in 2006 in comparison to 1993 $F(1,11)=12.80$ $p=0.004$ (Table 4-21). There was marginally significant difference increase in the relative density of *Benthamidia capitata* in 2006 ($p=0.14$), and marginally significant decrease in *Rhododendron arboreum* ($p=0.11$). There was no significance in the relative density of *Ficus hipsida* ($p=0.56$).

There was a significant increase in the crown position of *Quercus leucotrichophora* in the lopped forest between 1993 and 2006 ($p=0.01$) (Table 4-7 and Table 4-20). There was no significant difference in the condition of trees, lopping extent and the amount top cut.

In comparing other species that were also present in both the 1993 and 2006 protected forests, there was no significant difference in the crown position of *Benthamidia capitata*, and *Lyonia ovalifolia*. There also was no significant difference in the crown position of *Benthamidia capitata*, *Ficus hipsida*, *Lyonia ovalifolia*, *Pinus roxburghii*, *Quercus floribunda*, and *Rhododendron arboreum* in the lopped forest.

There was no significant change in the basal area of *Pinus roxburghii* between 1993 and 2006 (p=0.22) (Table 4-32). There was marginally significant decrease of the basal area of *Quercus leucotrichophora* (p=0.13) and a significant decrease of *Rhododendron arboreum* (p=0.01). There was a marginally significant increase of the basal area of *Quercus floribunda* in 2006 (p=0.15). However, there is a significant decrease of average DBH of *Q. floribunda* (p=0.07) and *Rhododendron arboreum* (p=0.10).

*Comparison of ground cover of 1 m x 1 m subplots in protected forest in 1993 and 2006*

In 1993 there were significantly greater numbers of stems of *Quercus leucotrichophora* in the protected forest in comparison to the lopped forest (Table 4-33 and Table 4-34). In 2006, there was no significant difference in the number of stems between the forests. The number of stems of *Q. leucotrichophora* and *Pinus roxburghii* were both significantly greater in 1993 than 2006. There was no significant difference in the number of stems of the other species. There was no significant difference in the relative density of any of the species present in the forest (Table 4-16).

Comparing the overall heights of ground cover stems of the protected forest between 1993 and 2006, there was significantly less height in 2006 compared to 1993, $F(1,95)=3.00$ $p=0.09$ (Table 4-33). There was no significant difference in the heights of *Pinus roxburghii* and *Quercus leucotrichophora* between 1993 and 2006 (Table 4-18 and Table 4-25).

There was significantly more cut tops in the protected forest in 1993 in comparison to 2006 ($p=0.001$) (Table 4-6). There were significantly more sprouts present in the protected forest in 2006 in comparison to 1993 ($p=0.01$).

*Comparison of ground cover in 1 m x 1 m subplots in lopped forest in 1993 and 2006*

There were significantly greater numbers of *Quercus leucotrichophora* ($p<0.001$), *Lyonia ovalifolia* ($p=0.03$), *Rhododendron arboreum* ($p=0.06$), *Viburnum cotonifolium* ($p<0.001$), *Mahonia borealis* ($p<0.06$), and *Abelia triflora* ($p<0.05$) in 2006 than in 1993. There were marginally significantly greater number of *Pinus roxburghii* ($p=0.12$), There was no significant difference in the number of stems of the other species over the two years (Table 4-33). There is no significant difference in the relative density of *Q. leucotrichophora* and *P. roxburghii* between 1993 and 2006 (Table 4-16).

Comparing the overall heights of stems of the lopped forest between 1993 and 2006, there was significantly greater height in 2006 compared to 1993, $F(1,529)=9.60$ $p=0.002$ (Table 4-26). The heights of *Benthamidia capitata* ($p=0.04$), *Rhododendron arboreum* ($p<0.001$), *Viburnum cotonifolium* ($p=0.001$), and *Viburnum mullaha* ($p=0.04$) were significantly greater in 2006 compared to 1993 in the lopped forest (Table 4-18).

There was no difference in the amount of lopping in the lopped forest between 1993 and 2006 (p=1.00). There was significantly fewer sprouts in 2006 compared to 1993 in the lopped forest (p=0.07).

### *Comparison of overstory spatial distribution, aggregation, and species diversity in 1993 and 2006*

Both the protected and lopped forests were significantly spatially aggregated at $\alpha = 0.05$ $X^2_{0.975,5}=12.83$ and $X^2_{0.975,5}=14.45$ for 2006 lopped forest (Table 4-23). The protected forest in 1993 was more highly aggregated than in 2006. There is no difference in the degree of spatial aggregation for the lopped forest from 1993 to 2006. *Quercus leucotrichophora* in both the protected and lopped forests are significantly aggregated in both 1993 and 2006. However, the protected forest for both 1993 and 2006 is much more aggregated than the lopped forest. There is a slight decrease in the amount of aggregation of *Q. leucotrichophora* in 2006 in the lopped forest in comparison to 1993. The degree of spatial aggregation of *Pinus roxburghii* is much lower than *Q. leucotrichophora* for both the forests for 1993 and 2006. However, it is still significantly aggregated for both the protected and lopped forests in 1993 and the lopped forest in 2006.

Both the Shannon Index H' and the Simpson's Index indicate that the protected forest has decreased in diversity from 1993 to 2006, whereas the lopped forest has increased in diversity (Table 4-23). In other words, in the protected forest, a fewer species dominate the forest, whereas, in the lopped forest, more species are assuming dominance. The Whittaker's measure of diversity indicates that the similarity between the protected and lopped forests has decreased considerably between 1993 and 2006. In other words, the forests are beginning to differ in species composition as noted by the different species that occur in each forest.

*Ground-cover spatial distribution, aggregation and species diversity (1 m x 1 m subplots)*

The variance mean ratio indicates that the spatial aggregation for both the protected and lopped forests were significantly aggregated in 1993 but not in 2006 at $\alpha = 0.05$ $X^2_{0.975,5}$=12.83 and $X^2_{0.975,5}$=14.45 for 2006 lopped forest only (Table 4-35). The spatial aggregation for both the protected and lopped forests are significantly aggregated in 1993 but not in 2006 at $\alpha = 0.05$ $X^2_{0.975,5}$=12.83 and $X^2_{0.975,5}$=14.45 for 2006 lopped forest only.

The Simpson's Index indicates that the protected forest has decreased considerably in diversity from 1993 to 2006. The Whittaker's measure of diversity indicates that the similarity between the protected and lopped forests has slightly decreased between 1993 and 2006 (Table 4-15 and Table 4-24).

## DISCUSSION

### Physical site factors

The main factor that creates the difference between mountain landscapes and non-mountainous landscapes is physiography. Physiography is influential because it determines the structure of the ecosystem (atmosphere, parent material, biota) which in turn determines the function and processes of the ecosystem such as nutrient cycling, water flow, and succession (Barnes *et al.* 1998). The three important characteristics of physiography that influence the mountain landscape are: (1) the form of the land, (2) slope aspect, shape, position, and inclination, and (3) elevation. In other words, physiography in the mountain landscape determines the soil type, site conditions, temperature, rainfall, and composition and diversity of the vegetation. These three main characteristics of the physiography all interact and create sites which are favorable to certain organisms. Therefore, physiographic properties of the plots in the protected and lopped forests were compared to determine whether there were factors that may influence the vegetation and ecosystem processes.

In 1993, there was no significance difference in most of the parameters between the protected and lopped forests except the exposure class and elevation. All the plots in the protected forest were classified as exposed to wind, whereas most of the plots in the lopped forest were classified as insulated indicating that there was considerably more ground-cover of the lopped forest. The difference in the elevation is expected because the lopped forest is located at a slightly higher elevation than the protected forest. The difference in elevation explains the increase in *Quercus floribunda*, an oak species occurring primarily in higher elevation.

To ensure consistency of properties between 1993 and 2006, the site properties were examined again in 2006. There was no significance difference in the site properties between the protected and lopped forest except in the average elevation of the plots, as was expected. The comparison of the protected forest site properties in 1993 and 2006 indicate that there were no significant differences except for a significant change in exposure class from wind exposure in 1993 to insulation in 2006. This difference may be due to the increase in the density of the vegetation in the protected forest from 1993 to 2006.

Nevertheless, the physiography of the protected forest has not changed significantly over the years and still can be used as a control to compare with the lopped forest to determine the vegetative changes that have occurred in the lopped forest over 13 years. In other words, there were no systemic physiographic and soil differences that may affect the forest regeneration and the ecosystem as a whole.

In this study, the protected forest was used as the control forest, and the lopped forest was the forest with the treatment of lopping. Since the site properties have been controlled for, it makes it possible to compare the impacts of the lopping treatment. The only difference in the site property was the difference in the average elevations of the protected and lopped forests. However, this does not affect the overall purpose of the research, which was to examine whether the impact of lopping was causing the forest to change from an oak dominated forest to a pine forest and whether lopping has exceeded the capacity of the forest ecosystem to continue to regenerate.

## Soil and nutrient properties

Lopping of oak leaves can potentially impact the nutrient content of the forest soil. Rawat and Singh (1988) report that in oak and pine forests of the Central Himalayas, leaf fall accounts for 81-85% and wood litter fall for 15-19% of the nutrients returning to the soil. The removal of oak foliage and branches by the local practice of lopping potentially decreases the amount of fresh litter falling onto the forest floor, thereby, decreasing the amount of nutrients returning to the soil. The villagers also remove forest floor litter to use as composting material and fuel, which further decreases the amount of litter remaining on the forest floor. The cumulative decrease in leaf and other litter may create a shortage of nutrients necessary for the growth and establishment of trees. In my interviews, people claimed that the trees are progressively providing fewer and fewer leaves every year. Therefore, lack of nutrient availability also may be affecting the production of foliage in trees.

Furthermore, *Pinus roxburghii* competes best on sites which are relatively poor in N and P; whereas, *Quercus leucotrichophora* competes best on sites relatively rich in N, P, and K (Singh *et al.* 1984b; Singh & Bisht 1992). Furthermore, the lopped forest has significantly less overstory density of 47.2% compared to 68.2% in the protected forest in 2006. Therefore, change in nutrients coupled with the creation of canopy gaps due to lopping that allow more light to filter to the forest floor, may make the site more favorable for light tolerant species such as pine to regenerate.

The fact that there was no significant difference in the N% in the A horizon but a difference in nutrient content of the leaves between the protected and lopped forests may indicate that the lopping process was affecting the trees but not affecting the soil nutrient content. Since the leaves in the lopped forest consist more of epicormic sprouts than the leaves in the protected forest, the nutrients in the lopped forest would be expected to be concentrated into fewer leaves. However, these results need to be treated with caution because of the limitations in sample size. More samples will need to be gathered in each forest over time to determine whether the difference in nutrient content of the soils and leaves was simply due to site differences or due to the influences of lopping of the two oak species.

The greater acidity of the A horizon in the protected forest would be expected when there was an increase in the number of oaks. The higher pH in the A horizon (mean = 7.2) of the lopped forest compared to the protected forest (mean=6.8) indicates more favorable nutrient and nitrogen situation in the soil which was also reflected in the higher nitrogen content of the leaves in the lopped forest (Barnes *et al.* 1998).

The deeper rooting in the lopped forest may be due to markedly more irradiance caused by gaps in the canopy, driving roots deeper (Johnson 1973; Keator & Bazell 1998). The relatively lower percentage of coarse fragments in the soil of the lopped forest compared to the protected forest also allows for more root development.

There was significantly greater depth of Oi horizon in the lopped forest indicating that the lopping and the removal of oak foliage do not appear to affect the amount of litter on to the forest floor. The significantly less occurrence of Oe horizon in the protected forest may mean that the conditions in the protected forest were more favorable for decomposition in comparison to the lopped forest. However, when comparing the depth of the Oe horizon present in both forests, there was no significant difference. The deeper Oi and greater presence of the Oe horizon in the lopped forest may be a reflection of the presence of a greater number pioneer (i.e. early successional) trees which grow faster and shed their leaves faster, and the presence of *Rhododendron arboreum* and *Pinus roxburghii* trees which have leaves that take longer to decompose than deciduous species.

Further analysis of the leaf litter will need to be conducted to determine whether there was a difference in the composition of evergreen and deciduous leaf litter in the Oi and Oe horizons. Since there was no significant difference in the dry weight of Oi horizon between the protected and lopped forests it is clear that lopping does not impact the air-dry litter mass in the two stands.

The key finding is that lopping and the removal of oak foliage for fodder did not decrease the amount of litter on the forest floor, and that based on limited data, the nutrient content of A horizon and live plant foliage appears not to be markedly different between protected and lopped forests.

## Forest regeneration

### *Overstory*

The mid-altitude range between 1000-2800 m of the central Himalaya region where *Quercus leucotrichophora*, *Quercus floribunda*, and *Pinus roxburghii* coexist is the more biologically diverse in comparison to the lower and higher altitudes of the Himalayan Mountains (Kandari & Gusain 2001). Though long-term successional studies have not been carried out in this region, inferences can be made from regeneration occurring on sites with landslides and anthropogenic disturbances.

The life histories of *Quercus leucotrichophora*, *Quercus floribunda*, and *Pinus roxburghii* are synchronized so that they can coexist in natural forest ecosystems over the long-term. Each of the species has adapted to optimize their location on the elevation gradient, soil water availability primarily during the three to four month annual rainy season, and their individual levels of shade tolerance. *P. roxburghii* tends to dominate the forests at lower altitudes ranging from 450 – 2300 m. Forests dominated by *Q. leucotrichophora* are found at 1200 – 2400 m. *Q. leucotrichophora* tends to occur in mixture with pines at the lower altitudes and with *Q. floribunda* at the higher altitudes. The range of *Q. floribunda* extends from 2100 to 2800 m. The climate generally gets cooler and the availability of soil moisture increases at the higher altitudes. *P. roxburghii* is the most shade intolerant of the three, followed by mid-tolerant *Q. leucotrichophora* and *Q. floribunda* which is more shade tolerant of the two.

These three species are able to coexist because of their regeneration ecology as well as their characteristics as early- or mid-successional species (Troup 1921; International 2002). *Pinus roxburghii*, being an early successional species, is highly shade intolerant and grows very rapidly in open spaces. Therefore, though the dispersal of seeds takes place at the same time as *Quercus leucotrichophora*, it competes well for survival on the same site. *Q. leucotrichophora,* on the other hand, is slower growing and moderately shade tolerant in the seedling stage and can survive under *P. roxburghii*. At higher altitudes, *Q. leucotrichophora* gets a head start by dispersing and germinating before the rainy season, whereas *Quercus floribunda* is only dispersed and germinates after the rainy season. However, *Q. floribunda* can survive under *Q. leucotrichophora* seedlings because it is more shade tolerant.

The life histories of the oaks and pines were clearly demonstrated in the forests in Beli village. First, it is important to note that there was no significant difference between the crown position, lopping extent and amount of tops cut-off of *Quercus leucotrichophora* in the overstory of the protected forest between 1993 and 2006. This means that the protected forest has continued to be protected and can still be used as the control forest to which to compare with the lopped forest.

In the protected forest, *Pinus roxburghii* decreased in relative dominance in 2006, whereas, *Quercus leucotrichophora* increased in relative dominance as would be expected in succession. Also, a similar phenomenon was occurring in the lopped forest. The increase in crown position of *Q. leucotrichophora* and no difference in that of *P. roxburghii* indicate that the faster growth of *Q. leucotrichophora* was probably spurred by gaps in the canopy where it out-competed *P. roxburghii*.

In both the lopped and protected forests, the numbers of regenerating stems (<1.5 m high) have decreased. This decrease may be due to self thinning due to increased overstory density. Though there were significantly more stems in the ground cover of the protected forest in 1993 in comparison to 2006, there was no significant difference in their relative density. The increase in the relative dominance of oaks in 2006 from 1993 indicates that the oaks have continued to be established in the lopped forest in the last 13 years. Therefore, it may indicate that the few stems that have survived have been able to establish themselves.

In 2006, the lopped forest had significantly less overstory density of 47.2% compared to 68.2% in the protected forest. Yet, there was no marked difference in the number of live stems between the lopped (95%) and protected (99%) forests. Therefore, the decrease in overstory density can be interpreted as gaps in the overstory canopy created by decrease in foliage by lopping instead of being created by dead trees.

It is important to mention that in 2006, for the purposes of this research comparing the influence of lopping, six plots were established the protected forest and six plots in the lopped forest. However, two plots in the lopped forest from 1993 had been converted to agricultural fields by 2006. Therefore, there was an overall decrease in the number of overstory trees in the lopped forest caused by agriculture and not by lopping.

### ***Ground cover***

#### *1 m x 1 m subplots*

What is noteworthy is that in 2006, the pine was not beginning to dominate the ground cover (1 m x 1 m subplots) in either the protected or lopped forests. Therefore, there is limited likelihood that the lopped forest is turning into a pine forest. However, there was a distinct difference in the type of species present in the ground-cover of both the forests. There was distinctly more species present in the lopped forest in comparison to the protected forest in 2006 (Table 4-15).

In the lopped forest, the lower number of species in the ground cover (13 species) in 2006 even though there is an increase in species richness of overstory (18 species) may indicate that the shade intolerant species are no longer regenerating (Table 4-15 and Table 4-22). The lopped and the protected forests are beginning to differ in species composition and species richness (Table 4-15). It follows that the height of ground-cover species in the protected forest in 2006 would be lower than in 1993 because of the increase in density of the overstory, which would provide increasingly more shading. Moreover, there was no significant difference in the heights of *Pinus roxburghii* and *Quercus leucotrichophora* trees <1.5 m high between 1993 and 2006 in the protected forest. This relationship further indicates that pine is not becoming dominant. However, in the lopped forest, due to increase in gaps in the canopy, the heights of ground-cover, such as *Benthamidia capitata*, *Rhododendron arboreum*, *Viburnum conitifolium* and *Viburnum mullaha* are significantly higher in 2006 compared to 1993 (Table 4-19). By comparing the lopped forest between 1993 and 2006, it also became apparent that the species that were dominant in 1993 were being outcompeted and significantly decreased in their numbers, whereas there were new species that have appeared.

The significantly greater presence of acorns and aborted acorns in the protected forest than in the lopped forest may be evidence that lopping is affecting the number of oak acorns that were reaching the forest floor. However, the significantly greater presence of female pine strobili in the protected forest in comparison to the lopped forest confirms that the lopping in the lopped forest has not stimulated the reproductive capacity of pine in the lopped forest. Further data on the oak and pine dispersal, using seed types need to be collected over several years to determine whether this trend is real.

### *5 m x 10 m subplots*

The analysis of the coverage in the 5 m x 10 m subplots also substantiates the 1 m x 1 m subplot findings. The greater presence of moss in the protected forest likely means that the protected forest has a higher density overstory and ground cover layer (Table 4-21). The significantly lower presence of shade intolerant species in the protected forest in comparison to the lopped forest also indicates that the overstory of the protected forest is denser than the lopped forest and that the lopped forest has more gaps which encourage the growth of light-favoring species.

A key finding is that the oaks were continuing to regenerate in both the protected and lopped forests. Because there was no significant difference in the number of regenerating pine stems (<1.5 m), the pines were not replacing the oaks in either of the forests. The gaps created due to the lopping in the lopped forest may not be causing the decrease of oaks or pines but may be encouraging the increase in the growth of herbaceous species.

There was also significantly more cutting of the tops of the ground cover plants in the lopped forest in comparison to the protected forest, which was consistent with the classification of protected and lopped forest stands. More basal sprouting of stems of *Q. leucotrichophora* in the protected forest than the lopped forest would likely be the result of the forest being lopped 40 years ago and subsequently being protected. The significantly greater amount of woody debris in the coverage of the protected forest in comparison to the lopped forest is likely due to the practice of villagers collecting dead wood to be used as fuelwood from the lopped forest.

A similar relationship of oaks replacing the pine after an initial increase in species diversity after a disturbance has been found in other parts of the Central Himalaya. Reddy *et al.* (1993) found that the old landslide sites were first dominated by herbal species and was then followed by shrubs. The herbs and shrubs decreased rapidly after six to 15 years with an increase in tree species. In formerly pine dominated sites, pine seedlings appeared within the first year and reached the overstory by the 18$^{th}$ year after the landslide. In the formerly oak dominated sites, the early successional pines were established within the first six years but were replaced by the late successional oak by the 35th year. The replacement of pines by oaks has also been observed in Nepal in heavily grazed sites (Mohns *et al.* 1988). Thandani *et al*. (1995) found that the success of oak regeneration is dependent on the presence of adult oaks close to the regeneration site. They also found that once a dense oak canopy is established, it prevents further regeneration of pines and other oaks due to the lack of adequate light reaching the forest floor.

The dominance of a pine or oak is determined by the severity of disturbance experienced at the site. Moderate disturbance promotes the establishment of oaks whose saplings can survive under moderate shade. When there is a gap in the canopy, the oak saplings grow by taking advantage of the light in oak-dominated forests. In Bhutan, Wangda *et al*. (2006) found that fine-scale human disturbances facilitated the regeneration of oak species. Interestingly, Thandani *et al.* (1995) reported that though the removal of leaf litter by the villagers in the Central Himalayas influenced the amount of carbon in the soil, it did not influence oak seedling numbers in pine dominated forests. However, selective felling opened a mosaic of canopy gaps promoting the regeneration of pine and enabling it to continue dominating the forest.

In sites with high levels of disturbance such as fire, landslides, and erosion, which create large gaps in canopy or destroy less fire-resistant species, pines, tend establish rapidly. Kumar *et al.* (2005) studied eight forests varying in anthropogenic disturbance frequencies in Uttaranchal, Central Himalaya. They defined the level of disturbance based on the distance the forest was from the village settlement. The areas closer to the village were classified as highly disturbed and the areas further away, as least disturbed.

This definition may be flawed in that the villagers go to high elevation forests at certain times of the year (Makino 1994). However, their findings may be useful in understanding the impact of disturbance on forests. They found that disturbance decreased the dominance of single species and increased the plant biodiversity by mixing species of different successional status. Species richness and diversity for all the vegetation layers were higher in low elevation - high disturbance forests. Mean tree density decreased from high to moderate and increased in low disturbance. The shrub density decreased from high to low disturbance while the reverse occurred for herbs (Kumar & Ram 2005). However, Thandani et al. (1995) found in the Central Himalayas, that moderate disturbance appears to benefit oak regeneration. They found that small gaps in the canopy provide light to the forest floor enabling oak saplings to grow; whereas, in forests with full canopy, there was limited regeneration.

### *Other factors influencing regeneration*

There are also socio-economic factors occurring the in the village not treated in the scope of this study that directly affect forest use and ultimately regeneration. Since 2000, there has been a gradual trend of the villagers moving away from agriculture as the main source of livelihood, leading to decreased dependence of the villagers on the forest for fodder and ultimately, decrease in the practice of lopping.

## Limitations of study

There are five limitations in this study which may confine the extent of extrapolation possible with the findings of this study: (1) the 1993 and 2006 sets of data were collected only during the months May – August. Therefore, the information on forest use during the other seasons were based upon interviews; (2) in 2006, the two of the plots set up in the lopped forest in 1993 had been converted into agricultural fields. This information in itself is valuable in determining forest use, however, to make up for the change, new plots had to be set up in northwest facing slopes; (3) there were no other villages with a protected forest in the region to allow for replication of the protected forest data. However, there was enough evidence in the literature to determine that the ecosystem processes that were taking place in the protected forest followed other similar ecosystems; (4) ecological data collected in 2006 was much more detailed than the data collected in 1993. Therefore, statistical comparisons between 1993 and 2006 could only be made on regeneration and overstory composition of the protected and lopped forests; and (5) since the focus of this study was regeneration, there were limitations in sample size for soil and leaf nutrient comparisons. For further understanding of the impact of lopping on nutrient dynamics, it would be necessary to collect more samples over extended periods of time and do a detailed analysis of the nutrient cycling.

## CONCLUSIONS

This study provides compelling evidence that the oaks are maintaining themselves in the forest overstory and in the ground cover. The findings indicate that the soil and forest floor conditions in the lopped forest were not in worse conditions in comparison to the protected forest. The soil in the lopped forest had relatively deeper A horizon, neutral pH, deeper rooting, and fewer coarse fragments. Moreover, the Oe horizon of the lopped forest was deeper and had heavier dry weight than the protected forest.

The oaks have also maintained their abundance and pines have not overtaken the overstory or the ground cover. Oaks accounted for 69.3% of the overstory stems in the lopped forest, whereas, pines only accounted for 1%. This is also supported by the high relative density and basal area of oaks in comparison to pines in the lopped forest. Furthermore, the percentage of live trees in the overstory continues to be above 95% in the lopped forest and there is no significant difference in the number of live stems between the protected and lopped forests.

The ground cover findings also indicate that oaks are maintaining their abundance. The greater number of oak stems regenerating in the ground cover of the lopped forest in comparison to the pines indicates that oaks continue to establish themselves. Oaks are also able to compete well with pines in that the oaks have similar heights between 1993 and 2006, whereas, the pines have decreased in height significantly. The oaks also have the greatest coverage in the ground-cover of both the protected and lopped forests.

Therefore, the concern about losing oak and its replacement by pine due to extensive lopping of oak branches by the villagers may be overstated. Furthermore, two of the plots that were measured in 1993 had been converted into agricultural fields by 2006. Hence, agricultural expansion may be more detrimental to forest loss than the practice of lopping.

**Figure 4-1** Beli village with the protected forest immediately above the village and the lopped forest diagonally to the right of the village. Jaunpur Range, Tehri Garhwal, Uttarachal, India.

**Table 4-1** Comparison of site properties of protected forest in 1993 and 2006.

| Year | Plot # | Aspect | %Slope | Slope Position[1] | Exposure Class[2] | Surface Shape[3] | Moisture Regime[4] | Drainage Class[5] | Erosion | Elevation (m) | McNab's Index[6] | Terrain Shape[7] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1993** | 1 | SW | 68.3 | 4 | 1 | 3 | 3 | 3 | NA | 2030 | NA | NA |
| | 2 | SW | 73.3 | 3 | 1 | 3 | 3 | 3 | NA | 2060 | NA | NA |
| | **3** | SW | 53.3 | 2 | 1 | 3 | 3 | 3 | NA | 2090 | NA | NA |
| | 4 | SW | 86.6 | 4 | 1 | 3 | 3 | 3 | NA | 2030 | NA | NA |
| | 5 | SW | 60.0 | 3 | 1 | 3 | 3 | 3 | NA | 2080 | NA | NA |
| | 6 | SW | 100.0 | 2 | 1 | 3 | 3 | 3 | NA | 2090 | NA | NA |
| **2006** | | | | | | | | | | | | |
| | 2 | SW250 | 74.0 | 3 | 2 | 3 | 3 | 3 | 2 | 1963 | 0.6 | Concave |
| | 3 | W280 | 75.0 | 3 | 2 | 1 | 3 | 3 | 2 | 1975 | 1.75 | Concave |
| | 4 | W270 | 62.0 | 2 | 1 | 3 | 3 | 3 | 2 | 2026 | 0.75 | Concave |
| | 5 | W270 | 83.0 | 3 | 2 | 3 | 3 | 3 | 2 | 1949 | -0.6 | Convex |
| | 6 | SW254 | 105.0 | 3 | 2 | 3 | 3 | 3 | 1 | 1963 | 2 | Concave |

[1] Slope position: summit=1, 2=upper slope, 3=midslope, 4=lower slope, 5=bottom of slope, 6=level terrain

[2] Exposure class: 1=wind, 2=insulation, 3=frost, 4=cold air drainage, 5=other

[3] Site surface shape: 1=concave, 2=convex, 3=straight

[4] Ecological moisture regime: 1=very xeric, 2=xeric, 3=dry-mesic, 4=mesic, 5=wet-mesic, 6=hyrdric

[5] Soil drainage: 1=excessively drained, 2=somewhat excessively drained, 3=well-drained, 4=moderately well-drained, 5=somewhat poorly drained, 6=poorly drained, 7=very poorly drained

[6,7] McNab's index is a terrain shape index which quantifies the surface shape of plot calculated by taking the average slope gradient from the plot center to the perimeter. Larger values indicate concave terrain shape and lower values indicate convex terrain shape.

**Table 4-2** Comparison of **s**ite properties of lopped forest in 1993 and 2006.

| Year | Plot # | Aspect | % Slope | Slope Position[1] | Exposure Class[2] | Surface Shape[3] | Moisture Regime[4] | Drain-age Class[5] | Erosion | Elevation (m) | McNab's Index[6] | Terrain Shape[7] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1993** | | SW | 73.3 | 4 | 4 | 3 | 3 | 3 | NA | 2150 | NA | NA |
| | 8 | SW | 53.3 | 3 | 2 | 3 | 3 | 3 | NA | 2190 | NA | NA |
| | 9 | SW | 55.0 | 2 | 2 | 3 | 3 | 3 | NA | 2240 | NA | NA |
| | 10 | SW | 53.3 | 4 | 2 | 3 | 3 | 3 | NA | 2150 | NA | NA |
| | 11 | SW | 90.0 | 3 | 2 | 3 | 3 | 3 | NA | 2190 | NA | NA |
| | 12 | SW | 60.0 | 2 | 2 | 3 | 3 | 3 | NA | 2240 | NA | NA |
| **2006** | 7 | SW 230 | 95.0 | 3 | 1 | 3 | 3 | 2 | 2 | 2000 | 2 | Concave |
| | 8 | NW286 | 96.0 | 3 | 2 | 3 | 3 | 3 | 2 | 2048 | -1.7 | Convex |
| | 9 | SW254 | 62.0 | 2 | 1 | 3 | 2 | 3 | 2 | 2040 | 1.05 | Concave |
| | 10 | NW340 | 90.0 | 4 | 2 | 3 | 3 | 3 | 2 | 2016 | -0.35 | Convex |
| | 11 | NW344 | 88.0 | 3 | 2 | 3 | 3 | 3 | 1 | 2039 | -0.8 | Convex |
| | 12 | NW290 | 78.0 | 2 | 2 | 3 | 2 | 3 | 2 | 2059 | -0.2 | Convex |
| | 13 | SW224 | 55.0 | 2 | 2 | 3 | 3 | 2 | 2 | 2068 | -0.25 | Convex |

[1] Slope position: summit=1, 2=upper slope, 3=midslope, 4=lower slope, 5=bottom of slope, 6=level terrain

[2] Exposure class: 1=wind, 2=insulation, 3=frost, 4=cold air drainage, 5=other

[3] Site surface shape: 1=concave, 2=convex, 3=straight

[4] Ecological moisture regime: 1=very xeric, 2=xeric, 3=dry-mesic, 4=mesic, 5=wet-mesic, 6=hyrdric

[5] Soil drainage: 1=excessively drained, 2=somewhat excessively drained, 3=well-drained, 4=moderately well-drained, 5=somewhat poorly drained, 6=poorly drained, 7=very poorly drained

[6,7] McNab's index is a terrain shape index which quantifies the surface shape of plot calculated by taking the average slope gradient from the plot center to the perimeter. Larger values indicate concave terrain shape and lower values indicate convex terrain shape.

**Table 4-3** Comparison of mean values of soil Nitrogen and C:N ratio of the soil and leaves of the protected forest, lopped forests, and soil located above the agricultural fields in 2006.

| Variable | N | Protected forest (SD) | N | Lopped forest (SD) | N | Soil above fields |
|---|---|---|---|---|---|---|
| Soil N | 4 | 0.60 (0.22) | 6 | 0.87 (0.35) | 2 | 0.63 (0.40) |
| Soil C:N | 4 | 14.90 (3.11) | 6 | 16.81 (2.28) | 2 | 15.82 (4.02) |
| Quercus leucotrichophora Leaf N | 4 | 1.35 (0.10) | 6 | 1.68 (0.29) | | |
| Quercus leucotrichophora Leaf C:N | 4 | 37.84 (3.39) | 6 | 30.13 (4.93) | | |
| Pinus roxburghii Leaf N | 3 | 1.37 (0.21) | 1 | 1.20 | | |
| Pinus roxburghii Leaf C:N | 3 | 36.59 (5.26) | 1 | 41.14 | | |

**Table 4-4** Comparison of soil properties of the protected and lopped forests in 2006.

| Variable | N | Protected Forest (SD) | N | Lopped Forest (SD) |
|---|---|---|---|---|
| Mean depth of A Horizon (cm) | 5 | 1.96 (1.54) | 7 | 3.10 (2.26) |
| Average pH of A Horizon | 5 | 6.75 (0.22) | 7 | 7.21 (0.39) |
| Average pH of C Horizon | 5 | 5.17 (0.49) | 7 | 6.11 (0.68) |
| Rooting depth (cm) | 6 | 11.75 (4.96) | 6 | 31.17 (3.45) |
| % Coarse fragments | 6 | 40.83 (13.57) | 6 | 30.71 (20.70) |
| Depth of Oi Horizon (cm) | 30 | 1.31 (8.10) | 42 | 2.00 (9.66) |
| Depth of Oe Horizon (cm) | 30 | 0.14 (4.80) | 42 | 0.42 (5.88) |
| Depth of Oe excluding zero values (cm) | 4 | 0.99 (1.32) | 22 | 0.80 (3.96) |
| Dry weight of Oi (mg) | 30 | 9.45 (5.96) | 42 | 9.62 (5.14) |
| Dry weight of Oe (mg) | 30 | 2.73 (9.10) | 42 | 6.88 (7.83) |
| Dry weight of Oe excluding zero values (mg) | 4 | 20.50 (17.73) | 22 | 13.13 (5.82) |

**Table 4-5** Comparison of overstory composition of the protected forest in 1993. The standard error is given in parenthesis.

| TREE SPECIES | NUMBER STEMS/HA | DBH (cm) | BA ($m^2$/ha) | CROWN POSITION[1] | % LIVE STEMS | LOPPING EXTENT[2] | %TOP CUT |
|---|---|---|---|---|---|---|---|
| *Quercus leucotricophora* A. Camus | 544.4 | 8.46 (0.26) | 3.50 (1.33) | 3.40 (0.05) | 99.3 | 3.61 (0.15) | 0 |
| *Lyonia ovalifolia* (Wallich) Drude | 122.2 | 7.75 (0.85) | 1.54 (0.80) | 2.91 (0.07) | 100 | 2.52 (0.12) | 0 |
| *Pinus roxburgii* Sarg. | 233.3 | 17.30 (1.90) | 8.83 (2.30) | 2.65 (0.14) | 95.2 | 1.87 (0.17) | 0 |
| *Rhododendron arboreum* SM. | 7.4 | 12.25 (5.75) | 0.64 --- | 2.50 (0.50) | 100 | 2.50 (0.50) | 0 |
| *Benthamidia capitata* (Wallich) Drude | 7.4 | 6.65 (1.15) | 0.16 --- | 3.00 (0.00) | 100 | 1.00 (0.00) | 0 |
| *Ficus hipsida* Linn. | 3.7 | 6.90 --- | 0.83 --- | 4.00 --- | 100 | 6 --- | 0 |
| *Prunus cornuta* Wall. | 7.4 | 7.35 (1.34) | 0.10 (0.02) | 2.00 (1.41) | 100 | 1.00 (0.00) | 0 |

[1]Crown position: 1=dominant, 2=codominant, 3=intermediate, 4=suppressed; [2] Extent of lopping: 1= not lopped, 2=lower 1 to 20% lopped, 3=lower 21 to 40% lopped, 4=lower 41% to 60% lopped, 5=lower 61 to 80% lopped, and 6=81 to 100% lopped

**Table 4-6** Comparison of species regenerating in the ground cover data of protected forest in 1993. The standard error is given in parenthesis.

| TREE SPECIES | NUMBER /HA | HEIGHT (m) | LOPPING EXTENT[1] | SEEDLING & BASAL SPROUTS (%) |
|---|---|---|---|---|
| *Quercus leucotricophora* A. Camus | 48,333.3 | 0.62<br>(0.05)[2] | 2.78<br>(0.30) | 0.30<br>(0.06) |
| *Pinus roxburgii* Sarg. | 6,666.7 | 0.49<br>(0.20) | 1.57<br>(0.43) | 0.2<br>(0.2) |
| *Benthamidia capitata* (Wallich) Drude | 833.3 | 1.32<br>--- | 1<br>--- | 1<br>--- |
| *Cedrus deodara* Loud. | 2500.0 | 0.23<br>(0.05) | 1<br>--- | --- |
| *Pyrus pashia* Ham. | 2500.0 | 0.57<br>(0.00) | 1<br>--- | --- |

[1] Extent of lopping: 1 = not lopped, 2 = lower 1 to 20% lopped, 3 = lower 21 to 40% lopped, 4 = lower 41 to 60% lopped, 5 = lower 61 to 80% lopped, and 6 = 81 to 100% lopped.

**Table 4-7** Comparison of overstory tree species in lopped forest for 1993. The standard error is given in parenthesis.

| TREE SPECIES | NUMBER STEMS/HA | DBH (cm) | BA ($m^2$/ha) | CROWN POSITION [1] | % LIVE STEMS | LOPPING EXTENT [2] | %TOP CUT |
|---|---|---|---|---|---|---|---|
| *Quercus leucotricophora* A. Camus | 700.0 | 15.69 (0.53) | 16.42 (4.60) | 3.95 (0.02) | 99.5 | 5.68 (0.05) | 41.80 |
| *Quercus floribunda* Rehder | 163.0 | 9.62 (0.61) | 1.39 (0.55) | 3.75 (0.09) | 100 | 5.30 (0.20) | 22.73 |
| *Lyonia ovalifolia* (Wallich) Drude | 111.1 | 13.58 (1.36) | 2.50 (0.66) | 2.97 (0.12) | 100 | 2.03 (0.36) | 3.33 |
| *Pinus roxburgii* Sarg. | 51.9 | 17.62 (3.58) | 2.91 (1.18) | 2.79 (0.32) | 92.9 | 2.86 (0.51) | 0 |
| *Rhododendron arboreum* Sm. | 144.4 | 11.60 (0.91) | 2.25 (0.94) | 2.79 (0.12) | 100 | 1.79 (0.28) | 0 |
| *Benthamidia capitata* (Wallich) Drude | 11.1 | 6.53 (0.56) | 0.11 (0.01) | 2.67 (0.33) | 100 | 1.33 (0.33) | 0 |
| *Ficus hipsida* Linn. | 22.2 | 10.03 (1.90) | 0.62 0.28) | 2.83 (0.40) | 100 | 1.67 (0.67) | 16.67 |

[1]Crown position: 1=dominant, 2=codominant, 3=intermediate, 4=suppressed; [2] Extent of lopping: 1= not lopped, 2=lower 1 to 20% lopped, 3=lower 21 to 40% lopped, 4=lower 41% to 60% lopped, 5=lower 61 to 80% lopped, and 6=81 to 100% lopped

**Table 4-8** Comparison of tree species in the ground cover for lopped forest for 1993. The standard error is given in parenthesis.

| TREE SPECIES | NUMBER /HA | HEIGHT (m) | LOPPING EXTENT [1] | SEEDLING & BASAL SPROUTS (%) |
|---|---|---|---|---|
| *Quercus leucotricophora* Roxb. | 131,666.7 | 0.64<br>(0.03) b) | 2.43<br>(0.12) | 0.39<br>(0.04) |
| *Quercus floribunda* Rehder | 17,500.0 | 0.43<br>(0.06) | 1.14<br>(0.08) | 0.86<br>(0.08) |
| *Lyonia ovalifolia* (Wallich) Drude | 25,833.3 | 0.52<br>(0.07) | 1.39<br>(0.17) | 0.84<br>(0.07) |
| *Pinus roxburgii* Sarg. | 18,333.3 | 0.55<br>(0.07) | 1.36<br>(0.04) | 0.73<br>(0.10) |
| *Rhododendron arboreum* Sm. | 114,166.7 | 0.17<br>(0.02) | 1.07<br>(0.03) | 0.96<br>(0.02) |
| *Benthamidia capitata* (Wallich) Drude | 5,000.0 | 0.50<br>(0.14) | 2.00<br>(0.63) | 0.67<br>(0.21) |
| *Ficus hipsida* Linn. | 4,166.7 | 0.31<br>(0.19) | 1.00<br>(0.00) | 1.00<br>(0.00) |
| *Prunus cornuta* Wall. | 1,666.7 | 1.13<br>(0.03) | 3.00<br>(0.00) | 0.00<br>(0.00) |

[1] Extent of lopping: 1 = not lopped, 2 = lower 1 to 20% lopped, 3 = lower 21 to 40% lopped, 4 = lower 41 to 60% lopped, 5 = lower 61 to 80% lopped, and 6 = 81 to 100% lopped.

**Table 4-9** Comparison of the percentage of live stems and the percentage of trees with the tops in the protected and lopped forests in 1993 and 2006. Standard deviation is given in parenthesis.

| Variable | Protected forest | | Lopped forest | |
|---|---|---|---|---|
| | **1993** | **2006** | **1993** | **2006** |
| Live trees | 98.1 (6.5) | 98.7 (5.8) | 99.3 (3.2) | 95.0 (17.3) |
| Trees with tops | 100.0 | 84.8 (24.9) | 77.2 (37.2) | 61.2 (34.8) |

**Table 4-10** Comparison of the tree species present in the overstory of the protected forest in 2006. Standard deviation is presented in perenthesis.

| TREE SPECIES | NUMBER OF STEMS /Ha | DBH (cm) | BA (m2/ha) | CROWN POSITION | %LIVE STEMS | LOPPING EXTENT | %TOP CUT |
|---|---|---|---|---|---|---|---|
| Aegle marmelos | 7.4 | 7.30 (1.84) | 0.09 (0.04) | 4.00 | 100.0 | 1.50 (0.71) | 50.0 |
| Berberis asiatica | 3.7 | 25.40 (NA) | 1.06 (NA) | 2.00 | 100.0 | 1.00 | 0.0 |
| Benthamida capitata | 33.3 | 4.58 (4.70) | 0.07 (0.12) | 3.56 (0.53) * | 100.0 | 1.33 (1.00) * | 16.7 |
| Indigofera cassioides | 3.7 | 1.70 (NA) | 0.01 (NA) | 4.00 (NA) | 100.0 | 1.00 (NA) | 0.0 |
| Myrica esculenta | 7.4 | 1.30 (0.14) | 0.003 (0.0006) | 3.00 (0.00) | 100.0 | 1.00 (0.00) | 0.0 |
| Lyonia ovalifolia | 355.6 | 4.66(4.00)* | 0.06 (0.14) | 3.29 (0.83)* | 100.0 | 1.85 (1.41) | 21.7 |
| Pyrus pashia | 37.0 | 6.69 (2.03) | 0.08 (0.04) | 3.60 (0.97) | 100.0 | 1.00 (0.00)* | 30.0 |
| Pinus roxburghii | 77.8 | 23.88 (18.20) | 1.38 (1.96) | 1.75 (1.12) | 89.3 (15.4) | 1.05 (0.22) * | 9.2 |
| Quercus floribunda | 37.0 | 6.88 (5.53) | 0.12 (0.19) | 3.00 (0.94) | 100.0 | 1.00 (0.00) * | 5.6 |
| Quercus leucotrichophora | 1944.4 | 7.87 (4.96)* | 0.14 (0.25) | 3.03 (0.97) | 99.1 (2.2) | 1.10 (0.54) * | 21.4 |
| Rhododendron arboreum | 3.7 | 9.00 | 0.13 (NA) | 3.00 | 100.0 | 1.00 | 0.0 |
| Rhamnus persica | 11.1 | 2.60 (0.95) | 0.01 (0.01) | 2.00 (0.00) | 100.0 | 1.00 (0.00) | 0.0 |
| Rhus parviflora | 3.7 | 5.00 | 0.04 (NA) | 4.00 | 100.0 | 1.00 | 0.0 |
| Rhus wallichii | 22.2 | 3.25 (1.81) | 0.02 (0.02) | 3.17 (1.17) | 100.0 | 1.00 | 0.0 |
| Scurrula elata | 7.4 | 5.15 (3.89) | 0.06 (0.07) | 4.00 | 100.0 | 1.00 | 0.0 |
| Viburnum cotinifolium | 37.0 | 4.58 (4.33) | 0.06 (0.10) | 3.70 (0.48) | 100.0 | 1.00 (0.00) | 0.0 |
| Wikstroemia canescens | 3.7 | 7.20 | 0.09 (0.08) | 4.00 | 100.0 | 1.00 | 0.0 |

* statistically significant

**Table 4-11** Comparison of the relative density of overstory trees of the protected forest in 1993 and 2006. Standard deviation presented in parenthesis.

| Species | 1996 | 2006 | p-value |
|---|---|---|---|
| Quercus leucotrichophora | 0.49 (0.21) | 0.72 (0.15) | 0.049 |
| Quercus floribunda | 0.00 (0.00) | 0.01 (0.02) | 0.25 |
| Lyonia ovalifolia | 0.12 (0.17) | 0.16 (0.10) | 0.56 |
| Pinus roxburghii | 0.37 (0.23) | 0.04 (0.04) | 0.01 |
| Rhododendron arboreum | 0.004 (0.01) | 0.001 (0.003) | 0.48 |
| Benthamida capitata | 0.004 (0.01) | 0.02 (0.02) | 0.19 |
| Ficus hipsida | 0.01 (0.02) | 0.00 (0.00) | 0.34 |
| Prunus cornuta | 0.01 (0.02) | 0.00 (0.00) | 0.15 |
| Rhus parviflora | 0.00 (0.00) | 0.001 (0.003) | 0.34 |
| Viburnum cotinifolium | 0.00 (0.00) | 0.01 (0.02) | 0.046 |
| Rhus wallichii | 0.00 (0.00) | 0.01 (0.01) | 0.09 |
| Berberis asiatica | 0.00 (0.00) | 0.003 (0.01) | 0.34 |
| Aegle marmelos | 0.00 (0.00) | 0.01 (0.01) | 0.34 |
| Wikstroemia canescens | 0.00 (0.00) | 0.003 (0.006) | 0.34 |
| Myrica esculenta | 0.00 (0.00) | 0.004 (0.01) | 0.34 |
| Scurrula elata | 0.00 (0.00) | 0.002 (0.005) | 0.34 |
| Indigofera cassioides | 0.00 (0.00) | 0.001 (0.003) | 0.34 |
| Mahonia borealis | NA | NA | |
| Grewia optiva | NA | NA | |
| Viburnum mullaha | NA | NA | |
| Aesculus indica | NA | NA | |
| Benthamidia capitata | NA | NA | |
| Juglans regia | NA | NA | |
| Coriaria nepalensis | NA | NA | |

**Table 4-12** Comparison of the mean DBH (cm) of overstory trees the protected and lopped forests of 1993 and 2006. Standard deviation presented in parenthesis.

| Forest type | Species | 1993 | 2006 | p-value |
|---|---|---|---|---|
| **Protected** | Lyonia ovalifolia | 5.97 (0.65) | 4.95 (3.33) | 0.63 |
| | Pinus roxburghii | 26.93 (13.65) | 17.48 (11.70) | 0.23 |
| | Quercus leucotrichophora | 9.94 (3.74) | 9.73 (3.69) | 0.93 |
| | Rhododendron arboreum | 6.5 | 9.0 | NA |
| **Lopped** | Benthamida capitata | 6.95 (0.92) | 6.32 (4.46) | 0.86 |
| | Ficus hipsida | 14.60 (0.85) | 6.3 | 0.08 |
| | Lyonia ovalifolia | 14.26 (7.77) | 7.95 (6.36) | 0.23 |
| | Pinus roxburghii | 30.93 (17.40) | 10.10 (6.36) | 0.19 |
| | Quercus floribunda | 9.90 (4.92) | 5.60 (2.46) | 0.07 |
| | Quercus leucotrichophora | 17.28 (8.44) | 13.00 (6.00) | 0.31 |
| | Rhododendron arboreum | 16.27 (9.73) | 3.87 (2.25) | 0.10 |

**Table 4-13** Comparison of heights and ages of the tallest Quercus leucotrichophora and Pinus roxburghii trees in protected and lopped forests in 2006. Standard deviation is presented in parenthesis.

| Forest type | Species | DBH (cm) | | | Height (m) | | | Age (yr) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Mean | Min | Max | Mean | Min | Max | Mean |
| **Protected** | Pinus roxburghii | 6.0 | 67.4 | 29.41 (21.78) | 5.50 | 25.00 | 12.68 (8.11) | 14 | 131 | 53.22 (40.48) |
| | Quercus leucotrichophora | 11.3 | 39.7 | 19.39 (7.05) | 5.25 | 14.30 | 9.02 (2.47) | 32 | 164 | 81.54 (38.80) |
| | Lyonia ovalifolia | 7.5 | 8.5 | 8.0 (0.71) | | | | 16 | 25 | 20.50 (6.36) |
| **Lopped** | Pinus roxburghii | 2.7 | 14.6 | 8.53 (5.95) | 2.75 | 5.75 | 3.833 (1.67) | 21 | 34 | 27 (6.56) |
| | Quercus floribunda | 8.0 | 21.7 | 13.19 (5.36) | 4.50 | 11.50 | 7.06 (2.04) | 22 | 137 | 61.25 (35.53) |
| | Quercus leucotrichophora | 11.7 | 36.5 | 21.31 (7.15) | 4.00 | 19.00 | 11.61 | 44 | 161 | 102.00 (38.08) |

**Table 4-14** Comparison of mean basal area ($ft^2$ per acre) of species present in the protected and lopped forests in 2006 using BAF-10 prism.

| Tree species | Protected forest | Lopped forest |
|---|---|---|
| Quercus leucotrichophora | 59.44 (27.92) | 34.76 (16.65) |
| Quercus floribunda | 0 | 7.14 (8.03) |
| Lyonia ovalifolia | 10.56 (10.20) | 5.71 (8.76) |
| Pinus roxburghii | 7.22 (9.53) | 2.38 (3.17) |
| Rhododendron arboreum | 0 | 1.43 (2.62) |
| Benthamidia capitata | 0 | 2.38 (6.30) |
| Indigofera cassioides | 0 | 0.48 (1.26) |
| Juglans regia | 0 | 0.48 (1.26) |
| Rhus parviflora | 0 | 0.95 (2.52) |
| Viburnum cotinifolium | 0 | 0.95 (2.52) |

**Table 4-15** Comparison of the species present in the ground cover of the protected and lopped forests in 1993 and 2006.

| Protected forest | | Lopped forest | |
|---|---|---|---|
| **1993** | **2006** | **1993** | **2006** |
| Quercus leucotrichophora | Quercus leucotrichophora | Quercus leucotrichophora | Quercus leucotrichophora |
| | Quercus floribunda | Quercus floribunda | |
| Pinus roxburghii | Pinus roxburghii | Pinus roxburghii | Pinus roxburghii |
| | Indigofera cassioides | | Indigofera cassioides |
| Benthamida capitata | | Benthamida capitata | Benthamida capitata |
| Pyrus pashia | | Rhododendron arboreum | Rhododendron arboreum |
| Cedrus deodara | | Lyonia ovalifolia | Lyonia ovalifolia |
| | | Viburnum cotinifolium | Viburnum cotinifolium |
| | | Viburnum mullaha | Viburnum mullaha |
| | | Rhus parviflora | Rhus punjabensis |
| | | Mahonia borealis | Mahonia borealis |
| | | Abelia triflora | Grewia optiva |
| | | Coriaria nepalensis | Abelia triflora |
| | | Rhamnus persica | Ficus hipsida |
| | | Myrica esculenta | |
| | | Prunus cornuta | |

**Table 4-16** Comparison of the relative density (%) of the ground cover of Quercus leucotrichophora and Pinus roxburghii in the protected and lopped forests in 1993 and 2006. Standard deviation is presented in the parenthesis.

| Forest | Species | Year | |
|---|---|---|---|
| | | 1993 | 2006 |
| **Protected** | Quercus leucotrichophora | 0.56 (0.45) | 0.42 (0.49) |
| | Pinus roxburghii | 0.14 (0.16) | 0.17 (0.41) |
| **Lopped** | Quercus leucotrichophora | 0.38 (0.27) | 0.19 (0.16) |
| | Pinus roxburghii | 0.07 (0.13) | 0.10 (0.19) |

**Table 4-17** Comparison of the overall mean heights (cm) of all the ground cover stems present in the protected and lopped forests in 1993 and 2006. Standard error presented in parenthesis.

| Forest type | Year | Height |
|---|---|---|
| **Protected** | 1993 | 60.77 (4.53) |
| | 2006 | 44.67 (8.13) |
| **Lopped** | 1993 | 41.06 (1.71) |
| | 2006 | 63.32 (6.98) |

**Table 4-18** Comparison of mean heights (cm) of ground cover stems of tree species in the protected and lopped forests in 1993 and 2006. Standard deviation provided in parenthesis.

| Species | Protected | | Lopped | |
|---|---|---|---|---|
| | 1993 | 2006 | 1993 | 2006 |
| Abelia triflora | 0.00 | 0.00 | 36.91 (30.66) | 0.00 |
| Berberis asiatica | 0.00 | 5.30 | 0.00 | 0.00 |
| Cotoneaster bacillaris | 0.00 | 0.00 | 72.50 (33.23) | 0.00 |
| Benthamida capitata | 132.00 | 0.00 | 50.17 (33.86) | 154.00 |
| Cedrus deodara | 23.00 (8.66) | 0.00 | 0.00 | 0.00 |
| Coriaria nepalensis | 0.00 | 0.00 | 90.00 (11.31) | 0.00 |
| Ficus hipsida | 0.00 | 0.00 | 0.00 | 11.00 |
| Grewia optiva | 0.00 | 0.00 | 0.00 | 62.00 (25.46) |
| Indigofera cassioides | 0.00 | 4.37 (2.26) | 0.00 | 19.13 (6.61) |
| Mahonia borealis | 0.00 | 0.00 | 40.37 (41.09) | 33.75 (10.96) |
| Myrica esculenta | 0.00 | 0.00 | 73.00 | 0.00 |
| Prunus cornuta | 0.00 | 0.00 | 112.50 (3.54) | 0.00 |
| Lyonia ovalifolia | 0.00 | 0.00 | 52.26 (39.77) | 0.00 |
| Pyrus pashia | 57.00 (0.00) | 0.00 | 0.00 | 0.00 |
| Pinus roxburghii | 56.44 (52.24) | 56.67 (44.02) | 55.41 (30.93) | 25.50 (NA) |
| Quercus floribunda | 0.00 | 58.00 (NA) | 42.71 (28.32) | 0.00 |
| Quercus leucotrichophora | 61.82 (38.35) | 65.50 (32.83) | 64.38 (37.85) | 62.30 (51.92) |
| Rhododendron arboreum | 0.00 | 0.00 | 16.90 (24.69) | 81.00 (39.77) |
| Rhamnus persica | 88.00 (NA) | 5.67 (4.62) | 16.84 (11.56) | 0.00 |
| Rhus parviflora | 0.00 | 0.00 | 27.00 (5.66) | 0.00 |
| Rhus punjabensis | 0.00 | 0.00 | 0.00 | 15.00 |
| Rhus wallichii | 0.00 | 60.00 (33.42) | 0.00 | 0.00 |
| Viburnum cotinifolium | 0.00 | 0.00 | 33.44 (27.65) | 112.50 (101.12) |
| Viburnum mullaha | 0.00 | 0.00 | 36.33 (34.35) | 127.00 (35.36) |

**Table 4-19** Comparison of the number acorns and pine female strobili found in the ground cover in 2006. Standard deviation is presented in parenthesis.

| Forest type | Oak acorn | Aborted oak acorn | Pine female strobili |
|---|---|---|---|
| Protected | 3.21 (6.53) | 1.17 (1.93) | 9.67 (21.56) |
| Lopped | 1.29 (3.94) | 0.82 (3.01) | 2.18 (3.91) |

**Table 4-20** Comparison of the tree species present in the overstory of the lopped forest in 2006. Standard deviation is presented in parenthesis.

| TREE SPECIES | NUMBER OF STEMS/ha | DBH (cm) | Mean BA ($m^2$/ha) | CROWN POSITION | %LIVE STEMS | LOPPING EXTENT | %TOP CUT |
|---|---|---|---|---|---|---|---|
| Aesculus indica | 3.2 | 6.90 (NA) | 0.08 (NA) | 1.00 | 100.0 | 4.00 | 0.0 |
| Benthamida capitata | 60.3 | 7.52 (4.57) | 0.13 (0.13) | 2.74 (0.99) | 100.0 | 2.74 (1.70) | 25.7 |
| Coriaria nepalensis | 3.2 | 14.10 (NA) | 0.33 (NA) | 2.00 (NA) | 0 | 6.00 (NA) | 100.0 |
| Ficus hipsida | 9.5 | 6.23 (1.40) | 0.07 (0.03) | 4.00 (0.00) | 100.0 | 2.67 (2.89) | 33.3 |
| Grewia optiva | 9.5 | 12.20 (6.68) | 0.29 (0.24) | 2.33 (0.58) | 100.0 | 4.33 (2.89) | 75.0 |
| Juglans regia | 3.2 | 5.90 (NA) | 0.06 (NA) | 4.00 (NA) | 100.0 | 1.00 (NA) | 0.0 |
| Mahonia borealis | 19.1 | 5.63 (4.62) | 0.08 (0.14) | 3.67 (0.52) | 100.0 | 1.33 (0.52) | 0.0 |
| Lyonia ovalifolia | 98.4 | 11.57 (8.11) | 0.32 (0.40) | 2.61 (1.02) | 94.4 (7.9) | 2.19 (1.58) | 23.1 |
| Pyrus pashia | 28.6 | 4.74 (2.98) | 0.05 (0.06) | 3.11 (0.93) | 100.0 | 3.11 (2.15) | 0.0 |
| Pinus roxburghii | 15.9 | 7.70 (4.40) | 0.12 (0.13) | 2.20 (1.10) | 100.0 | 1.40 (0.55) | 25.0 |
| Quercus floribunda | 434.9 | 8.37 (4.64) | 0.15 (0.16) | 1.99 (0.12) | 98.8 (2.1) | 3.69 (2.26) | 47.0 |
| Quercus leucotrichophora | 596.8 | 11.88 (6.66) | 0.30 (0.34) | 2.94 (1.12) | 94.5 (9.1) | 4.98 (1.86) | 65.7 |
| Rhododendron arboreum | 34.9 | 8.36 (5.37) | 0.16 (0.20) | 2.91 (1.30) | 100.0 | 1.73 (1.56) | 73.3 |
| Rhamnus persica | 9.5 | 3.13 (1.31) | 0.02 (0.02) | 4.00 (0.00) | 100.0 | 1.00 (0.00) | 0.0 |
| Rhus parviflora | 9.5 | 9.93 (8.93) | 0.25 (0.36) | 2.00 (0.00) | 100.0 | 1.00 (0.00) | 0.0 |
| Viburnum cotinifolium | 107.9 | 3.30 (0.75) | 0.02 (0.01) | 3.56 (0.56) | 100.0 | 1.00 (0.00) | 25.9 |
| Viburnum mullaha | 38.1 | 4.48 (3.23) | 0.05 (0.08) | 3.33 (1.07) | 96.7 (5.8) | 2.08 (2.02) | 33.3 |

**Table 4-21** Comparison of the relative density of overstory trees in lopped forest in 1993 and 2006. Standard deviation presented in parenthesis.

| Species | 1996 | 2006 | p-value |
|---|---|---|---|
| Quercus leucotrichophora | 0.62 (0.13) | 0.46 (0.18) | 0.101 |
| Quercus floribunda | 0.11 (0.06) | 0.32 (0.13) | 0.004 |
| Lyonia ovalifolia | 0.08 (0.06) | 0.05 (0.07) | 0.414 |
| Pinus roxburghii | 0.10 (0.16) | 0.02 (0.03) | 0.217 |
| Rhododendron arboreum | 0.08 (0.09) | 0.02 (0.02) | 0.114 |
| Benthamida capitata | 0.01 (0.02) | 0.03 (0.03) | 0.137 |
| Ficus hipsida | 0.01 (0.02) | 0.01 (0.01) | 0.555 |
| Prunus cornuta | NA | NA | |
| Rhus parviflora | 0.00 (0.00) | 0.003 (0.01) | 0.377 |
| Viburnum cotinifolium | 0.00 (0.00) | 0.05 (0.08) | 0.167 |
| Rhus wallichii | NA | NA | |
| Berberis asiatica | NA | NA | |
| Aegle marmelos | NA | NA | |
| Wikstroemia canescens | NA | NA | |
| Myrica esculenta | NA | NA | |
| Scurrula elata | NA | NA | |
| Indigofera cassioides | NA | NA | |
| Mahonia borealis | 0.00 (0.00) | 0.01 (0.02) | 0.203 |
| Grewia optiva | 0.00 (0.00) | 0.01 (0.01) | 0.203 |
| Viburnum mullaha | 0.00 (0.00) | 0.02 (0.03) | 0.189 |
| Aesculus indica | 0.00 (0.00) | 0.004 (0.01) | 0.377 |
| Juglans regia | 0.00 (0.00) | 0.002 (0.004) | 0.377 |
| Coriaria nepalensis | 0.00 (0.00) | 0.003 (0.008) | 0.377 |

**Table 4-22** Comparison of spatial distribution and aggregation of the overstory of protected and lopped forests for 2006 using Variance Mean Ratio.

| Variable | Year | Forest type | |
|---|---|---|---|
| | | Protected | Lopped |
| Entire forest | 1993 | 103.46 | 104.02 |
| | 2006 | 78.34 | 106.88 |
| Quercus leucotrichophora | 1993 | 121.45 | 38.84 |
| | 2006 | 120.34 | 28.18 |
| Pinus roxburghii | 1993 | 14.62 | 15.14 |
| | 2006 | 9.57 | 13.2 |

**Table 4-23** Comparison of overstory species diversity of the protected and lopped forests in 2006.

| Measure | Forest type | | | |
|---|---|---|---|---|
| | Protected | | Lopped | |
| | 1993 | 2006 | 1993 | 2006 |
| Species richness | 7 | 16 | 7 | 17 |
| Shannon Index H’ | 1.07 | 0.94 | 1.31 | 1.71 |
| Simpson’s index | 2.36 | 1.81 | 2.63 | 3.71 |
| Whittaker’s Measure | 0.14 | 0.46 | 0.14 | 0.46 |

**Table 4-24** Comparison of species diversity of the ground cover of the protected and lopped forests in 2006.

| Measure | Forest type | | | |
|---|---|---|---|---|
| | Protected | | Lopped | |
| | 1993 | 2006 | 1993 | 2006 |
| Species richness | 5 | 4 | 15 | 13 |
| Shannon Index H' | 0.73 | 0.95 | 1.98 | 2.36 |
| Simpson's index | 2.36 | 1.81 | 2.63 | 3.71 |
| Whittaker's Measure | 1 | 0.65 | 1 | 0.65 |

**Table 4-25** Comparison of the average heights of ground cover stems (cm) in the protected and lopped forests of 1993 and 2006. Standard error is given in parenthesis.

| Forest type | Species | 1993 Height of stems | 2006 Height of stems | F statistic | p-value |
|---|---|---|---|---|---|
| **Protected** | Pinus roxburghii | 56.44 (17.87) | 56.67 (29.17) | F(1,9)=0.00 | 1.00 |
| | Quercus leucotrichophora | 61.82 (4.96) | 65.50 (13.36) | F(1,64)=0.07 | 0.80 |
| | Rhamnus persica | 88.00 (4.62) | 5.67 (2.67) | F(1,2)=238.32 | 0.004 |
| **Lopped** | Benthamida capitata | 50.17 (13.82) | 154.00 (33.86) | F(1,5)=8.06 | 0.04 |
| | Mahonia borealis | 40.38 (13.66) | 33.75 (27.32) | F(1,8)=0.05 | 0.83 |
| | Pinus roxburghii | 55.41 (6.60) | 25.50 (30.93) | F(1,21)=0.89 | 0.36 |
| | Quercus leucotrichophora | 64.38 (3.08) | 62.30 (12.25) | F(1,166)=0.03 | 0.87 |
| | Rhododendron arboreum | 16.90 (2.15) | 81.00 (12.55) | F(1,139)=25.34 | 0.00 |
| | Viburnum cotinifolium | 33.44 (4.27) | 112.50 (21.75) | F(1,52)=12.72 | 0.001 |
| | Viburnum mullaha | 30.60 (18.62) | 127.00 (29.44) | F(1,5)=7.66 | 0.04 |

**Table 4-26** Comparison of coverage representing all vascular plants, bare soil, grasses, woody debris, fern, mosses, and rocks in the protected and lopped forests in 2006 (5 m x 10 m subplots). Sample frame represents 0.1% (1000cm$^2$) of sample area. Protected forest N= 12; Lopped forest N=14. Standard deviation is given in parenthesis.

| Variable | Protected forest | Lopped forest | p-value |
|---|---|---|---|
| Bare soil | 1.77 (2.11) | 2.44 (2.80) | 0.56 |
| Grasses | 6.66 (6.69) | 3.28 (3.66) | 0.18 |
| Woody debris | 2.10 (3.14) | 1.54 (3.26) | 0.15 |
| Fern | 2.34 (3.03) | 2.65 (3.25) | 0.94 |
| Mosses | 4.81 (5.35) | 1.82 (1.70) | 0.12 |
| Rocks | 3.04 (2.75) | 6.70 (17.70) | 0.32 |
| Quercus leucotrichophora | 5.36 (5.32) | 6.39 (5.59) | 0.49 |
| Quercus floribunda | 0.00 | 1.85 (1.94) | 0.004 |
| Lyonia ovalifolia | 1.47 (3.27) | 1.66 (2.78) | 0.78 |
| Pinus roxburghii | 0.08 (0.24) | 1.09 (1.91) | 0.40 |
| Rhododendron arboreum | 0.03 (0.07) | 1.97 (2.76) | 0.03 |
| Benthamida capitata | 0.00 | 0.75 (1.55) | 1.00 |
| Ficus hipsida | 0.11 (0.22) | 0.00 | 0.30 |
| Prunus cornuta | 0.00 | 0.00 | 1.00 |
| Cedrus deodara | 0.00 | 0.00 | 1.00 |
| Pyrus pashia | 0.35 (0.84) | 0.21 (0.40) | 0.94 |
| Viburnum cotinifolium | 1.35 (2.20) | 2.15 (1.96) | 0.13 |
| Rhus wallichii | 1.43 (3.10) | 0.11 (0.28) | 0.20 |
| Aegle marmelos | 0.00 | 0.00 | 1.00 |
| Myrica esculenta | 0.00 | 0.00 | 1.00 |
| Rhamnus persica | 0.05 (0.14) | 0.00 | 0.49 |
| Rhus parviflora | 0.16 (0.39) | 0.09 (0.15) | 0.78 |
| Indigofera cassioides | 0.27 (0.43) | 2.33 (3.37) | 0.002 |
| Grewia optiva | 0.00 | 0.11 (0.27) | 0.56 |
| Wikstroemia canescens | 0.00 | 0.39 (0.56) | 0.03 |
| Scurrula elata | 0.00 | 0.00 | 1.00 |
| Viburnum mullaha | 0.00 | 0.31 (0.86) | 0.37 |
| Mahonia borealis | 0.00 | 0.28 (0.56) | 0.03 |
| Aesculus indica | 0.00 | 0.00 | 1.00 |
| Benthamidia capitata | 0.00 | 0.00 | 1.00 |
| Juglans regia | 0.00 | 0.05 (0.20) | 0.78 |
| Coriaria nepalensis | 0.00 | 0.00 | 1.00 |
| Rhus punjabensis | 0.00 | 0.33 (0.84) | 0.56 |
| Boenninghausenia albiflora | 0.13 (0.16) | 0.53 (1.91) | 0.25 |
| Rubus paniculatus | 0.54 (1.49) | 0.04 (0.08) | 0.27 |
| Berberis asiatica | 0.39 (0.25) | 0.36 (0.47) | 0.23 |
| Pteracanthus alatus | 0.80 (1.54) | 0.46 (0.69) | 0.71 |
| Smilax cf. menispermoidea | 0.05 (0.08) | 0.15 (0.14) | 0.04 |
| Rosa brunonii | 0.04 (0.09) | 0.00 | 0.49 |

| | | | |
|---|---|---|---|
| Desmodium cf. podocarpum | 0.65 (1.02) | 0.61 (0.90) | 0.82 |
| Eupatorium adenophorum | 0.78 (1.69) | 0.02 (0.05) | 0.30 |
| Unidentified forb 1 | 0.21 (0.18) | 0.07 (0.15) | 0.07 |
| Unidentified forb 2 | 0.12 (0.19) | 0.00 | 0.08 |
| Artemisia roxburghiana | 0.17 (0.25) | 0.08 (0.08) | 0.74 |
| Rabdosia coetsa | 0.04 (0.10) | 0.10 (0.14) | 0.23 |
| Erigeron spp. | 0.01 (0.04) | 0.16 (0.41) | 0.53 |
| Jasminum humile | 0.47 (0.78) | 0.13 (0.14) | 0.63 |
| Bergenia ciliata | 0.06 (0.14) | 0.00 | 0.49 |
| Hedera nepalensis | 0.13 (0.21) | 0.33 (0.42) | 0.18 |
| Martynia annua | 0.13 (0.43) | 0.00 | 0.74 |
| Rumex dentatus | 0.10 (0.23) | 0.00 | 0.49 |
| Begonia dioica | 0.10 (0.29) | 0.13 (0.33) | 0.67 |
| Unidentified forb 3 | 0.09 (0.17) | 0.15 (0.25) | 0.37 |
| Cotoneaster microphylus | 0.01 (0.03) | 0.06 (0.17) | 0.40 |
| Rumex spp. | 0.11 (0.29) | 0.00 | 0.49 |
| Unidentified forb 4 | 0.21(0.46) | 0.15 (0.63) | 0.68 |
| Unknown herbacious vine 1 | 0.13 (0.43) | 0.00 | 0.74 |
| Abelia triflora | 0.00 | 0.36 (1.09) | 0.23 |
| Cotinus coggygria | 0.00 | 0.06 (0.17) | 0.56 |
| Unidentified forb 5 | 0.00 | 0.71 (2.45) | 0.37 |
| Lamiaceae spp. | 0.00 | 0.02 (0.07) | 0.78 |
| Gerbera Gossypina | 0.00 | 0.00 (0.01) | 0.78 |
| Rhamnus spp. | 0.00 | 3.31 (4.02) | 0.004 |
| Cotoneaster bacillaris | 0.00 | 0.54 (1.49) | 0.131 |
| Lespedeza gerardiana | 0.00 | 0.05 (0.08) | 0.23 |
| Urticaceae spp. Pilea scripta | 0.00 | 0.04 (0.15) | 0.78 |
| Parthenocissus semicordata | 0.02 (0.07) | 0.28 (0.32) | 0.005 |

**Table 4-27** Comparison of the average number of stems present in the ground cover of the 5 m x 10 m subplots of the protected and lopped forest in 2006. Standard error is given in parenthesis.

| Species | Forest type | | N | Wald $\chi^2$ | df | p-value |
|---|---|---|---|---|---|---|
| | Protected | Lopped | | | | |
| Quercus leucotrichophora | 7.08 (1.35) | 7.71 (1.73) | 26 | 0.08 | 1 | 0.77 |
| Quercus floribunda | 0.17 (0.15) | 1.64 (0.54) | 26 | 6.89 | 1 | 0.01 |
| Pinus roxburghii | 0.33 (0.15) | 1.71 (1.09) | 26 | 1.58 | 1 | 0.21 |
| Rhododendron arboreum | 0.25 (0.16) | 5.21 (3.11) | 26 | 2.54 | 1 | 0.11 |
| Pyrus pashia | 1.67 (0.54) | 0.36 (0.36) | 26 | 5.45 | 1 | 0.02 |
| Viburnum cotinifolium | 4.50 (1.39) | 0.93 (0.36) | 26 | 6.16 | 1 | 0.01 |
| Cotinus coggygria | 1.92 (0.78) | 1.50 (1.17) | 26 | 0.09 | 1 | 0.77 |
| Rhus punjabensis | 7.42 (3.62) | 2.93 (1.75) | 26 | 1.25 | 1 | 0.26 |

**Table 4-28** Comparison of the mean number of vascular species with the tops cut off in the ground cover of the 5 m x 10 m subplots in the protected and lopped forests in 2006. Standard error is given in parenthesis.

| Species | Protected (SE) | Lopped (SE) | df | F | p-value |
|---|---|---|---|---|---|
| Cotinus coggygria | 1.00 (0.04) | 1.10 (0.05) | 1,42 | 2.30 | 0.14 |
| Lyonia ovalifolia | 1.00 (0.11) | 1.43 (0.10) | 1,24 | 8.31 | 0.01 |
| Pyrus pashia | 1.00 (0.05) | 1.40 (0.10) | 1,23 | 12.27 | 0.002 |
| Pinus roxburghii | 1.00 (0.15) | 1.11 (0.06) | 1,29 | 0.47 | 0.50 |
| Quercus floribunda | 1.00 (0.34) | 1.35 (0.10) | 1,23 | 0.98 | 0.33 |
| Quercus leucotrichophora | 1.00 (0.04) | 1.39 (0.04) | 1,191 | 54.99 | 0.00 |
| Rhododendron arboreum | 1.00 (0.20) | 1.14 (0.04) | 1,74 | 0.46 | 0.50 |
| Viburnum cotinifolium | 1.00 (0.03) | 1.39 (0.06) | 1,65 | 32.74 | 0.00 |

**Table 4-29** Comparison of the mean lopping extent of the vascular species present in the ground cover of the 5 m x 10 m subplots in the protected and lopped forests in 2006. Standard error is given in parenthesis.

| Species | Protected | Lopped | df | F | p-value |
|---|---|---|---|---|---|
| Lyonia ovalifolia | 1.33 (0.39) | 1.79 (0.36) | 1, 24 | 0.74 | 0.40 |
| Pyrus pashia | 1.05 (0.06) | 1.20 (0.12) | 1,23 | 1.18 | 0.29 |
| Pinus roxburghii | 1.00 (0.94) | 1.93 (0.36) | 1,29 | 0.85 | 0.36 |
| Quercus floribunda | 1.00 (1.18) | 1.78 (0.35) | 1,23 | 0.41 | 0.53 |
| Quercus leucotrichophora | 2.16 (0.24) | 3.00 (0.22) | 1,191 | 6.72 | 0.01 |
| Rhododendron arboreum | 1.00 (0.51) | 1.19 (0.10) | 1,74 | 0.14 | 0.71 |
| Viburnum cotinifolium | 1.22 (0.16) | 1.92 (0.33) | 1,65 | 3.71 | 0.06 |

**Table 4-30** Comparison of the mean number of seedling and basal-sprouts of vascular species in the ground cover of the 5 m x 10 m subplots in the protected and lopped forests in 2006.

| Species | Number of sprouts (SE) | | df | F | p-value |
|---|---|---|---|---|---|
| | Protected | Lopped | | | |
| Cotinus coggygria | 1.96 (0.07) | 1.71 (0.08) | 1,42 | 5.16 | 0.03 |
| Lyonia ovalifolia | 1.92 (0.12) | 1.36 (0.11) | 1,24 | 11.75 | 0.002 |
| Pyrus pashia | 1.90 (0.08) | 1.80 (0.15) | 1,23 | 0.35 | 0.56 |
| Pinus roxburghii | 2.00 (0.24) | 1.48 (0.09) | 1,29 | 4.03 | 0.05 |
| Quercus floribunda | 1.00 (0.35) | 1.44 (0.10) | 1,23 | 1.42 | 0.25 |
| Quercus leucotrichophora | 1.37 (0.05) | 1.35 (0.05) | 1,191 | 0.14 | 0.71 |
| Rhododendron arboreum | 2.00 (0.22) | 1.82 (0.04) | 1,74 | 0.63 | 0.43 |
| Rhus punjabensis | 2.00 (0.01) | 1.98 (0.01) | 1,133 | 2.32 | 0.13 |
| Viburnum cotinifolium | 1.98 (0.04) | 1.54 (0.07) | 1,65 | 31.73 | 0.00 |

**Table 4-31** Comparison of the mean height of the vascular species found in the ground cover of the 5 m x 10 m subplot in the protected and lopped forests in 2006. Standard error is given in parenthesis.

| Species | Protected forest | Lopped forest | F value |
|---|---|---|---|
| Cotinus coggygria | 44.30 (7.52) | 24.14 (7.87) | F(1,42) = 3.432, p=0.071 |
| Lyonia ovalifolia | 71.42 (12.36) | 63.36 (11.45) | F(1,24)=0.23, p=0.64 |
| Pyrus pashia | 64.06 (12.15) | 109.37 (19.65) | F(1,9)=3.85 p=0.08 |
| Pinus roxburghii | 34.25 (18.12) | 49.56 (6.97) | F(1,29)=0.62 p=0.44 |
| Quercus floribunda | 118.00 (36.00) | 70.15 (11.85) | F(1,11)=1.60 p=0.23 |
| Quercus leucotrichophora | 109.23 (6.61) | 79.07 (6.14) | F(1,9)=11.32 p=0.01 |
| Rhododendron arboreum | 131.17 (23.62) | 70.99 (11.48) | F(1,6)=5.25 p=0.06 |
| Rhus punjabensis | 34.90 (2.57) | 25.29 (3.89) | F(1,133)=4.24 p=0.04 |
| Viburnum cotinifolium | 53.84 (9.73) | 115.72 (14.94) | F(1,4)=12.04 p=0.02 |

**Table 4-32** Comparison of the basal area ($m^2$/ha) of tree species in the overstory of the protected and lopped forests in 1993 and 2006. Standard deviation is given in parenthesis.

| Forest type | Species | 1993 | 2006 | p-value |
|---|---|---|---|---|
| **Protected** | Lyonia ovalifolia | 2.40 (2.00) | 1.57 (1.38) | 0.48 |
| | Pinus roxburghii | 13.28 (8.56) | 7.72 (11.66) | 0.37 |
| | Quercus leucotrichophora | 6.29 (6.17) | 19.91 (7.77) | 0.01 |
| | Rhododendron arboreum | 0.96 | 0.21 | NA |
| **Lopped** | Benthamida capitata | 0.17 (0.03) | 0.76 (0.45) | 0.14 |
| | Ficus hipsida | 0.93 (0.59) | 0.32 | 0.55 |
| | Lyonia ovalifolia | 3.74 (2.22) | 4.01 (4.45) | 0.91 |
| | Pinus roxburghii | 4.37 (3.54) | 0.50 (0.55) | 0.22 |
| | Quercus floribunda | 2.09 (2.01) | 4.68 (3.64) | 0.15 |
| | Quercus leucotrichophora | 24.62 (16.91) | 13.03 (7.76) | 0.13 |
| | Rhododendron arboreum | 5.47 (1.36) | 0.92 (0.86) | 0.01 |

**Table 4-33** Comparison of the average number of stems present in the ground cover (1m x 1 m subplots) in the protected and lopped forest between 1993 and 2006. Standard error is given in parenthesis.

| Forest type | Species | Year | | N | Wald $\chi^2$ | df | p-value |
|---|---|---|---|---|---|---|---|
| | | **1993** | **2006** | | | | |
| **Protected** | Quercus leucotrichophora | 4.92 (2.20) | 0.42 (0.21) | 36 | 3.94 | 1 | 0.047 |
| | Pinus roxburghii | 0.50 (0.17) | 0.13 (0.11) | 36 | 7.04 | 1 | 0.01 |
| **Lopped** | Quercus leucotrichophora | 10.85 (2.53) | 0.36 (0.12) | 40 | 16.66 | 1 | 0.00 |
| | Lyonia ovalifolia | 2.24 (0.99) | 0.11 (0.07) | 40 | 4.73 | 1 | 0.03 |
| | Pinus roxburghii | 1.85 (1.14) | 0.07 (0.04) | 40 | 2.38 | 1 | 0.12 |
| | Rhododendron arboreum | 10.43 (5.47) | 0.18 (0.11) | 40 | 3.66 | 1 | 0.06 |
| | Benthamida capitata | 0.42 (0.30) | 0.11 (0.10) | 40 | 0.84 | 1 | 0.36 |
| | Viburnum cotinifolium | 4.21 (1.11) | 0.11 (0.05) | 40 | 14.46 | 1 | 0.00 |
| | Viburnum mullaha | 0.43 (0.30) | 0.11 (0.05) | 40 | 1.38 | 1 | 0.24 |
| | Mahonia borealis | 0.67 (0.30) | 0.07 (0.04) | 40 | 3.70 | 1 | 0.06 |
| | Abelia triflora | 0.92 (0.45) | 0.04 (0.03) | 40 | 3.86 | 1 | 0.049 |

**Table 4-34** Comparison of the mean number of stems present in the ground-cover of the protected and lopped forests in 1993 and 2006 (Only species that were present in both forests were included in the analysis). Standard error is given in parenthesis.

| Year | Species | Forest type | | N | Wald $\chi^2$ | df | p-value |
|---|---|---|---|---|---|---|---|
| | | **Protected** | **Lopped** | | | | |
| **1993** | Quercus leucotrichophora | 4.92 (2.20) | 10.83 (2.53) | 24 | 3.12 | 1 | 0.08 |
| | Pinus roxburghii | 0.50 (0.17) | 1.83 (1.15) | 24 | 1.32 | 1 | 0.25 |
| | Benthamida capitata | 0.08 (0.08) | 0.42 (0.30) | 24 | 1.17 | 1 | 0.28 |
| **2006** | Quercus leucotrichophora | 0.42 (0.21) | 0.36 (0.12) | 52 | 0.06 | 1 | 0.81 |
| | Pinus roxburghii | 0.13 (0.11) | 0.07 (0.04) | 52 | 0.19 | 1 | 0.66 |
| | Indigofera cassioides | 0.04 (0.04) | 0.14 (0.07) | 52 | 1.66 | 1 | 0.20 |

**Table 4-35** Comparison of spatial distribution and aggregation of the ground cover of the protected and lopped forests using Variance Mean Ratio for measurement year 2006.

| Variable | Year | Forest type | |
|---|---|---|---|
| | | Protected | Lopped |
| Entire forest | 1993 | 48.55 | 142.43 |
| | 2006 | 7.00 | 12.77 |
| Quercus leucotrichophora | 1993 | 43.35 | 21.72 |
| | 2006 | 13.48 | 8.98 |
| Pinus roxburghii | 1993 | 4.55 | 56.94 |
| | 2006 | 15.00 | 5.78 |

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# CHAPTER V

# CONCLUSIONS

Forest ecosystem management in Tehri Garhwal, Uttaranchal, located in the Central Himalayan Mountains of India, cannot be considered in isolation from the livelihood of the local people. The livelihood of the people of Beli village, which I examined intensely in 1993 and 2006, has been entirely dependent on the forest. Their livelihood is maintained by complex interactions between traditional gender and age roles in households, availability of oak foliage, number and type of livestock, and type of agricultural production.

The primary link between the villagers and their forests is their practice of lopping used to collect oak foliage from forest stands. The use of oak foliage for livestock fodder had not changed between 1993 and 2006. In 2006, the people of Beli village continued to collect oak foliage daily as they did in 1993 and for decades in the past. They continued to vary the oak species collected and rotated the location of lopping throughout the year. Yet, the practice of lopping had undergone some fundamental changes between 1993 and 2006.

When examining the diameter of branches lopped and the weight of fodder bundles carried out of the forest, there were distinct changes that had occurred. The diameter of branches lopped in 2006 was significantly smaller, and weight of fodder bundles carried by females was significantly greater in 2006. Both of these effects reflected the response of the villagers to the changes in the forest stand had undergone over the last 13 years.

The changes in the forest stand were initiated indirectly with the opening of the road in 1978 between the village and nearby towns. The increased access to markets brought about a gradual change in agricultural production from subsistence agriculture to cash crops i.e. vegetables. These new agricultural practices increased the demand for compost and in turn, intensified the collection of oak foliage. The intensified lopping of trees eventually led to a perceived decline in oak foliage.

All the villagers interviewed stated that they began consciously thinking about changing agriculture as their main source of livelihood when they noticed that the amount of oak foliage was decreasing in the forest. They felt they could no longer rely entirely on the forest to support their agriculture. In order to reduce their reliance on agriculture as their main source of livelihood, the villagers' strategy was to educate their children in preparation for future employment. This new focus on education is reflected in the literacy rates where in 2001, female literacy rate increased from zero to 19%, and male literacy increased from 30 % to 71%.

The increased number of children going to school in the recent years has resulted in changing the lopping practice that had continued for centuries. The age and gender composition of fodder groups changed. Fewer fodder collection trips were made to the collect fodder, and the numbers of individuals in fodder collection groups decreased. Ultimately, each household adjusted the number and type of livestock they owned depending on the amount of labor available. Most households decreased the number of buffaloes and cows which require fodder and increased the number of goats which were grazed.

Subsequently, the villagers began to perceive agriculture as unreliable for their predominant source of income in the future. The villagers began to diversify their income sources and searched for employment outside the village. Accordingly, parents began to send their children to school to prepare them for future employment. Thus, the number of people and the group composition going into the forest changed. In turn, this change is reducing their influence on the forest and allowing it to recover and regenerate. Today, the villagers do not picture traditional agriculture as an important aspect of their children's lives, and thus they place less reliance on the forest for their livelihood.

Comparison of the protected and lopped forest stands surrounding Beli village provides compelling evidence that the oaks are maintaining themselves in the forest overstory and in the ground cover. The findings indicate that the soil and forest floor conditions in the lopped forest were not worse than those in the protected forest. The soil in the lopped forest had relatively deeper A horizon, neutral pH, deeper rooting, and fewer coarse fragments. Moreover, the Oe horizon of the lopped forest was deeper and had heavier air-dry weight than the protected forest.

The oaks have also maintained their abundance, and pines have not become abundant or dominant in the overstory or the ground cover. Oaks accounted for 69.3% of the overstory stems in the lopped forest, whereas, pines only accounted for 1%. Alos, this relationship of oaks to pine is supported by the high relative density and basal area of oaks in comparison to pines in the lopped forest. Furthermore, the percentage of live trees in the overstory continues to be above 95% in the lopped forest, and there is no significant difference in the number of live stems between the protected and lopped forests.

The ground cover findings indicate that oaks are maintaining their abundance. The greater number of oak stems regenerating in the ground cover of the lopped forest compared to that of pine indicates that oaks continue to establish themselves. Oaks are also able to compete well with pines in that the oaks have similar heights between 1993 and 2006, whereas, the pines have significantly decreased in height. The oaks also have the greatest coverage in the ground-cover layer of both the protected and lopped forests.

Therefore, the concern about losing oak and its replacement by pine due to extensive lopping of oak branches by the villagers appears to be overstated. Furthermore, two of the plots that were measured in 1993 had been converted into agricultural fields by 2006. Hence, agricultural expansion may be more detrimental to forest loss than the practice of lopping.

Finally, the complex relationship between the people, forest, livestock, and agriculture that has maintained the livelihood of the people for centuries has changed and will continue to change in the future. The perception of the government foresters that the villagers will gradually degrade the oak forests beyond their ability to regenerate or form pine stands is not borne out by the results of my research. With the gradual decrease in forest use by the villagers, forest succession will likely continue in a trend based on natural disturbances and site-species relationships rather than intensive human disturbance to the crowns of oak species by lopping. Therefore, there will need to be some fundamental changes in the thinking and approach by the government foresters to the management of the forests in the Central Himalayas.

# APPENDICES

## APPENDIX A

The three categories of questions asked during the face-to-face interviews conducted in Beli village.

1. Forest perception & use
    - What does the forest provide for you?
    - How important is the forest to you, your family, and village?
    - Why is it important?
    - What are the benefits the forests provides to you, your family, and village?
    - Are there plants that you used to use but do not use anymore?
    - In what ways has this changed in your lifetime? During specific times in their lives.
    - If the forest was not here, what would happen to you, your family, and village?
2. Forest management
    - What if any, concerns do you have about the using the forest in this way?
    - What you, your family, village will do so that your children and grandchildren will continue to have the same benefits from the forest? What are your ideas for continued productive use of the forest?
    - What needs to happen – family, village, and government?

- If you had the opportunity to speak to the government people, to ask a question or recommend managing the forest differently, what would you say? What would you do differently?

3. Emotional/religious/supernatural conception of forest

- Are there places you do not go in the forest?
- Are there things you will not use from the forest?
- Do you ever get nervous in the forest? When? Why?
- Are there important places in the forest? Places you will not cut? Use? Why?
- Thinking throughout your life, how have your feelings changed about the forest?
- Where is your favorite place to collect fodder? Why?

# APPENDIX B

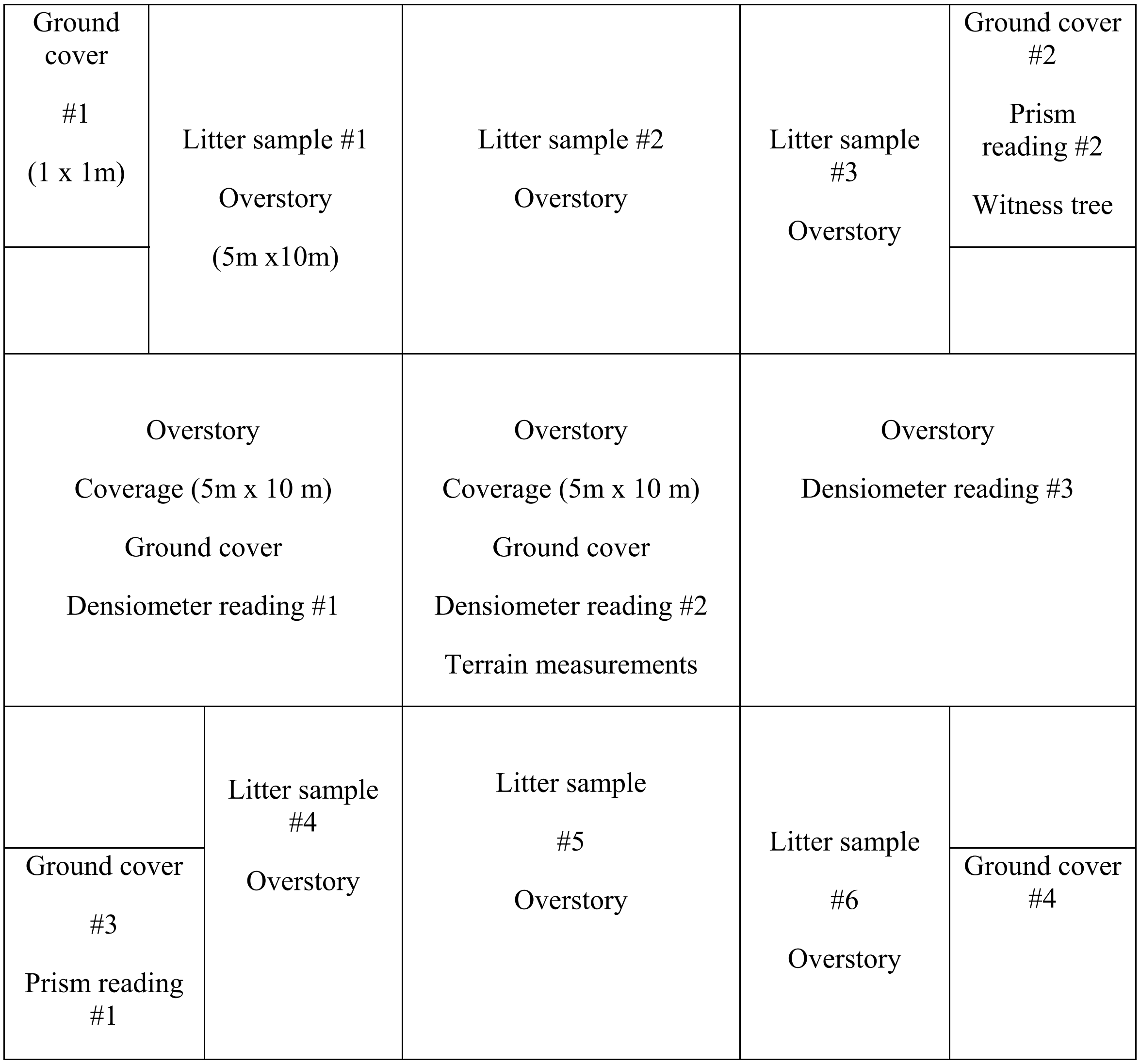


Diagram illustrating a 15 m x 30 m plot divided into subplots for sampling the overstory, understory, ground-cover, litter, coverage, light density, basal area, and terrain. Overstory and understory measurements were taken for the entire plot. Witness tree measurements were taken from the northeast corner of the plot.